MADHA ENGINEERING COLLEGE

(A Christian Minority Institution)

KUNDRATHUR, CHENNAI – 600 069

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

GE3791 - HUMAN VALUES AND ETHICS

SEMESTER VII

REGULATIONS 2021

NOTES
&
QUESTION BANK

GE3791 **HUMAN VALUES AND ETHICS** **LT P C 2 0 0 2**

COURSE DESCRIPTION

This course aims to provide a broad understanding about the modern values and ethical principles that have evolved and are enshrined in the Constitution of India with regard to the democratic, secular and scientific aspects. The course is designed for undergraduate students so that they could study, understand and apply these values in their day to day life.

COURSE OBJECTIVES: ¬ To create awareness about values and ethics enshrined in the Constitution of India ¬ To sensitize students about the democratic values to be upheld in the modern society. ¬ To inculcate respect for all people irrespective of their religion or other affiliations. ¬ To instill the scientific temper in the students' minds and develop their critical thinking. ¬ To promote sense of responsibility and understanding of the duties of citizen.

UNIT I DEMOCRATIC VALUES 6

Understanding Democratic values: Equality, Liberty, Fraternity, Freedom, Justice, Pluralism, Tolerance, Respect for All, Freedom of Expression, Citizen Participation in Governance – World Democracies: French Revolution, American Independence, Indian Freedom Movement. Reading Text: Excerpts from John Stuart Mills' On Liberty

UNIT II SECULAR VALUES 6

Understanding Secular values – Interpretation of secularism in Indian context - Disassociation of state from religion – Acceptance of all faiths – Encouraging non-discriminatory practices. Reading Text: Excerpt from Secularism in India: Concept and Practice by Ram Puniyani

UNIT III SCIENTIFIC VALUES 6

Scientific thinking and method: Inductive and Deductive thinking, Proposing and testing Hypothesis, Validating facts using evidence based approach – Skepticism and Empiricism – Rationalism and Scientific Temper. Reading Text: Excerpt from The Scientific Temper by Antony Michaelis R

UNIT IV SOCIAL ETHICS 6

Application of ethical reasoning to social problems – Gender bias and issues – Gender violence – Social discrimination – Constitutional protection and policies – Inclusive practices. Reading Text: Excerpt from 21 Lessons for the 21st Century by Yuval Noah Harari

UNIT V SCIENTIFIC ETHICS 6

Transparency and Fairness in scientific pursuits – Scientific inventions for the betterment of society - Unfair application of scientific inventions – Role and Responsibility of Scientist in the modern society.

Reading Text: Excerpt from American Prometheus: The Triumph and Tragedy of J.Robert Oppenheimer by Kai Bird and Martin J. Sherwin.

REFERENCES:

1. The Nonreligious: Understanding Secular People and Societies, Luke W. Galen Oxford University Press, 2016.

2. Secularism: A Dictionary of Atheism, Bullivant, Stephen; Lee, Lois, Oxford University Press, 2016.

3. The Oxford Handbook of Secularism, John R. Shook, Oxford University Press, 2017.

4. The Civic Culture: Political Attitudes and Democracy in Five Nations by Gabriel A. Almond and Sidney Verba, Princeton University Press,

5. Research Methodology for Natural Sciences by Soumitro Banerjee, IISc Press, January 2022

UNIT I – HUMAN VALUES

VALUES

1. Values are individual in nature.
2. Values are comprised of personal concepts of responsibility, entitlement and respect.
3. Values are shaped by personal experience, may change over the span of a lifetime and may be influenced by lessons learned.
4. Values may vary according to an individual's cultural, ethnic and/or faith-based background.

"Never change your core values."

In spite of all the change around you, decide upon what you will never change: your core values. Take your time to decide what they are but once you do, do not compromise on them for any reason.

Integrity is one such value.

MORALS

1. Morals are guiding principles that every citizen should hold.
2. Morals are foundational concepts defined on both an individual and societal level.
3. At the most basic level, morals are the knowledge of the difference between right and wrong.

PERSONAL ETHICS

1. Simply put, all individuals are morally autonomous beings with the power and right to choose their values, but it does not follow that all choices and all value systems have an equal claim to be called ethical.
2. Actions and beliefs inconsistent with the Six Pillars of Character - trustworthiness, respect, responsibility, fairness, caring and citizenship - are simply not ethical.

PERSONAL ETHICS - everyday examples

- Software piracy
- Expense account padding
- Copying of homework or tests
- Income taxes
- "Borrowing" nuts and bolts, office supplies from employer
- Copying of Videos or CD's
- Plagiarism
- Using the copy machine at work

RELIGION AND ETHICS

- The "Golden Rule" is a basic tenet in almost all religions: Christian, Hindu, Jewish, Confucian, Buddhist, Muslim.

- "Do unto others as you would have others do unto you."
- "Treat others as you would like them to treat you" (Christian).
- "Hurt not others with that which pains you" (Buddhist)
- "What is hateful to yourself do not do to your fellow men" (Judaism)
- "No man is a true believer unless he desires for his brother that which he desires for himself" (Islam)

MORALITY AND ETHICS

- Concerns the goodness of voluntary human conduct that affects the self or other living things
- Morality (Latin mores) usually refers to any aspect of human action
- Ethics (Greek ethos) commonly refers only to professional behavior
- Ethics consist of the application of fundamental moral principles and reflect our dedication to fair treatment of each other, and of society as a whole.
- An individual's own values can result in acceptance or rejection of society's ethical standards because even thoughtfully developed ethical rules can conflict with individual values.

ASPECTS OF ETHICS

There are two aspects to ethics:

1. The first involves the ability to discern right from wrong, good from evil and propriety from impropriety.
2. The second involves the commitment to do what is right, good and proper. Ethics entails action.

INTEGRITY

- Integrity is defined as the unity of thought, word and deed (honesty) and open mindedness.
- It includes the capacity to communicate the factual information so that others can make well-informed decisions.
- It yields the person's peace of mind, and hence adds strength and consistency in character, decisions, and actions.
- This paves way to one's success. It is one of the self-direction virtues. It enthuse people not only to execute a job well but to achieve excellence in performance. It helps them to own the responsibility and earn self-respect and recognition by doing the job.
- Moral integrity is defined as a virtue, which reflects a consistency of one's attitudes, emotions, and conduct in relation to justified moral values.
- Integrity involves in two fundamental intuitions:
    - It is primarily a formal relation one has to oneself
    - It is connected in an important way to acting morally.

- Integrity is a bridge between responsibility in private and professional life.
- Integrity makes possible the virtues of self-respect and pride in one's work. It precludes the attitude that one is not personally accountable for one's work.
- It implies a concern for achieving excellence in the technical aspects of one's work, a strong desire to see the work done well. In turn, this desire constituted a potent stimulus for professional conduct.

Integrity is accounted in the following aspects

- Integrity as self-integration
- Integrity as maintenance of identity
- Integrity as standing for something
- Integrity as moral purpose
- Integrity as a virtue

WORK ETHICS

Work ethic is a set of values based on hard work and diligence. It is also a belief in the moral benefit of work and its ability to enhance character. A work ethic may include being reliable, having initiative, or pursuing new skills. Workers exhibiting a good work ethic in theory should be selected for better positions, more responsibility and ultimately promotion. Workers who fail to exhibit a good work ethic may be regarded as failing to provide fair value for the wage the employer is paying them and should not be promoted or placed in positions of greater responsibility. Work ethic is not just hard work but also a set of accompanying virtues, whose crucial role in the development and sustaining of free markets.

Benjamin Franklin wrote: 'Remember, that time is money. He that can earn ten shillings a day by his labor, and goes abroad, or sits idle, one half of that day, though he spends but sixpence during his diversion or idleness, ought not to reckon that the only expense; he has really spent, or rather thrown away, five shillings besides. Remember, that money is the prolific, generating nature.

Money can beget money, and its offspring can beget more, and so on. Five shillings turned is six, turned again is seven and three pence, and so on, till it becomes a hundred pounds. The more there is of it, the more it produces every turning, so that the profits rise quicker and quicker. He that kills a breeding sow, destroys all her offspring to the thousandth generation. He that murders a crown, destroys all that it might have produced, even scores of pounds.'

SERVICE LEARNING

- Service learning refers to learning the service policies, procedures, norms, and conditions, other than the technical trade practices.
- The service learning includes the characteristics of the work, basic requirements, security of the job, and awareness of the procedures, while taking decisions and actions.

- It helps the individuals to interact ethically with colleagues, to effectively coordinate with other departments, to interact cordially with suppliers as well as the customers, and to maintain all these friendly interactions.
- Alternatively, the service learning may be defined as the non-paid activity, in which service is provided on voluntary basis to the public (have-nots in the community), non-profitable institutions, and charitable organizations.
- It is the service during learning. This includes training or study on real life problems and their possible solutions, during the formal learning, i.e., courses of study.
- In the industrial scenario, adoption, study, and development of public health or welfare or safety system of a village or school is an example of service learning by the employees. The engineering student analyzing and executing a socially-relevant project is another example of service learning.
  - 1. Connection to curriculum: Integrating the learning into a service project is a key to successful service learning. Academic ties should be clear and built upon existing disciplinary skills.
  - 2. Learner's voice: Beyond being actively engaged in the project, trainees have the opportunity to select, design, implement, and evaluate their service activity.
  - 3. Reflection: Structured opportunities are created to think, talk, and write about the service experience. The balance of reflection and action allows the trainee to be constantly aware of the impact of their work.
  - 4. Partners in the community: Partnership with community agencies are used to identify genuine needs, provide mentorship, and contribute input such as labor and expertise towards completing the project.

Civic virtue :

Civic virtue is the moral underpinning of how a citizen behaves and is involved in society. It is a standard of righteous behavior in relation to a citizens' involvement in society. A individual may exhibit civic virtue by voting, volunteering and organizing other community activities. Without an understanding of civic virtue, citizens are less likely to look beyond their families, friends and economic interests. They are less likely to help others in the community, to volunteer their time, to give to nonprofit organizations or to participate in group activity that benefits society. Related ideas for civic virtue are citizenship, philanthropy, public good, voluntarism and social capital.

Valuing Time:

A first step in good time management is to understand the value of your time. If you are employed by someone else, you need to understand how much your employer is paying for your time, and how much profit he or she expects to make from you. If you are working for yourself, you should have an idea of how much income you want to bring in after tax. By working these figures back to an hourly rate, this gives you an idea of the value of your time. By knowing the value of your time, you should be able to tell what tasks are worthwhile to perform, and which tasks give a poor return. This helps you cut away the low value jobs, or argue for help with them.

Respect for others :

Respect for others is based on self-respect. It really is following the Golden Rule: Do unto others as you would have others do unto you. Being a polite and courteous person makes one a rare individual in today's world. Politeness, and a genuine concern for the rights and feelings of others in our society seems to have slammed the door in our faces. A culture of rudeness has become a feature of modern society. Whether it's loud cellphone conversations, line cutting, or terrible customer service by staff people, finding politeness in the world is on the decline. You can very easily find people who view politeness and good manners as weakness and as character flaws to be overcome. They argue that rudeness succeeds and common courtesy is a mark of failure. They view rudeness to others as a sign of their superiority as people, and a badge of their status. They couldn't be more wrong. Politeness and common courtesy are more likely to achieve success, in business and in life, than a selfish, bullying attitude.

Commitment and cooperation:

Commitment means acceptance of the responsibilities and duties and cooperation means help and assistance. By developing team commitment and cooperation in a work team you are assisting the team to meet its goals and objectives. Work teams that are committed and cooperative are more likely to achieve the goals the business has set. There are a number of signals that indicate the work team is committed and cooperating.

These include:

- maintaining or increasing quality
- reaching or exceeding production targets
- decreasing complaints from team members
- limited conflict between team members
- fewer workplace injuries.

There are degrees of team involvement in decision making. Your knowledge of the skills and abilities of the team members will guide your decision about the extent supported employees can contribute to making a decision. There are no rules for when and how team members should be involved. It is a matter for your judgement.

Empathy

Empathy is the ability to mutually experience the thoughts, emotions, and direct experience of others. The ability to understand another person’s circumstances, point of view, thoughts, and feelings is empathy. When experiencing empathy, you are able to understand someone else’s internal experiences.

Self-confidence

Self-confidence relates to self-assuredness in one's personal judgment, ability, power, etc., sometimes manifested excessively. Being confident in yourself is infectious if you present yourself well, others will want to follow in your foot steps towards success. Promise yourself, no matter how difficult the problem life throws at you, that you will try as hard as you can to help yourself. You acknowledge that sometimes your efforts to help yourself may not result in success, as often being properly rewarded is not in your control

Spirituality:

Spirituality is the concept of an ultimate or an alleged immaterial reality, an inner path enabling a person to discover the essence of his/her being; or the "deepest values and meanings by which people live. Spiritual practices, including meditation, prayer and contemplation, are intended to develop an individual's inner life. Spiritual experiences can include being connected to a larger reality, yielding a more comprehensive self; joining with other individuals or the human community; with nature or the cosmos; or with the divine realm. Spirituality is often experienced as a source of inspiration or orientation in life. It can encompass belief in immaterial realities or experiences of the immanent or transcendent nature of the world.

YOGA

- Yoga is a science of life to develop the sixth sense to its fullness and to enable and equip man to enjoy peaceful and blissful life. It is essentially an art of understanding all about the soul, which is one of the life force and realizing its relationship with the body, the society, the world and the universe, maintaining its harmony and finally getting it merged with the universal soul.
- In nature, man is an unique living being in that he alone is gifted with sixth sense. The sixth sense is a higher level of mind which is able to understands its own existence and functions. It is a divine meter measuring all the functions of the universe and understanding oneness among multiplicity and unit in diversity.

Purpose of Yoga

- For the liberation of the soul,
- (i) The attachment with material enjoyments should be neutralized and full
- satisfaction should be achieved, and
- (ii) The impressions of sins should be obliterated.
- In order to attain these two, Soul Consciousness is imperative.
- Yoga provides all the facilities and opportunities for improving the esoteric awareness to get satisfaction with worldly enjoyment and also to obtain detachment and obliterate the impressions of sins by streamlining the activities of the mind.
- Yoga will help man in the performance of all his duties in harmony with the Law of Nature and the sentiments and conventions of the society, enable him to lead a successful life and to achieve satisfaction and peace of sharpening his intellect, cultivating constant awareness and strengthening the will, streamlining the mind and moralizing the behavior. Yoga is a well-balanced and perfect process for success and peace in life.

UNIT II - ENGINEERING ETHICS

"**ENGINEERING ETHICS** is:

- the study of moral issues and decisions confronting individuals and organizations involved in engineering and
- the study of related questions about moral ideals, character, policies and relationships of people and organizations involved in technological activity.

TRAINING IN PREVENTIVE ETHICS

- Stimulating the moral imagination
- Recognizing ethical issues
- Developing analytical skills
- Eliciting a sense of responsibility
- Tolerating disagreement and ambiguity

IMPEDIMENTS TO RESPONSIBILITY

- Self-interest.
- Fear.
- Self-deception.
- Ignorance.
- Egocentric tendencies.
- Microscopic vision.
- Groupthink.

QUESTIONABLE ENGINEERING PRACTICES

- Trimming – "smoothing of irregularities to make data look extremely accurate and precise"
- Cooking – "retaining only those results that fit the theory and discarding others".
- Forging – "inventing some or all of the research data…"
- Plagiarism – misappropriating intellectual property.
- Conflicts of interest (such as accepting gifts.)

– actual

– potential

– apparent

CLEARLY WRONG ENGINEERING PRACTICES

- Lying

- Deliberate deception
- Withholding information
- Failing to adequately promote the dissemination of information
- Failure to seek out the truth
- Revealing confidential or proprietary information
- Allowing one's judgment to be corrupted

SENSES OF EXPRESSION OF ENGG. ETHICS

1. Ethics is an activity and area of inquiry. It is the activity of understanding moral values, resolving moral issues and the area of study resulting from that activity.

2. When we speak of ethical problems, issues and controversies, we mean to distinguish them from non moral problems.

3. Ethics is used to refer to the particular set of beliefs, attitudes and habits that a person or group displays concerning moralities.

4. Ethics and its grammatical variants can be used as synonyms for 'morally correct'.

VARIETIES or APPROACHES OF MORAL ISSUES

MICRO-ETHICS emphasizes typically everyday problems that can take on significant proportions in an engineer's life or entire engineering office.

MACRO-ETHICS addresses societal problems that are often shunted aside and are not addressed until they unexpectedly resurface on a regional or national scale.

MORAL PROBLEMS IN ENGINEERING *(SOME EXAMPLES)*

4.1. An inspector discovered faulty construction equipment and applied a violation tag, preventing its use. The supervisor, a construction manager viewed the case as a minor abrasion of the safety regulations and ordered the removal of the tag to speed up the project. When the inspector objected to this, he was threatened with disciplinary action.

4.2. An electric utility company applied for a permit to operate a nuclear power plant. The licensing agency was interested in knowing what emergency measures had been established for humans safety in case of reactor malfunctioning. The utility engineers described the alarm system and arrangements with local hospitals for treatment. They did not emphasize that this measures applied to plant personnel only and that they had no plans for the surrounding population. When enquired about their omission, they said it was not their responsibility.

4.3. A chemical plant dumped wastes in a landfill. Hazardous substances found their way into the underground water table. The plant's engineers were aware of the situation but did not change the method of disposal because their competitors did it the same cheap way, and no law explicitly forbade the practice.

4.4. Electronics Company ABC geared up for production of its own version of a popular new item. The product was not yet ready for sale, but even so, pictures and impressive specifications appeared in advertisements. Prospective customers were led to believe that it was available off the shelf and were drawn away from competing lines.

TYPES OF INQUIRIES

1. NORMATIVE INQUIRY

These are about 'what ought to be' and 'what is good'. These questions identify and also justify the morally desirable norms or standards.

Some of the questions are:

A. How far engineers are obligated to protect public safety in given situations?

B. When should engineers start whistle blowing on dangerous practices of their employers?

C. Whose values are primary in taking a moral decision, employee, public or govt?

D. Why are engineers obligated to protect public safety?

E. When is govt justified in interfering on such issues and why?

2. CONCEPTUAL INQUIRY:

These questions should lead to clarifications on concepts, principles and issues in ethics. Examples are:

A) What is 'SAFETY' and how is it related to 'RISK'

B) 'Protect the safety, health and welfare of public'-What does this statement mean?

C) What is a bribe?

D) What is a 'profession' and who are 'professionals'?

3. FACTUAL (DESCRIPTIVE) INQUIRIES

These are inquiries used to uncover information using scientific techniques. These inquiries get to information about business realities, history of engineering profession, procedures used in assessment of risks and engineers psychology.

Why study ENGINEERING ETHICS

ENGINEERING ETHICS is a means to increase the ability of concerned engineers, managers, citizens and others to responsibly confront moral issues raised by technological activities.

MORAL DILEMMMA

There are three types of complexities.

1,. VAGUENESS: This complexity arises due to the fact that it is not clear to individuals as to which moral considerations or principles apply to their situation.

2. CONFLICTING REASONS: Even when it is perfectly clear as to which moral principle is applicable to one's situation, there could develop a situation where in two or more clearly applicable moral principles come into conflict.

3. DISAGREEMENT: Individuals and groups may disagree how to interpret, apply and balance moral reasons in particular situations.

Steps in confronting MORAL DILEMMAS:

i) Identify the relevant moral factors and reasons.

ii) Gather all available facts that are pertinent to the moral factors involved.

iii) Rank the moral considerations in the order of their importance as they apply to the situation.

iv) Consider alternative course of action, tracing the full implications of each, as ways of solving dilemma.

v) Talk with colleagues, seeking the suggestions and perspectives of the dilemma.

vi) Arrive at a carefully reasoned judgment by weighing all the relevant moral factors and reasons in light of facts.

MORAL AUTONOMY

- This is viewed as the skill and habit of thinking rationally about ethical issues on the basis of moral concerns independently or by self-determination.
- Autonomous individuals think for themselves and do not assume that customs are always right.
- They seek to reason and live by general principles.
- Their motivation is to do what is morally reasonable for its own sake, maintaining integrity, self-respect, and respect for others.

One who breaks an unjust law must do so openly, lovingly, and with a willingness to accept the penalty. I submit that an individual who breaks a law that conscience tells him is unjust and willingly accepts the penalty… is in reality expressing the highest respect for the law." Rev. Martin Luther King, Jr. in Letter from a Birmingham Jail, 1963.

A person becomes morally autonomous by improving various practical skills listed below:

i) Proficiency is recognizing moral problems and issues in engineering.

ii) Skill in comprehending, clarifying and critically assessing arguments on opposing sides of moral issues.

iii) The ability to form consistent and comprehensive viewpoints based upon consideration of relevant facts.

iv) Awareness of alternate responses to issues and creative solutions for practical difficulties.

v) Sensitivity to genuine difficulties and subtleties

vi) Increased precision in the use of a common ethical language necessary to express and also defend one's views adequately.

vii) Appreciation of possibilities of using rational dialogue in resolving moral conflicts and the need for tolerance of differences in perspective among orally reasonable people.

viii) A sense of importance of integrating one's professional life and personal convictions i.e. maintaining one's moral integrity.

KOHLBERG'S THEORY

STAGES OF MORAL DEVELOPMENT

- Pre-conventional Level

Whatever benefits oneself or avoids punishment. This is the level of development of all young children. -Avoid punishment & Gain Reward

- Conventional Level

Uncritical acceptance of one's family, group or society are accepted as final standard of morality. Most adults do not mature beyond this stage. -1.Gain Approval & Avoid Disapproval & 2. Duty & Guilt

- Post-conventional Level

Motivation to do what is morally reasonable for its own sake, rather than solely from ulterior motives, with also a desire to maintain their moral integrity, self-respect and the respect of other autonomous individuals. They are 'Morally autonomous' people. -1. Agreed upon rights & 2. Personal moral standards

GILLIGAN'S THEORY

- Pre-conventional Level

This is the same as Kohlberg's first level in that the person is preoccupied with self centered reasoning, caring for the needs and desires of self.

- Conventional

Here the thinking is opposite in that, one is preoccupied with not hurting others and a willingness to sacrifice one's own interests in order to help or nurture others (or retain friendship).

- Post-conventional Level

Achieved through context-oriented reasoning, rather than by applying abstract rules ranked in a hierarchy of importance. Here the individual becomes able to strike a reasoned balance between caring about other people and pursuing one's own self-interest while exercising one's rights.

Differences between the TWO THEORIES

KOHLBERG	GILLIGAN
Ethics of rules and rights	Ethics of care
Studies based on well educated, white male's only, tending male bias.	Studies included females and colored peoples
Application of abstract rules ranked in the order of importance	Application of context-oriented reasoning.
Studies were hypothesized for both the genders even though the study was conducted mostly on males	Study was conducted on both genders and it was found, men based their reasoning on 'justice' and women based theirs on 'care'

HEINZ'S DILEMMA

The famous example used by Kohlberg was called "Heinz's dilemma". A woman living in Europe would die of cancer unless she was given an expensive drug. Her husband, Heinz, could not afford it. But the local pharmacist, who had invented the drug at only one tenth of the sale price refused to sell it to Heinz who could only raise half the required money from borrowings. Desperation drives Heinz to break into the pharmacy and steal the drug to save his wife.

When respondents were asked whether and why Heinz should or should not steal a drug to save his wife from a life-threatening illness. The responses of the individuals were compared with a prototypical response of individuals at particular stages of moral reasoning. Kohlberg noted that irrespective of the level of the individual the response could be same, but the reasoning could be different.

For example, if a child reasoning at a 'preconventional' level might say that it is not right to steal because it is against law and someone might see you.

At a 'conventional' level, an individual might argue that it is not right to steal because it is against law and laws are necessary for society to function.

At a 'postconventional' level, one may argue that stealing is wrong because is against law and it is immoral.

CONSENSUS AND CONTROVERSY

CONTROVERSY:

- All individuals will not arrive at same verdict during their exercising their moral autonomy.
- Aristotle noted long ago that morality is not as precise and clear-cut as arithmetic.
- Aim of teaching engg ethics is not to get unanimous conformity of outlook by indoctrination, authoritarian and dogmatic teaching, hypnotism or any other technique but to improve promotion of tolerance in the exercise of moral autonomy.

CONSENSUS:

The conductor of a music orchestra has authority over the musicians and his authority is respected by them by consensus as otherwise the music performance will suffer. Hence the authority and autonomy are compatible.

On the other hand, tension arises between the needs for autonomy and the need for concerns about authority. The difference between the two should be discussed openly to resolve the issue to the common good.

PROFESSIONS AND PROFESSIONALISM

Engineers normally imagine that they are servants to organizations rather than a public guardian. Responsibility to the public is essential for a professional.

Who is a professional?

- Obviously a member of a profession.

What is a profession?

'JOB' or 'OCCUPATION' that meets the following criteria from which a person earns his living.

- Knowledge – Exercise of skills, knowledge, judgment and discretion requiring extensive formal criteria.
- Organization - special bodies by members of the profession to set standard codes of ethics,
- Public good-The occupation serves some important public good indicated by a code of ethics.

Who is a professional engineer?

- Has a bachelor's degree in engineering from an accredited school
- Performs engineering work
- Is a registered and licensed Professional Engineer
- Acts in a morally responsible way while practicing engineering

Differing views on Professionals

"Only consulting engineers who are basically independent and have freedom from coercion can be called as professionals." -Robert L.Whitelaw

"Professionals have to meet the expectations of clients and employers. Professional restraints are to be imposed by only laws and government regulations and not by personal conscience." -Samuel Florman

"Engineers are professionals when they 1) attain standards of achievement in education, job performance or creativity in engineering and 2) accept the most basic moral responsibilities to the public as well as employers, clients, colleagues and subordinates." -Mike Martin & Roland Schinzinger

MOTIVES FOR PROFESSIONALISM

- A desire for interesting and challenging work and the pleasure in the act of changing the world.
- The joy of creative efforts. Where a scientist's interest is in discovering new technology, engineers interest is derived from creatively solving practical problems.
- The engineer shares the scientist's job in understanding the laws and riddles of the universe.
- The sheer magnitude of the nature – oceans, rivers, mountains and prairies – leads engineers to build engineering marvels like ships, bridges, tunnels, etc., which appeal to human passion.
- The pleasure of being in the presence of machines generating a comforting and absorbing sense of a manageable, controlled and ordered world.
- Strong sense of helping, of directing efforts towards easing the lot of one's fellows.

The main pleasure of the engineer will always be to contribute to the well-being of his fellow-men.

MODELS OF PROFESSIONAL ENGINEERS

1. SAVIOR: The representative engineer is a savior who will redeem society from poverty, inefficiency, waste and the drudgery of manual labour.

2. GUARDIAN: Engineers know, the directions in which and pace at which, technology should develop.

3. BUREAUCRATIC SERVANT: The engineer as the loyal organization person uses special skills to solve problems.

4. SOCIAL SERVANT: Engineers, in co-operation with management, have the task of receiving society's directives and satisfying society's desires.

5. SOCIAL ENABLER AND CATALYST: Engineers play a vital role beyond mere compliance with orders. They help management and society understand their own needs and to make informed decisions.

6. GAME PLAYER: Engineers are neither servants nor masters of anyone. They play by the economic game rules that happen to be in effect at a given time.

TYPES OF ETHICAL THEORIES

S.NO	TYPES	BASED ON
1	Virtue ethics	Virtues and vices
2	Utilitarianism	Most good for most people
3	Duty ethics	Duties to respect persons
4	Rights ethics	Human Rights

VIRTUE ETHICS

Virtue Ethics

- Focuses on the type of person we should strive to be
- Actions which reflect good character traits (virtues) are inherently right
- Actions which reflect bad character traits (vices) are inherently wrong
- Virtue ethics are tied more to individual behavior than to that of an organization (e.g. business, government)

Virtue	Too much	Too less
(Golden mean between extremes)		
Courage	Foolhardiness	Cowardice
Truthfulness	Revealing all in violation of tact and confidentiality	Being secretive or lacking in candor
Generosity	Wasting one's resources	Being miserly
Friendliness	Being annoyingly effusive	Sulky or surly

PROFESSIONAL RESPONSIBILITY

- Being morally responsible as a professional.
- Most basic and comprehensive professional virtue.
- Creation of useful and safe technological products while respecting the autonomy of clients and public, especially in matters of risk taking.

This encompasses a wide variety of the more specific virtues grouped as follows:

1. SELF DIRECTION VIRTUES:

Fundamental virtues in exercising our moral autonomy and responsibility. e.g. self understanding, humility, good moral judgment, courage, self discipline, perseverance, commitments, self-respect and dignity

2. PUBLIC SPIRITED VIRTUES:

Focusing on the good of the clients and public affected by the engineers' work by . not directly and intentionally harming others i.e. 'nonmaleficence'.

Benificence, sense of community, generosity are other virtues falling in this category.

3. TEAMWORK VIRTUES:

Enables professionals to work successfully with others. E.g. collegiality, cooperativene ss, the ability to communicate, respect for authority, loyalty to employers and leadership qualities.

4. PROFICIENCY VIRTUES:

Mastery of one's craft that characterize good engineering practice e.g. competence, diligence, creativity, self-renewal through continuous education.

MORAL INTEGRITY

Moral integrity is the unity of character on the basis of moral concern, and especially on the basis of honesty. The unity is consistency among our attitudes, emotions and conduct in relation to justified moral values.

SELF-RESPECT

1. Valuing oneself in morally appropriate ways.

2,. Integral to finding meaning in one's life and work

3. A pre-requisite for pursuing other moral ideals and virtues.

4. Self-respect is a moral concept of properly valuing oneself but self-esteem is a psychological concept of positive attitude towards oneself.

Self-respect takes two forms.

1. Recognition self-respect is properly valuing oneself because of one's inherent moral worth, the same worth that every other human being has.

2. Appraisal self-respect is properly valuing ourselves according to how well we meet moral standards and our personal ideals.

VARIOUS SENSES OF RESPONSIBILITY

Responsibility ascribed by i) virtue, ii) obligations, iii) general moral capacities of people, iv) liabilities and accountability for actions and v) blameworthiness or praiseworthiness.

1. By virtue: A person is said to be a responsible person when we ascribe a moral virtue to the person. We expect that the person is regularly concerned to do the right thing, is conscientious and diligent in meeting obligations. In this sense, professional responsibility is the central virtue of engineers.

2. By obligation: Moral responsibilities can be thought of as obligations or duties to perform morally right acts.

3. By general moral capacity: When we view a person as a whole rather than one with respect to a specific area, we are actually thinking about the active capacity of the person for knowing how to act in morally appropriate ways e.g. the capacity of children grow as they mature and learn.

4. By accountability: Responsibility also means being accountable, answerable or liable to meet particular obligations. The virtue of professional responsibility implies a willingness to be accountable for one's conduct.

5. By being blameworthy: When accountability for a wrongdoing is at issue, responsible becomes a synonym for blameworthy. When right conduct is the issue, the context is praiseworthiness

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CAUSAL AND LEGAL RESPONSIBILITIES

Causal Responsibility: consists simply in being a cause of some event. E.g. lightning as being responsible for a house catching fire.

Legal Responsibility: consists simply in being a cause for harm that was so unlikely and also unforeseeable that no moral responsibility is involved.

UTILITARIANISM

- That which produces the maximum benefit for the greatest number of people (e.g. Democracy)
- Tries to achieve a balance between the good and bad consequences of an action
- Tries to maximize the well-being of society and emphasizes what will provide the most benefits to the largest group of people
- This method is fundamental to many types of engineering analysis, including risk-benefit analysis and cost-benefit analysis

Drawbacks:

1. Sometimes what is best for the community as a whole is bad for certain individuals in the community

2. It is often impossible to know in advance which decision will lead to the most good

Organizing Principles to Resolving Ethical Issues

3. Utilitarian thinking

– a standard that promotes those individual actions or rules that produce the greatest total amount of utility to those affected.

– A code that enjoins engineers to promote the safety, health, and welfare of the public.

2. Preference utilitarianism

– promote those conditions that allow each individual to pursue happiness as he or she conceives it.

– Two conditions necessary for this: freedom and well-being.

– Practically, for engineers, this advocates cost/benefit analyses.

Problems with Utilitarianism

- Difficult to quantify benefits for ALL those affected.
- "Greatest good" difficult to apply to an all-inclusive population.
- Someone gets "shafted" – approach justifies perpetrating injustice on individuals, i.e., someone gets left out.
- Three approaches:

1. Cost/benefit – quantifiable approach. Maximize positive utilities (benefits) against negative utilities (costs).

2. Act utilitarian – "Will the course of action produce more good than any alternative course of action that I could take"?

3. Rule utilitarian – "Would utility be maximized if everyone did the same thing in the same circumstances"? Adoption of commonly accepted rules.

1. COST-BENEFIT ANALYSIS:

1. Assess the available options

2. Assess the costs and benefits of each option for the entire audience affected

3. Make the decision that is likely to result in the greatest benefit relative to cost.

2. ACT-UTILITARIANISM:

(professed by John Stuart Mills)

1. Focuses on individual actions, rather than general rules.

2. An act is right if it is likely to produce the most good for the most people involved in the particular situation.

3. Rules may be broken whenever doing so will produce the most good in a specific situation.

4 Happiness is the only 'intrinsic' good and all others are 'instrumental' goods that serve as the means of happiness.

3. RULE-UTILITARIANISM:

(professed by Richard Brandt)

1. This regards moral values as primary.

2. We should follow the rules and avoid bribes, even when those acts do not have the best consequences in a particular situation, because the general practice of following rules and not bribing produce the most overall good

3. Rules should be considered in sets called 'moral codes'. A moral code is justified when followed, would maximize the public good more than alternative codes would.

DUTY ETHICS (Immanuel Kant's view)

Contends that certain acts (or duties) should be performed because they are inherently ethical such as:

- be honest,
- keep promises,
- do not inflict sufferings on other people,
- be fair,
- make reparation when you have been unfair,
- how gratitude for kindness extended by others
- seek to improve own intelligence and character,
- develop one's talents,
- don't commit suicide.
- Duties, rather than good consequences, is fundamental.
- Individuals who recognize their ethical duties will choose ethically correct moral actions

These duties should meet Kant's 3 conditions i.e.

1. It should express respect for persons,

- People deserve respect because they have capacity to be autonomous and for exercising goodwill.

- Goodwill is the conscientious and honest effort to do what is right according to universal principles of duties.
- Moral motives and intentions play a prominent role in duty ethics rather than utilitarianism.

2. It is an universal principle

- Duties are binding on us only if they are applicable to everyone. They must be universalisable.

3.It expresses command for autonomous moral agents. Duties prescribe certain actions categorically, without qualifications or conditions attached. Valid principles of duties are Categorical Imperatives. They contrast with non-moral commands called Hypothetical Imperatives which are conditional.

The above → 'RESPECT for PERSONS'

<u>Drawback of Kant's duty ethics:</u> It has failed to be sensitive to how principles of duty can conflict with each other thereby creating Moral dilemmas.

Rawls Development on Kant's Duty Ethics

Rawls argues that all rational people would agree to abide by two basic moral principles:

1. Each person is entitled to the most extensive amount of liberty compatible with an equal amountfor others and

2. Differences in social power and economic benefits are justified only when they are likely to benefit everyone, including members of most disadvantaged groups.

<u>RIGHTS ETHICS (JOHN LOCKE – 1632-1704)</u>

- Everyone has inherent moral rights
- Everyone has rights that arise from EXISTING (i.e. right to Life, maximum individual Liberty, and human Dignity are Fundamental Rights).
- Other rights arise as a Consequence.
- Duties arise because people have rights, not vice versa.
- Any act that violates an individual's moral rights is ethically unacceptable.
- Rights ethics was highly individualistic.
- Rights are primarily entitlements that prevent other people from meddling in one's life. These are referred to as Liberty Rights or Negative Rights that place duties on other people not to interfere with one's life.

e.g. Individuals do not have rights to life because others have duties not to kill them. Instead, possessing the right to life is the reason why others ought not to kill them.

<u>Drawbacks</u>

- How do we prioritize the rights of different individuals?
- Rights ethics often promote the rights of individuals at the expense of large groups/society

A.I.Melden's version of Rights Ethics

- Human rights are intimately related to communities of people.
- This version is known as POSITIVE WELFARE RIGHTS and is defined as rights to community benefits for living a minimally decent human life.

EVALUATION OF ETHICAL THEORIES

We are basically not interested in which of the ethical theories is the best. It is believed that there are areas in which each theory complements others by how they differ.

Procedure for General Evaluation:

1. The theory must be clear and formulated with concepts that are coherent and applicable.
2. It must be internally consistent in that none of its tenets contradicts any other.
3. Neither the theory nor its defense can rely upon false information.
4. It must be sufficiently comprehensive to provide guidance in specific situations of interest to us.
5. It must be compatible with our most carefully considered moral convictions about concrete situations.

CUSTOMS and ETHICAL RELATIVISM

Relativism:

- Distinction between "morals" ("treatment of others") and "mores" ("harmless customs")

Cultural (Descriptive) Relativism:

- Factual Claims: "x is considered right in society y at time t" and "is considered wrong in society z at time t"
- Empirical Conclusion: Moralities are relative
- This is either true or false (anthropology –a study of mankind , its customs, beliefs, etc.can figure it out)

Normative (Ethical) Relativism:

- Normative Claim: "What is considered right in society x at time t is right for that society"
- A particular culture cannot be judged from outside of that culture.
- 'Ethical Relativism' says that actions are morally right when they are approved by law and custom.

- They are wrong when they violate laws and custom.

- Ethical egoism tries to reduce moral reasons to matters of self interest, 'ethicalrelativism' attempts to reduce moral values to laws, conventions and customs of particular societies.

Consequences of Normative Relativism

- We cannot say other "morals" are inferior to our own society's

- We decide the value of our actions based only on what our particular society thinks

- We should show a lot of tolerance for different customs and outlooks in a society in which we live in. It means that customs can have moral significance in deciding how we should act. This view is called 'ethical pluralism'.

Reasons for Acceptance Of Ethical Relativism

The reasons professed for acceptance of ethical relativism is threefold.

1. Laws seem so tangible and clear-cut. They provide a public way ending seemingly endless disputes about rights and wrongs. But many times, moral reasons seem to be at variance with laws e.g. apartheid laws.

2. Moral standards vary dramatically from one culture to another. The only kind of objectivity possible is limited to a given set of laws in a given society. Acknowledging this relativity of morality encourages the virtue of tolerance of differences among societies.

3. Moral judgments should be made in relation to factors that from case to case, usually making it impossible to formulate rules which are simple. Customs and laws are usually morally relevant factors that should be taken into account.

RELIGION and DIVINE COMMAND ETHICS

Ethics and Religion:

Moral issues and religious belief are related in several positive ways.

- First, they are shaped over time from the central moral values of major world religions.

- Second, religious views often support moral responsibility by providing additional motivation for being moral.

- Third, sometimes religions set a higher moral standard than is conventional.

- Societies often benefit from a variety of religions that make prominent particular virtues, inspiring their members to pursue them beyond what is ordinarily seen as morally obligatory.

Divine Command Ethic:

- This says that an act which is right is commanded by god and the one which is wrong is forbidden by God.

- The difficulty in this is to know precisely what God's commands are and in knowing whether God exists.

We can view that moral reasons are not reducible to religious matters, although religious belief may provide an added inspiration for responding to them.

Uses Of Ethical Theories

1. Ethical theories aid in identifying the moral considerations or reasons that constitute a dilemma.

2. They provide a precise sense of what kinds of information are relevant to solving moral development.

3. They sometimes, offer ways to rank the relevant moral considerations in order of importance and provide a rough guidance in solving moral problems.

4. The theories help us identify the full moral ramifications of alternative courses of action, urging a wide perspective on the moral implications of the options and providing a systematic framework of comparing alternatives.

5. The theories augment the precision with which we use moral terms and they provide frame works for moral reasoning when discussing moral issues with colleagues..

UNIT – III

ENGINEERING AS SOCIAL EXPERIMENTATION

ENGINEERING AS EXPERIMENTATION

Experimentation plays an important role in the process of designing the product. When it is decided to change a new engineering concept into its first rough design, preliminary tests or simulation should be conducted. Using formal experimental methods, the materials and methods of designing are tried out. These tests may be based on more detailed designs. The test for designing should be evolved till the final product produced. With the help of feedback of several tests, further modification can be made if necessary. Beyond these tests and experiments, each engineering project has to be viewed as an experiment.

Similarities to Standard Experiments

There are so many aspects, which are of virtual for combining every type of engineering works to make it suitable to look at engineering projects as experiments. The main three important aspects are:

1) Any engineering project or plan is put into practice with partial ignorance because while designing a model there are several uncertainities occurred. The reason to the fact that engineers don't have all the needed facts available well in advance before starting the project. At some point, both the theoretical examining and the laboratory testing must be by-passed for the sake of completing the project. Really, the success of an engineer is based on the his talent which is exactly being the ability to succeed in achieving jobs with only a partial knowledge of scientific laws about the nature and society.

2) The final outcomes of engineering projects are generally uncertain like that of experiments what we do.

In engineering, in most of the cases, the possible outcomes may not be known and even small and mild projects itself involve greater risks.

The following uncertainities occur in the model designs

1. Model used for the design calculations
2. Exact characteristics of the material purchased.
3. Constancies of materials used for processing and fabrication.
4. About the nature of the pressure the finished product will encounter.

For instance, a reservoir may cause damage to the surroundings and affect the eco-system. If it leaks or breaks, the purpose will not be served. A special purpose fingerprint reader may find its application in the identification and close observation on the disagreeing persons with the government. A nuclear reactor may cause unexpected problems to the surrounding population leading to a great loss to the owners. A hair dryer may give damage to the unknowing or wrong users from asbestos insulation from its barrel.

3) Good and effective engineering depends upon the knowledge possessed about the products at the initial and end stages.

This knowledge is very useful for increasing the effectiveness of the current products as well as for producing better products in future. This can be achieved by keenly observing on the engineering jobs by the way of experimentation. This monitoring is done by making periodic observations and tests by looking at for the successful performance and the side effects of the jobs. The tests of the product's efficiency, safety, cost-effectiveness, environmental impact and its value that depends upon the utility to the society should also be monitored. It also extends to the stage of client use.

Learning from the past

It has been expected that the engineers have to learn not only form their own design and the production system but also the results of others. Due to lack of communication, prejudiced in not asking for clarification, fear of law and also mere negligence, these things can happen to the continuation of past mistakes. The following are some of the examples:

1. The tragedy of 'Titanic' happened because of the sufficient number of life boats. The same disaster took place in the steamship "the Arctic" some years before, because of the same problem.
2. The fall down of "the Sunshine Skyline Bridge" in the bay of Thamba at Sweden in 1980, on a moving ship due to improper matching of horizontal impact forces in mind. This could have been avoided of the engineers had known about the striking of the ships with the Maracaibo Bridge at Venezulea in 1964 and the Tasman Bridge of Australia in 1975.
3. The nuclear reactor accident at Three Mile Island on March 1979, was due to malfunctioning of the valves. Valves though minute items, are being among the least reliable components of hydraulic systems. It was a pressure relief valve and lack of information about its opening or closing state contributed to a nuclear reactor accident at Three Mile Island. This malfunction was already happened because of the same reasons at other locations.
4. The disaster of Tettron Dam in Los Angles was due to rapid flow of water and sudden break down. The builder didn't consider the case of the Fontenelle Dam, which was also collapsed due to the same problem.

So, to say that engineers should not fully depend on handbooks and they should have some review of the past cases relating to their current task.

Comparisons with standard Experiments

Engineering is entirely different from standard experiments in few aspects. Those differences are very much helpful to find out the special responsibilities of engineers and also help them in knowing about the moral irresponsibilities which are involved in engineering.

1. **Experimental Control**

Members for two groups should be selected in a standard experimental control, i.e Group A and Group B. The members of the group 'A' should be given the special experimental treatment. The group 'B' do not receive the same though they are in the same environment. This group is called the ***'control group'***

Though it is not possible in engineering but for the projects which are confirmed to laboratory experiments. Because, in engineering the experimental subjects are human beings who are out of the control of the experimenters. In engineering, the consumers have more control as they are the selecting authority of a project. So in engineering it is impossible to follow a random selection. An engineer has to work only with the past data available with various groups who use the products.

So engineering can be viewed as a natural experiment which uses human subjects. But today, most of the engineers do not care for the above said Experimental Control.

2. **Informed Consent**

Engineering is closely related to the medical testing of new drugs and techniques on human beings as it also concerned with human beings.

When new medicines have been tested, it should be informed to the persons who undergo the test. They have moral and legal rights to know about the fact which is based on **"informed consent"** before take part in the experiment. Engineering must also recognize these rights. When a producer sells a new product to a firm which has its own engineering staff, generally there will be an agreement regarding the risks and benefits form that testing.

Informed consent has two main principles such as knowledge and voluntariness.

First, the persons who are put under the experiment has to be given all the needed information to make an appropriate decision. Second, they must enter into the experiment without any force, fraud and deception. The experimenter has also to consider the fundamental rights of the minorities and the compensation for the harmful effects of that experiment.

In both medicine and engineering there may be a large gap between the experimenter and his knowledge on the difficulties of an experiment. This gap can be filled only when it is possible to give all the relevant information needed for drawing a responsible decision on whether to participate in the experiment or not.

In medicine, before prescribing a medicine to the patient, a responsible physician must search for relevant information on the side effects of the drug. The hospital management must allow him to undergo different treatments to different patients and finally the patient must be ready to receive that information from the physician. Similarly it is possible for an engineer to give relevant information about a product only when there is a better co-operation by the management and quick acceptance from the customers.

The following conditions are essential for a valid informed consent

a. The consent must be given voluntarily and not by any force.

b. The consent must be based on the relevant information needed by a rational person and should be presented in a clear and easily understandable form.

c. The consenter must be capable of processing the information and to make rational decisions in a quick manner.

d. The information needed by a rational person must be stated in a form to understand without any difficulty and has to be spread widely.

e. The experimenter's consent has to be offered in absentia of the experimenter by a group which represents many experiments.

Knowledge Gained

Scientific experiments have been conducted to acquire new knowledge. Whereas engineering projects are conducted as experiments not for getting new knowledge. Suppose the outcomes of the experiment is best, it tells us nothing new, but merely affirms that we are right about something. Mean while, the unexpected outcomes put us search for new knowledge.

ENGINEERS AS RESPONSIBLE EXPERIMENTERS

The engineers have so many responsibilities for serving the society.

1. A primary duty is to protect the safety of human beings and respect their consent. [A conscientious commitment to live by moral values].
2. Having a clear awareness of the experimental nature of any project, forecasting of its possible side effects, and an effort to monitor them comprehensive perspective or relative information].
3. Unrestricted free personal involvement in all the steps of a project.
4. Being accountable for the results of a project [Accountability]
5. Exhibiting their technical competence and other characteristics of

Conscientiousness

Conscientiousness implies consciousness (sense of awareness). As holding the responsible profession with maintaining full range moral ethics and values which are relevant to the situation. In order to understand the given situation, its implications, know-how, person who is involved or affected, Engineers should have open eyes, open ears and open mind.

The present working environment of engineers, narrow down their moral vision fully with the obligations accompanied with the status of the employee. More number of engineers are only salaried employees, so, they have to work within large bureaucracies under great pressure to work smoothly within the company. They have to give importance only to the obligations of their employers. Gradually, the small negative duties such as not altering data by fraud, not violating patent right and not breaking confidentiality, may be viewed as the full extent of moral desire.

As mentioned, engineering as social experimentation brings into light not only to the person concerned but also to the public engineers as guardians of the public interest i.e., to safeguard the welfare and safety of those affected by the engineering projects. This view helps to ensure that this safety and welfare will not be affected by the search for new knowledge, the hurry to get profits, a small and narrow follow up of rules or a concern over benefits for the many and ignoring the harm to the few.

The social experimentation that involved in engineering should be restricted by the participants consent.

Relevant Information

Without relevant factual information, conscientious is not possible. For showing moral concern there should be an obligation to obtain and assess properly all the available information related to the fulfillment of one's moral obligations. This can be explained as:

1) To understand and grasp the circumstance of a person's work, it is necessary to know about how that work has a moral importance. For example, A person is trying to design a good heat exchanger. There is nothing wrong in that. But at the same time, if he forgets the fact that the heat exchanger will be used in the manufacture of an illegal product, then he is said to be showing a lack of moral concern. So a person must be aware of the wider implication of his work that makes participation in a project.
2) Blurring the circumstance of a person's work derived from his specialization and division of labour is to put the responsibilities on someone else in the organization. For example if a company produces items which are out of fashion or the items which promotes unnecessary energy wastage, then it is easy to blame sales department.

The above said means, neglecting the importance of a person's works also makes it difficult in acquiring a full perspective along a second feature of factual information i.e., consequence of what one does.

So, while giving regard to engineering as social experimentation, points out the importance of circumstances of a work and also encourage the engineers to view his specialized activities in a project as a part of a large social impact.

Moral Autonomy

This refers to the personal involvement in one's activities. People are morally autonomous only when their moral conduct and principles of actions are their own i.e., genuine in one's commitment to moral values.

Moral beliefs and attitudes must be integrated into an individual's personality which leads to a committed action. They cannot be agreed formally and adhered to merely verbally. So, the individual principles are not passively absorbed from others. When he is morally autonomous and also his actions are not separated from himself.

When engineering have seen as a social experimentation, it helps to keep a sense of autonomous participation in a person's work. An engineer, as an experimenter, is undergoing training which helps to form his identity as a professional. It also results in unexpected consequence which helps to inspire a critical and questioning attitudes about the current economic and safety standards. This also motivates a greater sense of personal involvement in a person's work.

Accountability

The people those who feel their responsibility, always accept moral responsibilities for their actions. It is known as accountable. In short, 'accountable' means being culpable and hold responsible for faults. In general and to be proper, it means the general tendency of being willing to consider one's actions to moral examinations and be open and respond to the assessment of others. It comprises a desire to present morally convincing reasons for one's conduct when called upon in specific circumstances.

The separation of causal influence and moral accountability is more common in all business and professions and also in engineering. These differences arising from several features of modern engineering practices are as follows:

1. Large – scale engineering projects always involve division of work. For each and every piece of work, every person contributes a small portion of their work towards the completion of the project. The final output us transmitted from one's immediate work place to another causing a decrease in personal accountability.
2. Due to the fragmentation of work, the accountability will spread widely within an organization. The personal accountability will spread over on the basis of hierarchies of authority.
3. There is always a pressure to move on to a different project before finishing the current one. This always leads to a sense of being accountable only for fulfilling the schedules.
4. There is always a weaker pre-occupation with legalities. In other words this refers to a way a moral involvement beyond the laid down institutional role. To conclude, engineers are being always blamed for all the harmful side effects of their projects. Engineers cannot separate themselves from personal responsibilities for their work.

CODES OF ETHICS

The codes of ethics have to be adopted by engineering societies as well as by engineers. These codes exhibit the rights, duties, and obligations of the members of a profession. Codes are the set of laws and standards.

A code of ethics provides a framework for ethical judgment for a professional. A code cannot be said as totally comprehensive and cover all ethical situations that an engineer has to face. It serves only as a starting point for ethical decision-making. A code expresses the circumstances to ethical conduct shared by the members of a profession. It is also to be noted that ethical codes do not establish the new ethical principles. They repeat only the principles and standards that are already accepted as responsible engineering practice. A code defines the roles and responsibilities of professionals.

Roles of codes and its functions

1. **Inspiration and Guidance**

Codes give a convinced motivation for ethical conduct and provide a helpful guidance for achieving the obligations of engineers in their work. Codes contribute mostly general guidance as they have to be brief. Specific directions may also be given to apply the code in morally good ways. The following engineering societies have published codes of ethics.

AAES - American Association of Engineering Societies

ABET - Accreditation Board for Engineering and Technology (USA) NSPE

- National Society of Professional Engineer (USA)

IEEE - Institute of Electrical and Electronics Engineering (USA) AICTE

- All India Council for Technical Education (India)

Most of the technological companies have established their own codes such as pentagon (USA), Microsoft etc. These codes are very much helpful to strengthen the moral issues on the work of an engineer.

2. **Support**
   Codes always support an engineer who follows the ethical principles. Codes give engineers a positive, a possible good support for standing on moral issues. Codes also serve as a legal support for engineers.
3. **Deterrence and Discipline**
   Codes act as a deterrent because they never encourage to act immorally. They also provide discipline among the Engineers to act morally on the basis of codes does not overrule the rights of those being investigated.
4. **Education and Mutual Understanding**
   Codes have to be circulated and approved officially by the professionals, the public and government organizations which concern with the moral responsibilities of engineers and organizations.
5. **Contributing to the profession's Public Image**
   Codes help to create a good image to the public of an ethically committed profession. It helps the engineers in an effective manner to serve the public. They also

gives self-regulation for the profession itself.

6. **Protecting the Status Quo**

   Codes determine ethical conventions which help to create an agreed upon minimum level of ethical conduct. But they can also suppress the disagreement within the profession.

7. **Promoting Business Interests**

   Codes help to improve the business interests. They help to moralize the business dealings to benefit those within the profession.

Limitations of Codes

1. Codes are restricted to general and vague wordings. Due to this limitation they cannot be applicable to all situations directly. It is also impossible to analyze fully and predict the full range of moral problems that arises in a complex profession.
2. Engineering codes often have internal conflicts. So they can't give a solution or method for resolving the conflict.
3. They cannot be treated as the final moral authority for any professional conduct. Codes represent a compromise between differing judgments and also developed among heated committee disagreements.
4. Only a few practicing engineers are the members of Professional Societies and so they can not be compelled to abide by their codes.
5. Many engineers who are the members of Professional Societies are not aware of the existence of the codes of their societies and they never go through it.
6. Codes can be reproduced in a very rapid manner.
7. Codes are said to be coercive i.e., implemented by threat or force.

A BALANCED OUTLOOK ON LAW

A balanced outlook on laws stresses the necessity of laws and regulations and their limitations in directing engineering practice.

In order to live, work and play together in harmony as a society, there must be a balance between individual needs and desires against collective needs and desires. Only ethical conduct can provide such a balance. This ethical conduct can be applied only with the help of laws. Laws are important as the people are not fully responsible and because of the competitive nature of the free enterprise system which does not encourage moral initiative.

The model of engineering as social experimentation allows for the importance of clear laws to be effectively enforced.

Engineers ought to play an effective role in promoting or changing enforceable rules of engineering as well as in enforcing them. So the codes must be enforced with the help of laws. The following are the two best examples.

1. **Babylon's Building Code: (1758 B.C.)**

This code was made by Hammurabi, king of Babylon. He formed a code for builders of his time and all the builders were forced to follow the code by law. He ordered

"If a builder has built a house for a man and has not made his work sound, and the house which he has built was fallen down and so caused the death of the householder, that builder shall be put to death. If it causes the death of the house holder's son, they shall put that builder's son to death. If it causes the death of the house holder's slave, he shall give slave to the householder. If it destroys property he shall replace anything it has destroyed; and because he has not made the house sound which he has built and it has fallen down, he shall rebuild the house which has fallen down from his own property. If a builder has built a house for a man and does not make his work perfect and the wall bulges, that builder shall put that wall in to sound condition at his own cost".

The above portion of Babylon's building code was respected duly. But the aspects find only little approval today. This code gives a powerful incentive for self- regulation.

2. **The United States Steamboat Code: [1852 A.D]**

Steam engines in the past were very large and heavy. James Watt, Oliver Evans and Richard Trevethik modified the old steam engines by removing condensers and made them compact. Beyond careful calculations and guidelines, explosions of boiler happened on steam boats, because of the high speed of the boats. The safety valves were unable to keep steam pressure up causing explosion. During that period in 18th century, more than 2500 people were killed and 2000 people were injured because of the explosion of boilers in steam boats.

Due to this, the ruling congress in USA passed a law which provided for inspection of the safety aspects of ships and their boilers and engines. But his law turned out to be ineffective due to the corruptions of the inspectors and also their inadequate training regarding the safety checking. Then Alfred Guthiro, an engineer of Illinoise had inspected about 200 steam boats on his own cost and found out the reasons for the boiler explosions and made a report. His recommendations were published by a Senator Shields of Illinoise and incorporated in senate documents. With the help of this, another law was passed. Now it is in the hands of the American Society of Mechanical Engineers who formulated the standards for producing steam boats.

THE CHALLENGER CASE STUDY

The world has known about many number of accidents. Among them the explosion of the space shuttle 'Challenger' is the very familiar one. In those days this case had been reviewed vigorously by media coverage, government reports and transcripts of hearings. This case deals with many ethical issues which engineers faced. It poses many questions before us. What is the exact role of the engineer when safety issues are concern? Who should have the ultimate authority for decision making to order for a launch? Whether the ordering of a launch be an engineering or a managerial decision?

Challenger space shuttle was designed to be a reusable one. The shuttle mainly consisted of an orbiter, two solid propellant boosters and a single liquid-propeller booster. All the boosters was ignited and the orbiter was lifted out the earth. The solid rocket booster was of reusable type. The liquid propellant booster was used to finish the lifting of the shuttle in to the orbit. This was only a part of the shuttle which has been reused.

The accident took place on 28th January 1986, due to the failure of one of the solid boosters. In the design of the space shuttle, the main parts which needed careful design of the fields joints where the individual cylinders were placed together. The assembly mainly consists of tang and clevis joints which are sealed by two O-rings made up of synthetic rubber only, not specifically hat resistant. The function of the O-rings are to prevent the combustion gases of the solid propellant from escaping. The O-rings were eroded by hot gases, but this was not a serious problem, as the solid rocket boosters were only for reuse initially for the few minutes of the flight. If the erosion of the O-rings could be in a controlled mannaer, and they would not completely burnt through, then the design of the joint would be acceptable, however the design of the O-rings in this shuttle was not so.

In the post flight experiment in 1985, the Thiokol engineers noticed black soot and grease on the outside of the boosters due to leak of hot gases blown through the O-rings. This raised a doubt on the resiliency of the materials used for the O-rings. Thiokol engineers redesigned the rings with steel billets to withstand the hot gases. But unfortunately this new design was not ready by that time of flight in 1986.

Before launching, it was necessary to discuss the political environment under which NASA was operating at that time. Because the budget of NASA has decided by Congress. These factors played the main cause for unavoidable delay in the decision to be taken for the shuttle performance, the pressures placed for urgency in launching in 1986 itself, before the launch of RUSSIAN probe to prove to the congress that the program was on processing. The launching date had already been postponed for the availability of vice president GEORGE BUSH, the space NASA supporter. Later further delayed due to a problem in micro switch in the hatch-locking mechanism. The cold weather problem and long discussions went on among the engineers. The number of tele-conferences further delayed the previous testing in 1985 itself. The lowest temperature was 53^{O}F but O-ring temperature during the proposed launch period happened to be only 29 ^{O}F, which was far below the environment temperature at which NASA had the previous trail. Somehow, the major factor that made the revised final decision was that previous trial. Somehow, the major factor that made the revised final decision was that with the available data at that time there seemed to be no correlation between the temperature and the degree at which O-rings had eroded by the blow-by gas in the previous launch. Assuming a safety concern due to cold weather, though the data were not concluded satisfactorily, a decision was taken not to delay further for so many reasons, and the launch was finally recommended.

But unexpectedly the overnight temperature at the time of launch was 8 ^{O}F colder than ever experienced. It was estimated that the temperature of the right hand booster would be only at 28 ^{O}F. The camera noticed a puff of smoke coming out from the field joints as soon as the boosters were ignited. But the O-rings were not positioned properly on their seats due to extreme cold temperature. The putty used as heat resistant material was also too cold that it failed to protect the O-rings. All these effects made the hot gases to burn past both the O- rings, leading to a blow-by over an arc around the O-rings. Though immediately further sealing was made by the by-products of combustion in the rocket propulsion, a glassy oxide formed on the joints. The oxides which were temporarily sealing the field joints at high temperature, later were shattered by the stresses caused by the wind. Again the joints were opened and the hot gases escaped from the solid boosters. But the boosters were attached to the large liquid fuel boosters as per the design. This made the flames due to blow-by from the solid fuel boosters quickly to burn through the external tank. This led to the ignition of the liquid propellant making the shuttle exploded.

Later the accident was reviewed and investigations were carried out by the number of committees involved and by various government bodies. President Regan appointed a commission called Rogers Commission which constituted many distinguished scientists and engineers. The eminent scientists in the commission after thorough examination and investigations gave a report on the flexibility of the material and proved that the resiliency of the material was not sufficient and drastically reduced during the cold launch.

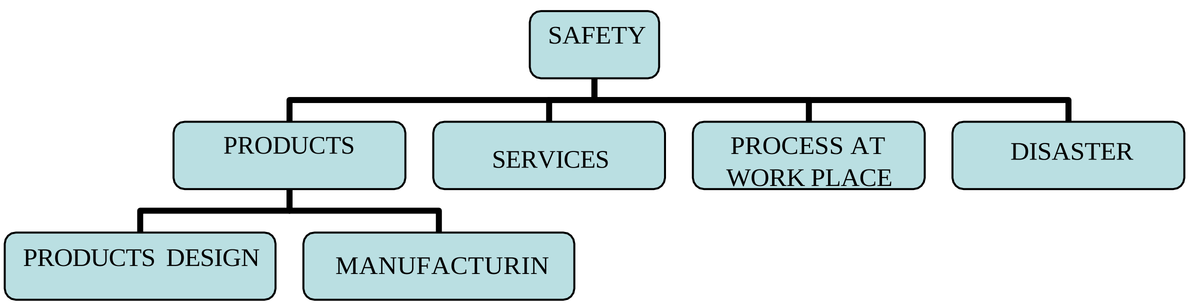
As the result of commission hearings, a lot of controversial arguments went on among the Thiokol engineers. Thiokol and NASA investigated possible causes of the explosion. Mr.Boisjoly, the main member in the investigation team, accused Thiokol and NASA of intentionally downplaying the problems with the O-rings while looking for the other causes of the accidents. The hot discussions hurted the feelings and status of the headed engineers like Mr.Boisjoly, Mr.Curtis and Mr.Mellicam. Finally the management's atmosphere also became intolerable. This event shows the responsibility, functions, morality, duties of the engineers leading to ethical problems.

UNIT IV - SAFETY, RESPONSIBILITIES AND RIGHTS

Safety:

A thing is safe, if were **its risks fully known and their risks could be judged acceptable** in the light of settled value principles. More fully, a thing is safe with respect to a given person or group at a given time if, were they fully aware of its risks and expressing their most settled values, they would judge those risks to be acceptable.

If people know the risks, and were biasing their judgments on their most settled values. safety is relative term 'fairly safe' or highly safe. A comparison gives us this. Air travel is fairly safe with less number of accidents. But this is highly safe if there were no accident in the past year. Hence **the perception safe** is based **only on past experience and data**.



Safety for engineers means **safety operation** of system and the **prevention of either human caused or process caused disasters.**

Product Safety:

Engineers will have to design the product to reduce accidents and ease of operation for the consumers.

Ex: The electrical appliances should be **inter locked**,

ex: isolator with earth switch. Products should be tested before marketing, If marketed with out proper testing for safety cause accidents. No compromise in safety quality standard.

Services:

Engineers to educate and train the consumers of handling of the product **including pre sales and post sales services**. During repair, original spares to be used and avoid spurious spares.

Process at work place:

Shop floors are to be **kept clean** and not oily and slippery. The process should be designed in such a way that mal-functions are avoided; short term and long term safety should be considered.

Disasters:

Engineers should plan for disaster management. Proper training and education to users in the event of disaster is a must. In the Titanic disaster there were insufficient boats to save all. The captain was not been trained to handle the disaster management.

Risks:

Absolute safety is what every one wants. But it is neither attainable nor affordable. **A thing is safe if its risks are judged to be acceptable.** Risk is key element in engineering design. **Risk is said to be the potential that some thing unwanted and harmful may occur**. Bodily harm, loss of property , environmental degradation are **side effects of risks**. Risk can be viewed as danger. Hence safety means free from injury, damage or risk.

Safety and risk are **subjective.** It depends on many factors. Risks can be classified as **personal risk and public** risk.

Personal risk is the risk **taken by individuals**.

Public risk is the **risk to the society**.

Ex: Nuclear disasters.

Personal risk can be classified into **voluntary and involuntary risk**.

Voluntary risk is knowingly taking a risk.

Ex: purchasing a plot near a factory which is emitting toxic wastes. If a person is living near an industry prior to industry may not accept the level of pollution. This is involuntary risk.

A risk is acceptable when those affected are generally no longer apprehensive about it.

Doubtfulness depends mainly on how people take the risk or how people **perceive it**. Some feel pride in taking risk. Ex: Car race, driving motor at neck brake speed. They know fully well the risk. Such thing may cause short term and long term disabilities.

Short term and long term Consequences:

Some feel that short lived illness or disability seems safer than the result in permanent disability. Ex: Fracture of leg compared with break in spinal cord.

Expected probability:

Many feel that one in hundred thousand chances of a severe injury to be acceptable risk whereas fifty : fifty chances of fairly minor injury as not acceptable.

Ex: Swimming in beach, where there are lot of jelly fish would be unacceptable to many whereas, the risk of shark attack is low enough that it does not deter anyone from swimming.

Reversible effect:

Something will be seeing less risky if the bad effects are reversible. This is similar to short term and long term risk.

Threshold level of risk:

Something that is risky only at fairly high exposure will seen safer than something with a uniform exposure to risk. Low levels of nuclear radiations have beneficial effects on human health. Only at high levels, severe health problems occur.

Delayed and Immediate Risk:

An activity which considered as risky, whose harm is delayed for very many years may seems to be less risky. Eating high fat foods would lead to heart problem; people ignored it and finally were victims of the disease after many years. The reason is the risk is not immediate and taken lightly.

Assessment of safety and risk:

Absolute safety is not attainable and any improvement in safety in analyzing product is by an increase in the cost of that product. Hence manufacturers and users should understand the cost to reduce the risk.

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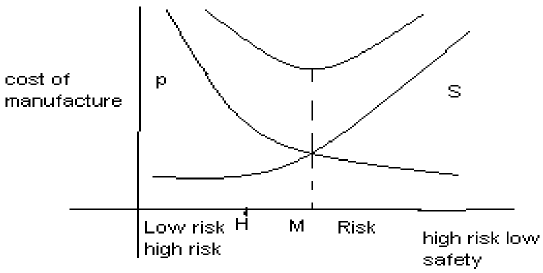


P = Primary cost of product including safety measures

S= Secondary cost including warranty, loss of customer goodwill, litigation costs, cost of downtimes.

T= Total cost.

Minimum cost occurs at 'M' after which incremental saving in primary cost is offset by an equal increment in secondary cost. Hence highest acceptable risk (H) may fall below risk at low cost 'M'

. This must **be selected as design or operation point.**

Uncertainties in design : Regarding application, designs that do quite well under static loads may fail under dynamic loading

Ex. Napoleon's army marching on a bridge with uniform steps shook the bridge violently.

Uncertainties regarding materials: They may not perform as expected so engineers use factor of safety in the design.

Engineer and safety:

As safety is the prime consideration of engineer , criteria to be followed by engineers for **safe design are**

How to ensure safety in design?

1. Design must **comply with applicable** law, legal standards for safety to be followed.

2. Design product must meet the standard of **accepted engineering practice.**

3. You cannot create a design that is less safe than what every one else in the **profession understands to be acceptable**.

4. Alternative designs that are **potentially safer** must be explored. This requires fair amount of creativity in seeking alternative solutions.

5. **Foresee** potential misuse of the product by the customers and design to avoid them.

6. The product must, while prototype and finished shall be rigorously tested. Testing is not for checking the specification but to meet whether the product is safe.

In short **Steps** involved in safe design:

1. Define the problem. (Determine the needs and requirements)
2. Generate several solutions
3. Analyze each solution to determine pros and cons of each
4. Test the solution
5. Select the best.
6. Implement the chosen solution.

Effect of information on risk assessment:

The manner in which information necessary for decision making is presented can greatly influence how risks are perceived.

Ex. use of car belts. Previously no one used it. When they were informed on the statistics of fatal lists, they use now.

The manner in which an information about danger is presented can lead to **a striking reversal** of preferences about how to deal with danger.

Ex: An experiment was conducted on two groups of 150 people each on the strategies available for combating a disease

First group was given the following description.

Imagine an unusual dis- ease is going to outbreak and is expected to kill 600 people.

Two alternative programs are available to combat it.

If program A is adopted – 200 people will be saved.

If program B is adopted there is 1/3probability that 600 people will be saved and 2/3 probability that no people will be saved. Which of the two program do you favor?

72% people selected program A.

Only 28% selected B.

Saving 200 people lead many of them to feel averse of taking a risk on possibility of saving 600 people.

The second group was given the same problem but worded differently.

If program C is adopted 400 people will die

If program D is adopted 1/3 probability that no body will die. 2/3 probability ,that 600 people will die. Which of the two will you choose?

22% choose program C which is same as A in previously.

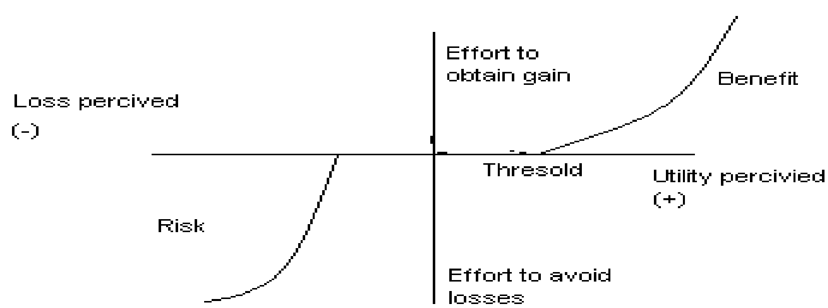
78% choose program D which is identical to program B.

Conclusions:

1. Options perceived as yielding **firm gains** will tend to be preferred over those from which gains are perceived as risky
2. Options emphasizing **firm looses** will tend to be avoided in favor of those whose chances of success are perceived as probable.

Risk – Benefit analysis.

Risk –benefit value function curve



The curve is more steeply drops on loss portion than it rises on the gain portion. Threshold is human habits of ignoring small hazards i.e. no value is attached to a first small amount of loss. Similarly there is a small threshold on gain side to accommodate for normal human inertia. Threshold is important since different people have different tolerance.

This is a <u>tool to asses whether the project can be proceeded or not.</u> The risks and benefits of a project are <u>assigned money values</u> and the most favorable ratio between risk and benefit is sought. There are difficulties in assigning money value to human lives.

Therefore it is not possible to quantify the risks and fix a price tag for it. However this is used widely. The risk and benefits are based on **the perception of probable gain and probable loss**. Starr who had studied in detail on this, says risk is proportional to the cube of the incremental wages. Doubling wages tend to convince a worker to take eight times risk.

Risk analysis involves

- Define all the possible alternatives
- Specifies the objectives & measure the effects
- Identify the consequences of the actions taken
- Quantify the alternatives based on the best available information.
- Analyze the alternatives to arrive at the best choice for cost /risk.

Engineer's first obligation is to public safety. Some risk is unavoidable. Engineering professionals must learn how to convince their managers that minimizing risk is worth at little bit high cost.

How to avoid risk?

Large number of Techniques are available to reduce the risk. A few is:

- Applying **inherent safety concepts** in the design itself.
- Creating **redundancy** in instrumental protection systems.
- Regular **inspection & testing** of safety systems to ensure reliability.
- **Training** operating personal & regular audits to ensure workability of the systems & procedures.
- Developing well considered **emergency plan** together with regular drills to ensure preparedness.

Engineers should think that reducing risk is not an impossible task even though it costs a bit high. A positive perspective should be taken from the design stage itself, so that the risks are reduced.

Responsibility of Professional Engineers: People with character accept responsibility. Accepting responsibility involves taking calculated and not foolish risks and being accountable.

There are internal and external responsibilities i.e., responsibility to employers and to the outside world.

Technical excellences combined with ethics yields success to project. In any project large number of professionals join together as teams and works for the success of the project. Team play involves affection and respect for one another and a helping attitude. All the members of a team may not have same capability .A team consists of different types of people. Team play involves virtues of **Collegiality, loyalty, respect for authority and collective bargaining.**

<u>**Collegiality**:</u> This is an important virtue. (Desirable feature of character). It is **tendency to support and co-operate** with the colleagues. This is an essential characteristic needed for a professional engineer. The central element of collegiality is **respect, commitment, connectedness and co-operation.**

Respect is **valuing one's merits** for his professional expertise and devotion to the social goods promoted by the profession.

This means acknowledging the worth of the other engineers employed in the production of useful and safe products. An engineer is said to have collegiality if he **does not harm the reputation, prospects, practice or employment of other engineer.**

Commitment: This is **sharing the devotion** to moral ideals in the profession. There is competition among professionals working for rival project-making corporations. There should be a sense that other engineers share a concern for the overall good of the users of their product. This is similar to members of competing teams in sports.

Connectedness: This is **an awareness of being** a part of a co-operative undertaking created by the shared commitments and expertise. This sense of unity with other engineers evokes co-operation and mutual support.

Now **whether collegiality, a valuable character is to be encouraged among engineers or not**?

Viewed from the perspective of society, collegiality is an instrumental value. It is good as a means to promoting professional aims. Collegiality supports personal efforts to act responsibility in concert with colleagues. Hence it strengthens one's motivation to live up to professional standards.

Viewed from the perspective of professionals, collegiality is valuable. It is part of what defines the professional community as composed of many individuals jointly perusing the public good.

Collegiality can be misused and distorted. Collegiality can not be used as shield for irresponsible conduct. Cut throat competition in any profession lowers the meaning of collegiality.

LOYALTY:

Loyalty is a virtue, an engineer should posses. This paves way for **fulfilling the obligations of the engineers to his employers**. It also calls for **obeying rules of the authority** with in the organization.

There are moral issues involved in the relationship between engineers and employers. Loyalty to one's employer is being considered as more important than loyalty to the public. Engineers oftentimes have to choose between the two. Which he is to choose?

Loyalty is **more than** 'obligation' or 'duty' which are more specific. Obligation and duty are more functional responsibility oriented. Their base is legal and positional. By contrast loyalty is **more a function of attitude, emotions and a sense of identity.** People may hate the job that they do and not like their employer, but they still perform their duty as long as they are employee. Loyalty is important to an employer and it would be expected from all employees when they work for him.

The court had given definition of loyalty as 'we have to read into every contract of employment and it is an implied duty that <u>an employee is to act solely for the benefit for his/her employer in all matters within the scope of employment.</u>

Asking an individual to perform an illegal activity for a firm would not be to the firm's long term advantage since any illegal action would ultimately harm the firm. Loyalty has **two senses**.

1. Agency loyalty 2.Identification loyalty.

Agency loyalty is an act of being **loyal to the employer in fulfilling the obligations contractually to him.** Obligations or duties are clearly specified in terms of tasks to be carried out for which one is paid. In a nutshell we can say that agency loyalty is essentially a matter of actions whatever may be its motive. There is no room for emotions, attitudes of one self.

<u>Identification loyalty:</u> By contract has more to do with attitudes, emotions and sense of personal identity and actions. It can also be understood as agency loyalty that is motivated by identification with the group to which one is loyal.

one identifies himself with a group **if two conditions satisfy.**

1. **Some of his own goals are met.**
2. **Receive a share of benefit and burden (Personal goals and fairness)**

Professionals who grudgingly and half heartedly perform their duties are not loyal in the sense, though they may adequately carry out their duties and hence branded as ones having **agency** loyalty.

Hence by considering both types of loyalty, it can be said that loyalty is a **desirable character** attribute. Codes of ethics, also says engineers ought to be loyal to their employers or they should act as their employer's faithful agents or trustees.

A company that regards its workers as mere tools for maximizing profits, can require only agency loyalty but will probably not foster identification loyalty. Employees can be expected to be loyal to companies only when the company **shows strong commitments** to them as well.

Both agency and identification loyalty can be shown towards corporations as a whole or towards smaller divisions within corporations. For ex, an engineer might identify closely with a group of committed professional while working on a particular project, but feel less identification with the more impersonal vast conglomerate comprising a large international firm. Conversely an engineer might identify with the corporation but not with a particular team to which she is assigned. Sometimes inappropriate or **misguided loyalty** to a project team or supervisor can harm corporation, as well as the general public. We will see this thro a case study of Ford.

Case study:

The 1970 Clean Air Act requires car manufacturers to conduct 50000 mile durability test on new engines using only one tune-up. Test results on emissions must be reported to the Environmental Protection Agency (EPA).which decides whether engines meet current pollution standards. In May 1972 top mangers of Ford Motor Company were eagerly awaiting government approval of the test results they had submitted on the engines for 1973 Ford Cars. They had every reason to be confident of the results they had submitted to EPA, which were based upon tests conducted by their own employees, their only concern was about meeting tight production schedules once the EPA's approval was received.

Their confidence was shattered however, when then Ford president Lee received a memo from a specialist to the computer division. The computer specialist had been examining the computer tapes from the test to review the effectiveness of his division in support of engine development. His memo identified numerous irregularities in the test records, showing unauthorized maintenance of which EPA was not notified. The memo also stated that when the specialist sought an explanation of the irregularities from the engine division he was urged to burn the computer tapes and forget the matter.

Investigating the matter, management quickly verified the information contained in the memo. Evidently four supervisory technical employees who had conducted the original tests had ordered or engaged in over **300 acts of illegal maintenance on the test engines. Spark plugs and points had been replaced frequently, carburetors cleaned and ignition timing repeatedly reset**. These adjustments lowered the levels of pollution emitted.

Within three days the Chairman revealed to EPA officials all he had learned about the tests and withdrew Ford's application for certification of four major types of engines. In spite of its full co-operation with EPA investigators, the company **was fined $7 million** in criminal and civil fines for conducting improper tests and issuing false reports to the government. Because of the record size of the fines, Ford received damaging publicity in front page news paper articles. It was also hurt by the cost of new tests that had to be conducted on an around the clock emergency basis and by having to delay production schedule.

Ford test scandal tells what motivated the supervisors and other engineers & technicians involved as **only a self interested** concern – a desire to make they look good by ensuring their engines would pass the qualifying tests. It is equally possible that they were acting as loyal employees. Ford had been late in obtaining some government approvals the previous year, & perhaps the individuals believed, how ever mistakenly, that they were serving the companies best interests by avoid such difficulties this year. In any case management was not punitive, no one who had participated in the rigging the tests was fired and the four supervisors were merely transferred to new positions.

Professionalism and Loyalty:

There is a relationship between professional responsibility and loyalty to employers and organizations.

1. Commitment to the public is the effective way to serve an organization, instead of merely, though may be willingly following the direction of the organization.

2. Loyalty to the organizations or employers should not be the same as obeying the immediate boss.

3. Obligation to the public and employer should be in the same direction of achieving the desired goal. They should not oppose each other.

By the study of misguided loyalty of Ford case it can be seen that acting on **professional commitments to the public can be a more effective way to serve a company than a mere willingness to follow the company** orders. Ford would have been benefited much more from the engineers committed to professional standards than it did by the misguided loyalty shown to it by its employees.

Second, it is clear from the example that loyalty to companies or their current owners **should not be equated with merely obeying one's immediate supervisor.** It would have shown a greater loyalty to Ford to act in a way consistent with the mission of the company and concerns of higher management, rather than in a manner consistent with the aims of an immediate supervisor.

The third, the case illustrate how **an engineer might have professional obligations to both an employer and to the public that reinforce rather than contradict each other.**

Thus there need no general contrast between the moral status of employees and professional

To conclude agency and identification loyalty are virtues depending on the specific groups, organization, or cause involved and on circumstances in which they are displayed. Loyalty **has its limits and needs to be balanced with other virtues. It needs to b**e balanced against the virtues of responsible concern for the good of the public. Loyalty is a dependant virtue, depends on the values of the projects and commitments to which it contributes.

<u>**Conflict between commitments**</u>.

1. A police man's wife is on her deathbed. He is by her side when he gets a call to handle a crime emergency where 10 lives are at stake. What should he do?
2. A surgeon is on his way to attend his only daughter's graduation once in a life time event, which he has promised to attend. Minutes before the start of the ceremony he gets an emergency call to operate on an accident victim to save his life. What will he choose?

Choosing one option does not mean a lack of commitment to the other. The process of choosing between the two commitments <u>involves priorities, </u>responsibilities and duties. **Value based** priority help us to choose one commitment over the other. The issue is to whom do we owe our loyalty? Is it to individuals or the organization? The answer is neither. We owe loyalty to values. When value system are conflicting, people find it difficult to co –exist in the work place.

Respect for Authority:

Employed engineers have obligations to respect the authority of their employers. Authority is required to run any organization smoothly and to achieve the set goal. But salaried engineers think what is the nature of this authority and how for should it be recognized. Authority is a way to identify the areas of personal responsibility and accountability so far as the salaried engineers are concerned.

Institutional Authority:

This is the Authority with in the organization. It is the right of the employers & managers to exercise power on their subordinate employees to achieve the institutional goals. Institutional right is acquired, exercised & defined within institutions. It may be defined as right given to a person to exercise power based on the resources of the institutions.

Managerial tasks are to allocate money or other resources, to make policy decisions or the recommendations or to oversee projects and issue directions to sub-ordinates on a particular topic. In order to meet those duties, the organization assigns requisite authority to the managers.

Institutional rights (authorities) and duties are two sides of the same coin. They deal with the same activity & functions.

Projects engineers have the institutional duties to ensure that the projects are successfully completed & they are given the institutional rights (authority) necessary to carry out the duty.

But in practice there is not always a perfect match between the authority granted and the qualifications needed to exercise it. In -competence is found in all large institutions. To avoid such institutional problem **expert authority** comes in. The expert authority signifies the possession of special knowledge, skill or competence to carry out the given job.

Ex: Doctors are authorities on health.

The Civil Engineers are authorities on structures /transportation.

One of the key competences for management is leadership ability. It is possible for engineers **to have expert authority in matters in which they have little or no institutional authority to make decisions**.

Ex. The engineers can design or give suggestions on the construction of nuclear plants but hey can not decide where the plant can be installed. It is to be decided by the elected representative of the people. Hence the engineers may have expert authority but they can not decide in matters where they do not have institutional authority.

In large companies the staff engineers, advisors and consultants carry expert authority while institutional authority is vested in line managers.

Institutional authority and power are to be clearly understood. Ex. A manager who **lacks the skills** of leadership may be unable to inspire encourage employees to produce the result. People who **are effective** acquire power-power goes beyond the authority attached to the positions they hold. Ex. Charismatic leaders have influence outside their domains of authority. Highly respected engineers of proven integrity may have power within an organization exceeding their explicit institutional rights.

An employer has the institutional authority to direct the engineers to do a thing which is not morally justifiable. The Engineers may have the duty institutionally to obey the order of the employer. In such cases, institutional rights and duties can not be and should not be applied in the same sense with rights and duties that are morally justified.

Institutional authority is morally justified only when the institutional goals are morally justified and acceptable and the authority does not transgress into the domain of the moral and ethical duties of engineers.

Zone of Acceptance: When the employees obey the rules and regulations framed by the employer, they accept the authority of their employer with in the frame work of institutional authority. When the employees simply accept and obey the orders of the boss without analyzing is not totally acceptable. The subordinate should also analyze the instructions so as to verify whether it is morally acceptable. This analysis would help them to find out what is their **zone of acceptance** of the authority of the employer.

Paramount obligations of engineers:

Code of ethics clearly indicates that an engineer's paramount obligation is to protect the public health, safety and welfare. This takes priority over their obligations of loyalty and faithful and sincere service to their employers. But is it feasible in the professional life? Employers have high powers to hire or fire engineers who do not meet their expectations. Moral dilemma occurs to engineers whether to which obligation i.e., whether the obligation to the public or to employer is to be given precedence over the others. The obligation to the public is the priority naturally.

Collective Bargaining.

This is a process which is used by companies to solve inter personal problems between them and the employees. It adopts a negotiation process. The guide lines of negotiations are:

1. Attack problems and not people.
2. Build trust.
3. Begin with interest, not positions.
4. Listen.
5. Brainstorm develope multiple options.
6. Agree on how something will be measured.

Collective bargaining means we think about union. Can a professional engineer become a member in a union?

To answer this we must know what kind of union and union activities are at issue. Often employees feel that employers are exploiting and cheating them. **Unions** are formed **to take care of the interests of the employees**. Unionism and professionalism are incompetent. **Professionalism holds the interest of the society and of employer.**

Unionism is a collective bargaining agent that **places economic interest** of members. Unions should be viewed as conduits for expressions of collective will. They have lot of bargaining power due to size. Unions can often prevent unethical acts of employers. They give job security and protection against ill treatment.

Whether unions and collective bargaining practices are ethical or unethical ?

Ex, A small scale company have 120 persons and growth rate was more than 100%. As the eyes of the management were on growth rate they missed the feelings of the pulse of the dissatisfaction of employees. The employees thought that the growth was in the interest of all. Diploma engineers formed a union and external leader came in. They demanded a lot of amenities that the company could ill afford.

Lot of time was expended on bargaining. The employees went on go slow strike production suffered, and the company performance went down. The company had to be sold and the new buyer closed the factory. All of them lost their jobs and livelihood. The union did not realize that what they were doing was against their own interest. By the time they realized it was too late. **For seeking short term gains, they lost long term benefits.**

Codes of the professional societies specify engineers shall not actively participate in strikes, pickets or other collective coercive actions. Most employers are allergic with the word 'union'. They feel unionism is an **impediment to the smooth functioning of industry.**

When collective bargaining exists, loyalty to employers and public **cannot exist**. Engineers view that unions are the limited institutions performing limited functions. The effects of collective bargaining whether it is good or bad can be assessed on issue basis only and not as general rule. Unions have misused their power and acted with public in an irresponsible manner. In those cases, the sympathy from public had been lost.

Ex. 1) Transport union strike.

2) Secretariat staff strike.

Arguments in favor of UNIONS:

1. Unions play a leading role **in getting higher salaries** to the workers; thereby their standard of living is increased. Non-member of a particular union also gets the increased salary and benefits.
1. Unions help **in creation of greater sense of participation** among the employees in the affairs of the company like decision-making
3. Unions give **job security** and protection against unreasonable treatment to employees.
4. Unions can **resist obeying unethical orders to perform unethical acts.**
5. Unions help to **provide a grievance procedure** for the complaints of the employees and thereby a stable environment is maintained.
6. Unions help **to avoid extreme political interference** which exploits the employees in many a times.

Arguments against Union:

1. Unions are the main **cause for inflationary** condition of a country.

2. Unions can cause **destruction to the economy** of a nation by placing misrepresenting influences on the efficient uses of labor force.
3. Unions **encourage an opponent decision-making** rather than co- operating decision-making.
4. Unions remove the individual negotiations between employer and employee as part of the collective bargaining group.
5. Unions discourage initiative among workers by stressing job security and making **promotion by mere seniority** only.
6. Unions prevent the management to reward an individual worker for his personal achievement because they insist on salary negotiation **only according to job description** and seniority.
7. Unions encourage a dissatisfied and tensed relationship between employer and workers.

The external responsibilities of professional engineers i.e. to the society are **confidentiality, conflict of interest & occupational crime.**

CONFIDENTIALITY:

Confidential information is information deemed desirable to keep secret. This implies that a communication is kept secret and will remain private. Codes of ethics require their members to maintain total confidentiality of any privileged information they are in possession. A piece of information /communication that is conveyed to some one else with the expectancy that it will remain **private is privileged**. This type of information has no access to all and only to some who are on special assignments. In case of engineers, design and drawings, process charts etc are to be kept confidence. Also the information about yet to be released products, design of such products are confidential information.

One may ask **keep secret with whom?** In Govt. agencies and private companies, engineers and other employees are expected to withhold confidential information from **unauthorized people both inside and outside the organization**.

A doctor has to keep the patients personal data as confidential information. Lawyers should keep their client's information as confidential likewise engineers shall keep their companies information as confidential.

Proprietary information: It is the information that a company owns or is the proprietary of. This can be taken as 'Trade Secret' i.e. any information **not made known to the public**. It is the information the employer prefers to keep as secret.

Trade Secret:

It is a type of secret given a limited legal protection against employee or contractor abuse or misuse. An employer can sue an employee for divulging the trade secrets or even planning to do so.

These secrets may be about designs, list of clients, process methods, facilities available, and quality control methods.

Patents:

This is different from trade secrets. Patents legally protects some specific products from **being manufactured by other companies without proper permission of the patent holder**. The patent holder possesses legally protected monopoly power under GATT 1995 agreement (General Agreement on Tariffs and Trade). The period of patent right is 20 years.

Justification and limit of confidentiality:

What are the moral limits or restrictions on the confidentiality obligations of employees? The obligation of confidentiality can be justified at **two levels**.

The obligation to hold the confidential information is focused first on the **moral considerations**. This is **first level** of confidentiality-obligation which is to appeal the three ordinary moral consideration. They are

Respect for autonomy

Respect for promises

Regard for public well being.

Respect for autonomy means respect the freedom and self determination of individuals and institutions **to exercise control over private information** about their companies.

Just as patients should be allowed to maintain substantial control over personal information, the employers should have some control over the private information about their companies.

Respect for promise:

Promises are given to others only to respect and carried out. They are not to be flouted. Employees should not disclose the promises made with their employer.

Employees often make promises in the form of signing contracts not to divulge certain information considered sensitive by the employers. These promises should be respected.

Regard for social wellbeing:

This is essential in identifying confidentiality relationships with in the professional areas.

A patient gets confidence in a doctor if the doctor does not disclose the personal information to others. This will enable patient to discuss freely with the doctor on their personal problems. **Clients feel free to talk when there is a trust of confidentiality is created.** This is analogy to the economic benefits of competitiveness with in a free market are promoted when companies can maintain some degree of confidentiality concerning their products.

Ex: Developing new products requires investing resources in acquiring new knowledge. The motivation to make those investments might diminish if that knowledge were immediately dispersed to competitors, who could then quickly make better products at lesser cost, since they did not have to make comparable investment in
R& D.

The **second level of confidentiality** obligation- will be to appeal to major **ethical theories**. Advocate of every theory would probably agree that employers have some moral & institutional rights to decide what information about their organization can be released publicly.

Different ethical theory will justify the rights differently & will also differ in the limits they place on them.
These can be broadly stated as

Right based theories

Duty based theories

Utilitarian theories

Right based theory simply **justifies employee's confidentiality obligations** by appealing to basic human rights. NO employer has a right to safe guard proprietary information by preventing engineers from whistle blowing in cases were public knowledge of such information (Say the composition of toxic wastes indicative of a products ingredients) would save human lives & there by protect the rights of people to live.

Duty based theories insists to the employers & employees to keep up the trust placed in them, in case of an agreement between them. These theories may also appeal to general duties not to abuse the property of others. **Utilitarian theories** justify the rules of confidentiality only when such **rule benefits the public**.

The stress is on how the investors get profit & how the society is benefited. The theory focuses on each & every situation when an employer decides on some matters to be treated as confidential information.

Changing of Jobs :

Employees when switchover to the other job, they sell the information they had relating to the erstwhile employer for a price. In some cases the employees are placed in the same type of job in which they were with the previous employer. This puts them in dilemma. In the sense, that they have to use the knowledge gained by them earlier, but the new employer is happier. To restrict future employment, certain employers provide positive benefits

Ex. Companies offer pension plan to employees in exchange for an agreement not to work for a competitor on certain kinds of projects for a certain member of years after leaving the company. Some other companies offer a special post employment annual consulting fees for several years on the conditions that he or she not work for a direct competitor during that period.

The relationship between employer and employee in regard to confidentiality continues beyond the formal period of employment. Unless employer gives consent, former employees are barred indefinitely from revealing trade secrets. This provides the way in which the professional integrity of engineers involves much more than mere loyalty to one's employer.

Conflict of interest:

Conflict of interest occur when employees have interests that, if pursued could keep **them away** from meeting their obligations to serve **the interests of the employer** or client for whom they work , such conflicts are to be avoided so as to prevent one from fully meeting these obligations. Professional conflicts of interest occur to an engineer in a situation in which **he works in a company and also acts as consultant to the competitor's firm**. If he continuous the same, he may not be in a position to meet the obligation to his employers or client. He would be more loyal to the competitor's firm if he invests in that company. So the threats posed by such acts by engineers led to giving prominence in the code of ethics, in management policy statements and in the law.

There are three types of conflicts of interest.

-Actual conflict of interest

-Potential conflict of interest

-Apparent conflict of interest.

Actual conflict of interest is **based on weak judgment** and service. Conflicting interest means a person has two or more desires that can not all be satisfied in the given circumstances.

Ex:A student may have interest in excelling on four final exams. She knows however that there is time to study adequately for only three of them and so she must choose which interest not to pursue.

Conflicting interest means a person has two or more desires that cannot all be satisfied given the circumstances.

Potential conflicts of interest are based on **the difference between gifts and bribes.** In the event of a friend of the engineer turning as a supplier to his firm, the judgment might becomes conflicted in order to maintain his friendship. This type of conflicts arises when the engineer accept large gifts from suppliers.

Bribe is a **large amount of money or substantial amount** of goods offered with the aim of gaining the contract. Kickback is another word for bribe. Pre arranged payment done in exchange for contracts actually granted later are termed as kickbacks. Bribes are illegal and immoral.

Gift is a **small amount** of money given for the services rendered in the normal conduct of business.

Gift is a bribe if you cannot eat, drink or smoke it in a day. If you think that your acceptance of a particular gift would have grave or a merely embarrassing consequences for your company if made public, then the gift should be considered as bribe.

Engineers' code of ethics is clear on accepting gifts/bribes.

Engineers shall not accept gratitude's directly or individually from contractors, their agents or other parties dealing with clients or employers in connection with works for which they are responsible.

Apparent conflict of interest:

This happens when the engineer is **paid based on the cost** of the design and there is no incentive offered to him if he cuts down the cost. Naturally the engineer would try to inflate the cost to get more commission. The engineer will be branded as distrustful, though he could have reduced the cost using his professional capability and judgment.

Conflicts of interest **arises** due to

1. Financial investment
2. Insider Trading
3. Bribe
4. Gifts
5. Kickbacks.

Conflicts of interest will arise because of **financial investment** in a competitors' business.

Ex: If you are an engineer and CEO of firm and another firm which had bid for a large project of your company. You have financial stake in that company which has bid for it. The tendency will be to award the bid to the company when you have stakes. This will be regarded as unethical decision.

Insider Trading: This involves using privileged information unfairly when you are working for a company. You could have access to the confidential information which other would not be ale to get it. If such information relates to the financial performance of the company and you use it to trade in the shares of the company, this would be considered as insider trading.

MOONLIGHTING:

Working in one firm and in spare time working for another company is called moonlighting. This violates the right to pursue onc's legitimate self interest. This type of work makes one exhausted and the result is his inability to meet his professional obligation at both places. It also ends up with poor job performance.

Resolving conflict problems:

S is working in a chemical factory. A compound emitted from the stack of the plant has been linked by several side effects to respiratory problems that can be severe in a small percentage of the population. The Pollution control board, has not banned the compound Its elimination will be expensive and it may force the elimination of the product line. This will lead to loss of a number of jobs in the community i.e., heavily dependent on the plant for employment.

An added dimension is that the product line could become very successful in future, thus adding jobs in the community. S's supervisor instructs him not to bring up the issue in hearing of the Pollution board officials, because the supervisor felt that by the time the PCB takes the final decision, they can modify the process and eliminate the emission itself. The health problem is not fatal in any case. How should S respond? S is now in a dilemma of conflict problem. First code of ethics say that engineer **should hold**

paramount safety and health and welfare of the public in the performance of their professional carrier. On the other hand it also tells engineers **shall act in professional matters for each employer as faithful agents or trustees**. Further to the obligation to the public also puts S, in two different directions. One obligation, to protect the **physical health** of the community and the second obligation, to be concerned with **economic health** of the community.If public were enquired, they will support management since it gives many employment. Conflicts between competing obligations both of which appear to be valued are common features of life.

How to approach to such conflicts, which are **not between good and bad but between good and good.**

Creative midway should be adopted. The engineer should respect corporate hierarchy and protest in a private and a non confrontal way. The engineer should do every thing possible to avoid embarrassing their employer and give the employer an opportunity to correct the problem, in so far as consideration of the well being of the public permits. Another limitation is the employee is not to protest about minor risks to the health and safety of the public. If there is a mechanism where by the employees could register ethical concerns this could be eliminated.

Avoiding conflicts of interest:

The following ways can help in avoiding conflicts of interest.

1. follow the guidance from the company's policy.
2. Consult colleagues /sub ordinates or manager for a second opinion. This creates an opinion of being frank.
3. Use ethical problem solving technique.
4. Take refuge in code of ethics.

Occupational Crimes:

These are **illegal acts** made possible thro **one's lawful employment**. It can be treated as **secretive violation** of laws regulating work activities. If the occupational crimes are committed by office workers, professionals and managers, they are called **white collar crimes**.

Most of the occupational crimes are special instant of conflict of interest. It leads to the failure of meeting the professional obligations. The white collar crime meets with **less severe penalty**. There are three types of occupational crimes.

Industrial espionage,

Price fixing

Endangering of lives:

Industrial espionage: Espionage is secret gathering of information, in other words spying. Keeping something secret is a right but acquisition of others secret to your advantage is espionage which is not right and unethical. Espionage is made in a covert manner. The espionage agent is called spy. There is large extent of industrial espionage thro out the world. Ex: Santa Clara in California is known as silicon valley. Lot of young and enterprising engineers work there. Due to competitions among various manufacturers of computer parts, high industrial espionage is there. The reason is

1. The development of computer chip is a competitive area and also is fast moving one. Within two years, the product get outdated, due to continuous development of technology. Profitable technology suddenly becomes a loss proposition with the introduction of modified version of various parts. Ex: VCD player, DVD player and now Blue Ray players

2. Computer chips are expensive. Large savings can be made by adopting **"reverse Engineering**". This means breaking the competitor's device physically, mentally or by tests and re constructing to produce an identical or better device that can be offered at a lower price because of low development cost. By obtaining thro illegal ways the competitors design drawings, large savings are achieved.

3. Computer chips being small in size can be easily taken away secretly and chances of being caught are little.

4. Some agents buy secrets and sell them to competitions. They get the products from employee themselves.

Case study:

Peter was an expert in semiconductor application. He worked for a number of computer chip companies, before he started his own consulting company. He had a lot of acquaintance and contacts. Hence he was able to buy and sell the secrets of the company.

James, a skilled electronics technician worked for Peter under 'moon lighting' method. He worked in a company called National Semi Conductor corporation (NSC).Peter financed James to build a house . Peter asked James that he need not repay the finance, but wanted him to steal some documents from NSC. James gladly agreed and did so.

Peter sold this document to Intel Co-operation. As Peter got contacts with Intel he managed to steel some documents from them and sold it to NSC. By this exchange of documents, employees were in high demand and employee cost was high.

After some time NSC and Intel spread the "drag net", and finally Peter was trapped and punished in an court of law. But the penalty was only a fine of a small amount which he could easily part with.

While collar crimes meet with less sever penalties.

Prices Fixing:

This is known as "Cartelizing". **Competitors come together and decide on the prices to be charged.** The price fixation leads to restraint of free competetion and trade. It leads to unfair practices. To grab high valued order, major companies form a cartel and fix with in themselves the proposed price to be quoted. They would also preplan the share of the order to be executed by them individually between them, in the name of the successful bidder.

In US there is a law called Sherman Anti Trust Act 1980 which for bids companies jointly setting price. But by companies violate these laws.

Top managers of Westinghouse and G.E. joined together and allotted with in themselves, the share of the order. They also decided to quote a particular price and grab the order and share the same accordingly to the agreed plan. They called thus plan as **'Phase of the moon'**. But they were caught and sued. But being a 'white callar crime', they were only fined and let off.

Their agreement in the court was that they helped the public by stabilizing the prices and hence theirs was not unlawful. They argued that criminal action meant damaging some one and they did not do it. They were working on a survival basis in order to try to make enough to keep their plant and employers with job.

Endangering of lives:

Employers **expose** their employees **to safety hazards**. They escape criminal penalties, Victims sue them for damages under civil law and get compensations. Companies very well aware of this and hence they resort to payments of compensation, not to take preventive measures which are expensive. They disregard the value of individual's life.

In U.S. millions of asbestos workers were affected with a type of lung cancer called asbestosis and more than one million workers lost their lives. The victims were asking the companies for monetary benefits as compensation and no one preferred for asking criminal justice. Companies make use of this attitude and close the cases by paying compensation amount. Some company went to declare them **as insolvent and get** immunity from making payment. In the court the companies argue when asked why they have not got informed consent they said 'as long as they feel well, happy at home and at work and his physical conditions remains good, nothing should be said.

Another case: Film Recovery System was a small corporation that recycles silver from used photo graphic and x-ray plates. Used plates were soaked in a cyanide solution to leach out their silver content. Other companies use this process safely by protecting workers against inhaling cyanide gas and against making skin contact with liquid; they provided them rubber gloves, boots and apron as well as respirators and proper ventilation. None of these precautions were taken by Silver Recovery System Company. Workers were given paper masks, cloth gloves and ventilation was terrible and respirators were not provided. Workers were not complaining but in one incident autopsy of an employee revealed cyanide poisoning. Charges were brought against the executive of the company. During the trial, it was proved that the president, the plant manager, plant foreman all knew of the dangers of cyanide. They also knew the hazards conditions on their plant. Each was fined dollar ten thousand and jail term pf 25 years.

Professional rights:

Engineers have several types of moral rights which some times overlap.

Categories are

Human rights

Employee rights

Contractual rights

Professional rights

Engineers possess the fundamental rights to live in a state of freeness to pursue freely their legitimate interest. They have **human rights** to pursue their work and not to be unfairly discriminative. **Professional rights** are vested to the engineers by **virtue of their being** professionals. Fundamental professional rights are

Right to form a professional judgment and to express it freely.

Right to refuse and refrain from participating in unethical activities.

Right to disagree on issues relating to the profession

Right to warn and caution the public about dangers

Right to obtain a fair remuneration for the professional services

Right to talk on the job he holds.

Right to engage in the activities of professional society.

Basic right of professional **consciences**:

Engineers, using professional responsibility involves in exercising both technical judgment and reasoned moral convictions. This basic right is referred as the right of professional conscience.

In practice the duties of engineers are not clearly defined. In engineering profession decisions to be taken by engineers are morally complex in nature. The basic professional right of the engineer is termed **as 'Negative' Right**, as it asks other to stay away without interference.

But engineers while taking a decision on a project they need an atmosphere of trust and the management has to ensure this. In such situation the basic right of the engineer is considered as '**Positive right'.**

Institutional recognition of rights: Moral rights of engineers have to be recognized and respected by the organization to which they belong.

Specific rights: In some specific instance it is difficult to apply professional rights.

Right of conscientious refusal. This is to refuse to engage in unethical behavior and to refuse to do so, solely because of one views it as unethical. This situation arises when a discussion being held among a group of engineers and there exists a chance to disagree on the nature of action to be taken in an issue by a member of group.

As per this right no employee can be forced to do something by his employer, which is unethical in the opinion of the employee. **To correct the data already existing, forging the document, altering test results, taking bribes, telling lies intentionally fall under this category.**

In case an engineer has to work in an environmentally unfriendly & dangerous situation, he has the right to refuse, which is in all most all cases the employer does not understand.

Engineers have a **right to professional recognition** for their work & accomplishments. Part of this involves fair monetary remuneration & part non monetary forms of recognition.

If a patent leads to millions of dollars of revenue for a company, it is unfair to give the discoverer a nominal bonus & a thank you letter. It is not possible to pin point what a reasonable salary is or what a fair remuneration for patent discovering, because it depends on both the resources of a company & the bargaining position of engineers. Non monetary forms of recognition are also important.

Foundation of professional rights:

The principles of professional rights can be **justified as rights ethics, duty ethics & utilitarianism.**

<u>**Right ethics**</u> insists the moral rights as of the fundamental grounds of morality. The public have human rights to be warned of any safety hazards due to technology improvement. Public right recognizes of engineers in an indirect way.

Duty ethics: This view, rights are **not the ultimate moral** appeal instead they are mirror-image correlates of more basic. If an engineer has the right to do his work, it is because others have obligations to permit him to **carryout his work without any interference**. There by the engineer may not be able to meet their obligation to the public.

No employer has the right to threaten are engineer under him with loss of job, if he refuses to work on projects causing dangers to public.

Utilitarianism

This suggests that we should **produce the good things for the general or more people** being given equal opportunity to every one. This theory has two parts

Act utilitarian: This says that we have to focus only on individual actions and not on general rules. We have to see that we do not break the promises, do not deceive others and do not give or get bribes.

Rule utilitarian (BRANDT) takes efforts to setup the **best rule** or policy to follow their obligations to public at large.

Individuals actions are considered right only when they conform to moral rules. These moral rules, like refusing bribes etc., are termed as moral codes, accordin g to Brandt.

Employee rights:

By being an employee, he has got certain rights, of either <u>moral or legal in nature.</u> This right is called employee right.

He has **right to disobey** his employer in the event of forcing him to do unethical activities that would endanger the safety of public.

Another right, is the **right of not to be discriminated** against social causes.

Another employee right **called contracted employee rights**, which ensures the right to receive salary & right to receive company's benefits as eligible like increments etc.

Another form of employee right is 'Non-contractual employee rights' which exist even if they are not recognized by the existing practices of the company.

Choice of outside activity:

Employees have right of engaging in outside activity of their choice. This will not attract any punishment from the employers. This is a part of human rights to pursue the legitimate interests without any interference.

But the employee should not damage the interest of their employer outside the office hours. Outside activities should not spoil the normal duties or pose any impediment to their normal obligations to their employer.

Privacy:

Right to have outside activity is a matter of right to the employees. This right is also termed as 'Privacy'. This right is a **limited** one.

Ex. Prospective employees will be asked to undergo some tests that include questions on their criminal records, or a lie detector test, before hiring them. These tests are prone to be misused by certain employers.

This act of misuse is termed as unwanted **transgression into the domain of privacy of job seekers.** In the interest of the organization conducting and collecting such data by employer can not be totally denied.

Fixing surveillance camera in the factory, shops is the right of the employer. Frisking the employees at the entrance by the watch and ward staff can not be considered as an encroachment into the privacy of the employees.

Right to due process:

With out institutional recognition, the moral rights of conscience, free speech, out side activity and privacy would be **of little help** to employees. Institutional recognition includes formal encouragement of the rights, company policy statement, or employment contracts. It also requires creation of an institutional procedure for protecting those who exercise the rights.

A right to fair procedures, safeguarding the exercise of other rights is the right to due process.

The **right to due process** extends to fair procedures in firing, demotion and disciplinary actions.

Implementing the right to due process involves two general procedures.

First written explanation are owed to employees who are discharged, demoted or transferred to less enriching workings or in other ways penalized.

Second an appeal procedure should be established that is available to all employees who believe their rights have been violated. The procedures shall be part of organizations, effective, equitable and efficient. It must be easy to use and work quickly. For Govt. already a set procedure is available. But private companies, each has got its own procedures.

Intellectual Property Rights:

Intellectual property is a class of property **created out of human intellect**. Any property whether it is movable or immovable has legal protection to prevent it from being stolen. Intellectual property also means anything that **results due to intellectual activity** of an individual or a group of individuals. **The creations of the brain are the intellectual property**.

These could be **novel working ideas, and skills, improvements and unique solutions to problems in any aspect of human efforts**.

IPR rights are <u>the legal and statutory provisions available</u> to individuals to protect the ownership of their creations and the resulting, commercial benefits. IPR has <u>got wide range of social and economical impacts.</u>

There are various forms of IPR. Trade related intellectual property rights are often called as **TRIPS.**

WTO recognizes **seven** forms of IPR. They are

Patents,

Trade mark,

Geographical indications,

Industrial design,

Copy rights,

Integrated Circuits,

Trade secrets.

Patent: These are legal rights **granted for new inventions** using scientific and technical knowledge. The period is 20 years. It gives exclusives privilege of making, selling and using the invention and also authorizing others to do so thro' out the country.

Ex: A new drug for the treatment of AIDS , A new cellular phone

CONDITIOS FOR PATENTING:1

Any creation becomes eligible for a patent if the following **conditions** are satisfied.

1. It must be **inventive and unique**. Inventive means that it makes a feature that is not obvious to a person skilled in the art. An invention can be an unforeseen technical effect produced by a new combination of known elements.

2. It must be **Novel- (**Fresh, different, Original, Unsusal, imaginative, inventive, un conventional, innovative, ground-breaking)

3. It must have a **commercial value**

For applying patent, the following **document**s are needed.

-Problem of invention

-Current report of the problem to address

-Solution or procedure to the problem

-Extent of novelty or inventive

-Application or uses

-Details of inventor

-Resources of funding

Types of patent:

Three types are there. 1. Utility patents 2. Design patent 3. Plant patents

Utility patents can be granted to any one who discovers/invents any new and useful **process,** machines, **manufacture or composition** of matter. The utility duration will be 20 years.

Process refers to industrial and manufacturing methods.

Manufacture refers to the articles or goods manufactured

Composition of matter relates to chemical composition and includes mixture of ingredients as well as new chemical compounds.

Design patents can be granted to anyone who invents a new and original ornamental pattern for an article of manufacture. It protects the ornamental design or appearance of the article. This has validity 14 years from the date of applying for the patent with complete documents.

Plant Patent: can be granted to any one who invents or discovers and reproduces a variety of plant. Validity period is 20 years. Patents law varies from country to country. International or world patent are yet to come.

Copy right:

Copy right law prevents others from

-Copying the work,

-Publishing and selling copies commercially

-Renting and demonstrating the work in public.

Trade Mark: is a visual symbol in the **form of a word or label** applied to the product. This gives details to the buyer on the origin of manufacture of goods. Ex: Philips in electronic goods, Sony, Pioneer.

Geographical indications:

These indications identify the origin of the goods with respect to the country where they are manufactured ex: Kancheepuram silk, Dindigul lock.

Trade secrets:

Any **trade information kept confidential** can be said to be Trade secret. In engineering profession, certain formulae programming, processing and data collection can be treated as trade secret. Trade secrets are not registered. Protection for such trade secrets cannot be given on a time frame because at any point of time the secrecy is liable to be lost.

Engineers have responsibility to use the trade secrets without disclosing to others. If the information is intentionally or un intentionally leaked out, the rights owner can sue in a court for remedy.

Need for protection of IPR:

When IPR is protected, we can expect technology development and creativity. It will give stimuli to research.

IPR protection is based on the following needs.

- To prevent plagiarism (i.e., using the original work as his own
- To prevent others to use it.
- To prevent using it for financial gains.
- To support income generation
- To fulfill as an obligation to the sponsor

IPR is considered **important** because it gives

- The inventors' exclusive rights of dealing
- Permit avoidance of competitors
- Permit entry to technical market
- generate a steady income by issuing license.

IPR protection gives protection against piracy.

In India we have the following act to IPR

- The Patents Act 1970
- The copy rights act 1957
- Trade and Merchandise Mart Act 1958
- The Design Act 1911.

Discrimination:

This is to make unfair difference in one's treatment. Giving preference to gender, race, religion falls under this. **Morally unjustified** treatment to people can be called as discrimination.

Ex:

1) Vacancy exists for a very high post in a private company. Just because the best suitable person does not belong to the majority community of people working there he was denied promotion to that post.

The reason put forth is that if that person is posted, the other sub-ordinate world not extend co-operation to him and in the process the company would suffer. So the management promoted a person of lesser capability, just because he belongs to the majority community working there.

2) More number of woman engineers are appointed in the sales division of a company but they were **paid lesser** than male engineers.

In India we have laws to prevent such discrimination.

i.e., Factories Act, Labor Act, Wages Act.

The equal employment opportunity act in USA protects the weaker, minorities and woman from discrimination by gender, race, color or religion

Preferential treatment:

Weak preferential treatment gives benefit or preference to the members of traditionally discriminated against groups **over equally** qualified applicants who are the members of the other group

Ex: Hiring a woman or a member of minority over an equally qualified white male people.

Strong preferential treatment by contrast exist in giving preference to woman or minorities **over better** qualified white males.

There are **far and against** arguments on this.

The **far argument** will be that preference can be given to the under privileged now, as all along they were not treated by the society equally. To compensate this they can be given preferred.

The **against argument** is that equal opportunity concept is defeated by extending preferences. This is a violation of rights of other people.

UNIT – V GLOBAL ISSUES

Syllabus: Multinational corporations - Environmental ethics - computer ethics - weapons development - engineers as managers-consulting engineers-engineers as expert witnesses and advisors -moral leadership-sample code of Ethics like ASME, ASCE, IEEE, Institution of Engineers (India), Indian Institute of Materials Management, Institution of electronics and telecommunication engineers (IETE),India, etc.

MULTINATIONAL CORPORATIONS

A multinational corporation (MNC), also called a transnational corporation (TNC), or multinational enterprise (MNE), is a corporation or an enterprise that manages production or delivers services in more than one country. It can also be referred to as an international corporation. The International Labour Organization (ILO) has defined[citation needed] an MNC as a corporation that has its management headquarters in one country, known as the home country, and operates in several other countries, known as host countries.

The Dutch East India Company was the first multinational corporation in the world and the first company to issue stock. It was also arguably the world's first megacorporation, possessing quasi-governmental powers, including the ability to wage war, negotiate treaties, coin money, and establish colonies.

The first modern multinational corporation is generally thought to be the East India Company. Many corporations have offices, branches or manufacturing plants in different countries from where their original and main headquarters is located.

Some multinational corporations are very big, with budgets that exceed some nations' GDPs. Multinational corporations can have a powerful influence in local economies, and even the world economy, and play an important role in international relations and globalization

Multinational corporations have played an important role in globalization. Countries and sometimes subnational regions must compete against one another for the establishment of MNC facilities, and the subsequent tax revenue, employment, and economic activity. To compete, countries and regional political districts sometimes offer incentives to MNCs such as tax breaks, pledges of governmental assistance or improved infrastructure, or lax environmental and labor standards enforcement. This process of becoming more attractive to foreign investment can be characterized as a race to the bottom, a push towards greater autonomy for corporate bodies, or both.

However, some scholars for instance the Columbia economist Jagdish Bhagwati, have argued that multinationals are engaged in a 'race to the top.' While multinationals certainly regard a low tax burden or low labor costs as an element of comparative advantage, there is no evidence to suggest that MNCs deliberately avail themselves of lax environmental regulation or poor labour standards. As Bhagwati has pointed out, MNC profits are tied to operational efficiency, which includes a high degree of standardisation. Thus, MNCs are likely to tailor production processes in all of their operations in conformity to those jurisdictions where they operate (which will almost always include one or more of the US, Japan or EU) that has the most rigorous standards. As for labor costs, while MNCs clearly pay workers in, e.g. Vietnam, much less than they would in the US (though it is worth noting that higher American productivity—linked **to** technology—means that any comparison is tricky, since in America the same company would probably hire far fewer people and automate whatever process they performed in Vietnam with manual labour), it is also the case that they tend to pay a premium of between 10% and 100% on local labor rates.[10] Finally, depending on the nature of the MNC, investment in any country reflects a desire for a long- term return. Costs associated with establishing plant, training workers, etc., can be very high; once established in a jurisdiction, therefore, many MNCs are quite vulnerable to predatory practices such as, e.g., expropriation, sudden contract renegotiation, the arbitrary withdrawal or compulsory purchase of unnecessary 'licenses,' etc. Thus, both the negotiating power of MNCs and the supposed 'race to the bottom' may be overstated, while the substantial benefits that MNCs bring (tax revenues aside) are often understated

Market withdrawal

Because of their size, multinationals can have a significant impact on government policy, primarily through the threat of market withdrawal. For example, in an effort to reduce health care costs, some countries have tried to force pharmaceutical companies to license their patented drugs to local competitors for a very low fee, thereby artificially lowering the price. When faced with that threat, multinational pharmaceutical firms have simply withdrawn from the market, which often leads to limited availability of advanced drugs. In these cases, governments have been forced to back down from their efforts. Similar corporate and government confrontations have occurred when governments tried to force MNCs to make their intellectual property public in an effort to gain technology for local entrepreneurs. When companies are faced with the option of losing a core competitive technological advantage or withdrawing from a national market, they may choose the latter.

This withdrawal often causes governments to change policy. Countries that have been the most successful in this type of confrontation with multinational corporations are large countries such as United States and Brazil[citation needed], which have viable indigenous market competitors.

Lobbying

Multinational corporate lobbying is directed at a range of business concerns, from tariff structures to environmental regulations. There is no unified multinational perspective on any of these issues. Companies that have invested heavily in pollution control mechanisms may lobby for very tough environmental standards in an effort to force non-compliant competitors into a weaker position. Corporations lobby tariffs to restrict competition of foreign industries. For every tariff category that one multinational wants to have reduced, there is another multinational that wants the tariff raised. Even within the U.S. auto industry, the fraction of a company's imported components will vary, so some firms favor tighter import restrictions, while others favor looser ones. Says Ely Oliveira, Manager Director of the MCT/IR: This is very serious and is very hard and takes a lot of work for the owner.pk

Multinational corporations such as Wal-mart and McDonald's benefit from government zoning laws, to create barriers to entry.

Many industries such as General Electric and Boeing lobby the government to receive subsidies to preserve their monopoly.

Patents

Many multinational corporations hold patents to prevent competitors from arising. For example, Adidas holds patents on shoe designs, Siemens A.G. holds many patents on equipment and infrastructure and Microsoft benefits from software patents. The pharmaceutical companies lobby international agreements to enforce patent laws on others.

Government power

In addition to efforts by multinational corporations to affect governments, there is much government action intended to affect corporate behavior. The threat of nationalization (forcing a company to sell its local assets to the government or to other local nationals) or changes in local business laws and regulations can limit a multinational's power. These issues become of increasing importance because of the emergence of MNCs in developing countries.

Micro-multinationals

Enabled by Internet based communication tools, a new breed of multinational companies is growing in numbers.(Copeland, Michael V. (2006-06-29). "How startups go global". CNN. http://money.cnn.com/2006/06/28/magazines/business2/startupsgoglobal.biz2 /index.htm. Retrieved 2010-05-13.) These multinationals start operating in different countries from the very early stages. These companies are being called micro-multinationals. (Varian, Hal R. (2005-08-25). "Technology Levels the Business Playing Field". The New York Times. http://www.nytimes.com/2005/08/25/business/25scene.html. Retrieved 2010-05-13.) What differentiates micro-multinationals from the large MNCs is the fact that they are small businesses. Some of these micro-multinationals, particularly software development companies, have been hiring employees in multiple countries from the beginning of the Internet era. But more and more micro-multinationals are actively starting to market their products and services in various countries. Internet tools like Google, Yahoo, MSN, Ebay and Amazon make it easier for the micro-multinationals to reach potential customers in other countries.

Service sector micro-multinationals, like Facebook, Alibaba etc. started as dispersed virtual businesses with employees, clients and resources located in various countries. Their rapid growth is a direct result of being able to use the internet, cheaper telephony and lower traveling costs to create unique business opportunities.

Low cost SaaS (Software As A Service) suites make it easier for these companies to operate without a physical office.

Hal Varian, Chief Economist at Google and a professor of information economics at U.C. Berkeley, said in April 2010, "Immigration today, thanks to the Web, means something very different than it used to mean. There's no longer a brain drain but brain circulation. People now doing startups understand what opportunities are available to them around the world and work to harness it from a distance rather than move people from one place to another."

ENVIRONMENTAL ETHICS

Environmental ethics believes in the ethical relationship between human beings and the natural environment. Human beings are a part of the society and so are the other living beings. When we talk about the philosophical principle that guides our life, we often ignore the fact that even plants and animals are a part of our lives. They are an integral part of the environment and hence have a right to be considered a part of the human life. On these lines, it is clear that they should also be associated with our guiding principles as well as our moral and ethical values.

What is Environmental Ethics?

We are cutting down forests for making our homes. We are continuing with an excessive consumption of natural resources. Their excessive use is resulting in their depletion, risking the life of our future generations. Is this ethical? This is the issue that environmental ethics takes up. Scientists like Rachel Carson and the environmentalists who led philosophers to consider the philosophical aspect of environmental problems, pioneered in the development of environmental ethics as a branch of environmental philosophy.

The Earth Day celebration of 1970 was also one of the factors, which led to the development of environmental ethics as a separate field of study. This field received impetus when it was first discussed in the academic journals in North America and Canada. Around the same time, this field also emerged in Australia and Norway. Today, environmental ethics is one of the major concerns of mankind.

When industrial processes lead to destruction of resources, is it not the industry's responsibility to restore the depleted resources? Moreover, can a restored environment make up for the originally natural one? Mining processes hamper the ecology of certain areas; they may result in the disruption of plant and animal life in those areas. Slash and burn techniques are used for clearing the land for agriculture.

Most of the human activities lead to environmental pollution. The overly increasing human population is increasing the human demand for resources like food and shelter. As the population is exceeding the carrying capacity of our planet, natural environments are being used for human inhabitation.

Thus human beings are disturbing the balance in the nature. The harm we, as human beings, are causing to the nature, is coming back to us by resulting in a polluted environment. The depletion of natural resources is endangering our future generations. The imbalance in nature that we have caused is going to disrupt our life as well. But environmental ethics brings about the fact that all the life forms on Earth have a right to live. By destroying the nature, we are depriving these life forms of their right to live. We are going against the true ethical and moral values by disturbing the balance in nature. We are being unethical in treating the plant and animal life forms, which coexist in society.

Human beings have certain duties towards their fellow beings. On similar lines, we have a set of duties towards our environment. Environmental ethics says that we should base our behavior on a set of ethical values that guide our approach towards the other living beings in nature.

Environmental ethics is about including the rights of non-human animals in our ethical and moral values. Even if the human race is considered the primary concern of society, animals and plants are in no way less important. They have a right to get their fair share of existence.

We, the human beings, along with the other forms of life make up our society. We all are a part of the food chain and thus closely associated with each other. We, together form our environment. The conservation of natural resources is not only the need of the day but also our prime duty.

COMPUTER ETHICS

Ethics is a set of moral principles that govern the behavior of a group or individual. Therefore, computer ethics is set of moral principles that regulate the use of computers. Some common issues of computer ethics include intellectual property rights (such as copyrighted electronic content), privacy concerns, and how computers affect society. For example, while it is easy to duplicate copyrighted electronic (or digital) content, computer ethics would suggest that it is wrong to do so without the author's approval. And while it may be possible to access someone's personal information on a computer system, computer ethics would advise that such an action is unethical.

As technology advances, computers continue to have a greater impact on society. Therefore, computer ethics promotes the discussion of how much influence computers should have in areas such as artificial intelligence and human communication. As the world of computers evolves, computer ethics continues to create ethical standards that address new issues raised by new technologies.

WEAPONS DEVELOPMENT

A weapon is an instrument used for the purpose of causing harm or damage to people, animals or structures. Weapons are used in hunting, attack, self-defense, or defense in combat and range from simple implements like clubs and spears to complicated modern machines such as intercontinental ballistic missiles. One who possesses or carries a weapon is said to be armed.

In a broader context weapons include anything used to gain an advantage over an adversary or to place them at a disadvantage. Examples include the use of sieges, tactics, and psychological weapons which reduce the morale of an enemy

Classification

By user

- what person or unit uses the weapon

- Personal weapons (or small arms) - designed to be used by a single person.
- Hunting weapon - primarily for hunting game animals for food or sport
- Infantry support weapons - larger than personal weapons, requiring two or more to operate correctly.
- Fortification weapons - mounted in a permanent installation, or used primarily within a fortification.
- Mountain weapons - for use by mountain forces or those operating in difficult terrain.
- Vehicle weapons - to be mounted on any type of military vehicle.
- Railway weapons - designed to be mounted on railway cars, including armored trains.
- Aircraft weapons - carried on and used by some type of aircraft, helicopter, or other aerial vehicle.
- Naval weapons - mounted on ships and submarines.
- Space weapons - are designed to be used in or launched from space. y function

- the construction of the weapon and principle of operation

- Antimatter weapons (theoretical) would combine matter and antimatter to cause a powerful explosion.
- Archery weapons operate by using a tensioned string to launch a projectile.
- Artillery are capable of launching heavy projectiles over long distances.
- Biological weapons spread biological agents, causing disease or infection.
- Chemical weapons, poisoning and causing reactions.
- Energy weapons rely on concentrating forms of energy to attack, such as lasers or sonic attack.
- Explosive weapons use a physical explosion to create blast concussion or spread shrapnel.
- Firearms use a chemical charge to launch projectiles.
- Improvised weapons are common objects, reused as weapons.
- Incendiary weapons cause damage by fire.
- Non-lethal weapons are designed to subdue without killing.
- Magnetic weapons use magnetic fields to propel projectiles, or to focus particle
- Melee weapons operate as physical extensions of the user's body and directly impact **their** target.

- Missiles are rockets which are guided to their target after launch. (Also a general term for projectile weapons).
- Nuclear weapons use radioactive materials to create nuclear fission and/or nuclear fusion

detonations.

- Primitive weapons make little or no use of technological or industrial elements.
- Ranged weapons (unlike Mêlée weapons), target a distant object or person.
- Rockets use chemical propellant to accelerate a projectile
- Suicide weapons exploit the willingness of their operator to not survive the attack.
- Trojan weapons appear on face value to be gifts, though the intent is to in some way to harm the recipient

By targeT

- the type of target the weapon is designed to attack

- Anti-aircraft weapons target missiles and aerial vehicles in flight.
- Anti-fortification weapons are designed to target enemy installations.
- Anti-personnel weapons are designed to attack people, either individually or in numbers.
- Anti-radiation weapons target sources of electronic radiation, particularly radar emitters.
- Anti-satellite weapons target orbiting satellites.
- Anti-ship weapons target ships and vessels on water.
- Anti-submarine weapons target submarines and other underwater targets.
- Anti-tank weapons are designed to defeat armored targets.
- Area denial weapons target territory, making it unsafe or unsuitable for enemy use or travel.
- Hunting weapons are civilian weapons used to hunt animals.
- Infantry support weapons are designed to attack various threats to infantry units

CONSULTING ENGINEERS

Consultants are individuals who typically work for themselves but may also be associated with a consulting firm. They, for a fee, gives advice or provides a service in a field of specialized knowledge or training. Most consultants carry their own life and health insurance, pay their own taxes, most have their own tools and equipment. The consultant can work alone or with the client's staff.

Consultants can play a multi-faceted role. They can, for example function as advisors, fixers, bosses, generalists, stabilizers, listeners, advisors, specialists, catalysts, managers or quasi- employees. The actual work that consultants perform for one company to another may vary greatly, i.e. tax account to office decoration. However, the typical underlying reasons that a consultant is hired are universal. A problem exists and the owner or manager of the company has decided to seek the help of an expert.

Bringing in an expert can save time, effort and money. It has been estimated that approximately 3/4 of all companies call upon consultants at one time or another. Many companies claim that they receive a higher return for their invested dollars by using consultants for specific tasks.

Most companies have experienced the problem of needing short-term technical expertise. Perhaps the company's existing staff is already working to capacity. In many cases, the engineering skills required for a project can be satisfied with a full time employee. When they can not fully justify bringing someone on board full time, their answer is to hire a consultant. By doing so, the businessman solves his immediate problem without permanently increasing his payroll and payroll taxes.

Consultants can be hired when the company may not have anyone on staff capable of solving the specific problem. At such times, a costly learning curve on the part of the engineering staff is associated with the project. One example is using a consultant as a viable alternative during the development stages of new products. Hiring a consultant with experience in a given area can then cut days, weeks or even months off a project schedule. In addition, he can help the staff avoid mistakes they may otherwise make. When the project reaches a certain point, the permanent staff can then take over.

Consultants can deal directly with owners and upper management. In this role, consultants can provide an objective third-party view point. Critical objectives can then be identified and advise given in confidence

Consultants are a viable alternative in assisting in feasibility studies or in proposal preparation.

Perhaps the manager cannot justify shifting the duties of existing staff members.

Another time that consultants become useful is when a company is just starting a business. The development of the company's new product can be begun by the consultant while a full time permanent technical staff member is being hired.

Finding the right consultant can be difficult. Managers can rely on referrals from their friends or hire the consultant who happens to call at the right time. Once the decisions is made to hire a consultant, the need is immediate and one may not have the time to shop for a consultant. As a part of planning ahead, it is wise to meet various consultants on an informal basis before the need to hire one arises. Then when the time comes, you will know exactly who to call for you have already established an informal relationship

ETHICS IN ASCE

To preserve the high ethical standards of the civil engineering profession, the Society's ethics program includes:

- Edict

  The Society maintains a Code of Ethics.

- Enforcement

  The Society enforces the Code by investigating potential violations of the Code and taking disciplinary action if warranted.

- Education

  The Society endeavors to educate its members and the public on ethics issues.

IEEE code of Ethics

1. to accept responsibility in making decisions consistent with the safety, health and welfare of the public, and to disclose promptly factors that might endanger the public or the environment;
2. to avoid real or perceived conflicts of interest whenever possible, and to disclose them to affected parties when they do exist;
3. to be honest and realistic in stating claims or estimates based on available data;
4. to reject bribery in all its forms;
5. to improve the understanding of technology, its appropriate application, and potential consequences;
6. to maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations;
7. to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others;
8. to treat fairly all persons regardless of such factors as race, religion, gender, disability, age, or national origin;
9. to avoid injuring others, their property, reputation, or employment by false or malicious action;
10. to assist colleagues and co-workers in their professional development and to support them in following this code of ethics

Ethics in Indian Institute of Materials and Management

- To consider first, the TOTAL interest to one's organization in all transactions without impairing the dignity and responsibility to one's office;
- To buy without prejudice, seeking to obtain the maximum ultimate value for each Rupee of Expenditure;
- To subscribe and work for honesty and truth in buying and selling, to denounce all forms and manifestations of commercial bribery and to eschew anti-social practices;
- To accord a prompt and courteous reception so far as conditions will permit, to all who call upon a legitimate business mission;

To respect one's obligations and those of one's organization, consistent with good business practice

Ethics in Institute of Engineers

1.1 Engineers serve all members of the community in enhancing their welfare, health and safety by a creative process utilising the engineers' knowledge, expertise and experience.

1.2 Pursuant to the avowed objectives of The Institution of Engineers (India) as enshrined in the presents of the Royal Charter granted to the Institution, the Council of the Institution prescribed a set of "Professional Conduct Rules" in the year 1944 replacing the same with the "Code of Ethics for Corporate Members" in the year 1954 which was revised in the year 1997.

1.3 In view of globalisation, concern for the environment and the concept of sustainable development, it has been felt that the prevailing "Code of Ethics for Corporate Members" needs review and revision in letter and spirit. The engineering organisations world over have updated their Code of Ethics.

1.4 The Council of the Institution vested with the authority in terms of the Present 2(j) of the Royal Charter adopted at its 626th meeting held on 21.12.2003 at Lucknow the "Code of Ethics for Corporate Members" as provided hereinafter.

1.5 The Code of Ethics is based on broad principles of truth, honesty, justice, trustworthiness, respect and safeguard of human life and welfare, competence and accountability which constitute the moral values every Corporate Member of the Institution must recognize, uphold and abide by.

1.6 This "Code of Ethics for Corporate Members" shall be in force till the same is revised by a decision of the Council of the Institution.

CODE OF ETHICS FOR Institute of Engineers

1.0 Preamble

1.1 The Corporate Members of The Institution of Engineers (India) are committed to promote and practice the profession of engineering for the common good of the community bearing in mind the following concerns :

1.1.1 Concern for ethical standard;
1.1.2 Concern for social justice, social order and human rights;
1.1.3 Concern for protection of the environment;
1.1.4 Concern for sustainable development;
1.1.5 Public safety and tranquility.

2.0 The Tenets of the Code of Ethics

2.1 A Corporate Member shall utilise his knowledge and expertise for the welfare, health and safety of the community without any discrimination for sectional or private interests.

2.2 A Corporate Member shall maintain the honour, integrity and dignity in all his professional actions to be worthy of the trust of the community and the profession.

2.3 A Corporate Member shall act only in the domains of his competence and with diligence, care, sincerity and honesty.

2.4 A Corporate Member shall apply his knowledge and expertise in the interest of his employer or the clients for whom he shall work without compromising with other obligations to these Tenets.

2.5 A Corporate Member shall not falsify or misrepresent his own or his associates' qualifications, experience, etc.

2.6 A Corporate Member, wherever necessary and relevant, shall take all reasonable steps to inform himself, his employer or clients, of the environmental, economic, social and other possible consequences, which may arise out of his actions.

2.7 A Corporate Member shall maintain utmost honesty and fairness in making statements or giving witness and shall do so on the basis of adequate knowledge.

2.8 A Corporate Member shall not directly or indirectly injure the professional reputation of another member.

2.9 A Corporate Member shall reject any kind of offer that may involve unfair practice or may cause avoidable damage to the ecosystem.

2.10 A Corporate Member shall be concerned about and shall act in the best of his abilities for maintenance of sustainability of the process of development.

2.11 A Corporate Member shall not act in any manner which may injure the reputation of the Institution or which may cause any damage to the Institution financially or otherwise.

3.0 General Guidance

The Tenets of the Code of Ethics are based on the recognition that –

3.1 A common tie exists among the humanity and that The Institution of Engineers (India) derives its value from the people, so that the actions of its Corporate Members should indicate the member's highest regard for equality of opportunity, social justice and fairness;

3.2 The Corporate Members of the Institution hold a privileged position in the community so as to make it a necessity for their not using the position for personl and sectional interests.

4.0 And, as such, a Corporate Member –

4.1 should keep his employer or client fully informed on all matters in respect of his assignment which are likely to lead to a conflict of interest or when, in his judgement, a project will not be viable on the basis of commercial, technical, environmental or any other risks;

4.2 should maintain confidentiality of any information with utmost sincerity unless expressly permitted to disclose such information or unless such permission, if withheld, may adversely affect the welfare, health and safety of the community;

4.3 should neither solicit nor accept financial or other considerations from anyone related to a project or assignment of which he is in the charge;

4.4 should neither pay nor offer direct or indirect inducements to secure work;

4.5 should compete on the basis of merit alone;

4.6 should refrain from inducing a client to breach a contract entered into with another duly appointed engineer;

4.7 should, if asked by the employer or a client, to review the work of another person or organisation, discuss the review with the other person or organisation to arrive at a balanced opinion;

4.8 should make statements or give evidence before a tribunal or a court of law in an objective and accurate manner and express any opinion on the basis of adequate knowledge and competence; and

4.9 should reveal the existence of any interest – pecuniary or otherwise – which may affect the judgement while giving an evidence or making a statement.

5.0 Any decision of the Council as per provisions of the relevant Bye-Laws of the Institution shall be final and binding on all Corporate Members

ASME Code of Ethics of Engineers

ASME requires ethical practice by each of its members and has adopted the following Code of Ethics of Engineers as referenced in the ASME Constitution, Article C2.1.1.

CODE OF ETHICS OF ENGINEERS The
Fundamental Principles

Engineers uphold and advance the integrity, honor and dignity of the engineering profession by:

I. Using their knowledge and skill for the enhancement of human welfare;

II. Being honest and impartial, and serving with fidelity the public, their employers and clients; and

III. Striving to increase the competence and prestige of the engineering profession. The Fundamental Canons

1. Engineers shall hold paramount the safety, health and welfare of the public in the performance of their professional duties.
2. Engineers shall perform services only in the areas of their competence.
3. Engineers shall continue their professional development throughout their careers and shall provide opportunities for the professional and ethical development of those engineers under their supervision.
4. Engineers shall act in professional matters for each employer or client as faithful agents or trustees, and shall avoid conflicts of interest or the appearance of conflicts of interest.
5. Engineers shall build their professional reputation on the merit of their services and shall not compete unfairly with others.
6. Engineers shall associate only with reputable persons or organizations.
7. Engineers shall issue public statements only in an objective and truthful manner.
8. Engineers shall consider environmental impact in the performance of their professional duties.

The ASME criteria for interpretation of the Canons are guidelines and represent the objectives toward which members of the engineering profession should strive. They are principles which an engineer can reference in specific situations. In addition, they provide interpretive guidance to the ASME Board on Professional Practice and Ethics on the Code of Ethics of Engineers.

1. Engineers shall hold paramount the safety, health and welfare of the public in the performance of their professional duties.

   a. Engineers shall recognize that the lives, safety, health and welfare of the general public are dependent upon engineering judgments, decisions and practices incorporated into structures, machines, products, processes and devices.

   b. Engineers shall not approve or seal plans and/or specifications that are not of a design safe to the public health and welfare and in conformity with accepted engineering standards.

   c. Whenever the Engineers' professional judgments are over ruled under circumstances where the safety, health, and welfare of the public are

   endangered, the Engineers shall inform their clients and/or employers of the possible consequences.

(1) Engineers shall endeavor to provide data such as published standards, test codes, and quality control procedures that will enable the users to understand safe use during life expectancy associated with the designs, products, or systems for which they are responsible.

(2) Engineers shall conduct reviews of the safety and reliability of the designs, products, or systems for which they are responsible before giving their approval to the plans for the design.

(3) Whenever Engineers observe conditions, directly related to their employment, which they believe will endanger public safety or health, they shall inform the proper authority of the situation.

d. If engineers have knowledge of or reason to believe that another person or firm may be in violation of any of the provisions of these Canons, they shall present such information to the proper authority in writing and shall cooperate with the proper authority in furnishing such further information or assistance as may be required.

2. Engineers shall perform services only in areas of their competence.

a. Engineers shall undertake to perform engineering assignments only when qualified by education and/or experience in the specific technical field of engineering involved.

b. Engineers may accept an assignment requiring education and/or experience outside of their own fields of competence, but their services shall be restricted to other phases of the project in which they are qualified. All other phases of such project shall be performed by qualified associates, consultants, or employees.

3. Engineers shall continue their professional development throughout their careers, and should provide opportunities for the professional and ethical development of those engineers under their supervision.
4. Engineers shall act in professional matters for each employer or client as faithful agents or trustees, and shall avoid conflicts of interest or the appearance of conflicts of interest.

a. Engineers shall avoid all known conflicts of interest with their employers or clients and shall promptly inform their employers or clients of any business association, interests, or circumstances which could influence their judgment or the quality of their services.

b. Engineers shall not undertake any assignments which would knowingly create a potential conflict of interest between themselves and their clients or their employers.

c. Engineers shall not accept compensation, financial or otherwise, from more than one party for services on the same project, or for services pertaining to the same project, unless the circumstances are fully disclosed to, and agreed to, by all interested parties.

d. Engineers shall not solicit or accept financial or other valuable considerations, for specifying products or material or equipment suppliers, without disclosure to their clients or employers

e. Engineers shall not solicit or accept gratuities, directly or indirectly, from contractors, their agents, or other parties dealing with their clients or employers in connection with work for which they are responsible. Where official public policy or employers' policies tolerate acceptance of modest gratuities or gifts, engineers shall avoid a conflict of interest by complying with appropriate policies and shall avoid the appearance of a conflict of interest.

f. When in public service as members, advisors, or employees of a governmental body or department, Engineers shall not participate in considerations or actions with respect to services provided by them or their organization(s) in private or product engineering practice.

g. Engineers shall not solicit an engineering contract from a governmental body or other entity on which a principal, officer, or employee of their organization serves as a member without disclosing their relationship and removing themselves from any activity of the body which concerns their organization.

h. Engineers working on codes, standards or governmental sanctioned rules and specifications shall exercise careful judgment in their determinations to ensure a balanced viewpoint, and avoid a conflict of interest.

i. When, as a result of their studies, Engineers believe a project(s) will not be successful, they shall so advise their employer or client.

j. Engineers shall treat information coming to them in the course of their assignments as confidential, and shall not use such information as a means of making personal profit if such action is adverse to the interests of their clients, their employers or the public.

(1) They will not disclose confidential information concerning the business affairs or technical processes of any present or former employer or client or bidder under evaluation, without his consent, unless required by law or court order.

(2) They shall not reveal confidential information or finding of any commission or board of which they are members unless required by law or court order

(3) Designs supplied to Engineers by clients shall not be duplicated by the Engineers for others without the express permission of the client(s).

k. Engineers shall act with fairness and justice to all parties when administering a construction (or other) contract.

l. Before undertaking work for others in which Engineers may make improvements, plans, designs, inventions, or other records which may justify seeking copyrights, patents, or proprietary rights, Engineers shall enter into positive agreements regarding the rights of respective parties.

m. Engineers shall admit their own errors when proven wrong and refrain from distorting or altering the facts to justify their mistakes or decisions.

n. Engineers shall not accept professional employment or assignments outside of their regular work without the knowledge of their employers.

o. Engineers shall not attempt to attract an employee from other employers or from the market place by false or misleading representations.

5. Engineers shall build their professional reputation on the merit of their services and shall not compete unfairly with others.

a. Engineers shall negotiate contracts for professional services on the basis of demonstrated competence and qualifications for the type of professional service required.

b. Engineers shall not request, propose, or accept professional commissions on a contingent basis if, under the circumstances, their professional judgments may be compromised.

c. Engineers shall not falsify or permit misrepresentation of their, or their associates, academic or professional qualification. They shall not misrepresent or exaggerate their degrees of responsibility in or for the subject matter of prior assignments. Brochures or other presentations used to solicit personal employment shall not misrepresent pertinent facts concerning employers, employees, associates, joint venturers, or their accomplishments.

d. Engineers shall prepare articles for the lay or technical press which are only factual. Technical Communications for publication (theses, articles, papers, reports,etc.) which are based on research involving more than one individual (including students and supervising faculty, industrial supervisor/researcher or other co-workers) must recognize all significant contributors. Plagiarism, the act of substantially using another's ideas or written materials without due credit, is unethical. (See Appendix.)

e. Engineers shall not maliciously or falsely, directly or indirectly, injure the professional reputation, prospects, practice or employment of another engineer, nor shall they indiscriminately criticize another's work.

f. Engineers shall not use equipment, supplies, laboratory or office facilities of their employers to carry on outside private practice without consent.

6. Engineers shall associate only with reputable persons or organizations.

a. Engineers shall not knowingly associate with or permit the use of their names or firm names in business ventures by any person or firm which they know, or have reason to believe, are engaging in business or professional practices of a fraudulent or dishonest nature.

b. Engineers shall not use association with non-engineers, corporations, or partnerships to disguise unethical acts.

7. Engineers shall issue public statements only in an objective and truthful manner.

a. Engineers shall endeavor to extend public knowledge, and to prevent misunderstandings of the achievements of engineering.

b. Engineers shall be completely objective and truthful in all professional reports, statements or testimony. They shall include all relevant and pertinent information in such reports, statements or testimony.

c. Engineers, when serving as expert or technical witnesses before any court, commission, or other tribunal, shall express an engineering opinion only when it is founded on their adequate knowledge of the facts in issue, their background of technical competence in the subject matter, and their belief in the accuracy and propriety of their testimony.

d. Engineers shall issue no statements, criticisms, or arguments on engineering matters which are inspired or paid for by an interested party, or parties, unless they preface their comments by identifying themselves, by disclosing the identities of the party or parties on whose behalf they are speaking, and by revealing the existence of any financial interest they may have in matters under discussion.

e. Engineers shall be truthful in explaining their work and merit, and shall avoid any act tending to promote their own interest at the expense of the integrity and honor of the profession or another individual.

8. Engineers shall consider environmental impact in the performance of their professional duties.

a. Engineers shall concern themselves with the impact of their plans and designs on the environment. When the impact is a clear threat to health or safety of the public, then the guidelines for this Canon revert to those of Canon 1.

9. Engineers accepting membership in The American Society of Mechanical Engineers by this action agree to abide by this Society Policy on Ethics and procedures for its implementation.

Moral Leadership

Moral Leadership brings together in one comprehensive volume essays from leading scholars in law, leadership, psychology, political science, and ethics to provide practical, theoretical policy guidance. The authors explore key questions about moral leadership such as:

- How do leaders form, sustain, and transmit moral commitments?
- Under what conditions are those processes most effective?
- What is the impact of ethics officers, codes, training programs, and similar initiatives?
- How do standards and practices vary across context and culture?
- What can we do at the individual, organizational, and societal level to foster moral leadership?

ENGINEERS AS EXPERT WITNESS AND ADVISORS

Engineering expert witnesses are highly credentialed mechanical, safety & civil, geotechnical, chemical and electrical engineers specializing in the areas of design, construction & structural engineering, failure analysis, human factors, occupational safety, metallurgy and more. They provide litigation support through review and evaluation of distressed structures for land slide and erosion cases; performance of forensic studies on hydraulics, power plants, pipelines, boiler systems, traffic, automotive, electrical fire involving electrical systems of machinery; site research and inspection, laboratory testings, report writing, depositions and court testimony.

Engineers shall endeavor to extend public knowledge, and to prevent misunderstandings of the achievements of engineering.

b. Engineers shall be completely objective and truthful in all professional reports, statements or testimony. They shall include all relevant and pertinent information in such reports, statements or testimony.

c. Engineers, when serving as expert or technical witnesses before any court, commission, or other tribunal, shall express an engineering opinion only when it is founded on their adequate knowledge of the facts in issue, their background of technical competence in the subject matter, and their belief in the accuracy and propriety of their testimony.

UNIT-I HUMAN VALUES		Knowledge level
	PART – A (C410.1)	
1.	**What are human values? (May 2022)**	**BL1**
	Human values are the virtues that guide us to take into account the human element when we interact with other human beings. Human values are, for example, respect, acceptance, consideration, appreciation, listening, openness, affection, empathy and love towards other human beings. Values decide the standard of behavior. Some universally accepted values are freedom justice and equality. Other principles of values are love, care, honesty, integrity, self-respect.	
2.	**What are ethical values? (May 2022, May 2023)**	**BL1**
	Values which serve to distinguish between good and bad, right and wrong, and moral and immoral. At a societal level, these values frequently form a basis for what is permitted and what is prohibited. Trustworthiness, respect, responsibility, fairness, caring are ethical values.	
3.	**Distinguish values from ethics and culture.**	**BL2**
	Values are mainly related to individuals and since they are related to justice, they remain the same for everyone. Example: Truth, honesty, empathy, self-respect. Ethics is the intent to observe the spirit of the law. Ethics is mostly based on some code or law and judgment of any action which is based on code of conduct or law. Culture refers to conduct of a group. Example: System of worship, marriage. It may differ from society to society, nation to nation or religion to religion.	
4.	**What is integrity and how is it related to work ethics? (Nov 2018)**	**BL2**

	Integrity is the unity of character based on moral values. Consistency in attitudes, emotions and conduct in relations to morally justified actions and values are also the part of integrity of individual. It implies honesty, trustworthiness. Integrity is the bridge between responsibility in private and professional life.	
5.	**Define cooperation.**	**BL1**
	Cooperation in the ethically significant sense is defined as the participation of one agent in the activity of another agent to produce a particular effect or share in a joint activity. Co-operation means extending help to others, for a good cause. Co-operation may be through an idea, a suggestion, an assistance or physical work which extends to others for common benefit.	
6.	**Define work ethics. (May 2019)**	**BL1**
	Work ethics is a set of values centered on the importance of doing work and reflected especially in a desire or determination to work hard. By one's work one cannot harm others. Any worker cannot escape accountability. Worker has the moral responsibility to see that no other person's right, private or freedom is impaired or transgressed.	
7.	**List the elements of work ethics.**	**BL1**
	The elements of work ethics are: (i) Interpersonal skills. (ii) Initiatives. (iii) Being dependable.	
8.	**What is duty ethics?**	**BL1**
	Duty-based ethics teaches that some acts are right or wrong because of the sorts of things they are, and people have a duty to act accordingly, regardless of the good or bad consequences that may be produced. Duty ethics live in a universe of moral rules, such as, (i) It is wrong to kill innocent people. (ii) It is wrong to steal. (iii) It is wrong to tell lies.	

9.	**What is service learning? (Nov 2019)**	**BL1**
	Service learning is a teaching and learning strategy that integrates meaning community service with instruction and reflection to enrich the learning experience, teach civil responsibility and strengthen communities. Service learning tells that one has moral responsibility to increase the desirable effects and to decrease the harmful effects.	
10.	**What are the characteristics of service learning?**	**BL1**
	The characteristics of service learning are: (i) It links academic content and standard. (ii) It promotes skill associated with team work, community involvement & citizenship. (iii) It gives the ability to identify the critical issue in the society.	
11.	**Write short notes on caring and sharing.**	**BL1**
	Caring is the essence of moral life. Caring involves feelings, relationship, contends with other persons and protecting others and causing least damage to others. Sharing means sharing of feelings, ideas, thoughts, resources and profits. Sharing is always mutually beneficial. Sharing morally acceptable feelings, resources and materials is a value.	
12.	**What is honesty? (Nov 2019)**	**BL1**
	Honesty is a component of moral character that connotes positive and virtuous attributes, such as integrity, truthfulness, and openness — including clarity of conduct, along with the absence of lying, cheating, theft, etc. Honesty also involves being reliable, trustworthy, loyal, fair, and sincere. Honesty is the fundamental virtue in human relationship. Any human being should imbibe honesty i.e. honesty in acts, honesty in speech and honesty in beliefs, even though it may be difficult to follow some times.	
13.	**List out any two aspects of honesty.**	**BL1**

	The two aspects of honesty are truthfulness and trustworthiness. (i) Truthfulness means meeting responsibilities concerning truth-telling. (ii)Trustworthiness is meeting responsibilities concerning trust.	
14.	**What is courage as a value?**	**BL1**
	Courage implies self-respect and governs confrontations with danger and risk. It is not excessive rashes or cowardice, but it is the middle ground. Taking calculated risks and boldness in facing crises are the hallmarks of courage as a human value. It defines the mental makeup of an individual in taking bold decisions even under adverse situations.	
15.	**Define empathy. (May 2018, May 2022, May 2023)**	**BL1**
	Empathy means putting self in a position of someone else and thinking as the later and reasoning suitable action. Empathy is the ability to identify with or understand the perspective, experiences, or motivations of another individual and to comprehend and share another individual's emotional state.	
16.	**What is meant by civic virtues?**	**BL1**
	Civic virtue is morality or a standard of righteous behavior in relationship to a citizen's involvement in society. An individual may exhibit civic virtue by voting, volunteering, organizing a book group, or attending a PTA meeting. Civic virtue is the principle of not harming the surroundings. Good citizen demand civic virtue. It also includes living peacefully, respect for others, protecting the environment and being normally and ethically good.	
17.	**Define spirituality. (May 2019)**	**BL1**
	Spirituality is a sense or belief that there is something greater than oneself. Spirituality raises a man above the materialistic world into a realm where he seeks peace and real happiness.	
18.	**Write the objective of professional ethics and human values.**	**BL1**

<table>
<tr><td></td><td>The objective of professional ethics and human values are as follows:
(i)To understand the moral values to guide the engineering profession. (ii Resolve the moral issue. (iii)Justify the moral judgment. (iv)Develop a set of attitude, belief and habits.</td><td></td></tr>
<tr><td>19.</td><td>Define compromise. (May 2022)</td><td>BL1</td></tr>
<tr><td></td><td>Compromise means to settle differences by mutual concessions or to reconcile conflicts through adjustments in attitude and conduct. In a negative sense it means to undetermined integrity by violating one’s fundamental moral principles.</td><td></td></tr>
<tr><td>20.</td><td>Distinguish between profession and professionalism.</td><td>BL2</td></tr>
<tr><td></td><td>Professionalism relates to any work that a person does for an occupation, especially work which requires a special skill or training.
“Profession” means a type of job that requires special training and that brings a fairly high status.</td><td></td></tr>
<tr><td>21.</td><td>Differentiate Self-respect and Self-esteem.</td><td>BL2</td></tr>
<tr><td></td><td><table>
<tr><th>Self-respect</th><th>Self-esteem</th></tr>
<tr><td>Self-respect is a moral concept</td><td>Self-esteem is a psychological concept</td></tr>
<tr><td>Self-respect refers to the virtue properly valuing oneself</td><td>Self-esteem means having a positive attitude toward oneself, even if the attitude is excessive or otherwise unwarranted.</td></tr>
<tr><td>Self-respect is difficult to shatter since it is a form of acceptance.</td><td>Self-esteem can be shattered as it is mostly boosted by other’s opinions and reactions.</td></tr>
</table>
The key difference between self-respect and self-esteem is that while self-respect concentrates on the individual for who he is, self-esteem concentrates on the abilities and skills of the individual.</td><td></td></tr>
<tr><td>22.</td><td>Differentiate sympathy from empathy. (May 2021)</td><td>BL2</td></tr>
<tr><td></td><td><table>
<tr><th>Empathy</th><th>Sympathy</th></tr>
<tr><td>Empathy means experiencing so meone else’s feelings.</td><td>Sympathy means understandin someone else’s suffering.</td></tr>
<tr><td>It requires an emotional component of really feeling, what the other person is feeling.</td><td>It is more cognitive in nature and keeps a certain distance.</td></tr>
</table></td><td></td></tr>
</table>

23.	**Write the difference between ethics, morale and values. (May 2021)**	**BL2**
	Ethics are moral codes that drive people to decide which is right or wrong. This right or wrong can be related to a person or to a collective group of individuals. Values are principles that are unbiased and reflects the possessive virtue of a person irrespective of ethical or unethical backgrounds. Ethics and values may vary from person to person and from places to places. Morale is followed because a person believes that it is the right course of action.	
24.	**Define Moral values with suitable examples.**	**BL1**
	Moral values are the standards of good and evil, which govern an individual's behavior and choices. Individual's moral may derive from society, government, religion. Honesty, respect for others, loyalty, responsibility for personal actions, generosity and kindness are examples of moral values.	
25.	**What is meant by self-confidence? (Or) what are the qualities of a self- confident people? (Nov 2018)**	**BL1**
	Certainty in one's own capabilities, values, and goals, is self-confidence. Self-confidence is positive attitude, wherein the individual has some positive and realistic view of himself, with respect to the situations in which one gets involved. People with self-confidence are usually optimistic, flexible and adaptive in nature. They respect others so much as they respect themselves.	
26.	**How can stress management be achieved by yoga?**	**BL1**
	Yoga provides long term effect on anxiety reduction and helps to bring controlled response to stress. Yoga looks after mental well-being by calming the mind. Yoga brings an improved concentration to deal with situations with a calm mind. Meditation is an important factor in yoga for stress management. Breathing exercises are extremely important in yoga for stress management. The slow breath patterns along with inhaling and exhaling techniques bring more positive energy to your body and also helps to keep the heart rate and blood pressure normal.	
27.	**Define Engineering Ethics.**	**BL1**

	Engineering Ethics is the set of rules and guidelines that engineers adhere to as a moral obligation to their profession and to the world. It is study of the moral issues and decisions confronting individuals and organizations, engaged in engineering / profession. Study of related questions about the moral ideals, character, policies and relationships of people and corporations involved in technological activity. Moral standards / values and system of morals.	
	PART-B (C410.1)	
1.	Explain some important human values.	**BL4**
2.	Explain integrity and honesty in ethics. **(May 2019, May 2022, 2023)**	**BL4**
3.	What is integrity? How integrity plays a major factor in work ethics? Discuss with suitable examples **(May 2018).**	**BL4**
4.	Explain the importance of self confidence in ethics. **(May 2022, 2023)**	**BL4**
5.	What is Service Learning? Discuss its role in caring and sharing in society with suitable examples. **(Nov 2018)**	**BL4**
6.	Explain commitment and empathy.	**BL4**
7.	Explain character and spirituality and their importance in ethics.	**BL4**
8.	Write brief notes on yoga and meditation for professional excellence and stress management**. (Nov 2019, May 2021, May 2023)** (or) Explain the role of yoga in professional ethics **(May 2019)**	**BL4**
9.	(i)What is courage? What are salient features of courage? **(May 2022)** (ii) Write short notes on honesty.	**BL4**
10.	What is Empathy? Discuss its role in spiritual development for the excellence in an organization with suitable examples. **(Nov 2018)**	**BL4**
11.	Explain the scope and importance of professional ethics in Engineering. **(May 2019) [Probable part-C]**	**BL5**
12.	What is Spirituality? What are the spiritual traits to be developed for excellence in an organization? Discuss with suitable examples. **(May 2018, May 2022)** (or) Explain the different ways to improve the spirituality in corporate environment? **(Nov 2019)**	**BL4**

13.	Write the need and importance of studying ethics and how far the study of ethics improves the behavior of an individual and boosts the organization culture. **(May 2021) [Probable part-C]**	**BL5**
UNIT II- ENGINEERING ETHICS		
	PART-A (C410.2)	
1.	**What is the need to study ethics? Or Write the need of Engineering ethics. (May 2021, May 2022)**	**BL1**
	The need of Engineering ethics are, (i) To responsibly confront moral issues raised by technological activity. (ii) To recognize and resolve moral dilemma. (iii) To achieve moral autonomy. (iv) To integrate one's professional life and personal convictions.	
2.	**Define ethics. (May 2022)**	**BL1**
	Ethics is defined as study of morality. Ethics is based on well-founded standards of right and wrong that prescribe what humans ought to do, usually in terms of rights, obligations, benefits to society, fairness, or specific virtues.	
3.	**Define Engineering ethics. (May 2022)**	**BL1**
	Engineering ethics is the study of the decisions, policies and values that are morally desirable in engineering practices and research. As a set of values, Engineering ethics consist of responsibilities and rights that ought to be endorsed by those engaged in engineering and also, of desirable ideals and personal commitments in engineering.	
4.	**What are the senses of Engineering ethics?**	**BL1**

	There are two different senses of engineering ethics, namely the Normative and the Descriptive senses. The normative sense includes: (*a*) Knowing moral values, finding accurate solutions to moral problems and justifying moral judgments in engineering practices, (*b*) Study of decisions, policies, and values that are morally desirable in the engineering practice and research, and (*c*) Using codes of ethics and standards and applying them in their transactions by engineers. The descriptive sense refers to what specific individual or group of engineers believe an act, without justifying their beliefs or actions.	
5.	**What is the method used to solve an ethical problem?**	**BL1**
	The method used to solve an ethical problem is as follows: (i)Recognizing a problem or its need. (ii)Gathering information and defining the problem to be solved or goal to be achieved. (iii)Generating alternative solutions or methods to achieve the goal. (iv)Evaluate benefits and costs of alternate solutions. (v)Decision making & optimization. (vi)Implementing the best solution.	
6.	**State Rawl's principles.**	**BL1**
	Rawl's principles states that "Each person is entitled to the most extensive amount of liberty compatible with an equal amount for others. Differences in social power and economic benefits are justified only when they are likely to benefit everyone, including members of the most disadvantaged groups."	
7.	**What are the steps in confronting moral dilemma?**	**BL1**

	The steps in confronting moral dilemma are: (i) Identify the relevant moral factors and reasons. (ii) Gather all available facts that are pertinent to the moral factors involved. (iii) Rank the moral considerations in order of importance as they apply to the situation. (iv) Consider alternative courses of actions as ways of resolving dilemma, tracing the full implications of each.	
8.	**What is Moral Autonomy? (May 2018, Nov 2018, Nov 2019))**	**BL1**
	Moral Autonomy is the philosophy which is self-governing or self-determining, i.e., acting independently without the influence of others. Moral Autonomy is concerned with independent attitude of a person related to moral/ethical issues. Moral autonomy can be viewed as the skills and habit of thinking rationally about ethical issues on the basis of moral concern.	
9.	**What is meant by utilitarianism?**	**BL1**
	• Utilitarianism is a theory of morality, which advocates actions that foster happiness and oppose actions that cause unhappiness. Utilitarianism promotes the greatest amount of good for the greatest number of people. • When used in a sociopolitical construct, utilitarian ethics aims for the betterment of society as a whole. Utilitarianism does not account for things like feelings and emotions, culture, or justice.	
10.	**Define moral dilemmas. (May 2019, May 2021)**	**BL1**
	A moral dilemma is a conflict situation in which the choice one makes causes a moral harm, which cannot be restlessly repaired. Moral dilemmas are situations in which two or more moral obligations and ideas come into conflict with each other. Moral principles cannot be fully respected in a given situation. Solving one moral principle can create two or more conflicting applications.	

11.	**Differentiate moral and ethics.**	**BL2**

S. No	**MORAL**	**ETHICS**
1	Moral refers only to personal behavior.	Ethics refers only to professional behavior.
2	Social conventions about right or wrong conduct.	Ethics is critical reflection on what one does and why one does it.
3	Morals are mainly followed because an individual himself/herself think it is the right thing to do.	Ethics are mainly followed because the society believes something is right to be done.
4	Morals surpass cultural (or) professional boundaries (or) norms.	Ethics are governed by principles (or) guidelines which are legal or professional in nature and are considered at a specific time and place.

12.	**Give the importance of Lawrence Kohlberg's and Carol Gilligan's theory.**	**BL1**
	Kohlberg gives greater emphasis to recognizing rights and abstract universal rules. It had been observed that Kohlberg's theory was proposed based on the moral thinking of privileged white men and boys. Gilligan stresses the importance of maintaining personal relationships based on mutual caring. Gilligan's theory focused on both care-based morality and justice-based morality. Care-based morality is based on the following principles: Emphasizes interconnectedness and universality. Care-based morality is thought to be more common in girls because of their connections to their mothers.	
13.	**What do you mean by normative ethics?**	**BL1**
	Normative ethics deals with the professional codes of ethics that specify role norms or obligations that professions attempt to enforce. It is the recommendations of standards and guidelines for morally right or good behavior.	

14.	**What are the types of theories about morality?(Nov 2019)(May 2022, 2023)**	**BL1**
	The different theories about morality are : (i)Virtue ethics – Virtues and vices (ii) Utilitarianism – Most good for the most people. (iii) Duty ethics – Duties to respect people. (v) Rights ethics – Human rights.	
15.	**Give the drawbacks of utilitarianism. (May 2022)**	**BL2**
	The one disadvantage that Utilitarianism cannot escape is that, it focuses on the outcome of a choice instead of the act itself. There is no moral judgment on the actual actions that a person chooses to take. Society does not solely focus on happiness when making choices. Sometimes what is best for the community as a whole is bad for certain individuals in the community. It is often impossible to know in advance which decision will lead to the good.	
16.	**Differentiate ethical relativism and ethical egoism.**	**BL2**
	Ethical relativism –Ethical relativism states that there is no universally accepted ethical standard i.e., different culture have different ethical standards. The view that right action is merely what the law and customs of one's society require. Ethical egoism – It deals with self-interest. Ethical egoism is the prescriptive doctrine that all persons ought to act from their own self-interest. According to Ethical egoism right action is one, which emphasis on one's own good.	
17.	**Define Ethical Pluralism.**	**BL1**
	Ethical pluralism is the view that there may be alternative moral perspectives that are reasonable, but no one of which must be accepted completely by all rational and morally concerned persons.	
18.	**Give the uses of Ethical Theories. (May 2018, May 2023)**	**BL1**

	Ethical theories are useful in • Understanding moral dilemmas. • Justifying professional obligations and ideals. • Relating ordinary and professional morality. • Strengthening the ability to reach balanced and insightful judgments. • Providing a systematic framework of comparing alternatives course of action.	
19.	**List the theories about Right Action. (Nov 2018)**	**BL1**
	The theories about Right Action are 1) Utilitarian Ethics 2) Duty based Ethics 3) Right based Ethics.	
20.	**What are the attributes to a profession?**	**BL1**
	The attributes to a profession are (i) Advanced expertise: Professionals require sophisticated skills and theoretical knowledge. (ii) Self- regulation: Well established societies of professionals are allowed in drafting the codes of ethics, enforcing standards of conduct. (iii) The profession should serve some important public good.	
21.	**What the various types are of inquiry?**	**BL1**
	The various types of inquiries are (i) Normative Inquiry – Based on values. (ii) Conceptual Inquiry – Based on meaning. (iii) Factual Inquiry – Based in facts.	
22.	**What is meant by consensus?**	**BL1**
	Consensus means agreement and controversy means disagreement**.** The consensus and the controversies are playing the vital roles while considering the moral autonomy. When an individual exercise moral autonomy, he may not be able to attain the same results as other people obtain in practicing their moral autonomy. There might be some moral differences i.e. the results or verdicts will be of controversy.	

23.	**What are the major limitations of codes of ethics?**	**BL2**
	The major limitations of codes of ethics are: (i) They cannot serve as the final moral authority for professional conduct. (ii) Engineering codes often have internal conflicts. (iii) Codes can be reproduced in a very rapid manner. (iv) Codes are said to be coercive.	
24.	**What are the types of Industrial Standards?**	**BL1**
	The different types of Industrial Standards are (i) Quality (ii) Quality related to service. (iii) Safety (iv) Acceptance in procedures for usage (v) Physical properties and functions.	
25.	**What are the difficulties in implementing duty and rights ethics theories?**	**BL1**
	The two difficulties in implementing duty and right ethics theories are: 1. It is sometimes very difficult to prioritize the rights of individual or groups. Because the basic rights of an individual or groups of individual may conflict with the basic rights of another group. 2. As both duty and rights ethics theories concern more about the good of an individual, sometimes the overall good of society is not given much importance.	
26.	**State any two methods that can be applied when testing appropriate theories. (Nov 2019)**	**BL1**

	The following 8 questions called 8 Ethical Tests can help us make a good ethical decision in any situation: 1. The Golden Rule Test: Would I want people to do this to me? 2. The Truth Test: Does this action represent the whole truth and nothing but the truth? 3. The What-If-Everybody-Did-This Test: Would I want everyone to do this (lie, steal, etc.)? Would I want to live in that kind of world? 4. The Parents Test: How would my parents feel if they found out I did this? What advice would they give me if I asked them if I should do it? 5. The Religion Test: If I have religious beliefs, how do they apply to this action? What would a respected member of my religion advise? Are there any religious texts that I could draw on for guidance? 6. The Conscience Test: Does this go against my conscience? Will I feel guilty afterwards? 7. The Consequences Test: Might this action have bad consequences, such as damage to relationships or loss of self-respect, now or in the future? Might I come to regret doing this? 8. The Front Page Test: How would I feel if my action were reported on the front page of my hometown paper?	
	PART B (C410.2)	
1.	(i). Explain the scope of engineering ethics. Highlight the importance of ethics. (ii). Explain in details about the senses of engineering ethics**.** **(May 2022)**	**BL4**
2.	(i). Discuss in detail the various types of moral issues. (ii). Specify the various types of ethical inquiries available**. (May 2019, May 2023)**	**BL4**
3.	Discuss in detail about the concept of (i). Moral Dilemmas. (ii). Moral Autonomy. **(May 2018)**	**BL4**
4.	Discuss in details about (i) Gilligan's Theory (ii) Kohlberg's Theory. **(May 2019, May 2021, May 2022, May 2023).**	**BL4**
5.	Discuss in details the various theories about right action**.** **[Probable Part-C]**	**BL4**
6.	(i) Explain in detail about Professional and Professionalism**.** (ii)What are the different types of models of professional roles? **(May 2018,)**	**BL4**
7.	(i) Explain the theory of human right ethics and its classifications. (ii)What is meant by self-interest? Relate the term with "Ethical Egoism" with suitable examples.	**BL4**
8.	Explain about (a) Consensus and Controversy (b) Heinz's Theory.	**BL4**

9.	Explain in detail the traits of Self Interest, Customs and Religions.	**BL4**
10.	Explain in details the professionalism ideals and virtues. **[Probable Part-C]**	**BL4**
11.	Discuss the role of "Self-interest" with examples.	**BL4**
12.	Explain the three levels of moral developments with respect to Gilligan views.**(Nov 2019)**	**BL4**
13.	What is duty Ethics? Explain in detail. **(Nov 2019)**	**BL4**
14.	Write the various moral theories and discuss in detail the Gilligen's theory. (**May 2021)**	**BL4**
UNIT III-ENGINEERING AS SOCIAL EXPERIMENTATION		
	PART-A (C410.3)	
1.	**What is meant by valid consent?**	**BL1**
	The consent, which has been given voluntary is known as valid consent. It is also defined as consent based on the information a rational person would want together with any other requested information to make a rational decision.	
2.	**What are the two main elements which are included to understand informed consent?**	**BL1**
	Informed consent is understood by including two main elements: (i) Knowledge (Subjects should be given not only the information they request, but all the information needed to make a reasonable decision). (ii) Voluntariness (Subjects must enter into the experiment without being subjected to force, fraud, or deception).	
3.	**"Engineers as guardians" Discuss.**	**BL1**
	Engineers know the best direction in which the technology should develop, accordingly they give the position basis on the experience, so that they can guard the society by doing things i.e., involved for the best of the society.	
4.	**What are the general features of morally responsible Engineers? (May 2021)**	**BL1**

	General features of morally responsible Engineers are , • A conscientious commitment to live by moral values: protect the safety of human respect. • A Comprehensive perspective: Constant awareness of the experimental nature. • Autonomy: Personally motivated to have dedicated involvement in the project. • Accountability: Accountable for the results of the project.	
5.	**What are the conditions required to define a valid informed consent?**	**BL2**
	The conditions required to define a valid informed consent are as follows: • The consent should be given voluntarily. • The consent is based on the information that rational person would want, together with any other information requested, presented to them in understandable form. • The consenter was competent (not too young or mentally ill, for instance) to process the information and make rational decisions.	
6.	**What are the problems with the law in Engineering?**	**BL1**
	The problems with the law in Engineering are (i) Minimal compliance. (ii) Many laws are without enforceable sanctions.	
7.	**What is the purpose of various type of standards?**	**BL1**
	The purpose of various type of standards are (i) To provide accuracy in measurement, interchangeability, ease of handling. (ii) Prevention of injury, death and loss of income or property. (iii) Provide fair value of price and competence in carrying out tasks. (iv) Provide sound design, ease of communications and gives freedom from interference.	
8.	**What is N.S.P.E code?**	**BL1**

	NSPE – National Society of Professional Engineers (USA), has given their codes of ethics that the engineers shall not actively participate in strikes and other collective forcing action against their employers. Engineers shall not be influenced in their professional duties by conflicting interests.	
9.	**Enumerate the roles of codes. (May 2022, May 2023)**	**BL1**
	The roles of codes are (i) Inspiration and guidance and Support. (ii) Deterrence and discipline &Education and mutual understanding. (iii) Contributing to the Profession's public image. (iv) Protecting the Status Quo. (v) Promoting Business interests.	
10.	**Give the limitations of codes. (May 2018, Nov 2019, May 2022)**	**BL1**
	The limitations of codes are: (i) Codes are restricted to general and vague wording. (ii) Codes can't give a solution or method for solving the internal conflicts. (iii) Codes cannot serve as the final moral authority for professional conduct. (iv) Codes can be reproduced in a very rapid manner.	
11.	**State the importance of Ethical codes. (Nov 2018)**	**BL1**
	The importance of Ethical codes is (i)To provide framework for ethical judgment. (ii)Express the ethical principles and standards in an understanding manner. (iii)It defines the role of responsibilities of professions. (iv)Applying moral ethical principles in critical situation.	
12.	**What are the codes of ethics propagated by professional societies?**	**BL1**
	Societies play a vital role in propagating the code of ethics. They are, (i) Inspiration &Guidance (ii) Support for responsible conduct (iii) Deterring and disciplining unethical professional conduct (iv) Educational and promotion of mutual understanding.	

13.	**What is the need to view Engineering projects as experiments?**	**BL2**
	The need to view engineering projects as experiments are (i) Many projects are carried out in partial ignorance. (ii) The final outcomes of engineering projects are generally uncertain. Effective engineering relies upon knowledge gained about products, knowledge needed for improving current products and creating better ones.	
14.	**What is meant by Engineering Experimentation?**	**BL1**
	Engineers involve in research experimentation and testing of new products. Appling various experimental producers is called experimentation. In every stage of product development, experiments are conducted. One can view Engineering work & project as experiment.	
15.	**Comment on the importance of learning from the past, using the nuclear reactor accident at Three Mile Island, as an example.**	**BL2**
	Values are notorious for being among the least reliable components of hydraulic systems. It was a pressure relief valve, and lack of definitive information regarding its open or shut state. Similar malfunctions had occurred with the identical values on nuclear reactors because of the same reasons at other locations, but no attention had been given to them.	
16.	**Define ethical accountability.**	**BL1**
	The inherent tendency of accepting moral responsibility for the actions of an individual and also the spontaneous willingness to subject himself to the moral scrutiny in an open-minded manner is called ethical accountability.	
17.	**Define Conscientiousness.**	**BL1**

	Conscientiousness means sense of awareness or consciousness. People act responsibly based on the extent of their Conscientiousness. It means commitment or responsibility required in a situation. Engineering is a responsible profession, so the engineers must be very Conscientiousness in their profession while maintaining a full control of the given situation, know what good or bad takes place.	
18.	**Differentiate scientific experiments and Engineering projects. (May 2021)**	**BL2**
	Scientific experiments are conducted to gain new knowledge, while engineering projects are experiments that are not necessarily designed to produce very much knowledge. Scientists study how nature works and use the scientific method as a framework for performing experiments. To test whether an observation is true, scientific experiments ask questions and develop experiments to try and answer that question. Alternatively engineering experiments defines a problem create, build, and find solutions to problems using the creativity-based engineering design process.	
19.	**In what ways Engineering experiment differs from standard experiments?**	**BL2**
	In standard experiments, random members from two different groups have different experimental control, whereas in engineering experiments random selection of participants from different group is not possible hence it is not possible to study the effects that the changes in variables have on two or more comparable groups and one should simply work with available historical and retrospective data about various groups that use the product.	
20.	**What are the merits of Standardized Experimentation? (May 2018, May 2023)**	**BL1**
	The ethics in experimentation is concerned with the application of moral principles in the conduct of research in relation to human beings to protect the rights and welfare of the human beings involved in the research process.	

21.	**Comment on the importance of learning from the past, using Titanic disaster, as an example.**	**BL1**
	The lessons learned from Titanic disaster are, (i)Outdated Standards and Requirements – The Titanic was provided with insufficient number of lifeboats. (ii)Lack of Training – The 20 lifeboats were not used to full capacity. At least four lifeboats were filled at 50 percent capacity or less. One lifeboat that could carry 40 people only had 12 passengers. The lifeboat drill that was scheduled to take place the day the Titanic hit the iceberg was cancelled by Captain Edward J. Smith. There is speculation that the training could have impacted the outcome of the emergency escape, potentially saving more lives.	
22.	**Define Whistle Blowing and how it can be avoided.(May 2022)**	**BL1**
	When an employee or former employee conveys information about a significant moral problem to someone in a position to take action on the problem, and does so outside approved organizational channels is called Whistle Blowing .With external whistle blowing the information is passed outside the organization and with internal whistle blowing the information is conveyed within the organization. One way to discourage "unethical" whistleblowing is to offer an internal, anonymous channel for reporting wrongdoing.	
23.	**What are the uncertainties occurring in the model designs? (May 2019)**	**BL1**
	The uncertainties occurring in the model designs will be in (i) Model used for the design calculations. (ii) Exact characteristics of the materials purchased. (iii) Constancies of materials used for processing and fabrication. (iv) Nature of the pressure, the finished product will encounter.	
24.	**Give any two prominent features of contemporary engineering practice that differentiate casual influence and moral accountability in Engineering.**	**BL1**

	Features of contemporary engineering practice (i)Large-scale engineering projects involve fragmentation of work. (ii) Due to the fragmentation of work, the accountability will spread widely within the organization (iii)There is frequent pressure to move on to a new project before the current one has been operating long enough to be observed carefully. (iv)The contagion of malpractice suits currently afflicting the medical profession is carrying over into engineering.	
25.	**What are the two elements of two informed consent? (Nov 2019)**	**BL1**
	The two elements of two informed consent are knowledge and voluntariness. **Knowledge**: Person who participates in the experiments should be given all the information to make a reasonable decision. **Voluntariness**: Person should not be forced and he should have willingness to volunteer himself.	
26.	**Define Code. (May 2022)**	**BL1**
	A code of ethics is a guiding set of principles intended to instruct professionals to act in a manner that is honest and that is beneficial to all stakeholders.	
	PART-B (C410.3)	
1.	How can Engineer become a responsible experimenter? Highlight the code of ethics for Engineers **(May 2019, May 2023) (or)** Engineers are responsible experimenters. Discuss. **(Nov 2019, May 2022, May 2023)**	**BL4**
2.	What is the important code of ethics? What are the different roles and function of "Code of Ethics"? **(May 2022)**	**BL2**
3.	Discuss on the roles played by the codes of ethics set by professional societies. **(Nov 2019)**	**BL4**
4.	Compare and contrast the engineering experiments with the standard experiments. **(May 2018, Nov 2018, May 2022**)	**BL4**
5.	Explain in detail about Engineers as responsible experimenters.	**BL4**

6.	With the help of examples explain that the engineer would learn not only from their earlier design and operating results, but also from those of experience of other Engineers. **[Probable Part C]**	**BL4**
7.	Explain in detail about balanced outlook on law. **(May 2022)**	**BL4**
8.	Explain in detail about industrial standards.	**BL4**
9.	Explain in detail about Engineering as experimentation.	**BL4**
10.	(i)Explain in detail the powerful support and proper role of law in Engineering and also state the various problems of law in Engineering. (ii)With a case study explain "learn from the past" in Engineering experimentation. **[Probable Part C]**	**BL4**
11.	What is research Ethics? Discuss the models of research ethics with suitable examples. **(May 2018, Nov 2018)**	**BL4**
12.	Explain the characteristics of morally responsible Engineers. **(May 2019)**	**BL4**
13.	Write the importance of code of ethics for Engineers in order to maintain the industrial standards. **(May 2021)**	**BL1**
UNIT IV-SAFETY, RESPONSIBILITIES AND RIGHTS		
	PART-A (C410.4)	
1.	**List the factors that shape the self confidence in a person.**	**BL1**
	The factors that shape the self confidence in a person are , **Home:** Relationships with family members influence self-esteem this is because you „copy‟ their attitudes and reactions when you are still young and this influences the way you think of yourself and others **School and Workplace:** Experiences with schoolwork, extracurricular activities, sports, discipline, etc. can also play an important role in shaping the kind of person you are going to be in the future **Society**: Cope through different times will shape your characteristics. Experiences with standards and images created by others can also influence you. The nature of your community helps shape you.	

2.	**Define the term safety and relate it to risk. (May 2018,Nov 2018)**	**BL1**
	The terms of safety and risk are inter-related. It is amazing to know that what may be safe enough for one person may not be for someone else. According to William W Lowrance "A thing is safe if its risks are judged to be acceptable."	
3.	**State the reasons that may cause risk. (Nov 2019)**	**BL1**
	Risk is a potential that something unwanted and harmful may occur. Causes of risk or harms are caused by delayed job completion, faulty products or systems, and economically or environmentally injurious solutions to technological problems.	
4.	**What is 'Safe exists'? (Nov 2019)**	**BL1**
	It is almost impossible to build a completely safe product or one that will never fail. The best one can do is to assure that • When a product fails it will fail safely. • The product can be abandoned safely. • The user can safely escape the product. All these three conditions are referred to as 'safe exit'.	
5.	**What does Loyalty mean?**	**BL1**
	Loyalty means being truthful to one person. For engineer's loyalty should not be equated with merely obeying one's immediate superior, but to do good for the company and people. It is an important virtue. There are two senses of loyalty namely Agency Loyalty and Identification Loyalty.	
6.	**What do you understand by collegiality?**	**BL1**

	Engineers shall not attempt to injure, maliciously or falsely, directly or indirectly, the professional reputation, prospects, practice, or employment of other engineers, nor untruthfully criticize other engineer's work. Engineers who believe others are guilty of unethical or illegal practice shall present such information to the proper authority for proper action.	
7.	**Define risk – benefit analysis.**	**BL1**
	Risk benefit analysis is a method that helps the engineers to analyze the risk in a project and to determine whether a project should be implemented or not. In risk benefit analysis, the risks and benefits of a product are allotted to money amounts, and the most benefit able ratio between risks and benefits miscalculated.	
8.	**Differentiate between risk analysis and risk benefit analysis.**	**BL2**
	• A risk analysis is the process of identifying hazards and then assessing their potential for causing harm or loss. It also includes an evaluation of the consequences of a risk if it materializes and suggests what needs to be done to avoid or minimize the risk. • Risk benefit analysis is a method that helps the engineers to analyze the risk in a project and to determine whether a project should be implemented or not. In risk benefit analysis, the risks and benefits of a product are allotted to money amounts, and the most benefit able ratio between risks and benefits miscalculated.	
9.	**Define "Risk" in professional Ethics perspective.**	**BL1**
	Risk is the potential that something unwanted and harmful may occur. We take a risk when we undertake something or use a product that is not safe. Risk in technology could include dangers of bodily harm, economic loss, or environmental degradation. Risk = Probability X Consequences.	
10.	**What is the use of risk analysis?**	**BL1**

	Risk analysis can be used to align technology-related objectives with a company's business objectives. risk analysis is used to: (i) Anticipate and reduce the effect of harmful results from adverse events; (ii) Evaluate whether the potential risks of a project are balanced by its benefits to aid in the decision process when evaluating whether to move forward with the project. (iii) Plan responses for technology or equipment failure or loss from adverse events, both natural and human-caused; and identify the impact of and prepare for changes in the enterprise environment, including the likelihood of new competitors entering the market or changes to government regulatory policy.	
11.	**What does authority mean?**	**BL1**
	Authority is an assignment of the resources needed to complete a task one should have leadership quality and a good motivator to execute his authority to get work done. Hence, authority is necessary. Authority provides a way for identifying the areas of responsibility and accountability.	
12.	**Explain misguided loyalty.**	**BL1**
	Employee sometimes with overenthusiasm and loyalty will be misled to act on own and unknowingly exceed legal commitments to gain or profit for his employer, which may backfire sometime. Hence, this defines as Misguided Loyalty or inappropriate Loyalty.	
13.	**What is meant by the term confidentiality. (May 2018)**	**BL1**
	Keeping confidence is one of the most central and widely acknowledged duties of any professional. In this context, Confidential Information (Privileged Information) is information deemed desirable to keep secret. Keep secret is relational information.	
14.	**What is meant by institutional authority.**	**BL1**
	Institutional Authority is acquired, exercised, and defined within institutions. It may be defined as the institutional right given to a person to exercise power based on the resources of the institutions. It is given to individuals in order to meet their institutional duties, that is, their assigned tasks within an organization.	
15.	**List the classifications of Authority.**	**BL1**

	The classifications of Authority are (i)Institutional Authority (ii)Morally Justified Authority (iii)Accepting Authority	
16.	**What is meant by collective bargaining? (May 2023)**	**BL1**
	Unions are collective bargaining agents that sometimes place the economic interests of the members ahead of those of the clients or employer. A number of professional societies have also held that loyalty to employers and the public is incompatible with any form of collective bargaining.	
17.	**What is meant by the term confidentiality. (May 2018)**	**BL1**
	Keeping confidence is one of the most central and widely acknowledged duties of any professional. In this context, Confidential Information (Privileged Information) is information deemed desirable to keep secret. Keep secret is relational information.	
18.	**Write the advantages of collective bargaining. (May 2021)**	**BL1**
	Collective bargaining is usually part of a unionized workplace. Advantages of collective bargaining are, (i) Collective bargaining gives workers a larger voice. (ii) It improves a worker's quality of life. (iii) It encourages cooperation. (iv) It creates a binding result.	
19.	**What is meant by conflict of interest? (Nov 2018)**	**BL1**
	A situation in which a person, such as a public official, an employee, or a professional, has a private or personal interest sufficient to appear to influence the objective exercise of his or her official duties.	
20.	**Write about industrial espionage.(May 2022)**	**BL1**
	Industrial espionage means industrial spying. It has increased in the recent years due to a large number of competitions in the world, so the people started cheating other persons for their improvement. For example, the case of Peter Gopal at Silicon Valley.	

<table>
<tr><td>21.</td><td>Write the difference between manager and leader(May 2021, May 2023)</td><td>BL2</td></tr>
<tr><td></td><td>
<table>
<tr><th>Manager</th><th>Leader</th></tr>
<tr><td>A leader is a person who leads a particular team.</td><td>A manager is a person who manages the organization or a project.</td></tr>
<tr><td>Leaders create circles of influence and lead by inspiring.</td><td>Managers create circles of power and lead by authority.</td></tr>
<tr><td>A leader mainly facilitates the decisions.</td><td>A manager mostly makes decisions.</td></tr>
</table>
</td><td></td></tr>
<tr><td>22.</td><td>What is employee’s bill of rights?</td><td>BL1</td></tr>
<tr><td></td><td>No public or private organization shall discriminate against an employee for criticizing the ethical, moral, or legal policies and practices of the organization discriminate against an employee to engaging in outside activities of his choice or for objecting to a directive that violates common norms of morality.</td><td></td></tr>
<tr><td>23.</td><td>What are the paramount obligations of an Engineer?</td><td>BL1</td></tr>
<tr><td></td><td>Recent Code of ethics typically states that engineer’s paramount obligations are to protect the public health, safety and welfare rather than the obligations of loyalty and faithful service to employers. Paramount is to mean “Chief in importance or deserving primary emphasis”.</td><td></td></tr>
<tr><td>24.</td><td>What is patenting?</td><td>BL1</td></tr>
<tr><td></td><td>Patents differ from trade secrets. Patents legally protect specific products from being manufactured and sold by competitors without the express permission of the patent holder. Trade secrets have no such protections. Patents are protected by statute laws passed in order to provide incentives for creativity.</td><td></td></tr>
<tr><td>25.</td><td>What is meant by “Industrial design patent”?</td><td>BL1</td></tr>
</table>

	Idea or conception regarding features of shape, configuration, and pattern, ornamental with lines or colors applied to any article, two or three dimensional, made by industrial process. Patent has a term of 14 years from the date of filing the application, e.g., design applied to shoes, T.V., textiles.	
26.	**What is meant by discrimination in professionalism?**	**BL1**
	Discrimination is being bias or doing unfairness. Discrimination means to make an unfair difference in one's treatment of people. The other way of defining discrimination in professionalism is giving preference based on sex, race, religion, etc. so the type of discrimination behavior is said to be "Reverse Preferential Treatment." In general, discrimination in professionalism is "Morally unjustified treatment of people on irrelevant grounds."	
27.	**What is IPR and explain its main clauses? (May 2019)**	**BL1**
	Intellectual Property Rights (IPR) will have wide range of socio economic technological and political impacts. Intellectual Property is the information and original expression that derives its original value from creative ideas with a commercial value. Intellectual property permits the people to have fully independent ownership for their innovations and creativity like that for their own physical property.	
28.	**What is intellectual property right?**	**BL1**
	Intellectual Property right (IPR) refers to the creations of the human minds for which exclusive Rights are recognized. Innovators, artistes and business owners are granted certain exclusive rights to a variety of intangible assets for a specified duration.	
29.	**List some examples for discrimination.(May 2022)**	**BL1**

	Some examples of discrimination in the workplace include when an employer, supervisor, or co-worker treats another employee unfairly based on religion, age, ethnicity, gender, disability, skin color, or race. **Examples for discrimination** An opening arises for a chemical engineer plant. Normally such positions are filled by promotions. However, there was not proper person so they thought of an African person. Management believed that the most of the Whites working would not accept a black person as their boss. So the interest among the workers will decrease hence the efficiency of the workers will also reduce, so they appointed a White person by promotion. This is an example of discrimination in workplace based on race.	
30.	**What is a professional right? (May 2019)**	**BL1**
	Engineers have fundamental rights to live and freely pursue their legitimate interests. They have a human right to pursue their work and not to be fairly discriminated `against in employment based on sex, race, or age.	
	PART-B (C410.4)	
1.	What are the factors that affect risk acceptability? What is the use of knowledge of risk acceptance to Engineer? Discuss **(May 2023)**	**BL4**
2.	Define the term Risk and Safety. How we, Engineers assess the safety? **(May 2022)**	**BL4**
3.	Describe the concept of Risk-Benefit Analysis with an example. **(Nov 2018, May 2018, Nov 2019, May 2023)**	**BL4**
4.	Discuss the testing strategy for safety with suitable examples. Mention the difficulties in assessing the personal risk. **(May 2018) [Probable Part C]**	**BL4**
5.	Explain in detail challenger accident. What are the ethical problems involved in this? **(Nov 2019)**	**BL4**
6.	‘A nuclear accident anywhere is a nuclear accident everywhere’. Explain this with respect to Three Mile Island case study. **(Nov 2019)**	**BL4**

7.	What is the importance of loyalty and collegiality in teamwork?	**BL4**
8.	How are conflicts of interest solved? Discuss on the importance of Collective Bargaining **(May 2019)**	**BL4**
9.	Explain the process of collective bargaining in Indian context in the industries. **(May 2021)**	**BL4**
10.	Discuss the concept of safe exit in the Chernobyl case study.	**BL4**
11.	Discuss faithful agent and public service arguments. **(Nov 2018)**	**BL4**
12.	Discuss Intellectual Property Rights. **(May 2022)**	**BL4**
13.	Discuss in detail about the "Employee rights" and its role in the organizations. **(May 2019)**	**BL4**
14.	What are the procedures to be followed for Whistle Blowing? How can this be avoided? Discuss the ways and means of reducing occupational crime in industries.	**BL4**
15.	Discuss in detail on the ethical behavior of an individual. Is it same when he is "alone or in a Group of company" &"Should ethics be prompted or imposed".**(May 2021, May 2023) [Probable Part C]**	**BL4**
16.	What are the elements of Intellectual Property Rights? Explain. **(Nov 2019)**	**BL4**
17.	How far the intellectual property rights are protected statutorily in India. **(May 21)**	**BL4**
18.	Discuss Event Tree Analysis with some practical examples of Risk Analysis. **(May 2022)**	**BL4**
	UNIT V-GLOBAL ISSUES	
	PART-A (C410.5)	
1.	**What is meant by Multinational Corporation?**	**BL1**
	Multinational Corporation does extensive business in more than one country. For example, Hindustan lever ltd, Maruti, Hyundai, etc are multinational corporations. For example, Union Carbide (Bhopal) of USA has more than 37 branches across the world, which includes India also. The country in which the company is established is called the home country and the company's country is called as host country. In most of the multinational companies, the home company has a share of 51% and the host company has 49% of share.	
2.	**What is meant by Globalization?**	**BL1**

	Globalization refers to the increasing integration of nations through trade, investment, transfer of technology and exchange of ideas and culture. Globalization represents an accelerating integration and interweaving of national economies through the growing flows of trade, investments and capital across historical borders.	
3.	**What is technology transfer?**	**BL1**
	Technology transfer is a process of changing the technology to a new setting and implementing it. Technology includes hardware such as machines and installations as well as techniques such as technical, organizational, and managerial skills & procedures. The transfer of technology may be done by governments, universities private voluntary organizations, consulting firms and by multinational companies	
4.	**What is appropriate technology? (Nov 2019)**	**BL1**
	Appropriate Technology means identification, transformation, and implementation of the most suitable technology for a new set of conditions. These conditions include social factors, which are apart from economic and technical engineering constraints. Identification done, based on human values and needs.	
5.	**What are the normal issues that may arise in Multinational Corporation?**	**BL1**
	Multinational Corporation does extensive business in more than one country. As companies operate across diverse cultural and legal frameworks, moral dilemmas arise in labor standards, marketing practices, environment, corruption and human rights.	
6.	**Define environmental ethics. (May 2021, May 2023)**	**BL1**
	Environmental ethics is a branch of applied philosophy that studies the conceptual foundations of environmental values as well as more concrete issues surrounding societal attitudes, actions, and policies to protect and sustain biodiversity and ecological systems.	
7.	**What are the merits and demerits of MNC's to the host country. (May 2018,Nov 2018)**	**BL1**

	Merit of MNC's to host country – (i) MNCs boost economic growth, technological growth. (ii) Provision of significant employment and training to the labour force in the host country. Transfer of skills and expertise, helping to develop the quality of the host labor force. Demerits of MNC's to host country - (i) The presence of MNCs can restrict competition and may even cause a monopoly or monopolistic competition. (ii)They also use tactics like transfer pricing to avoid heavy tax liabilities.	
8.	**Who are hackers?**	**BL1**
	The individuals who directly meddle with any computer security system by implanting unwanted codes with the objective of paralyzing the network and destroying the equipment are called as hackers.	
9.	**What is meant by bio-centric ethics?**	**BL1**
	A bio-centric ethics regards all living organisms as having inherent worth. According to bio-centric ethics, a sincere effort to live by ideal and virtue of reverence of life would enable us to make inevitable decisions about when life must be maintained or when the life has to be sacrificed.	
10.	**What is computer ethics? (May 2022)**	**BL1**
	Computer Ethics is the analysis of the nature and social impact of computer technology and the corresponding formulation and justification policies for the ethical use of technology. It defines as a field concerned with "policy vacuums" and "conceptual muddles" regarding the social and ethical use of information technology.	
11.	**Explain your views on Engineers as managers.**	**BL1**

	Most of the engineers are experiencing the best methods of technical training like other professions. Many of the engineers move into managerial jobs. The reason being many companies wants to have the engineers as managers. Because they have thought that in order to manage technological corporation, the technical understanding of the engineers is very essential.	
12.	**What is meant by conceptual framework in computer ethics?**	**BL1**
	Computer ethics is a branch of philosophy that deals with how computer users can take decisions on professional and social behavior. Also is a set of laws that govern computer users and data produced. Example for computer program: guidelines for the below questions will be provided by conceptual framework in computer ethics. (i) Is copyright applicable to computer program? (ii) Is it a process protected by a patent? (iii) Is it proprietary information?	
13.	**Explain moral relationalism.**	**BL1**
	Moral relationalism or Contextualism states that moral judgments should be made in relation to the factor that varies from case to case. Customs and laws are usually morally relevant factors that should be taken into account. For example, in our country, we remove the shoes before entering a house as a symbol of respect, but we cannot expect it in western culture.	
14.	**Differentiate eye witness and expert witness in the legal system.**	**BL2**
	An eyewitness is one who testifies what they perceived through his or her senses. That perception might be either with the unaided human sense or with the aid of an instrument. An expert witness is one who allegedly has specialized knowledge relevant to the matter of interest, which knowledge purportedly helps to either make sense of other evidence, including other testimony, documentary evidence or physical evidence.	
15.	**Explain competitive bidding for consulting Engineers.**	**BL1**

	Competitive bidding means offering a price in order to achieve something in return by that offer. The professional codes of ethics forbid the consulting engineers from involving competitive bidding. They are restricted from competing for jobs based on submitting priced proposals.	
16.	**What do you mean by hired gun? (May 2021)**	**BL1**
	Hired gun is an unscrupulous Engineer who violate the standards of honesty and due care in conducting investigations by shading the truth by interpreting facts in a manner favorable to one's client. Hired guns considers the responsibilities to the public as minimal ones.	
17.	**List out the Engineers involvement in Weapon Development.**	**BL1**
	(i)Engineer's involvement in manufacturing of weapons is unavoidable. For engineers who design weapons, manufacture them, and use them have some reasons to support their involvement. The following are some of the justifying arguments. (ii)A nuclear engineer knows very well about the danger of increasing nuclear arsenal. Arsenal is a place where the weapons are being stored. He argued that he is working very hard to reduce the risk of nuclear accidents. (iii)From the above examples it is clear that all over the world talented engineers are engaged in the weapons work. They should think morally, before getting involved in weapons production.	
18.	**Define code of conduct. (May 2018)**	**BL1**
	A code of conduct is a set of rules outlining the social norms and religious rules and responsibilities of, or proper practices for, an individual, party or organization. Related concepts include ethical, honor, moral codes and religious laws.	
19.	**Explain descriptive relativism.**	**BL1**
	Descriptive Relativism is a matter of fact, values, beliefs and attitudes differ from culture to culture. It does not entail (involve) ethical relativism. As per this theory, there exists some difference between the moral beliefs and attitudes of different culture.	
20.	**What are the three senses of relative values?**	**BL1**

	Relative values mean relative principles. These relative values help in deciding how the multinational corporations and individuals have to act in host countries. The three senses of relative values are ethical relativism, descriptive relativism and moral relativism or Contextualism.	
21.	**Explain ethical relativism. (May 2022)**	**BL1**
	Ethical relativism: Actions are morally right within a particular society when they are approved by law, custom, or other conventions of that society. It is a false one as it implies ridiculous and illogical ways. It justifies a deliberate extermination of a race of people such as in Germany. They are not morally correct as it is criticized with human rights, public good, and duties to respect people.	
22.	**List some of the International Human Rights.**	**BL1**
	The following are some of the international human rights, namely (i)The right to freedom of physical movement (ii) The right to ownership of property (iii)The right to freedom from torture (iv) The right to fair trail (v)The right to physical security (vi) The right to freedom of speech and association (vii)The right to minimal education (viii)The right to political participation (ix)The right to subsistence. (x) The right to non-discrimination	
23.	**List the provision in NSPE codes on the advertisement by consultant.**	**BL1**
	The provision in NSPE codes on the advertisement by consultant has prohibited: • Statement containing misrepresentation or omission of a necessary fact, • Statement likely to create an unjustified expectation. • statement containing prediction of future success. • Statement likely to attract clients, by the use of slogans.	
24.	**What is meant by corporate social responsibility? (Nov 2018, May 2019, May 2023)**	**BL1**
	Corporate social responsibility (CSR) is how companies manage their business processes to produce an overall positive impact on society. It covers sustainability, social impact and ethics, and done correctly should be about core business - how companies make their money - not just add-on extras such as philanthropy.	

	PART-B (C410.5)	
1.	Discuss the pros and cons of multinational companies from ethical point of view**.**	**BL4**
2.	Explain in detail the various advantages and Disadvantages of MNCs.	**BL4**
3.	What are the philosophical views of nature? Discuss eco-centric ethics.	**BL4**
4.	Explain the significance of Environmental Ethics for an Engineer by giving examples of environmental issue. **(May 2019, May 2022)**	**BL4**
5.	Discuss in detail the concept of Business Ethics and Environmental ethics in the context of technological development and for the sustenance of sustainable development. **(May 2021)**	**BL4**
6.	What is Cyber Crime? Discuss in detail the various cybercrimes in the context of Ten Commandments of Computer Ethics. **(May 2021, May 2023)**	**BL4**
7.	Discuss in detail about the moral and ethical issues involved in the use of computer Technology**. (May 2019, May 2023)**	**BL4**
8.	Discuss the ethical issues related to computer ethics? **(Nov 2019)**	**BL4**
9.	Discuss an engineer’s involvement in weapons work. **(May 2022)**	**BL4**
10.	Explain the role of Engineers as managers.	**BL4**
11.	With various examples explain the various ethical issues faced by a consultant engineer. How an engineer can create a good ethical climate in any industry? **(May 2021) [Probable Part C]**	**BL4**
12.	Write in detail about Engineers used as Consultant and Advisors. **(May 2019)**	**BL4**
13.	Explain the role of Engineers as consultant and expert witnesses.	**BL4**
14.	(i)Explain engineers as expert witnesses and advisors**. (Nov 2018)** (ii)Explain Engineers as Consultants. **(May 2018, Nov 2018, Nov 2019)**	**BL4**
15.	Discuss 'morally creative leaders' and participation in professional societies. **[Probable Part C]**	**BL4**

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

EE3701- HIGH VOLTAGE ENGINEERING

SEMESTER VI

REGULATIONS 2021

NOTES

&

QUESTION BANK

EE3701 HIGH VOLTAGE ENGINEERING

L	T	P	C
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COURSE OBJECTIVES:

- Various types of over voltages in power system and protection methods.
- Generation of over voltages in laboratories.
- Measurement of over voltages.
- Nature of Breakdown mechanism in solid, liquid and gaseous dielectrics.
- Testing of power apparatus and insulation coordination.

UNIT I OVER VOLTAGES IN ELECTRICAL POWER SYSTEMS 9

Causes of over voltages and its effects on power system - Lightning, switching surges and temporary over voltages – Reflection and Refraction of Travelling waves- protection against over voltages_ Insulation Coordination.

UNIT II DIELECTRIC BREAKDOWN 9

Properties of Dielectric materials - Gaseous breakdown in uniform and non-uniform fields -Corona discharges – Vacuum breakdown – Conduction and breakdown in pure and commercial liquids, Maintenance of oil Quality - Breakdown mechanisms in solid and composite dielectrics- Applications of insulating materials in electrical equipment.

UNIT III GENERATION AND MEASUREMENTS OF HIGH VOLTAGES AND HIGH CURRENTS 9

Generation of High DC, AC, impulse voltages and currents - Analysis of DC/AC and Impulse generator circuits - Tripping and control of impulse generators, Measurement of High voltages and High currents – High Resistance with series ammeter – Dividers - Resistance, Capacitance and Mixed dividers - Peak Voltmeter, Generating Voltmeters, Electrostatic Voltmeters - Sphere Gaps, High current shunts- Digital techniques in high voltage measurement.

UNIT IV HIGH VOLTAGE TESTING & INSULATION COORDINATION 9

High voltage testing of electrical power apparatus- International and Indian standards – Power frequency, impulse voltage and DC testing of Insulators, circuit breakers, bushing, isolators and transformers - Insulation Coordination.

UNIT V APPLICATION IN INDUSTRY 9

Introduction - electrostatic applications- electrostatic precipitation, separation, painting / coating, spraying, imaging, printing, Transport of materials - manufacturing of sand paper - Smoke particle detector - Electrostatic spinning, pumping, propulsion - Ozone generation - Biomedical applications.

TOTAL: 45 PERIODS

COURSE OUTCOMES:

Upon the successful completion of the course, students will be able to:

CO1: Explain various overvoltage's and its effects on power systems.

CO2: Understand the breakdown phenomena in different medium under uniform and non-uniform fields.

CO3: Explain the methodsof generating and measuring High DC, AC, Impulse voltage andcurrents.

CO4: Suggest and Conduct suitable HV testing of Electrical power apparatus as per StandardsCO5: Explain the Industrial Applications of Electrostatic Fields.

TEXT BOOKS

1. M.S.Naidu and V. Kamaraju, 'High Voltage Engineering', Tata McGraw Hill, FifthEdition, 2013.
2. E. Kuffel and W.S. Zaengl, J.Kuffel, 'High voltage Engineering fundamentals',Newnes Second Edition, Elsevier , New Delhi, 2005.
3. C.L. Wadhwa, 'High voltage Engineering', New Age International Publishers, FourthEdition, 2020.

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1. L.L.Alston, High Voltage Technology, Oxford University Press, First Indian Edition 2006.
2. C.L.Wadhwa, High voltage Engineering, New Age International Publishers, Fourth Edition,2020
3. Mazen Abdel - Salam, Hussein Anis, Ahdab A-Morshedy, RoshdayRadwan, High VoltageEngineering - Theory &Practice,Second Edition, Taylor & Francis Gourp, 2019
4. Subir Ray." An Introduction to High Voltage Engineering "PHI Learning Private Limited, New Delhi,Second Edition-2011

UNIT-1

1) Explain briefly internal Causes of over voltage and its effect on power system? Dec-2008

The over voltage causes may be broadly divided in to two main categories:

i) INTERNAL OVER VOLTAGES CAUSES
- Switching surges.
- Insulation Failure.
- Arcing Ground.
- Resonance.

ii) EXTERNALOVER VOLTAGES CAUSES
- Lightning.

INTERNAL CAUSES OF OVER VOLTAGE:

Internal causes of over voltage on the power system are primarily due to oscillations set up by the sudden changes in the circuit conditions.

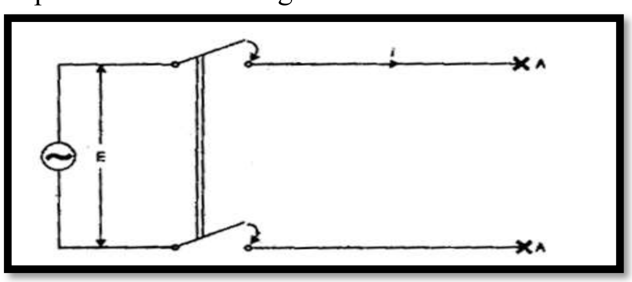
a) Switching surges:

The over voltage, produced on the power system due to switching operations are known as switching surges. the few causes will be discussed here.

- Case of open line
- Case of loaded line
- Current chopping

i)Case of open line:

- During switching operations of unloaded line, travelling waves are set up to produce over voltage on the line. When the unloaded line is connected to the voltage source a voltage wave is setup which travels along the line.



- On reaching the terminal point A it's reflected back to the supply end without change of sign. This causes voltage doubling. If E RMS is the supply voltage, then the instantaneous voltage that the lines have to with stand will be $2\sqrt{2}$ E.This over voltage is of temporary in nature.

ii) Case of loaded Line:

- Over voltage will also be produce during switching operations of a loaded line. suppose a loaded line is suddenly interrupted across the switch the voltage range is 2ZI

  Where

  I-Instantaneous value of current at the time of opening of line

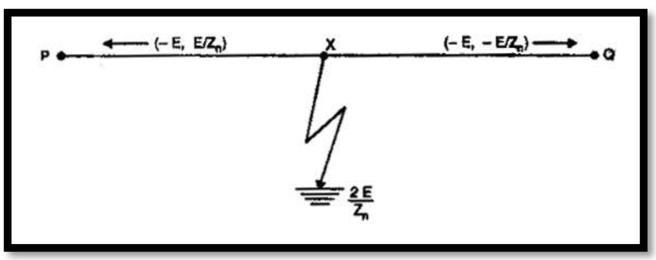
  Z-Natural impedance of the line.

iii) Current chopping:

- Current chopping results in the production of high voltage transients across the contacts of the air-blast circuit breaker. when breaking low currents with air-blast breaker, the powerful de-ionizing effects of air-blast causes the current to fall abruptly to zero will before the nature current zero is reached
- This phenomenon is called current chopping and produces high voltage across breaker contacts this current chopping are prevented by resistance switching.

b) Insulation Failure:

- The most case of insulation failure in a power system is grounding of conductor (insulation failure between line and earth) which may cause over voltage in the system.



- Suppose a line at potential E is earthed at point X.the earthling of the line cause two equal voltage of-E to travel along XQ and XP containing currents.-E/Z_n and + E/Z_n respectively. Both these current pass through X to earth. So that current to earth is $2E/Z_n$.

c) Arcing ground:

- The phenomenon of intermittent is taking place inline-to-ground fault of a three phase system with consequent productions transients is known as arcing ground.

d) Resonance:

- Resonance in an electrical system occurs when inductive reactance of the circuit becomes equal to the capacitive reactance. Under resonance the impedance of the circuit and the power factor is unity.

2) ***Explain briefly various charge formation theory and also explain briefly lightning mechanism?***

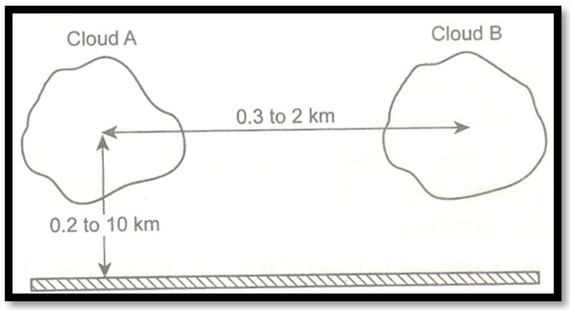
NOV-DEC 2012 NOV-DEC 2013

Lightning Phenomenon:

Lightning phenomenon is a peak discharge in which charge accumulated in the clouds discharge in to a neighboring cloud or to the ground.

Charge formation in the clouds:

During thunderstorms, positive and negative charges become separated by the heavy air currents with ice crystals in the upper part and rain in the lower part of the cloud. this charge separation depends on the height of the clouds which range from 0.2 to 10 k.m with their charge centers probably at a distance of about 0.35 to 2 K.m as shown in fig.



Charge inside the clouds - 1 to 100 coulomb

Potential of the cloud - 10^7 to10^8 Volt

Energy associated with the cloud - 250kwhr

The upper region of the clouds are usually positively charged where as lower region of the clouds are negative charged except the local region near the base and head which is positive as shown in fig.

Fair weather conditions - Max.gradient=1V/Cm.

Bad weather conditions - Maximum gradient reached.

At the ground level due to charged cloud - 300V/Cm.

Charge Distribution Theory:

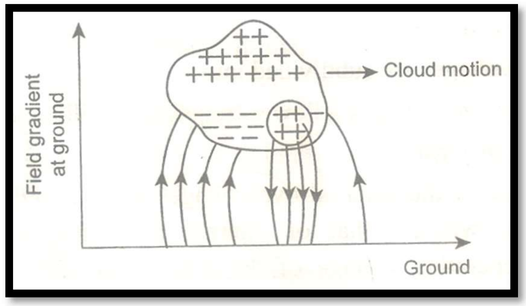
- Willson's theory of charge separations
- Simpson's theory
- Reynold and mason theory

i) Will son's theory:

Willson's theory based on the following assumption

- ✓ Large Number of ions present in the atmosphere.
- ✓ Many of the these ions attach themselves to small dust particles and water particles

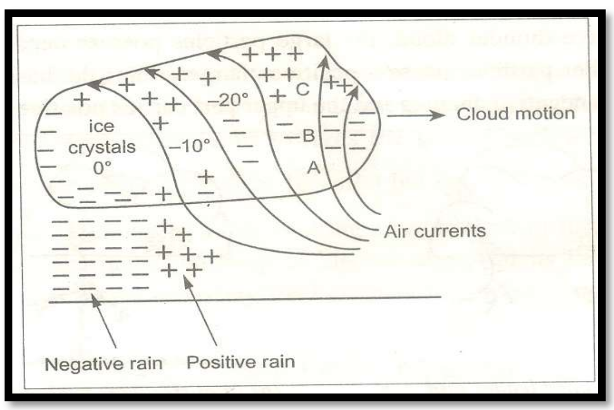
- ✓ Electric field exists in the earth atmosphere during fair weather which is directed downwards towards the earth.
- ✓ Subsequently the lower part of the drop attracts negative charges from the atmosphere and leaving positive charges in the air.



- ✓ Thus this theory says since large negatively charged drops settle on the base of the cloud and smaller positively charged settle on the upper direction of the clouds.

<u>ii)Simpson's Theory:</u>

The Simpson's theory explained with help of following regions shown in below figure.



<u>Below Region A:</u>

Air current travels above 800Cm/Sec and no rain drops fall through.

<u>In Region A:</u>

Air velocity is high enough to break the falling rain drops causing a positive charge sprays in the cloud and negative charge in the air.

The spray is blown upwards but as the velocity of air decreases, the positively charged water drops recombine with the large drops and fall again.

<u>In Region B:</u>

It becomes negatively charged by the air current.

<u>In Region C:</u>

The temperature is low (below freezing point) and only ice crystals exist. the impact of air on these crystals makes them negatively charged.

iii) Reynold and Mason Theory:

Thunder clouds are developed at heights of 1to 2 k.m above the ground level. And may extend upto 12 to 14 km above the ground

Air currents, moisture, specific temperature range are required for thunder clouds and charge formations.

The air current controlled by the temperature gradient move upwards carry moisture and water droplets below -40^{o}C (above 12 Km).

The water droplets in the cloud are blown up by air currents and get super cooled over a range of height and temperature. When such freezing occurs the crystals grow in to large masses. Due to weight and gravitational force it falls downwards.

3. Discuss about the mechanism of lightning Strokes: **May-2008, May-2012 ,NOV-DEC 2013**

The cloud and the ground form two plates of capacitor and dielectric medium is air. Since the lower part of the cloud is negatively charged the earth is positively charged by inductions.

Lightning discharge will require for break down the Air

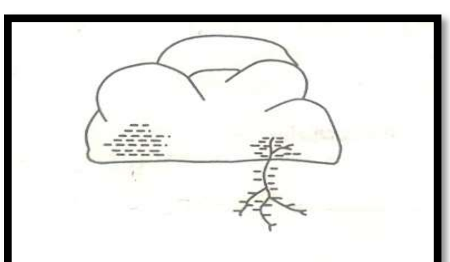
- ✓ Electric field required is 30 kv/Cm (peak)
- ✓ Electric field required is 10 Kv/cm(If the moisture content of the air is large)

Type of lightning streamer:

- ✓ Pilot streamer
- ✓ Stepped Leader
- ✓ Return Stroke
- ✓ Second Charge center
- ✓ Dart leader
- ✓ Heavy return Streamer

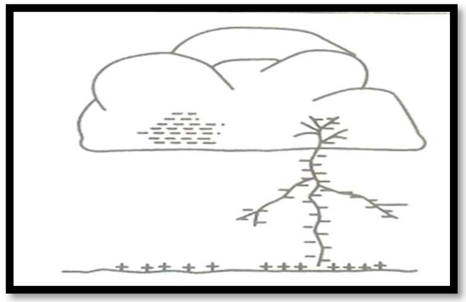
Pilot Streamer:

After the gradient of approximately 10Kv.cm is set up in the clouds the air surrounding gets ionized.In this condition a streamer starts from clouds towards earth. The current in the streamer is 100 A. and speed is 0.16m/μ Sec.This streamer is known as pilot streamer. This leads to the lighting phenomenon.



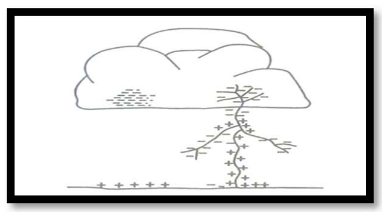
Stepped Leader:

Depending upon the state of ionization of the air surrounding the streamer it's branched to several paths and this is known as stepped leader.



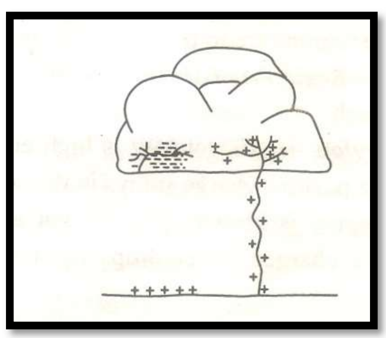
Return Stroke:

Once stepped layer contact with earth a power return stroke moves very fast up towards the clouds through the already ionized path by the leader.



Second charge center:

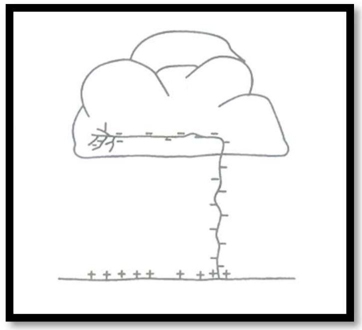
Negative charge of the cloud is being neutralized by the positive induced charge on the earth. this instant gives rise to lighting flash which we observes with our naked eyes. There may be another cell of charges in the cloud near the neutralize charged cell



Dart Leader:

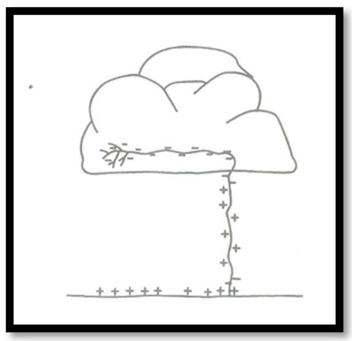
This charged cell will try to neutralize through this ionized path. This streamer is known as dart leader.

The velocity of dart leaderisabout3 % of the velocity of light. The effect of the dart leader is much more severe that of the return stroke.



Heavy return stroke:

The second charge center is discharging to ground through the dart leader. positive streamers are going up from ground. This is called heavy return stroke. This begins to discharge negative charge under the cloud and the second charge center in the cloud.



Rate of charging of thunder clouds

Let λ - conductivity of the medium
E - Electric field intensity
V - Velocity of separation of charges.
ρ - Charge density. Electric field intensity E is given by

$$\frac{dE}{dt} + \lambda E = \rho v$$

Solution of the equations is

$$E = \int \rho v dt + c$$

Multiply $e^{\lambda t}$ on both sides

$$Ee^{\lambda t} = \int \rho v e^{\lambda t} dt + c$$

$$Ee^{\lambda t} = \frac{\rho v}{\lambda} e^{\lambda t} + c$$

$$E = \frac{\rho v}{\lambda} + ce^{-\lambda}$$

……………………………………………………(1)

To find c, substitute E=0;t=0; in equation (1)

$$0 = \frac{\rho v}{\lambda} + c$$

$$c = -\frac{\rho v}{\lambda}$$

$$\therefore E = \frac{\rho v}{\lambda} - \frac{\rho v}{\lambda} e^{\lambda t}$$

$$E = \frac{\rho v}{\lambda}\left(1 - e^{-\lambda t}\right)$$

Let Q_s = separated charges; Q_g=generated charge

$$\rho = \frac{charge}{Area} = \frac{Q_g}{Ah}$$

Where A-cloud area ,h-height of the charged region.

$$E = \frac{Q_s}{A\varepsilon 0}$$

Where $\varepsilon 0 - permittivittyofthemedium$

$$A = \frac{Q_s}{\varepsilon 0 E}$$

$$Q_{g=}\rho A h = \rho \frac{Q_s}{\varepsilon 0 E} h$$

$$= \frac{\rho Q_s h}{\varepsilon o \frac{\rho v}{\lambda}(1 - e^{-\lambda t})}$$

$$Q_g = \frac{Q_s \boldsymbol{h}}{\varepsilon o \frac{v}{\lambda}(1 - e^{-\lambda t})}$$

4) Write shorts on Switching Surges and temporary overvoltage?(NOV-DEC 2011),(NOV-DEC 2013)(NOV **2015)**

For transmission voltages (400 Kv and above) the advantages generated due to switching is same as that of the magnitude of lightning over voltages. This over voltages exists for a long time so it's dangerous to the system.

Switching over voltages increases as the system voltage increases. In extra high voltage line, switching over voltages determine the insulation levels of the lines and their dimensional and cost.

Source (or) Origin of switching surges:

- Open and closing the switch gears
- High natural frequency of the system
- Damped normal frequency voltage components
- Restriking and recovery voltage with successive reflective wave form terminations
- Repeated restriking of the arc between the contacts off

Characteristics of switching surges:

Switching surges arise from any one of the following sources.

- De energizing of lines, cables, and shunt capacitor bank etc.
- Disconnection of unloaded transformer, reactors etc
- Opening and closing of protective devices connected to lines and reactive loads
- Switch off the loads suddenly

- Short circuit due to insulation failure, line to ground contact, line to line contact, L-L-G contacts, three phase to ground contacts etc
- Clearing of the faults
- Arcing ground.

Shape of switching surges:

Irregular

Power frequency with its harmonics

Relative magnitude-2.4 p.u for transformer energizing

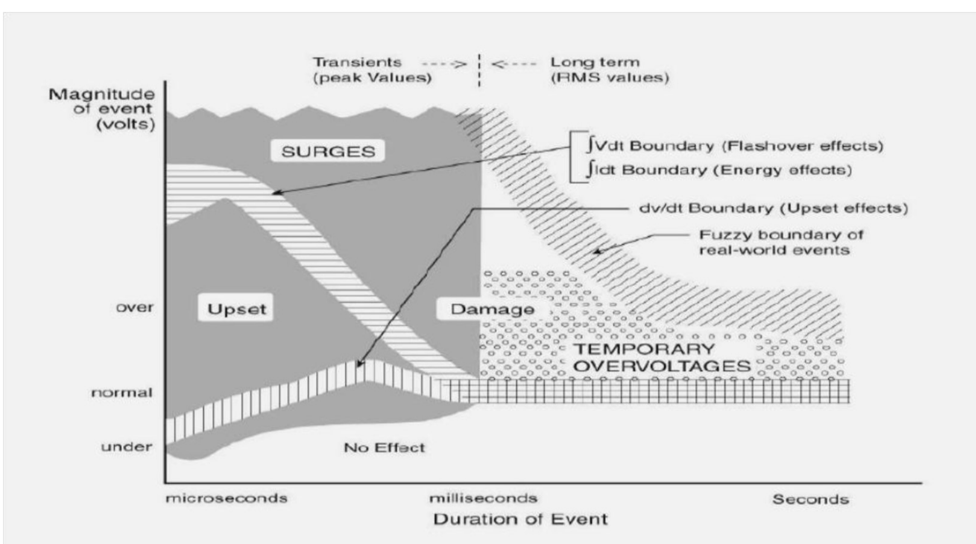
1.4 to 2.0 p.u for switching transmission line.

Switching overvoltage in EHV and UHV system

Switching over voltages in EHV and UHV systems are generated when a sudden release of internal energy stored due to electrostatic or electromagnetic form. This may happen due to

- Interruption of low inductive currents by high speed circuit breakers
- Interruption of small capacitive currents by switching off the unloaded line
- Ferro-resonance conditions
- Energization of long EHV or UHV lines
- Interruption of fault current when the fault is cleared
- Single pole closing circuit breakers
- Switching operations of series capacitor connected to line for compensation
- Sparking of the lightning arrester located at receiving end of line.

Temporary over voltage



Temporary over voltages represent a threat to equipment as well as to any surge protective devices that may have been provided for the mitigation of surges.
The scope of this Guide includes temporary over voltages only as a threat to the survival of SPDs(surge protection devices), and therefore includes considerations on the selection of suitable SPDs.

Following considerations are necessary to reach the goal of practical surge immunity:

Desired protection
Hardware integrity
Process immunity
Specific equipment sensitivities
The power environment
Surge characteristics
Electrical system
Performance of surge protective devices
Protection
Lifetime
The test environment
Cost effectiveness

Measure to control overvoltage due to switching and power frequency **NOV-DEC 2013(NOV 2015)**

In EHV or UHV lines we should control the switching voltages less than 2.5 p.u the following measures are taken to reduce over voltage.

- One or multi-step energization of lines by inserting resistors.
- Phase controlled closing of circuit breaker with proper sensors.
- Drain the trapped charges before reclosing of the lines
- Using shunt reactors
- By using lightning arresters or surge diverters

One or multistep energization of lines by inserting resisters

- During switching of circuit breaker, inserting a series resistance in series with circuit breaker contacts and short circuiting this resistance after a few cycles
- By using inserting resistance the transients due to switching reduces. If the resistance is inserted for a long time, successive reflections takes place and the over voltage reaches high value. therefore using the pre-inserting resistor limit the over voltage

Phase controlled closing of circuit breakers

- Life of the circuit breaker only depends on the no. Of. Time open and close of the contacts. Over voltage can be avoided by closing three phase exactly at the same instant by using phase controlled technique.

Drain and trapped charges before reclosing the lines

- If transmission line is suddenly closed or switched off the electric charge will be stored on capacitor and line conductors.
- These charges are drained by line insulator or through potential transformer.
- But the effective method is connecting temporary inserting to ground before re closure and removing before closure of switching or circuit breaker.

Using shunt reactors:

- Shunt reactors are used to limit voltage rise due to Ferranti effect in EHV lines and reduce surges due to sudden switching.
- But it will give oscillation with the capacitance of the system using connecting resistors are in series with reactors suppress the oscillation and limit over voltage.

5) Write short notes on Power frequency over voltage in power system? (NOV-DEC 2012, MAY-2013)OR

What are the causes for switching and power frequency over voltage ? how are they controlled in power system? NOV-DEC 2013,MAY-2014

In the lines (400 Kv and above) power frequency over voltages occurs arecaused during tap changing operations in transformer.

- Causes for power frequency over voltages;
- Sudden load rejection
- Disconnection of inductive loads
- Ferranti effect
- Unsymmetrical faults
- Saturation in transformer etc.
- Tap changing operations.

Sudden load rejections:

When sudden load rejection in the system cause the speeding up of generator prime movers hence the system frequency will raise.

The speed governing system will respond by reducing the mechanical power generated by the turbines. But initially both the frequency and voltage increases.

The approximate voltage rise is given by

$$v = \frac{f}{fo} E' \left[\left(1 - \frac{f}{fo} \right) \frac{x_s}{x_c} \right]$$

Where

x_s - Reactance of the generator
x_c - Capacitive reactance
E' - Voltage generated before over operating and load rejections.
f - Increased frequency.
fo - normal frequency.

Disconnection of inductive loads or connection of capacitive loads:

- For improving voltage in transmission lines, inductive loads disconnected or capacitive loads are added due to these switching operations, power frequency over voltages may occur.

Ferranti effect:

- The receiving end voltage greater than the sending end voltage during light load or no load operation. Due to Ferranti effect the power frequency over voltage may occurs. Shunt reactors are used to limit voltage rise due to Ferranti effect in EHV lines.

Un symmetrical faults:

- Unsymmetrical faults are single line to ground fault, line to line fault, double line to ground fault. Consider a single line to ground fault occurs at phase 'a' v_a=0

Voltage at healthy phases b and c increases for solidly grounded system

$$\frac{X_o}{X_1} \leq 3 \, and \, \frac{R_o}{X_1} \leq 1$$

Where

X_o - zero sequence reactance

R_o - Zero sequence resistance

X_1 - Positive sequence reactance

Rise in voltage $\ngtr 1.4\, p.u$

Saturation transformer:

- When voltage applied to the transformer is more than the rated value or saturation value magnetizing currents increases rapidly. This current produces harmonics due to harmonics produces over voltages.

Tap changing transformer:

- Tap changing operations are required when the voltages changes due to load variations so during these operations power frequency over voltages occurs.

6)(i)Explain the various methods of Protection against over voltages?**(NOV-DEC-2011, MAY-2013,DEC-2013)**

What are the requirements of ground wire for protecting power conductor against direct lightning stroke? Explain how they are achieved in practice.(MAY-JUNE-2014)

Types of faults that may occur in power lines

Symmetrical faults

- Three fault(LLLG)

Unsymmetrical faults

- L-G fault
- L-L fault
- L-L-G fault

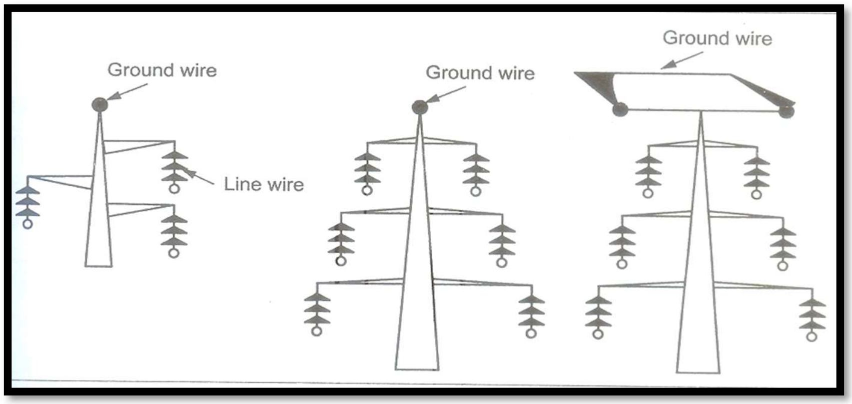
Protection of equipments in the power system from over voltages due to lightning can done by:

- Using ground wires above the phase wires.
- Using ground rods.

- Using counter-poise wires.
- Using protective devices like rod gap, expulsion type and valve type surge arrester, etc.

Ground wires:

Ground wire is a conductor run parallel to the main conductor of the transmission line, supported on the same tower and earthed at every equally and regularly spaced towers. The different arrangement of ground wires is as shown in below fig.

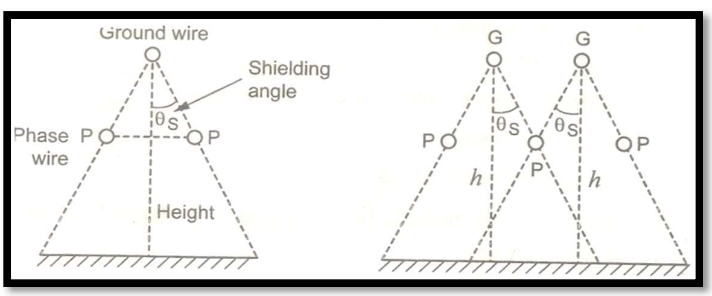


Important considerations of ground wires are:

- Ground wire selection should be based on mechanical considerations rather than electrical considerations.
- It should have high strength and non – corrosive.
- Ground resistance, insulation and clearances between the ground wire and the lines are important in the design.

Shielding angle or Protection angle **θ_s :**

The angle between the vertical line drawn through the vertical of tower and a line through the ground wire and the shielded conductor is as shown below.



Protection of Line Using Ground Wire

Assuming positively charged cloud is present above the line , it induces a negative charge near the line conductors and ground wire. Ground Wire is earthed at regular intervals , so that the negative charges drained to the Earth. As the ground wire is nearer to the line conductor , the induced charged on it will be much less and the potential rise is small.

A single ground wire reduces the induced voltage to one half of that without ground wire. For two ground wires, the reduction is one third of that without ground wire.

Effective protection depends on :

- h (height)
- θ_s (shielding angle) = 30°

Material used : Galvanized stranded steel conductors.

Uses

- It is used for direct stroke protection of lines for voltage of 110 KV and above.
- To protect lines from attenuation of travelling waves set up in the lines.

Using ground rods

Ground rods are used to reduce the tower footing resistance. These are buried into the ground surrounding the tower structure.

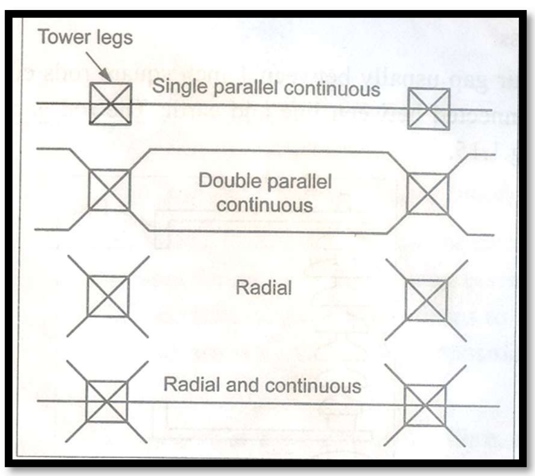
Ground rods are a number of rods about 15 mm diameter and 3 m long driven into the ground. The tower footing resistance can be varied by :

- Varying the space of the rod.
- Varying the number of rods.
- Varying the depth to which they are driven.

Material used: Galvanized iron or copper bearing steel.

Using Counter – Poise Wires

Counter- Poise Wires are buried in the ground at a depth of 0.5 to 1m, running parallel to the transmission line conductors and connected to the tower legs. Wire length may be 50 to 100 m long. The arrangement of counter – poise is as shown.



- ✓ When the lightning stroke, incident on the tower, discharges first through the tower to the ground and discharges through the counter – poise. For proper operation.
- ✓ Leakage resistance of counter poise< Surge impedance

- ✓ If lightning strikes a tower, current is injected and potential rises and flash over of insulator disc takes which results in a L.G faults. So the tower footing resistance value should be low.

Material used: Galvanized steel wire.

6)(ii)Basic Requirements of a Lightning Arrester or Surge Diverter and Explain its operation with V-I characteristics(MAY-2014)

Using Protective Devices

Protective devices are used to protect the power system components against the travelling waves caused by lightning.

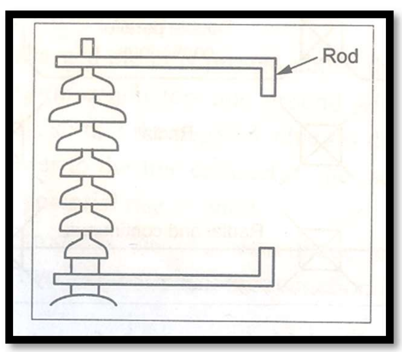
The basic Requirements of a Lightning Arrester are :

- It should not pass any current to the system component which is to be protected at abnormal conditions.
- It should break down as quickly as possible when abnormal condition occurs.
- It should discharge the surge current without damaging it.
- It should interrupt the power frequency follow current after the surge is discharge to ground.

Rod Gap(Nov 2015) 6 mark

Rod Gap is used to protect the system from lightning or thunderstorm activity is less.

A plain air gap usually between 1 inch square rods cut at right angles at the ends, connected between line and earth. The rod gap arrangement is shown.



Advantages

- Simple in construction.
- Cheap.
- Rugged construction.

Disadvantages

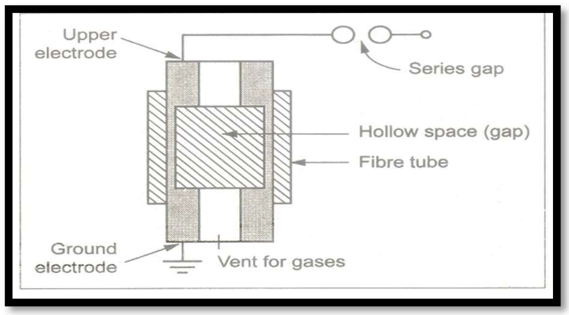
- It does not interrupt the power frequency follow current.
- Every operation of the rod gap results in L –G fault and the breakers must operate to isolate the faulty section.

Uses

- It is used as back – up protection.

Expulsion Type Lightning Arrester (Protector Tube)

- It is a device consists of a spark gap together with an arc quenching device which extinguishes the current arc when the gaps break over due to over voltages. The expulsion type lightning arrester is shown below.



- When lightning incidents, the series gap and the gap in the tube spark and provide low impedance path for power current to flow. The voltage across the terminals of the arrester drops to a low value after spark over occurs and arrester exerts little opposition to the flow of follow current.

The arc struck in the tube volatizes some of the fiber and emitting gas. This gas rushes out through the vent and is interruption takes place at zero current.

Advantages

- Cheap
- To protect small rural transformers where value type arresters are expensive.

Disadvantages

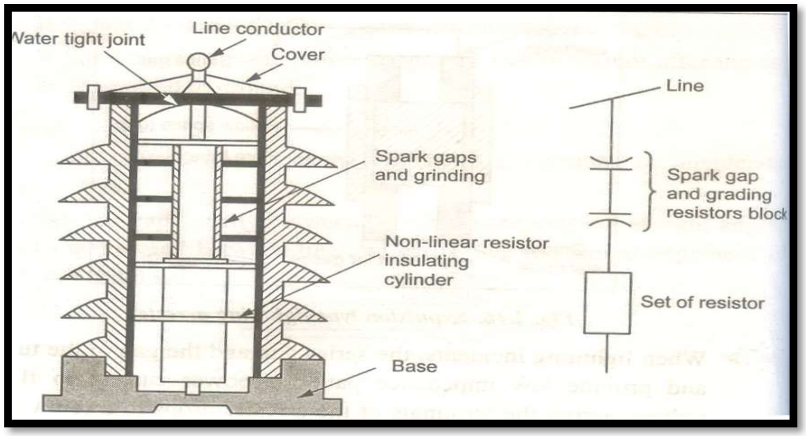
- It is not suitable for protection of expensive station equipment because of poor volt – time characteristics.

Uses

- To protect transmission line insulators(transmission line type)
- To protect distribution transformer(distribution type)

Value Type Lightning Arrester (Non – Linear Type)

Value Type Lightning Arresters are used to protect substations and at line terminations to discharge the lightning over voltages and short duration switching surges. A value type arrester is shown below.



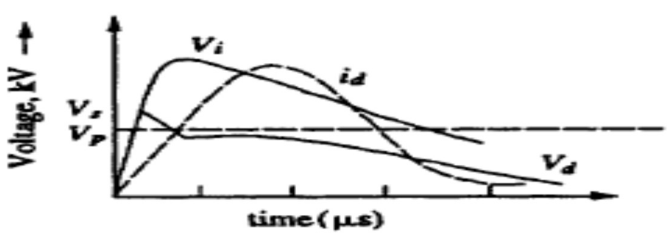
A number of non – linear resistor elements made of silicon carbide and stacked one over the other into two or three sections. They are separated by spark gaps. Spark gaps and resistors are protected by water tight housing. Non – linear resistor possess low resistance to high currents and high resistance to low currents.

Volt – ampere characteristics is given by ,

$$I = K\ V^n$$

Where

I=discharge current
N=valve lies between 2 and 6
K=constant
V=applied voltage across the elements.
As over voltage occurs due to lighting the resistance of the non-linear element decreases series gap sparks and the arrester discharges. If the current is more, number of series resistance can be added.

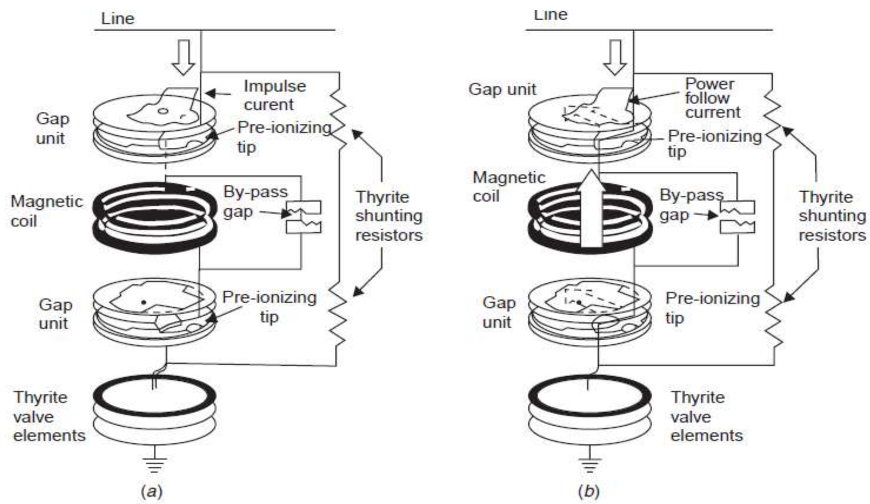


(b) Surge diverter operation

V_s — Sparkover voltage
V_p — Protective level
V_i — Surge voltage
i_d — Discharge current
V_d — Voltage across the diverter when discharging the current i_d

operation:

- When a surge voltage is applied to the surge arrester, it breaks down giving the discharge current i_d and maintains a voltage V_d across it. Thus it provides a protection to the protected above the protective level V_p.
- In heavy duty surge arrester the gaps are arranged that the arc burns in the magnetic field of the coils excited by power frequency follow on current.
- During lightning discharges, a high voltage is induced in the coil by steep front of surges and sparking occurs in the auxiliary gap.
- For power frequency follow on currents the auxiliary gap is extinguished, as sufficient voltage will not be present across the auxillary gap to maintain an arc.
- The main gap arcs occur in the magnetic field of coils.
- The magnetic field aided by the horn shaped main gap electrodes, elongate the arc and quenches it rapidly. The follow on current is limited by the voltage drop across the arc and the resistance element.



Schematic diagram of valve-type arrester indicating path of (a) Surge current, (b) Follow current.

Merits:

- ➢ To protect station equipment rated 400 KV and above.
- ➢ To protect motors and generators
- ➢ To protect distribution transformer.

7) Explain step by step procedure to draw (OR) constructing Bewley's lattice diagram?(MAY-2014)

Obtain the expression of reflected and transmission of travelling waves at transmission points (Dec-2014)

Bewley lattice diagram from which the motion of reflected and transmitted waves and their positions at every instant can be obtained. It overcomes the difficulty of keeping track of the multiplicity of successive reflections at the various junctions.

Procedure to draw lattice diagram:

➢ When a voltage surge of magnitude unity reaches a junction between two sections with surge impedance Z_1 and Z_2

➢ Then a part 'a' is reflected and a part 'b' is reflected back. In traversing the second line, on reaching the termination at the end of second line, its amplitude=α.b

➢ Set the ends of the lines at intervals equal to the time of transit of each line.

➢ If a suitable time scale is chosen, then the diagonals on the lattice diagram show the passage of the waves.

Properties of Bewley Diagram:

➢ The following are the properties of Bewley lattice diagram,

➢ All waves travel downhill, because time always increases.

➢ The positions of any wave at any time can be deduced directly from the diagram.

➢ The total potential at any instant of time is the superposition of all waves which arrive at the point until the instant of time, displaced in position from each other by time intervals equal to the time difference of their arrival.

➢ Attenuation is included so that the wave arriving at the far end of the line corresponding to the value entering multiplied by the attenuation factor

Open ended transmission line of surge impedance Z:

$$Z_1 = Z, Z_2 = \infty$$

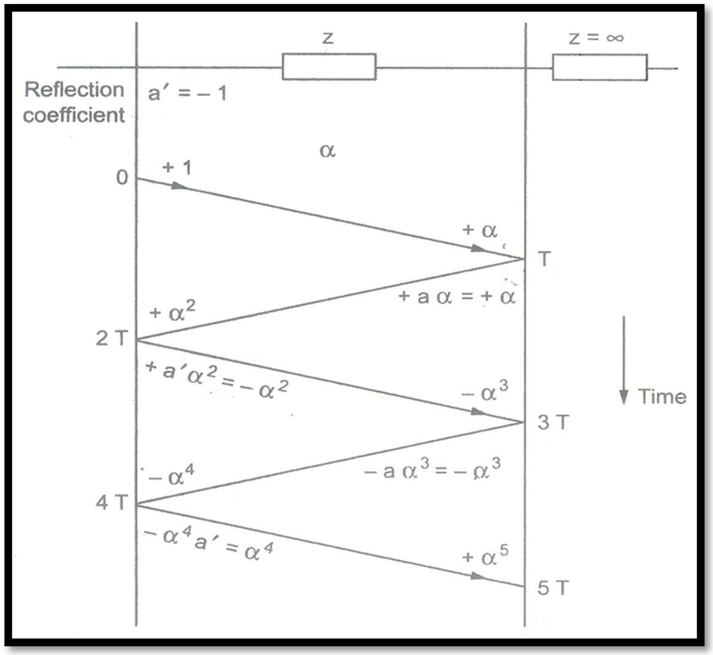
Reflection coefficient at the receiving end

$$a = \frac{Z_2 - Z_1}{Z_2 + Z_1} = \frac{1 - \frac{Z_1}{Z_2}}{1 + \frac{Z_1}{Z_2}}$$

$$= \frac{1 - \frac{Z}{\infty}}{1 - \frac{Z}{\infty}} = 1$$

Reflection coefficient at the sending end

$$a' = \frac{0 - Z}{0 + Z} = 1$$



Procedure:

- Assume T is the time taken for a wave to travel from one end to the end of line and α is the attenuation factor. Assume amplitude s unity.
- At time t=0, the magnitude is +1.the wave is attenuated and reaches at T with magnitude +1$\times \alpha = +\alpha$
- At time T, the wave is reflected and the amplitude is $+\alpha \times a = +\alpha$ and the wave is again attunated and reaches at 2T with magnitude+α^2
- At time 2T,the wave is reflected and the amplitude is $+\alpha^2 \times -a = -\alpha^2$ and the wave is again attenuated and reaches at 3T with magnitude $-\alpha^3$
- At time 3T, the wave is reflected and the amplitude is $-\alpha^3 \times a = -\alpha^3$ and the wave is attenuated and reaches at 4T with magnitude$-\alpha^4$ and so on.
- Voltage at the receving end

$$= 2[\alpha - \alpha^3 + \alpha^5 + \cdots + \alpha^{2n-1}]u(t)$$

$$= 2\alpha \frac{[1 - \alpha^{4(n+1)}]}{[1 + \alpha^2]} \times u(t)$$

At t=∞, $V_\infty = \frac{2\alpha}{1+\alpha^2}.u(t)$

8. A long transmission line is energized by a unit step voltage 1.0 V at the sending end and is open circuited at the receiving end. Construct the Bewley lattice diagram and obtain the value of the voltage at the receiving end after a long time. Take the attenuation factor a = 0.8.(Dec-2014)(Nov 2015)

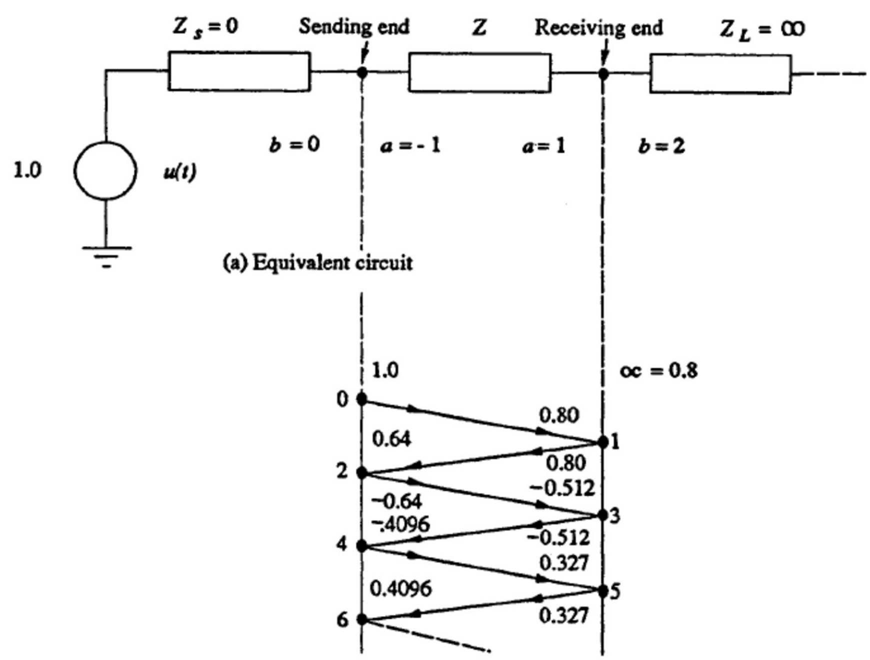
Solution: Let the time of travel of the wave = 1 unit

At the receiving end

Reflection coefficient γ= (∞ - Z)/ (∞ + Z) =1.0

Transmission coefficient = 1 + γ = 2.0
At the sending end
Reflection coefficient γ = (0 - Z)/(0+ Z) = - 1.0
Transmission coefficient = 1+γ = O
Since the source impedance Z_S= 0 and Z_2, the open receiving end impedance is ∞ (infinity), as shown in the lattice diagram of Fig Below.
From the lattice diagram, the wave magnitudes are tabulated as shown below:

At the receiving end	At the Sending end	Time unit
1	0	0
1	1	α
$1+\alpha^2$	2	2α
1	3	$2\alpha-\alpha^3$
$1-\alpha^4$	4	$2\alpha-2\alpha^3$
1	5	$2\alpha - 2\alpha^3+\alpha^5$
$1+\alpha^6$	6	$2\alpha - 2\alpha^3+2\alpha^5$



The voltage at the receiving end after *4n* units of time is
$V=2(\alpha-\alpha^3+\alpha^5-+.....)u(t)$
$= 2\alpha[(1-\alpha^{4(n+1)})/(1 + \alpha^2)]u(t)$
Voltage at the receiving end after a long time (i.e. t=∞) is $Vu(t)=[2\alpha /(1+\alpha^2)]u(t)$
Substituting α = 0.8, we get $V\infty$ = 0.9756 u(t)

9. Draw the mathematical model for lightning discharge and explain.(or)Briefly describe a method of recording the occurrence of lightning in an over head transmission line?

Mathematical Model for Lightning

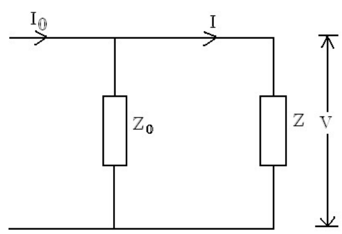
During the charge formation process, the cloud may be considered to be a nonconductor.

Hence, various potentials may be assumed at different parts of the cloud. If the charging process is continued, it is probable that the gradient at certain parts of the charged region exceeds the breakdown strength of the air or moist air in the cloud.

Hence, local breakdown takes place within the cloud. This local discharge may finally lead to a situation wherein a large reservoir of charges involving a considerable mass of cloud hangs over the ground, with the air between the cloud and the ground as a dielectric.

When a streamer discharge occurs to ground by first a leader stroke, followed by main strokes with considerable currents flowing, the lightning stroke may be thought to be a current source of value $I_0$with a source impedance Z_0 discharging to earth.

If the stroke strikes an object of impedance Z, the voltage built across it maybe taken as,



$$\begin{aligned} V &= IZ \\ &= I_0 \frac{ZZ_0}{Z+Z_0} \\ &= I_0 \frac{Z}{1+\frac{Z}{Z_0}} \end{aligned}$$

$$I_o - lightingstrokecurrent$$
$$Z_o - sourceimpedance$$
$$Z - objectimpedance\ (surgeimpedance)$$
$$V = IZ$$
$$= I_0\left(\frac{Z_0}{Z_0 + z}\right)Z$$
$$= I_0\left(\frac{Z}{1+\frac{Z}{Z_0}}\right)$$
$$Surgeimpedance = 1000\Omega to\ 3000\Omega oflighting.$$
$$Surgeimpedanceoftransmissionline < 500\Omega$$
$$Surgeimpedanceofgroundwire = 100\Omega to\ 150\Omega$$
$$Surgeimpedanceoftower = 10\Omega to\ 50\Omega$$

The source impedance of the lightning channels are not known exactly, but it is estimated to be about 1000 to 3000 Ω.

- The objects of interest to electrical engineers, namely, transmission line, etc. have surge impedances less than 500Ω (overhead lines 300 to 500Ω, ground wires 100 to 150Ω, towers 10 to 50Ω, etc.).

- Therefore, the value Z/Z_0 will usually be less than 0.1 and hence can be neglected. Hence, the voltage rise of lines, etc. may be taken to be approximately $V = I_0 Z$.
- where I_0 is the lightning stroke current and Z the line surge impedance.
- If a lightning stroke current as low as 10,000 A strikes a line of 400 Ωsurge impedance, it may cause an overvoltage of 4000 kV.
- This is a heavy overvoltage and causes immediate flashover of the line conductor through its insulator strings.
- In case a direct stroke occurs over the top of an unshielded transmission line, the current wave tries to divide into two branches and travel on either side of the line.
- Hence, the effective surge impedance of the line as seen by the wave is $Z_0/2$and taking the above example, the overvoltage caused may be only 10,000 x (400/2) = 2000 kV.
- If this line were to be a 132 kV line with an eleven 10 inch disc insulator string, the flashover of the insulator string will take place, as the impulse flashover voltage of the string is about 950 kV for a 2 μ sec front impulse wave.

- The incidence of lightning strikes on transmission lines and sub-stations is related to the degree of thunderstorm activity.
- It is based on the level of 'Thunderstorm days' (TD) known as "Isokeraunic Level" defined as the number of days in a year when thunder is heard or recorded in a particular location.
- But this indication does not often distinguish between the ground strikes and the cloud-to-cloud strikes. If a measure of ground flashover density *(Ng)* is obtained, then the number of ground flashovers can be computed from the TD level.
- From the past records and the past experience, it is found that *Ng* = (0.1 to 0.2) TD/strokes/km^2-year.
- It is reported that TD is between *5* and I5 in Britain, Europe and Pacific west of North America, and is in the range of 30 to 50 in Central and Eastern states of U.S.A.
- A much higher level is reported from South Africa and South America. No literature is available for the different regions in India, but a value of 30 to 50 may be taken for the coastal areas and for the central parts of India

10)Explain corona and its effect?

Definition

If the field is uniform , then an increase in voltage(A.C.) directly leads to breakdown without any preliminary discharge. However in non-uniform geometry, the increase in a.c. voltage will cause a luminous discharge with the production of hissing noise at points with highest electric field intensity. This form of discharge is termed as Corona discharge and is accompanied by the formation of ozone , as is indicated by the characteristic order of this gas.

If the voltage is d.c., then the appearance will be different . The positive wire will be having a uniform glow and negative wire has a more patchy glow often accompanied by streamers.

An important point in connection with corona that it is accompanied by a loss of power and this means that there is a flow of current to the wire. The current waveform is non-sinusoidal and the non-sinusoidal drop of volts caused by it may be more important than loss of power. It gives rise to **radio interference.**

Attenuation due to corona:

- The effect of corona is to reduce the crest of the voltage wave underpropagation, limiting the peak value to the critical corona voltage.
- Hence, the excess voltage above the critical voltage will cause power loss byionizing the surrounding air.

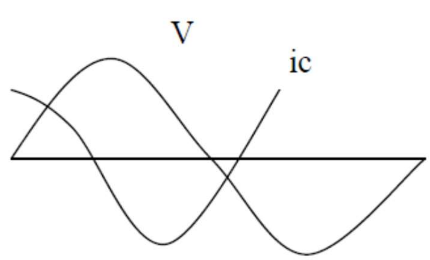
Practical Importance of Corona:

1.)Under normal conditions the loss of power due to corona is of no good importance , and consequently corona calculations do not enter directly into transmission line design. The basis of such design is entirely financially the most economical line being the most acceptable.

2.)The non-sinusoidal coronal current causes a non-sinusoidal drop of volts and these may cause some interference with neighbouring communication circuits due to electromagnetic and electrostatic induction .The current contains large third harmonic.

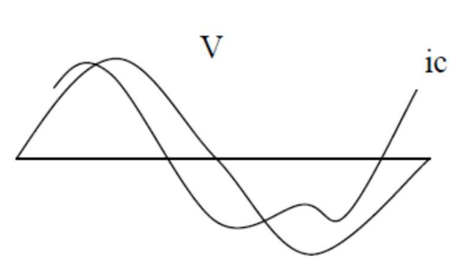
3.)Average corona loss on several lines from 345 KV to 750 KV gave 1 to 20 KW/Km in fair weather the higher values referring to higher voltages . In foul-weather the losses can go upto 300 KW/Km.

4)When a line is energized and no corona is present , the current is a pure sine wave and capacitive.



(a)

without corona voltage and current



(b)

with corona voltage and current

5)An advantage of corona is that it reduces transients , since charges induced on the line by lightning or other causes will be partially dissipated as a corona loss . In this way it acts as a safety value.

6)Audible noise: generation and characteristics.

When corona is present on the conductors EHV lines generate audible
noise which is especially high during foul weather . The noise is in broad band , which extends from a very low frequency to about 20 KHz.
Corona discharges generatepositive and negative ions which are alternatively attracted and repelled by the periodicreversal of polarity of the ac excitation .
Their movement gives rise to sound pressurewaves at frequencies of twice the power frequency and its multiples in addition to thebroadband spectrum which is the result of random motions of the ions as shown in Fig.
below.

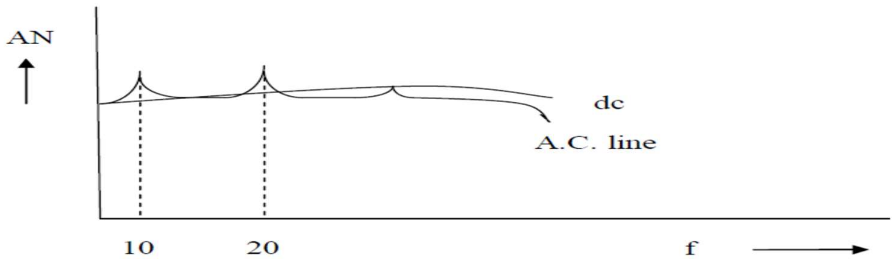


Fig.1.9 Audible noise spectra from ac and dc transmission lines

The audible noise generated by a line is a function of the following factors:
1. The surface voltage gradient on conductor.
2. The number of sub conductors in the bundle.
3. Conductor diameter.
4. Atmospheric conditions.
5. The lateral distance(aerial distance) from the line conductors to the point where noise is to be evaluated.
6) Radio interference:
There are in general two types of corona discharge from transmission line conductors
1. Pulse less or glow corona
2. Pulse type or streamer corona.
Both give rise to energy loss, but only the pulse type of ma gives interference to radio broadcast in the range of 5MHz to 1.6MHz. Besides thin, sparked discharges from broken insulators and loose guy wires interfere with TV reception in the 80-200MHz range. Corona on conductors also causes interference to carrier communication and signaling in the frequency range 30kHz to 500kHz.

11. Derive the expressions for reflection coefficient and refraction coefficient and explain the behavior of travelling waves at short circuited line ?

Whenever there is an abrupt change in the parameters of a transmission line such as an open circuit or a termination, the travelling wave undergoes a transition, of the wave is reflected or sent back and only a portion is transmitted forward.

Atthe transition point (or) junction, the voltage or current wave may attain a value which say vary from zero to twice its initial value.

The incoming wave is called the incident wave and the other waves are called reflected and transmitted (refracted waves at :3. transition point). Such waves are formed according to the Kirchoffs laws.

The current and voltage at any point on the line is written by

$$v=\frac{Coshpx+\frac{Z_0}{Z_t}Sinhpx}{Coshpx+\frac{Z_r}{Z_t}Sinhpx}E(x)$$

$$I=\frac{1}{Z_0}\left[\frac{Coshpx+\frac{Z_0}{Z_t}Sinhpx}{Coshpx+\frac{Z_r}{Z_t}Sinhpx}\right]E(x)$$

General differential solution of above equation

$$V(x)=Ae^{px}+Be^{-p}$$

$$I(x)=\frac{1}{Z_0}(Ae^{px}-Be^{-px})$$

The incident voltage and current consists of reflection and refraction waves.

$V(x)=V_1+V_2$

$I(x)=I_1+I_2$

$I_1=\frac{V_1}{Z_0}=\frac{Ae^{px}}{Z_0}$---------Forward travelling wave

$I_2=\frac{-V_2}{Z_0}=\frac{-Be^{-px}}{Z_0}$--------Backward travelling Wave

The Voltage expression can be written as

$$V=\left[\frac{e^{px}(1+\frac{Z_0}{Z_t})+e^{-px}\frac{Z_0}{Z_t}(1-\frac{Z_0}{Z_t})}{e^{pL}(1+\frac{Z_0}{Z_t})+e^{-pL}\frac{Z_0}{Z_t}(1-\frac{Z_0}{Z_t})}\right]E(x)$$

$Z_0-Sourceimpedance$
$Z_t-Lineterminatingimpedance$

Take x=0 from terminal and x=L at source end
At x=0

The above expression is changed as

$$V=\left[\frac{(1+\frac{Z_0}{Z_t})+0)}{e^{pL}(1+\frac{Z_0}{Z_t})+e^{-pL}\frac{Z_0}{Z_t}(1-\frac{Z_0}{Z_t})}\right]E(x)$$

$$V=\left[\frac{(1+\frac{Z_0}{Z_t})E(x)}{D}\right]$$

Where D is a denominator

The total voltage across Z_t=V= V_i+V_r

V_i-Incident voltage

V_r -reflected voltage

V -refracted voltage

$K_r = \frac{\text{reflected voltage}}{\text{Incident voltage}} = \frac{1+\frac{Z_0}{Z_t}}{1-\frac{Z_0}{Z_t}}$

K_r - reflection co efficient

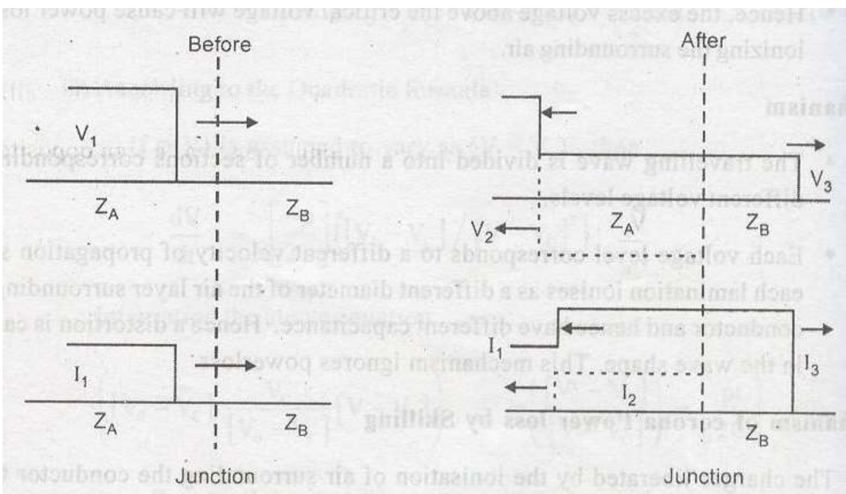
$K_r = \frac{Z_t - Z_0}{Z_t + Z_0}$

Refracted coefficient(or)Transmission coefficient

$K_t = \frac{\text{Total voltage at junction}}{\text{Incident voltage at junction}}$

$= (1 + \frac{Z_0}{Z_t}) + (1 - \frac{Z_0}{Z_t})$

$= \frac{(1+\frac{Z_0}{Z_t})+(1-\frac{Z_0}{Z_t})}{1-\frac{Z_0}{Z_t}} = \frac{2Z_t}{Z_t+Z_0}$



Case (ii):

When a wave travelling on a transmission line reaches a point where the line is joined to a second line of different characteristic impedance.(ie) when line is divided into n other lines

For the refracted wave

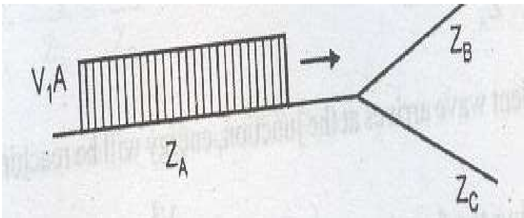
$$I_{3B} = \frac{V_{3B}}{Z_B}$$

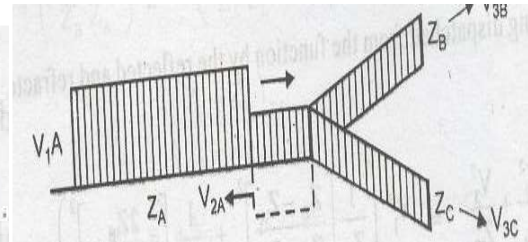
$$I_{3c} = \frac{V_{3c}}{Z_c}, \ldots . I_{3N} = \frac{V_{3N}}{Z_N}$$

For the reflected wave $$I_{2A} = \frac{-V_{2A}}{Z_{Ac}}$$

For continuity of voltage $$V_{1A} + V_{2A} = V_{3B} = V_{3c} = V_{3D....} = V_{3N}$$

and for continuity of current $I_{1A} + I_{2A} = I_{3B} = I_{3c} = I_{3D....} = I_{3N}$



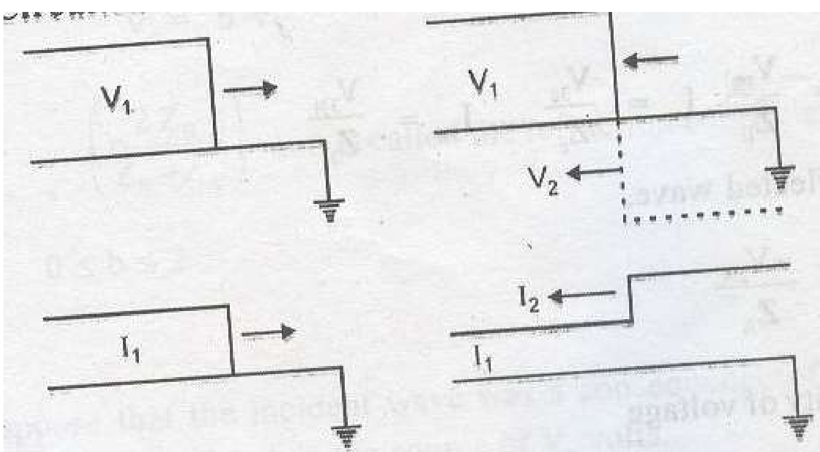


12. Explain the behaviour of travelling waves at line terminations?

Reflection and transmission of a travelling wave at junction points of unequal impedances in a transmission line are of great importance in transmission system.

Depending upon the type of impedance at transition points, the travelling wave is modifiedand sometimes voltage rise or build-up of voltage can occur. The following cases are practical importance.

Case (i) Short Circuited line:



When a travelling wave of voltage reaches a short circuit, the reflected voltagemust precisely cancel out the incident wave so that the refracted wave is zero.

Let,

V_1 — Incident voltage wave

I_1 — Incident current wave

Then Reflected voltage, $V_2 = -V_1$

Reflected current $I_2 = I_1$

The reflected wave of voltage is same as the incident wave as it returns, whilethe reflected current wave augments the incident current wave, doubling the currentflowing in the line.

Let take

Incident Voltage wave = V_1

Incident current wave = $I_1 = \frac{V_1}{Z_A}$

Surge impedances, $Z_A = Z$

$Z_B = 0$

Coefficient of reflection $a = (\frac{Z_B - Z_A}{Z_A + Z_B})$

$a = -1$

Reflected Voltage wave $V_2 = V_1$

Reflected Wave $I_2 = \frac{-V_2}{Z_A} = \frac{-(-V_1)}{Z_A}$

$I_2 = \frac{V_1}{Z_A} = I_1$

$I_2 = I_1$

The total current at the junction point

$= I_1 + I_2 = 2I$

Thus the current at the junction point rises to double the value of the incidentcurrent wave. .

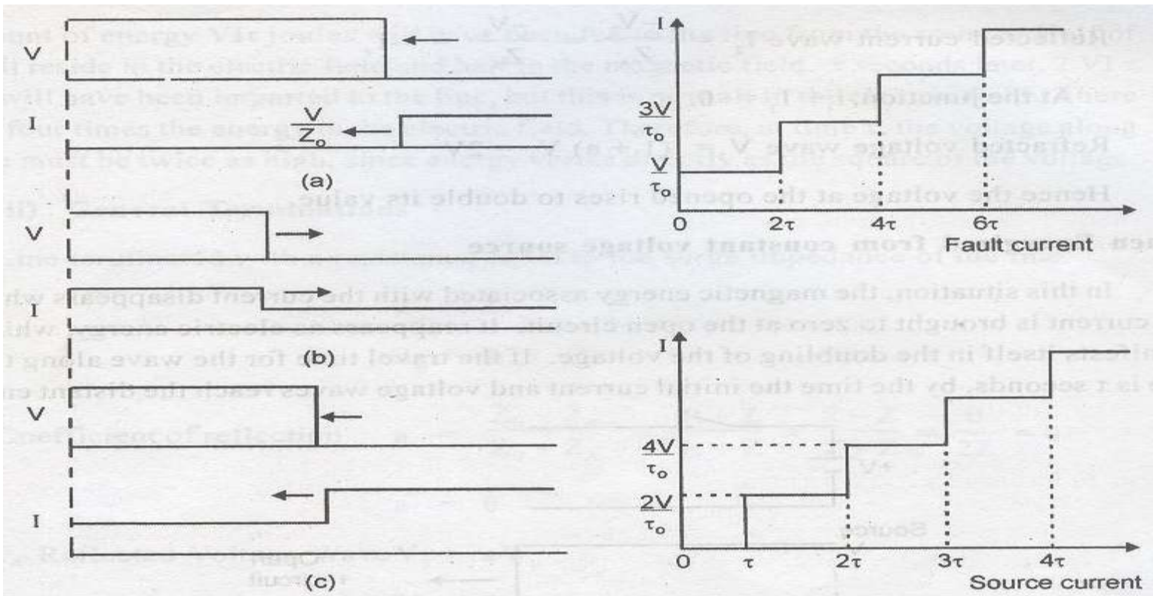
When fed by a voltage source:

When a short circuit is applied to a transmission line fed by a voltage source,(zero impedance and constant voltage V, neglect the line resistance), the fault current will increase indefinitely at a rate of E, where I_L is the inductance to the point of faultL meters away. This is approximately true as long as travelling wave phenomena areinvolved.

Our specification of the problem implies certain boundary conditions. These are that at the short circuit the voltage is always zero, but at the source it is V at all times.

To satisfy the first of these conditions,When the short circuit is applied,a wave of voltage —V travels toward the source, reducing the line voltage to zero.

When this wave reaches the source, the boundary condition there demands theinitiation of a new wave of voltage +V, which because of its direction, is associated V with current Z. This is shown in figure (b). These waves in due course reach the short circuit, where upon the cycle repeats figure (c), so that short circuit current as seen at the fault or at the source increases in discrete steps as shown in figure (d) and 2V figure (e)



Case (ii) Open Circuit:

An open circuit at the end of a transmission line demands that the current at thatpoint be zero at all times. Thus when a current wave of +1 arrives at the open circuit, a current wave of -1 is at once initiated to satisfy the boundary condition. This will travel toward the source with a voltage wave of +V.

Incident Voltage Wave = V_1
Incident Current Wave = I_1

$Z_A = Z$

$Z_B = \infty$

Coefficient of Reflection $a = (\frac{Z_B - Z_A}{Z_A + Z_B}) = \frac{1 - \frac{Z_A}{Z_B}}{1 + \frac{Z_A}{Z_B}} = \frac{1 - \frac{Z}{\alpha}}{1 + \frac{Z_A}{\alpha}} = 1$

Reflected voltage wave $V_2 = aV_1 = V_1$

Reflected current wave $I_2 = \frac{-V_2}{Z_A} = \frac{-V_1}{Z_A} = -1$

$I_1 + I_2 = 0$

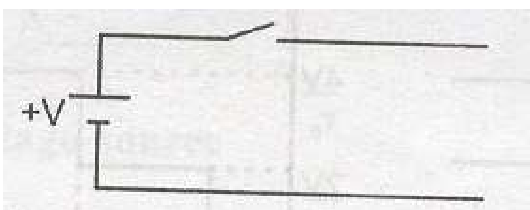
Refracted voltage wave $V_3 = (1+a)V_1 = 2V_1$

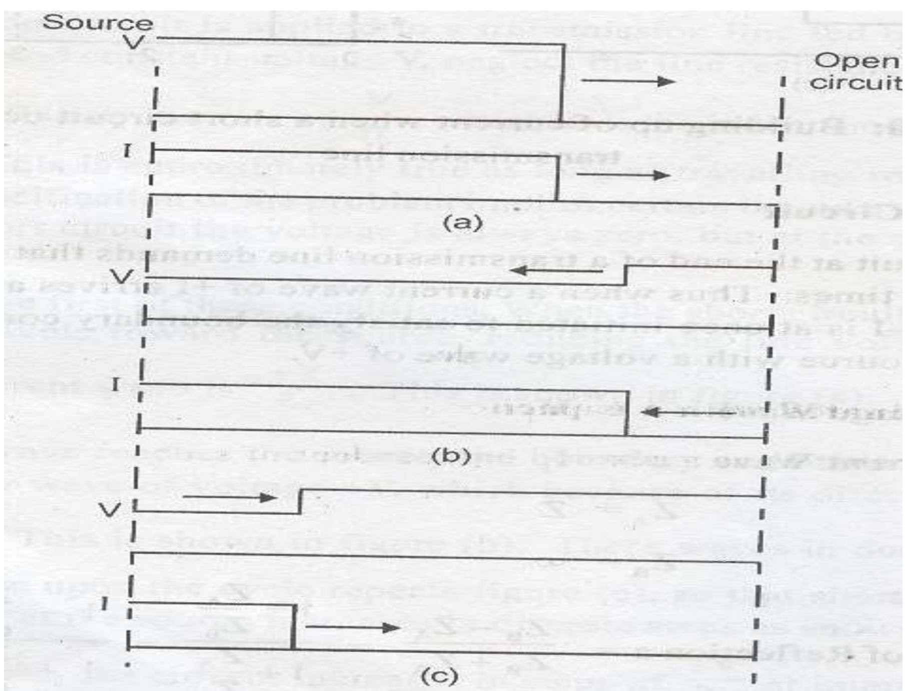
Hence the voltage at the opened rises to double its value.

When energized from constant voltage source:

In this situation, the magnetic energy associated with the current disappears whenthe current is brought to zero at the open circuit.

It reappears as electric energy, whichmanifests itselfin the doubling of the voltage. The travel time for the wave along theline is t seconds, by the time the initial current and voltage waves reach the distant end,





an amount ofenergy joules will have been fed to the line from the source.

Half of this will reside in the electric field and half in the magnetic field 1 seconds later, joules will have been imparted to the line, but this is now all in the electric field.

There is now four times the energy in the electric field. Therefore, at time 1 the voltage along the line must be twice as high, since energy varies directly as the square of the voltage.

Case (ii) General Terminations:

Line terminated with a resistance equal to the surge impedance of the line.

$Z_A = Z$

$Z_B = R = Z$

$$a = (\frac{Z_B - Z_A}{Z_A + Z_B}) = \frac{R - Z}{R + Z} = \frac{Z - Z}{Z + Z} = \frac{0}{2Z} = 0$$

$a = 0$

Reflected Voltage Wave $V_2 = aV_1$

$V_2 = 0$

Reflected Voltage Wave $V_3 = (1 + a)V_1$

$V_3 = V_1$

Thus, there is no reflected wave. There is no discontinuity of the line, and thetravelling wave proceeds without reflection and disappears. Thus there will be noreflections at thejunction, if a transmission line or cable is terminated with a resistanceequal to the surge impedance of the line or cable.

Case (iv) Line terminated with a capacitor:

$Z_A = Z_B$ (behaves as a resistor independent of s.)

$$Z_B = \frac{1}{C_1 s}$$

$$a = \frac{Z_B - Z_A}{Z_B + Z_A}$$

Reflection coefficient $a = \dfrac{(\frac{1}{C_1 s}) - Z_A}{(\frac{1}{C_1 s}) + Z_A}$

Refraction coefficient $b = \dfrac{2Z_B}{Z_B + Z_A} = \dfrac{(\frac{2}{C_1 s})}{(\frac{1}{C_1 s}) + Z_A}$

Thus the laplace transform of the reflected wave

$V_2(s) = aV_1(s)$

$$= \frac{V_1}{s}[\frac{(\frac{1}{C_1 s}) - Z_A}{(\frac{1}{C_1 s}) + Z_A}]$$

$$= \frac{V_1}{s}[\frac{(\frac{1}{C_1 Z_A}) - s}{(\frac{1}{C_1 Z_A}) + s}]$$

$$(\frac{1}{C_1 Z_A}) = \alpha$$

$$V_2(S) = \frac{V_1}{S}(\frac{\alpha - S}{\alpha + S})$$

$$= V_1(\frac{\alpha}{S(S+\alpha)} - \frac{1}{S+\alpha})$$

Taking inverse laplace transforms

$$V_2(t) = V_1[1 - e^{-\alpha t} - e^{-\alpha t}]$$

$$V_2(t) = V_1[2 - e^{-\alpha t}]$$

Refracted wave $V_3 = V_1 + V_2$

$$V_3 = V_1(2 - e^{-\alpha t})$$

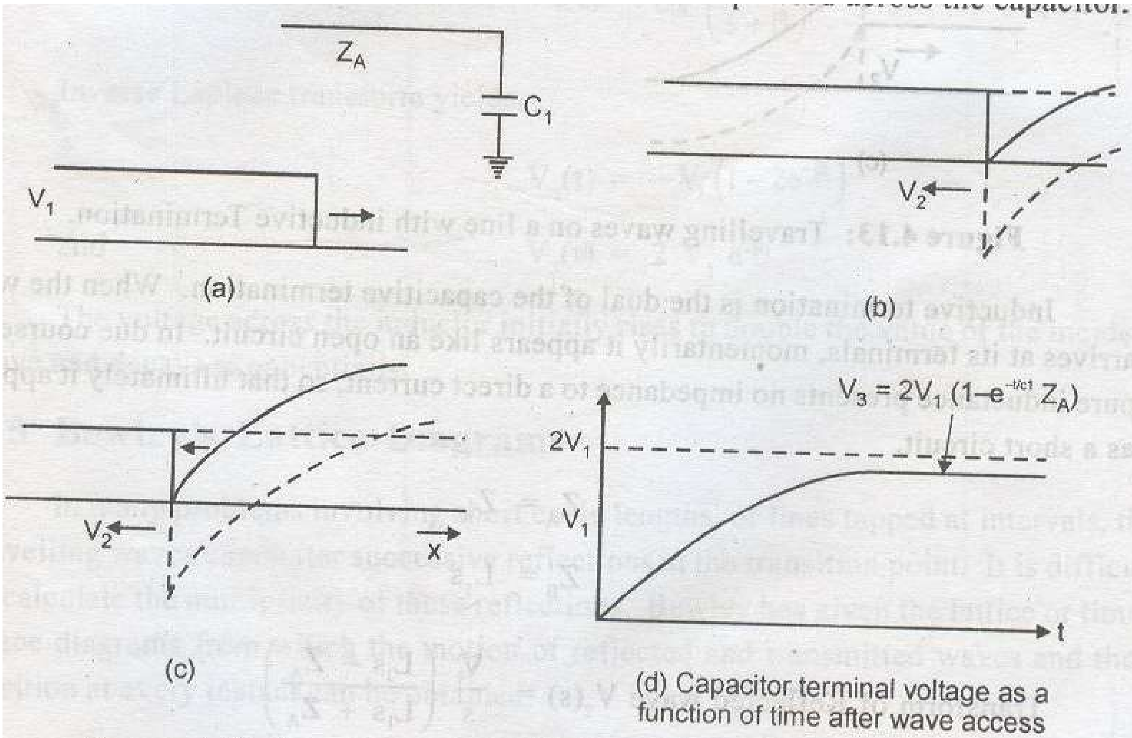
$$V_3(S) = bV_1(S)$$

$$= \frac{V_1}{s}[\frac{(\frac{2}{C_1 s})}{\frac{1}{C_1 s + Z_A}}]$$

$$= \frac{V_1}{s}[\frac{(\frac{2}{C_1 Z_A})}{\frac{1}{C_1 Z_A + s}}]$$

$$= V_1 \left(\frac{2\alpha}{s[s+\alpha]} \right)$$

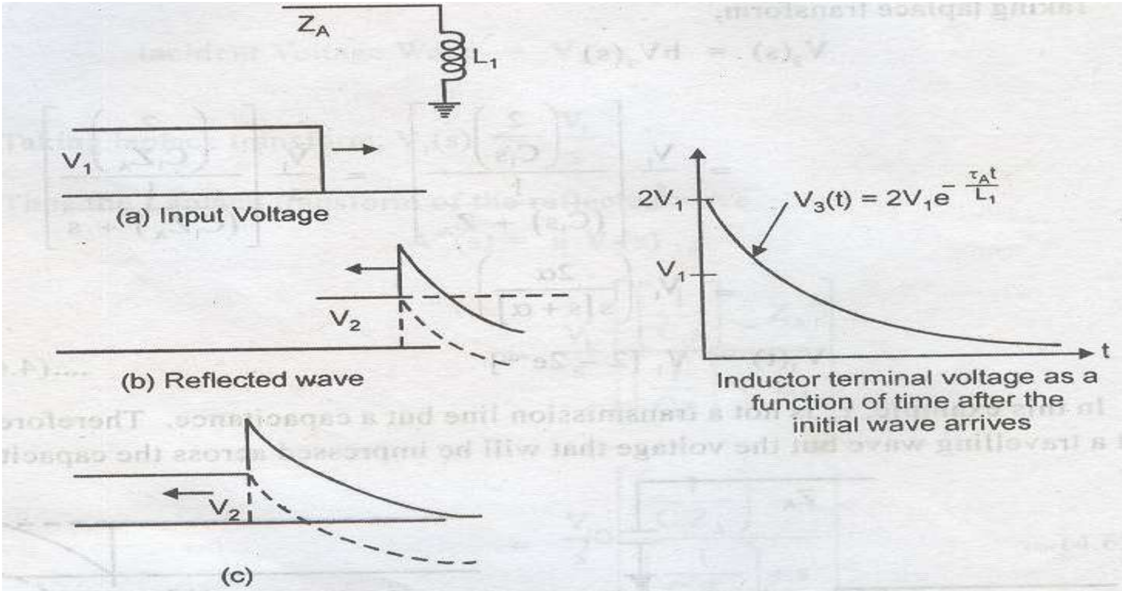
$$V_3(t) = V_1[2 - e^{-\alpha t}]$$



When the incident wave reaches the capacitor C, it cannot instantaneously change its potential. Momentarily, the capacitor behaves like a short circuit, the front of the reflected wave cancels out the incident wave as we observed with a short circuit.

It can be inferred that the steepness of the front is reduced and the wave rises slowly in an exponential manner. The voltage at the junction point finally rises to twice the magnitude of the incident wave.

Case (iv) Transmission line terminated by an inductance L:



Inductive termination is the dual of the capacitive termination. When the wavearrives at its terminals, momentarily it appears like an open circuit. In due course the pure inductance presents no impedance to a direct current, so that ultimately it appears ' as a short circuit.

$Z_A = Z_A$

$Z_B = L_1 s$

Transform of reflected wave $V_2(s) = \frac{V_1}{s}(\frac{L_1 s - Z_A}{L_1 s + Z_A})$

$$= \frac{s - \frac{Z_A}{L_1}}{s + \frac{Z_A}{L_1}} \frac{v_1}{s}$$

Taking partial fraction

$$v_2(s) = -v_1(\frac{1}{s} - \frac{2}{s + \frac{Z_A}{L_1}})$$

$$v_2(t) = -v_1(1 - 2e^{\frac{Z_A}{L_1}t})$$

Transform of refracted wave, $v_3(s) = \frac{v_1}{s}(\frac{2L_1 s}{L_1 s + Z_A})$

$$= \frac{v_1}{s}(\frac{2L_1 s}{L_1(s + \frac{Z_A}{L_1}})$$

$$= \frac{v_1}{1}(\frac{2}{(s + \frac{Z_A}{L_1}})$$

Taking inverse laplace transform we get

$$v_3(t) = 2v_1 e^{\frac{Z_A}{L_1}t}$$

The voltage across the inductor initially rises to double the value of the incident wave and decays exponentially.

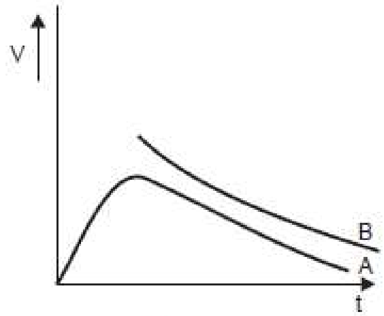
13) Explain Why a steep fronted surge wave form are more vulnerable to insulation?(May 2015)(8 mark)

- For steep fronted travelling waves, the voltages at different points in the sub-station can exceed the protective level by amounts that depend on the distance from the diverter location, the steepness of the wave front and other electrical parameters.
- Hence, it is necessary to decide the number of locations at which surge diverters are to be located and their ratings. It is necessary to keep this number to a minimum. Also, care must be taken regarding switching over-voltages generated due to current chopping which may destroy the transformer or the equipment near the circuit breakers.
- The Basic Impulse Level (BIL) is often determined as simply 1.25 to 1.30 times the protective level offered by the surge diverter. Usually, the next higher BIL value from the standard values is chosen.
- Usually the circuit breaker, the transformer and other equipment are placed at finite distances from the surge diverter and connected through a short distance overhead line or cable. When a surge arises, it suffers multiple reflections between each of the equipment which may give rise to over voltages of considerable magnitude (the travel time is usually less than a microSec).
- It can be shown that when a surge diverter, a breaker and a transformer are in line, the voltage that can build up at a distance *D* from the surge diverter point is given as *V(D) = Vp* + 2S7*, where *Vp* is the spark over voltage/protective level, *S* is the steepness of the wave front, and *T* is the travel time =*DIv.* Here, v is the velocity of the wave travel, assuming that the line extends to a large distance such that no reflections come from the line end.
- The maximum value of *V(D)* is attained when *2T = TQ,* the spark over time of the diverter.
- "Distance effect" is to be suitably allowed for when surge diverters are to be used for SDL also; a margin of 15 to 20% is normally allowed over the protective level.
- Distance effect is negligible for long fronted switching surges.

14)Briefly explain with the aid of suitable diagrams, the statistical method of insulation co-ordination?(16 mark)(May 2015)

- Insulation coordination means the correlation of the insulation of the various equipments in a power
- system to the insulation of the protective devices used for the protection of those equipments againstover-voltages.
- In a power system various equipments like transformers, circuit breakers, bus supports etc. have different breakdown voltages and hence the volt-time characteristics. In order that all the equipments should be properly protected it is desired that the insulation of the various protective devices must be properly coordinated.
- Curve *A* is the volt-time curve of the protective device and *B* the volt-time curve of the equipmentto be protected.

- Thus, any insulation having a withstand voltage strength in excess of the insulation strength of curve *B* is protected by the protective device of curve *A*.



Volt-time curve *A*
(protecting device and) volt-time curve *B* (device to be protected)

The insulation design of EHV and UHV system is based on the following principles.

- The station have transformers and other valuable equipment that have non self restoring insulation.
- The protective levels for lightning surges and switching surges are almost equal and even overlap.
- BIL cannot give protection against switching impulses. So separate SIL needed. So when controlling of switching voltage control device works fail that time surge arrester suppress switching surges.
- The protection level provided by the protective devices like surge arresters is same as for other apparatus difference is surge arrester absorb surge.
- The safety margin is arrived at by considering the risk factor R for the devices used for the protection and the insulation structure to be protected.
- In normal practice the insulation level and the protective safety margin are arrived at by
  i)Selecting the risk of failure(R)
  ii)Statistical safety factor(γ)
  iii)Fixing the withstand voltage and designing the insulation level of any equipment corresponding to 90%,95% of the withstand voltage thus fixed.

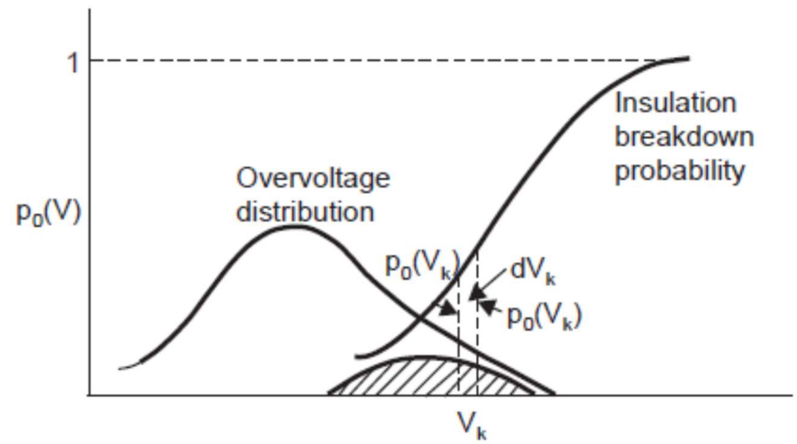
Statistical approach

- The statistical methods is a very rigorous experimentation and analysis work so as to find probability of occurence of over-voltages and probability of failure of insulation. It is found that the distribution of breakdown for a given gap follows with some exceptions approximately normal or Gaussian distribution. Similarly the distribution of over voltages on the system also follows the
- Gaussian distribution. In order to coordinate electrical stresses due to over-voltages with the electrical strengths of the dielectric media, it has been found convenient to represent overvoltage distribution in the form of probability density function and the insulation breakdown probability by the cumulative
- Distribution function as shown in Fig.
- Suppose $P0(V_k)$ is the probability density of an overvoltage Vk and $P0\ (Vk)\ dVk$ the probability of
  occurence of the over voltages having a peak value Vk. To obtain the probability to disruptive discharges due to these overvoltages having a value between Vk and $Vk + dVk$, their probability of occurrence $P0(Vk)\ dVk$, shall be multiplied by $Pb(Vk)$ that an impulse of the given type and of value Vk will produce a discharge.
  The resultant probability or risk of failure for overvoltage between Vk and $Vk + dVk$ is thus,

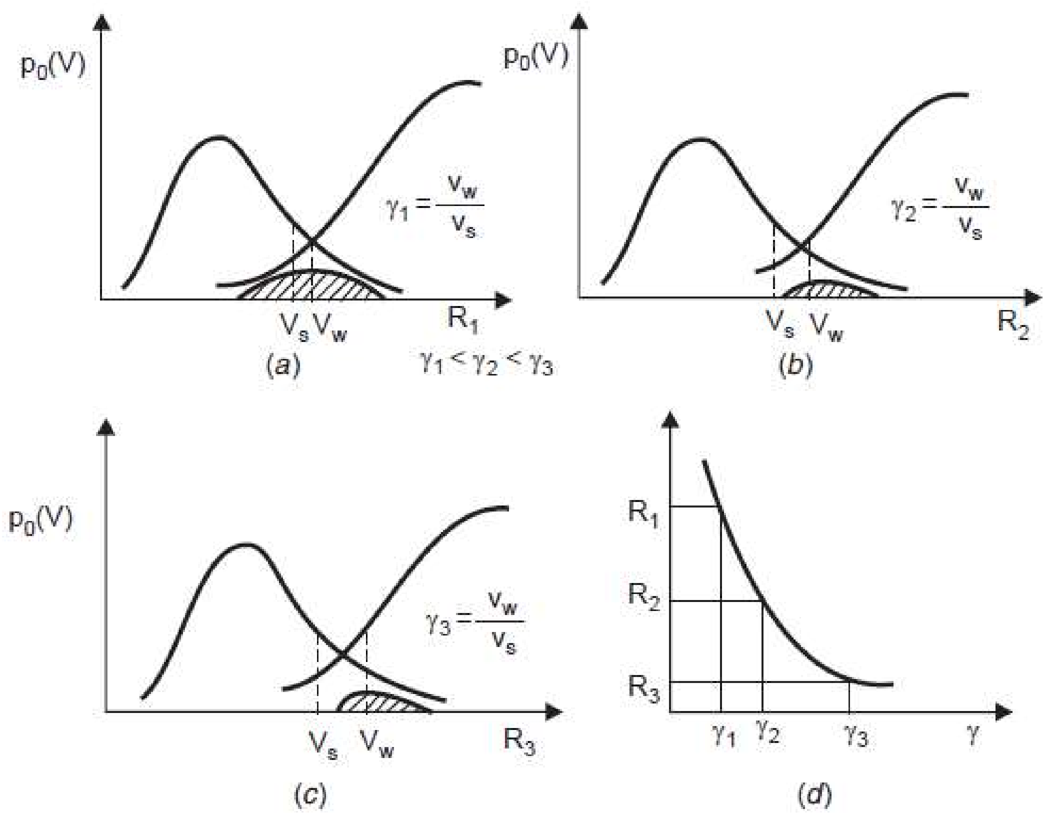
$dR = P_b(V_k)\, P_0(V_k)\, dV_k$

- For the total voltage range we obtain the total probability of failure or risk of failure.

  $R = \int_0^{\infty} P_b(V_k)\, P_0(V_k)\, dV_k$



I Overvoltage distribution and Insulation breakdown probability



Risk of failure as a function of statistical safety factor

UNIT-2

1. **Explain Townsend's criterion for a spark.(June-2009, May-2011)(or)From the fundamental principle derive Townsend's criteria for the breakdown of gaseous dielectric medium (May 2015)**

Townsend's second ionization coefficient

The current growth equation in the presence of secondary process is derived by

$\gamma = \gamma_1 + \gamma_2 + \gamma_3$ where γ is the second ionization coefficient and it is function of pressure,E/p

let we take n_+ −secondary electrons

n- total number of electron released from cathode and reached anode

n_0-no of electrons released by ultra violet radiation

$$n = n_0 + n_+$$

An electrons released from gas = $n - (n_0 + n_+)$

thereforeeach positive ionreleases γ effective electrons from the cathode

that is $n_+ = \gamma(n - (n_0 + n_+))$

$$n_+ = \gamma n - \gamma n_0 - \gamma n_+$$

$(1+\gamma)n_+ = \gamma(n - n_0)$

$$n_+ = \frac{\gamma(n - n_0)}{(1 + \gamma)}$$

w.k.t

$$n = (n_0 + n_+)e^{\alpha d}$$

substituting n_+ in the above expression
we get

$$n = (n_0 + \frac{\gamma(n - n_0)}{(1 + \gamma)})e^{\alpha d}$$

simplify we get

$$n = \frac{n_0 e^{\alpha d}}{1 - \gamma(e^{\alpha d} - 1)}$$

It is written in terms of current

$$I = \frac{I_0 e^{\alpha d}}{1 - \gamma(e^{\alpha d} - 1)}$$

The current becomes infinite if

$$1 - \gamma(e^{\alpha d} - 1) = 0$$

$$\gamma(e^{\alpha d} - 1) = 1$$

$$\gamma e^{\alpha d} = 1$$

normally $e^{\alpha d} >> 1$

the current in the anode equals the current in the external circuit. Theoretically the current becomes infinitely large under the above mentioned condition but practically it is limited by the resistance of the external circuit and partially by the voltage drop in the arc. The condition $\gamma e^{\alpha d}$= 1 defines the condition for beginning of spark and is known as the Townsend criterion for spark formation or Townsend breakdown criterion. Using the above equations, the following three conditions are possible.

(1**)** $\gamma e^{\alpha d}$ **=1** The number of ion pairs produced in the gap by the passage of arc electron avalanche is sufficiently large and the resulting positive ions on bombarding the cathode are able to release one secondary electron and so cause a repetition of the avalanche process. The discharge is then said to be self-sustained as the discharge will sustain itself even if the source

producing I_0 is removed. Therefore, the condition $\gamma e^{\alpha d}$ =1 defines the threshold sparking condition.

(2) $\gamma e^{\alpha d}$> **1** Here ionization produced by successive avalanche is cumulative. The spark discharge grows more rapidly the more $\gamma e^{\alpha d}$ exceeds unity.

(3) $\gamma e^{\alpha d}$**<1** Here the current I is not self-sustained i.e., on removal of the source the current I_0 ceases to flow.

2. **State the criteria for sparking potential and hence obtain the relation between sparking potential and (pd) values (Paschens Law).discuss on the nature of variation of sparking potential with (pd) values.(Dec-2007,MAY-2013,Dec-14)(May 2015)**

The Townsend's Criterion: $\gamma(e^{\alpha d} - 1)$ = 1---equ(1)

Which enables the evaluation of breakdown voltage of the gap by the use of appropriate values of α /p and V corresponding to the values E/p when the current is too low to damage the cathode and also the space charge distortions are minimum. The calculated and experimentally determined values are obtained when the gaps are short or long and the pressure is relatively low.

An expression for the breakdown voltage for uniform field gaps as a function of gap length and gas pressure can be derived from the threshold equation by expressing the ionization coefficient α/p as a function of field strength E and gas pressure p i.e.,:

$$\frac{\alpha}{p} = f(\frac{E}{p})$$

substituting this in equ 1

$(e^{\alpha d} - 1) = \frac{1}{\gamma}$

$$e^{\alpha d} = 1 + \frac{1}{\gamma}$$

$e^{f(\frac{E}{p})pd} = 1 + \frac{1}{\gamma}$

Take ln on both side

$f\left(\frac{E}{p}\right)pd = \ln\,(1 + \frac{1}{\gamma})$

for uniform field $E = \frac{V_b}{d}$

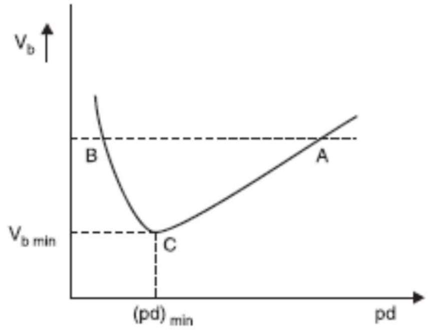
$\therefore\ f\left(\frac{\frac{V_b}{d}}{p}\right)pd$=K

$$f\left(\frac{V_b}{pd}\right) = \frac{K}{pd}$$

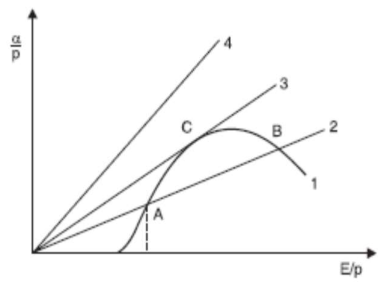
$$therefore\ V_b = F(pd)$$

This gives that the breakdown voltage of a uniform field gap is a unique function of the product of gas pressure and the gap length for a particular gas and electrode material. This relation is known as **Paschen's law**.

This relation does not mean that the breakdown voltage is directly proportional to product of **pd** even though it is found that for some region of the product **pd** the relation is linear i.e., the breakdown voltage varies linearly with the product **pd** values . The variation over a large range is shown in fig below.



compare Paschen's law and the Townsend's criterion for spark potential. We draw the experimentally obtained relation between the ionization coefficient α/p and the field strength f(E/p)



Now the Townsend's criterion αd = K can be re-written as

$$\frac{\alpha}{p}\cdot\frac{V}{E}=\frac{K}{p} \quad \text{or} \quad \frac{\alpha}{p}=\frac{K}{V}\cdot\frac{E}{P}$$

This is equation to a straight line with slope equal to K/V depending upon the value of K.

The higher the voltage the smaller the slope and therefore, this line will intersect the ionization curve at two points e.g., A and B in Fig above.

Therefore, there must exist two breakdown voltages at a constant pressure (p = constant), one corresponding to the small value of gap length i.e., higher E (E = V/d) i.e., point B and the other to the longer gap length i.e., smaller E or smaller E/p i.e., the point A.

At low values of voltage V the slope of the straight line is large and, therefore, there is no intersection between the line and the curve 1. This means no breakdown occurs with small voltages below Paschen's minimum irrespective of the value of **pd.**

The point C on the curve indicates the lowest breakdown voltage or the minimum sparking potential. The spark over voltages corresponding to points A, B, C are shown in the Paschen's curve in Fig. above.

By considering the efficiency of ionization of electrons traversing the gap with different electron energies.

Assuming that the Townsend's second ionization coefficient V is small for values pd > (pd)min., electrons crossing the gap make more frequent collision with the gas molecules than at (pd)min.

but the energy gained between the successive collision is smaller than at (pd). Hence, the probability of ionization is lower unless the voltage is increased.

In case of (pd) < (pd) $_{min}$., the electrons cross the gap without making any collision and thus the sparking potential is higher. The point (pd)$_{min}$., therefore, corresponds to the highest ionization efficiency and hence minimum sparking potential.

An analytical expression for the minimum sparking potential can be obtained using the general expression for α/p.

$$\frac{\alpha}{p} = Ae^{\frac{Bp}{E}} \quad or\ \alpha = pAe^{\frac{Bpd}{V_b}}$$

$$e^{\frac{Bpd}{V_b}} = \frac{pA}{\alpha} \quad or\ \frac{1}{\alpha} = \frac{e^{\frac{Bpd}{V_b}}}{pA}$$

$$\frac{1}{\alpha d} d = \frac{e^{\frac{Bpd}{V_b}}}{pA}$$

w.k.t

$$\alpha d = \ln\left(1 + \frac{1}{v}\right)$$

Therefore

$$d = \frac{e^{\frac{Bpd}{V_b}}}{pA} \ln\left(1 + \frac{1}{v}\right)$$

Assume $\ln\left(1 + \frac{1}{v}\right) = K$

so that

$$d = \frac{e^{\frac{Bpd}{V_b}}}{pA} \mathrm{k}$$

$$e^{\frac{Bpd}{V_b}} = \frac{dpA}{k}$$

Taking ln on both sides

$$\frac{Bpd}{V_b} = ln \frac{APd}{K}$$

$$V_b = \frac{Bpd}{ln\frac{APd}{K}}$$

Differentiating the above equation with respect to pd and equate to zero

we get

$$ln\frac{APd}{K} = 1$$

$$ln\frac{APd}{K} = e$$

$$pd_{min} = \frac{ek}{A}$$

W.K.T

$$V_{b\,min} = \frac{Bpd}{ln\frac{APd}{K}}$$

$$V_{b\,min} = \frac{B\ ek/A}{1}$$

The typical values for A, B and V for air are A = 12, B = 365 and V= 0.02.

3.Discuss Meek's theory of breakdown in gases under non-uniform field. (May-2008)

or

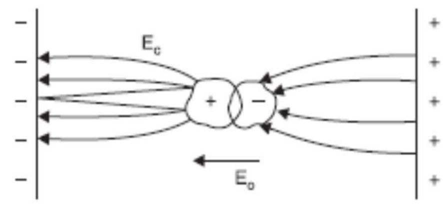
Discuss STREAMER OR KANAL MECHANISM OF SPARK in gases under non-uniform field.(MAY-2014)

the charges in between the electrodes separated by a distance **d**increase by a factor $e^{\alpha d}$ when field between electrodes is uniform.

This is valid only if we assume that the field E_0 = V/d is not affected by the space charges of electrons and positive ions. Rather has observed that if the charge concentration is higher than 10^6 but lower than 10^8 the growth of an avalanche is weakened i.e., $dn/dx<e^{\alpha d}$.

Whenever the concentration exceeds 10^8, the avalanche current is followed by steep rise in current and breakdown of the gap takes place.

The weakening of the avalanche at lower concentration and rapid growth of avalanche at higher concentration have been attributed to the modification of the electric field E_0 due to the space charge field



The above Fig shows the electric field around an avalanche as it progresses along the gap and the resultant field i.e., the superposition of the space charge field and the original field E_0.

Since the electrons have higher mobility, the space charge at the head of the avalanche is considered to be negative and is assumed to be concentrated within a spherical volume.

Due to the filed at the head of the avalanche is strengthened. The field between the two assumed charge centers i.e., the electrons and positive ions is the electrons and positive ions is decreased as the field due to the charge centers opposes the main field E_0

Again the field between the positive space charge centre and the cathode is strengthened as the space charge field aids the main field E_0 in this region.

It has been observed that if the charge carrier number exceeds 10^6, the field distortion becomes noticeable.

If the distortion of field is of 1%, it would lead to a doubling of the avalanche but as the field distortion is only near the head of the avalanche, it does not have a significance on the discharge phenomenon.

if the charge carrier exceeds 10^8, the space charge field becomes almost of the same magnitude as the main field E^0 and hence it may lead to initiation of a streamer. The space charge field, therefore, plays a very important role in the mechanism of electric discharge in a non-uniform gap.

Townsend suggested that the electric spark discharge is due to the ionization of gas molecule by the electron impact and release of electrons from cathode due to positive ion bombardment at the cathode.

According to this theory, the formative time lag of the spark should be at best equal to the electron transit time t_r.

At pressures around atmospheric and above p.d. > 10^3 Torr-cm, the space charge developed in an avalanche is capable of transforming the avalanche into channels of ionization known as streamers that lead to rapid development of breakdown. the avalanche head reaches a critical value of

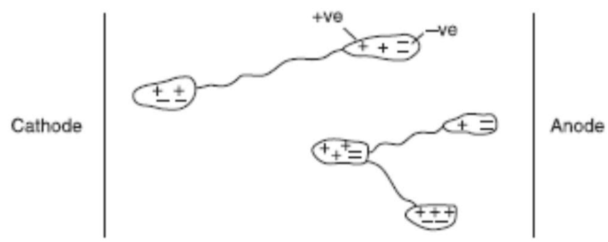
$n_0 e^{\alpha x} \approx 10^8$ or $\alpha x_c \approx 18$ to 20

where Xc is the length of the avalanche path in field direction when it reaches the critical size, If the gap length d <Xc, the initiation of streamer is unlikely.

The short-time lags associated with the discharge development led Raether and streamer of Kanal mechanism for spark formation, in which the secondary mechanism results from photo-ionization of gas molecules and is independent of the electrodes Raether and Meek have proposed that independently Meek and Loeb to the advancement of the theory of when the avalanche in the gap reaches a certain critical size the combined space charge field and externally applied field E_0 lead to intense ionization and excitation of the gas particles in front of the avalanche head.

There is recombination of electrons and positive ion resulting in generation of photons and these photons in turn generate secondary electrons by the photo-ionization process.

These electrons under the influence of the electric field develop into secondary avalanches as shown in Fig below since photons travel with velocity of light, the process leads to a rapid development of conduction channel across the gap.



Raether after thorough experimental investigation developed an empirical relation for the streamer spark criterion of the form

$$\alpha x_c = 17.7 + \ln x_c + \ln\frac{E_r}{E_0}$$

where E_r is the radial field due to space charge and E_0 is the externally applied field. Now for transformation of avalanche into a streamer $E_r \approx E$

Therefore, $\alpha x_c = 17.7 + \ln x_c$

For a uniform field gap, breakdown voltage through streamer mechanism is obtained on the assumption that the transition from avalanche to streamer occurs when the avalanche has just crossed the gap. The equation above, therefore, becomes

$\alpha d = 17.7 + \ln d$

When the critical length $x_c \geq \alpha d$ minimum breakdown by streamer mechanism is brought about.

The condition $X_c = d$ gives the smallest value of α(alpha) to produce streamer breakdown.

Meek suggested that the transition from avalanche to streamer takes place when the radial field about the positive space charge in an electron avalanche attains a value of the order of the externally applied field. He showed that the value of the radial field can be obtained by using the expression.

$$E_r = 5.3 \times 10^{-7} \frac{\alpha e^{\alpha x}}{\left(\frac{x}{p}\right)^{\frac{1}{2}}} \text{ volts/Cm}$$

where x is the distance in cm which the avalanche has progressed, p the gas pressure in Torr and α(alpha) the Townsend coefficient of ionization by electrons corresponding to the applied field E.

The minimum breakdown voltage is assumed to correspond to the condition when the valanche has crossed the gap of length d and the space charge field E_r approaches the externally applied field i.e., at x = d, E_r= E.

Substituting these values in the above equation, we have

$$E = 5.3 \times 10^{-7} \frac{\alpha e^{\alpha x}}{\left(\frac{d}{p}\right)^{\frac{1}{2}}}$$

taking ln on both sides

$$\ln E = -14.5 + \ln \alpha - \frac{1}{2} ln \frac{d}{p} + \alpha d$$

Add - ln p on both sides

$$\ln E - \ln p = -14.5 + \ln \alpha - \ln p - \frac{1}{2} ln \frac{d}{p} + \alpha d$$

$$\ln \frac{E}{p} = -14.5 + \ln \frac{\alpha}{p} - \frac{1}{2} ln \frac{d}{p} + \alpha d$$

The experimentally determined values of $\frac{\alpha}{p}$ and the corresponding E/p are used to solve the above equation using trial and error method. Values of $\frac{\alpha}{p}$ corresponding to E/p at a given pressure are chosen until the equation is satisfied.

4. What are the preferred properties of gaseous dielectric for high voltage applications? (May-2005)

The gases used in wide application of power system to provide insulation to various equipments and substations. The gases are also used in circuit breakers for arc interruption besides providing insulation between breaker contacts.

The various gases used are (i) air (ii) oxygen (iii) hydrogen (iv) nitrogen (v) CO_2 and (vi) electronegative gases like sulphur hexafluoride, arcton etc.

The various properties of gases are:

(i) High dielectric strength.

(ii) Thermal and chemical stability.

(iii) Non-inflammability.

(iv) High thermal conductivity. This assists cooling of current carrying conductors immersed in the gas and also assists the arc-extinction process.

(v) It should have a low dissociation temperature, a short thermal time constant (ratio of energy contained in an arc column at any instant to the rate of energy dissipation at the same instant) and should not produce conducting products such as carbon during arcing.

(vi) Commercial availability at moderate cost. Of the simple gases air is the cheapest and most widely used for circuit breaking.

Hydrogen has better arc extinguishing property but it has lower dielectric strength as compared with air. Also if hydrogen is contaminated with air, it forms an explosive mixture.

Nitrogen has similar properties as air, CO_2 has almost the same dielectric strength as air but is a better arc extinguishing medium at moderate currents. Oxygen is a good extinguishing medium but is chemically active.

SF_6 has outstanding arc-quenching properties and good dielectric strength. Of all these gases, SF_6 and air are used in commercial gas blast circuit breakers.

The suitable mixture of SF_6 with N_2 is a good replacement for SF_6. Mixture is not only cost effective, it is less sensitive to find non-uniformities present within the equipment.

GIS, C.B., capacitors, CT, PT and cables. A ratio 70% of SF6 and 30% of N_2 is found to be optimum for circuit breaking.

With this ratio, the C.B. has higher recovery rate than pure SF_6 at the same partial pressure. The future of using SF_6 with N_2 or He for providing insulation and arc interruption is quite bright.

5. Discuss the current growth in a gas subjected to uniform and non-uniform electric field and corona discharge. (Dec-2008) (or)

Explain clearly breakdown in non-uniform fields and corona discharge. (Dec-2004, June-2012, Dec-2013)

If the electric field is uniform and if the field is increased gradually, just when measurable ionization begins, the ionization leads to complete breakdown of the gap.

In non-uniform fields, before the spark or breakdown of the medium takes place, there are many manifestations in the form of visual and audible discharges. These discharges are known as *Corona discharges*.

The Corona is defined as a self-sustained electric discharge in which the field intensified ionization is localised only over a portion of the distance (non-uniform fields) between the electrodes.

The phenomenon is of particular importance in high voltage engineering where most of the fields encountered are non-uniform fields unless of course some design features are involved to make the filed almost uniform.

Corona is responsible for power loss and interference of power lines with

The communication lines as corona frequency lies between 20 Hz and 20 kHz.

This also leads to deterioration of insulation by the combined action of the discharge ion bombarding the surface and the action of chemical compounds that are formed by the corona discharge.

When a voltage higher than the critical voltage is applied between two parallel polished wires, the glow is quite even.

After operation for a short time, reddish beads or tufts form along the wire, while around the surface of the wire there is a bluish white glow. If the conductors are examined through a stroboscope.

i) The reddish tufts or beads are formed when the conductor is negative.

ii) Smoother bluish white glow when the conductor is positive.

The a.c. corona viewed through a stroboscope has the same appearance as direct current corona.

As corona phenomenon is initiated a hissing noise is heard and ozone gas is formed which can be detected by its characteristic colour.

When the voltage applied corresponds to the critical disruptive voltage, corona phenomenon starts but it is not visible because the charged ions in the air must receive some finite energy to cause further ionization by collisions.

For a radial field, it must reach a gradient (visual corona gradient) g_ua the surface of the conductor to cause a gradient g_0, finite distance away from the surface of the conductor.

The distance between g_0 and $g_v$is called the energy distance. According to Peek, this distance is equal to (r + 0.301 r) for two parallel conductors and (r + 0.308 r) for coaxial conductors.

this it is clear that $g_v$is not constant as g_0 is, and is a function of the size of the conductor. The electric field intensity for two parallel wires is given as

$$E = 30\left(1 + \frac{0.301}{\sqrt{r\delta}}\right)\delta \text{ kv/cm}$$

Investigation with point-plane gaps in air have shown that when point is positive, the corona current increases steadily with voltage.

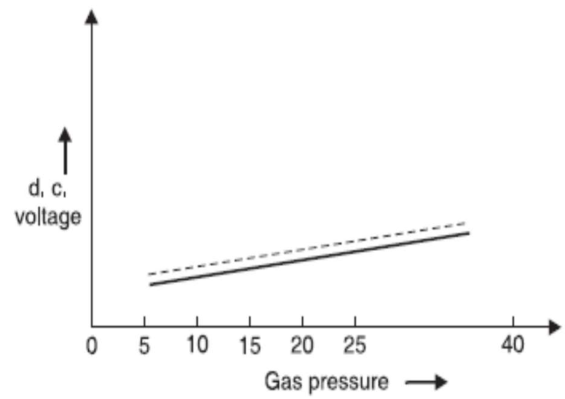
At sufficiently high voltage, current amplification increases rapidly with voltage up to a current of about 10^{-7}A, after which the current becomes pulsed with repetition frequency of about 1 kHz composed of small bursts. This form of corona is known as *burst corona*.

The average current then increases steadily with applied voltage, leading to breakdown. With point-plane gap in air when negative polarity voltage is applied to the point and the voltage exceeds the onset value, the current flows in vary regular pulses known as Trichel pulses.

The onsetvoltage is independent of the gap length and is numerically equal to the onset of streamers under positive voltage for the same arrangement. The pulse frequency increases with voltage and is a function of the radius of the cathode, the gap length and the pressure.

A decrease in pressure decreases the frequency of the pulses. It should be noted that the breakdown voltage with negative polarity is higher than with positive polarity except at low pressure.

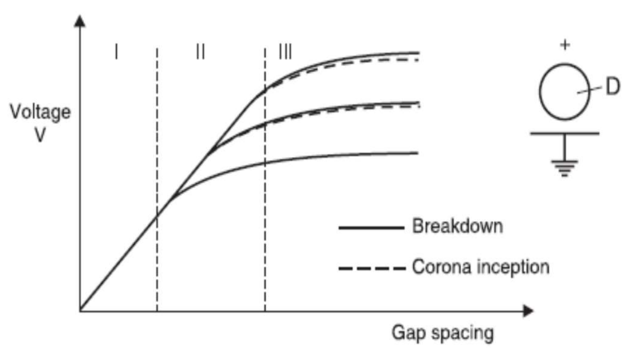
Therefore, under alternating power frequency voltage the breakdown of non-uniform field gap invariably takes place during the positive half cycle of the voltage wave.



When the spacing is small the breakdown characteristics for the two polarities nearly coincide and no corona stabilized region is observed.

As the spacing is increased, the positive characteristics display the distinct high corona breakdown up to a pressure of about 7 bars, followed by a sudden drop in breakdown strengths.

Under the negative polarity, the corona stabilized region extends to much higher pressures.



The above graph shows the corona inception and breakdown voltages of the sphere-plane arrangement.

(i) For small spacing's (Zone–I), the field is uniform and the breakdown voltage depends mainly on the gap spacing.

(ii) In zone–II, where the spacing is relatively larger, the electric field is non-uniform and the breakdown voltage depends on both the sphere diameter and the spacing.

(iii) For still larger spacings (Zone-III) the field is non-uniform and the breakdown is preceded by corona and is controlled only by the spacing. The corona inception voltage mainly depends on the sphere diameter.

6. Explain the properties and characteristics of liquid dielectrics. (May-2005)

The liquid dielectrics are:

The liquid dielectrics mostly used are petroleum oils. Other oils used are synthetic hydrocarbons and halogenated hydrocarbons and for very high temperature applications silicone oils and fluorinated hydrocarbons are also used.

Properties of liquid dielectric are:

i)The dielectric strength
(ii)The dielectric constant
(iii)The electrical conductivity. Other important properties are viscosity, thermal stability, specific gravity, flash point etc.

The factors which affect the dielectric strength of oil are:

- Presence of fine water droplets and the fibrous impurities. The presence of even 0.01% water in oil brings down the dielectric strength to 20% of the dry oil value.
- The presence of fibrous impurities brings down the dielectric strength much sharply. Therefore, whenever these oils are used for providing electrical insulation, these should be free from moisture, products of oxidation
- The main consideration in the selection of a liquid dielectric is its chemical stability.
- The other considerations are the cost, the saving in space, susceptibility to environmental influences etc.

7. Explain briefly various theories of breakdown in liquid dielectrics. (Dec-2008, May-2011,MAY-2013,Dec-2013,Dec-14)

The four theories of breakdown in liquid dielectrics are:

- ✓ Electronic Breakdown
- ✓ Electro convection Breakdown
- ✓ Cavity Breakdown
- ✓ Suspended Solid Particle Mechanism

Electronic Breakdown

Once an electron is injected into the liquid, it gains energy from the electric field applied between the electrodes.

It is presumed that some electrons will gain more energy due to field than they would lose during collision.

These electrons are accelerated under the electric field and would gain sufficient energy to knock out an electron and thus initiate the process of avalanche.

The threshold condition for the beginning of avalanche is achieved when the energy gained by the electron equals the energy lost during ionization (electron emission) and is given by

$e \lambda E = Chv$

where λ is the mean free path, hv is the energy of ionization and C is a constant.

Dielectric strengths of pure liquids:

Liquid Strength (MV/cm)
Benzene 1.1
Goodoil 1.0–4.0
Hexane 1.1–1.3
Nitrogen 1.6–1.88
Oxygen 2.4

Silicon 1.0–1.2
The electronic theory whereas predicts the relative values of dielectric strength satisfactorily, the formative time lags observed are much longer as compared to the ones predicted by the electronic theory.

Suspended Solid Particle Mechanism:

Commercial liquids will always contain solid impurities either as fibers or as dispersed solid particles. The permittivity of these solids (E_1) will always be different from that of the liquid (E_2). Let us assume these particles to be sphere of radius *r*. These particles get polarized in an electric field *E* and experience a force which is given as

$$F = r^3 \frac{\epsilon_1 - \epsilon_2}{\epsilon_1 + 2\epsilon_2} E \frac{dE}{dx}$$

and this force is directed towards a place of higher stress if $\varepsilon 1 > \varepsilon 2$ and towards a place of lower stress if $\varepsilon 1 < \varepsilon 2$ when$\varepsilon 1$ is the permittivity of gas bubbles. The force given above increases as the permittivity of the suspended particles ($\varepsilon 1$) increases. If $\varepsilon 1 \to \infty$

$$F = r^3 E \frac{dE}{dx}$$

Thus, the force will tend the particle to move towards the strongest region of the field. In a uniform electric field which usually can be developed by a small sphere gap, the field is the strongest in the uniform field region.

Here $\frac{dE}{dx} \to 0$ so that the force on the particle is zero and the particleremains in equilibrium. Therefore, the particles will be dragged into the uniform field region. Since the permittivity of the particles is higher than that of the liquid, the presence of particle in the uniform field region will cause flux concentration at its surface.

Other particles if present will be attracted towards the higher flux concentration.

If the particles present are large, they become aligned due to these forces and form a bridge across the gap.

The field in the liquid between the gap will increase and if it reaches critical value, breakdown will take place.

If the number of particles is not sufficient to bridge the gap, the particles will give rise to local field enhancement and if the field exceeds the dielectric strength of liquid, local breakdown will occur near the particles and thus will result in the formation of gas bubbles which have much less dielectric strength and hence finally lead to the breakdown of the liquid.

stressed oil volume mechanism

The movement of the particle under the influence of electric field is opposed by the viscous force posed by the liquid and since the particles are moving into the region of high stress, diffusion must also be taken into account.

We know that the viscous force is given by (Stoke's relation) $F_V = 6 \pi \eta r v$ where η is the viscosity of liquid, rthe radius of the particle and vthe velocity of the particle.
Equating the electrical force with the viscous force we have

$$6\pi \eta r v = r^3 E \frac{dE}{dx}$$

$$\nu = \frac{r^2}{6\pi\,\eta} E \frac{dE}{dx}$$

However, if the diffusion process is included, the drift velocity due to diffusion will be given by

$$v_d = -\frac{D}{N}\frac{dN}{dx} = -\frac{KT}{6\pi\,\eta r}\frac{dN}{Ndx}$$

where D = KT/6πηra relation known as Stokes-Einstein relation. Here K is Boltzmann's constant and Tthe absolute temperature. At any instant of time, the particle should have one velocity and, therefore,equation $v = v_d$

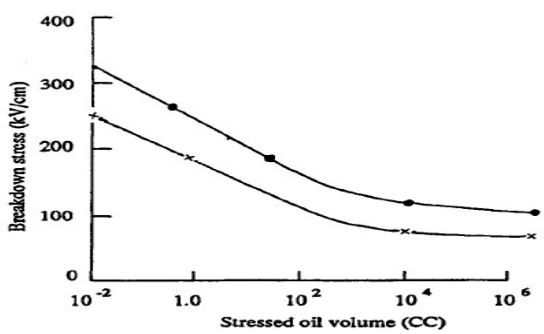
$$-\frac{KT}{6\pi\,\eta r}\frac{dN}{Ndx} = \frac{r^2}{6\pi\,\eta} E \frac{dE}{dx}$$

cancel dx both sides

$$\frac{KT}{r}\frac{dN}{N} = r^2\, E\, dE$$

$$\frac{KT}{r}\ln N = r^2 \frac{E^2}{2}$$

It is clear that the breakdown strength *E* depends upon the concentration of particles *N*, radius *r* of particle, viscosity η of liquid and temperature *T* of the liquid. The below fig shows variation of breakdown voltage stress with the stressed oil volume



It has been found that liquid with solid impurities has lower dielectric strength as compared toits pure form. Also, it has been observed that larger the size of the particles impurity the lower theoverall dielectric strength of the liquid containing the impurity.

Cavity Breakdown

It has been observed experimentally that the dielectric strength of liquid depends upon the hydrostatic pressure above the gap length.
The higher the hydrostatic pressure, the higher the electric strength, which suggests that a change in phase of the liquid is involved in the breakdown process.

In fact, smaller the head of liquid, the more are the chances of partially ionized gases coming out of the gap and higher the chances of breakdown.

This means a kind of vapour bubble formed is responsible for the breakdown. The following processes might lead to formation of bubbles in the liquids:
(*i*) Gas pockets on the surface of electrodes.
(*ii*) Due to irregular surface of electrodes, point charge concentration may lead to corona discharge, thus vapourizing the liquid.
(*iii*) Changes in temperature and pressure.
(*iv*) Dissociation of products by electron collisions giving rise to gaseous products.

It has been suggested that the electric field in a gas bubble which is immersed in a liquid of permittivity ε_2 is given by

$$E_b = \frac{3E_0}{\epsilon_2 + 2}$$

Where E_0 is the field in the liquid in absence of the bubble.
The bubble under the influence of the electric field E_0 elongates keeping its volume constant.

When the field $E_b$equals the gaseous ionization field, discharge takes place which will lead to decomposition of liquid and breakdown may follow.
A more accurate expression for the bubble breakdown strength is given as

$$E_b = \frac{1}{\varepsilon_2 - \varepsilon_1}\left\{\frac{2\pi\sigma(2\varepsilon_2+\varepsilon_1)}{r}\left[\frac{\pi}{4}\sqrt{\frac{V_b}{2rE_0}} - 1\right]\right\}^{\frac{1}{2}}$$

where σ is the surface tension of the liquid, ε_2 and ε_1 are the permittivities of the liquid and bubble, respectively, r the initial radius of the bubble and $V_b$the voltage drop in the bubble.

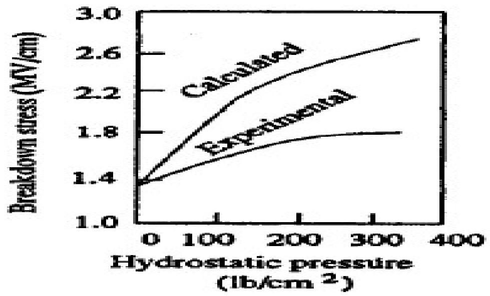
From the expressionit can be seen that the breakdown strength depends on the initial size of the bubble which of course depends upon the hydrostatic pressure above the bubble and temperature of the liquid.
Since the above formation does not take into account the production of the initial bubble, the experimental values of breakdown were found to be much less than the calculated values.

Later on it was suggested that only incompressible bubbles like water bubbles can elongate at constant volume according to the simple gas law $pV = RT$.

Such a bubble under the influence of electric field changes its shape to that of a prolate spheroid and reaches a condition of instability when β, the ratio of the longer to the shorter diameter of the spheroid is about 1.85 and the critical field producing the instability will be given by

$$E_c = 600\frac{\sqrt{\pi\sigma}}{\varepsilon_2 r}\left[\frac{\varepsilon_2}{\varepsilon_2-\varepsilon_1} - G\right]\mathrm{H}$$

For transformer oil ε_2 = 2.0 and water globule with r = 1 μm, σ= 43 dynes/cm, the above equation gives E_c= 226 KV/cm.



Theoretical and experimental breakdown stresses in *n*-hexane

Electro convection Breakdown

It has been recognized that the electro convection plays an important role in breakdown of insulating fluids subjected to high voltages.

When a highly pure insulating liquid is subjected to high voltage, electrical conduction results from charge carriers injected into the liquid from the electrode surface.

The resulting space charge gives rise to columbic forces which under certain conditions causes hydrodynamic instability, yielding convecting current. It has been shown that the onset of instability is associated with a critical voltage.

As the applied voltage approaches the critical voltage, the motion at first exhibits a structure of hexagonal cells and as the voltage is increased further the motion becomes turbulent.

Thus, interaction between the space charge and the electric field gives rise to forces creating an eddy motion of liquid.

It has been shown that when the voltage applied is near to breakdown value, the speed of the eddy motion is given by v*e* = ε ρ 2 / where ρ is the density of liquid. In liquids, the ionic drift velocity is given by

V_d=KV

where *K* is the mobility of ions.

Let

$$M\,\frac{V_e}{V_d} = \sqrt{\frac{\varepsilon_2}{\rho}}/\mathrm{KE}$$

The ratio Mis usually greater than unity and sometimes much greater than unity Thus in the theory of electro convection, Mplays a dominant role.

The charge transport will be largely by liquid motion rather than by ionic drift. The criterion for instability is that the local flow velocity should be greater than drift velocity.

8. Discusses in details any one mechanism of break down in solid dielectric, mention their dielectric properties. (Dec-2007, June-2009).

(Or)

Classify the various mechanisms occurring on solid dielectrics explain them briefly. (Dec-2004, June-2012 Dec-2013)

(Or)

State why the very high intrinsic strength of a solid dielectrics is not fully realized in practice? Explain the different mechanisms by which breakdown occurs in solid dielectrics in practice?(Nov 2015)

The various mechanisms are:
(i) Intrinsic Breakdown,
(ii) Electromechanical Breakdown,
(iii) Breakdown Due to Treeing and Tracking,
(iv) Thermal Breakdown,
(v) Electrochemical Breakdown.

<u>Intrinsic Breakdown</u>

1.Electronic breakdown

If the dielectric material is pure and homogeneous, the temperature and environmental conditions suitably controlled and if the voltage is applied for a very short time of the order of 10^{-8} second, the dielectric strength of the specimen increases rapidly to an upper limit known as intrinsic dielectric strength.

The intrinsic strength, therefore, depends mainly upon the structural design of the material i.e.,the material itself and is affected by the ambient temperature as the structure itself might change slightly by temperature condition.

In order to obtain the intrinsic dielectric strength of a material, the samples are so prepared that there is high stress in the centre of the specimen and much low stress at the corners as shown in Fig

Specimen designed for intrinsic breakdown

The intrinsic breakdown is obtained in times of the order of 10^{-8} sec. and, therefore, has been considered to be electronic in nature.

The stresses required are of the order of one million volt/cm.

The intrinsic strength is generally assumed to have been reached when electrons in the valance band gain sufficient energy from the electric field to cross the forbidden energy band to the conduction band.

In pure and homogenous materials, the valence and the conduction bands are separated by a large energy gap at room temperature, no electron can jump from valance band to the conduction band.

2.Avalanche or streamer breakdown

The conductivity of pure dielectrics at room temperature is, therefore, zero. However, in practice, no insulating material is pure and, therefore, has some impurities and/or imperfections in their structural designs.

The impurity atoms may act as traps for free electrons in energy levels that lie just below the conduction band is small.

An amorphous crystal will, therefore, always have some free electrons in the conduction band.

At room temperature some of the trapped electrons will be excited thermally into the conduction band as the energy gap between the trapping band and the conduction band is small.

As an electric field is applied, the electrons gain energy and due to collisions between them the energy is shared by all electrons.

In an amorphous dielectric the energy gained by electrons from the electric field is much more than they can transfer it to the lattice.

Therefore, the temperature of electrons will exceed the lattice temperature and this will result into increase in the number of trapped electrons reaching the conduction band and finally leading to complete breakdown.

When an electrode embedded in a solid specimen is subjected to a uniform electric field, breakdown may occur.

An electron entering the conduction band of the dielectric at the cathode will move towards the anode under the effect of the electric field.

During its movement, it gains energy and on collision it loses a part of the energy. If the mean free path is long, the energy gained due to motion is more than lost during collision.

The process continues and finally may lead to formation of an electron avalanche similar to gases and will lead finally to breakdown if the avalanche exceeds a certain critical size.

Electromechanical Breakdown

When a dielectric material is subjected to an electric field,charges of opposite nature are induced on the two opposite surfaces of the material and hence a force of attraction is developed and the specimen is subjected to electrostatic compressive forces and when these forces exceed the mechanical withstands strength of the material, the material collapses.

If the initial thickness of the material is d_0 and is compressed to a thickness dunder the applied voltage V then the compressive stress developed due to electric field is

$$F = \frac{1}{2}\varepsilon_0\varepsilon_r\frac{v^2}{d^2}$$

where $\varepsilon_r$is relative permittivity of the specimen.If is the young modulus,the mechanical compressive strength is

$$\gamma \ln\frac{d_0}{d}$$

equating the two under equilibrium condition ,we have

$$\frac{1}{2}\varepsilon_0\varepsilon_r\frac{v^2}{d^2} = \gamma \ln\frac{d_0}{d}$$

$$v^2 = d^2\frac{2\gamma}{\varepsilon_0\varepsilon_r}\ln\frac{d_0}{d}$$

$$v^2 = d^2\, k \ln\frac{d_0}{d}$$

Differentiating with respect to d,we have

$$2v\frac{dv^2}{dd} = k\left[2d\ln\frac{d_0}{d} - d^2\frac{d}{d_0}.\frac{d_0}{d^2}\right] = 0$$

$$2d\ln\frac{d_0}{d} = d$$

$$\ln\frac{d_0}{d} = \frac{1}{2}$$

$$\frac{d_0}{d} = 0.6$$

For any real value of voltage V,the reduction in thickness of the specimen cannot be more than 40%.

If the ratio V/d at this value of V is less than the intrinsic strength of the specimen, a further increase in Vshall make the thickness unstable and the specimen collapses.
The highest apparent strength is then obtained by substituting d = 0.6 $d_0$in the above expressions.

$$\frac{v}{d} = \sqrt{\frac{2\gamma}{\varepsilon_0\varepsilon_r}\ln 1.67}$$

$$\frac{v}{d_0} = E_0 = 0.6\sqrt{\frac{\gamma}{\varepsilon_0\varepsilon_r}}$$

The above equation is approximate only as γ depends upon the mechanical stress. The possibility of instability occuring for lower, average field is ignored.

<u>Breakdown due to Treeing and Tracking</u>

- We know that the strength of a chain is given by the strength of the weakest link in the chain. Similarly whenever a solid material has some impurities in terms of some gas pockets or liquid pockets in it the dielectric strength of the solid will be more or less equal to the strength of the weakest impurities.
- Suppose some gas pockets are trapped in a solid material during manufacture, the gas has a relative permittivity of unity and the solid material ε_r,the electric field in the gas will be $\varepsilon_r$times the field in the solid material. As a result,the gas breaks down at a relatively lower voltage.
- The charge concentration here in the void will make the field more non-uniform. The charge concentration in such voids is found to be quite large to give fields of the order of 10 MV/cm which is higher than even the intrinsic breakdown.
- These charge concentrations at the voids within the dielectric lead to breakdown step by step and finally lead to complete rupture of the dielectric.
- Since the breakdown is not caused by a single discharge channel and assumes a tree like structure as shown in Fig,below it is known as breakdown due to treeing.
- The treeing phenomenon can be readily demonstrated in a laboratory by applying an impulse voltage between point plane electrodes with the point embedded in a transparent solid dielectric such as Perspex.

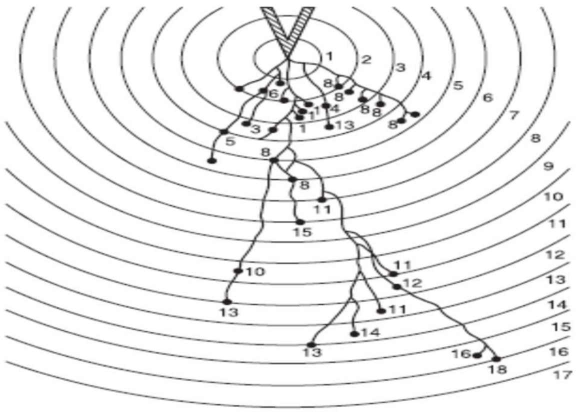
- The treeing phenomenon can be observed in all dielectric wherever non-uniform fields prevail.
- prevention

  using clean, dry, undamaged surface. It is mostly observed in capacitors and cables

<u>Tracking</u>

- Suppose we have two electrodes separated by an insulating material and the assembly is placed in an outdoor environment.
- Some contaminants in the form of moisture or dust particles will get deposited on the surface of the insulation and leakage current starts between the electrodes through the contaminants say moisture.
- The current heats the moisture and causes breaks in the moisture films. These small films then act as electrodes and sparks are drawn between the films.
- The sparks cause carbonization and volatilization of the insulation and lead to formation of permanent carbon tracks on the surface of insulations.
- Therefore, tracking is the formation of a permanent conducting path usually carbon across the surface of insulation.

- For tracking to occur, the insulating material must contain organic substances. For this reason, for outdoor equipment, tracking severely limits the use of insulation having organic substances.
- The rate of tracking can be slowed down by adding filters to the polymers which inhibit carbonization.



- Prevention

  material chosen should be resistant to tracking, moisture repellent greases are used, adding filters to the polymers

Electrochemical Breakdown

Whenever cavities are formed in solid dielectrics, the dielectric strength in these solid specimen decreases. When the gas in the cavity breaks down, the surfaces of the specimen provide instantaneous anode and cathode.

Some of the electrons dashing against the anode with sufficient energy shall break the chemical bonds of the insulation surface.

Similarly, positive ions bombarding against the cathode may increase the surface temperature and produce local thermal instability.

Similarly, chemical degradation may also occur from the active discharge products e.g.,O_3, NO_2 etc. formed in air.

The net effect of all these processes is a slow erosion of the material and a consequent reduction in the thickness of the specimen.

Normally, it is desired that with ageing, the dielectric strength of the specimen should not decrease.

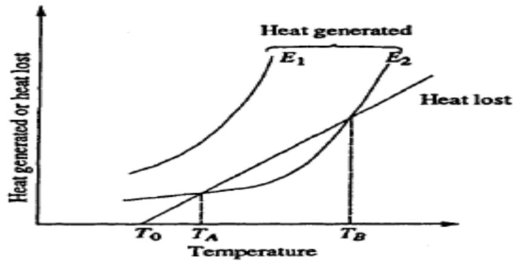
However, because of defects in manufacturing processes and/or design, the dielectric strength decreases with time of voltage application or even without voltage application and in many cases, the decrease in dielectric strength (E_b) with time follows the following empirical relation.

$$t\, E_b^n = \text{constant}$$

where the exponent ndepends upon the dielectric material.

Thermal Breakdown

The breakdown voltage of solid dielectric increase with its thickness.Heat is generated due to flow of current,this current heats up material and further temp rises.The heat generated is transferred to the surrounding medium by conduction through the solid dielectric and by radiation from its outer surfaces. Equilibrium is reached when the heat used to raise the temperature of the dielectric, plus the heat radiated out, equals the heat generated.Breakdown occurs when heat generated exceeds heat dissipated. The thermal instability condition is shown in below Fig.



Breakdown Due to Internal Discharges

Solid insulating materials contain voids orcavities within the medium or at the boundaries between the dielectric and theelectrodes. These voids are generally filled with a medium of lower dielectricstrength, and the dielectric constant of the medium in the voids is lower than that ofthe insulation. Hence, the electric field strength in the voids is higher than that acrossthe dielectric. Therefore, even under normal working voltages the field in the voidsmay exceed their breakdown value, and breakdown may occur.

Let us consider a dielectric between two conductors as shown in Fig.If we divide the insulation into three parts, an electrical network of C_1, C_2,C_3formed as shown in Fig. In this C1 represents the capacitance of the void or cavity, $C_2$is the capacitance of the dielectric which is in series with the void, and C_3 is the capacitance of the rest of the dielectric. When the applied voltage is *V,* the voltage across the void, v_1 is given by the same equation.

$$V_1 = \frac{Vd_1}{d_1 + d_2 \frac{\varepsilon_0}{\varepsilon_1}}$$

where $d_1$and d_2 are the thickness of the void and the dielectric, respectively, having permittivities $\varepsilon_0, \varepsilon_1$.

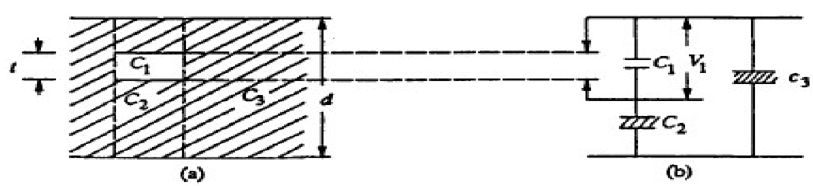
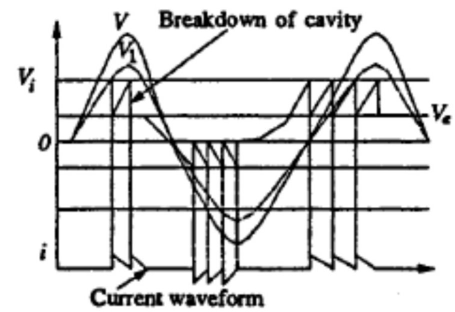


Fig. Electrical discharge in a cavity and its equivalent circuit

When a voltage *V*is applied, V_1reaches the breakdown strength of the medium in the cavity (V_i) and breakdown occurs. *Vi*is called the' 'discharge inception voltage". When the applied voltage is a.c., breakdown occurs on both the half cycles and the number of discharges will depend on the applied voltage.



Sequence of cavity breakdown under alternating voltages

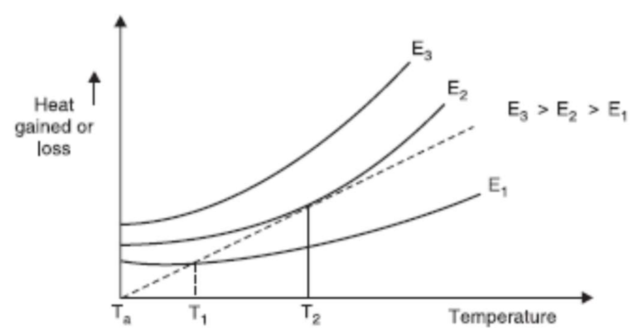
9. Explain the phenomenon of thermal breakdown in solid dielectrics. Derive an expression for critical thermal breakdown voltage (V_C) and critical electrical field (E_C) for the same. State clearly assumption made. (May-2008,May-2014)

The insulating material is subjected to an electric field, the material gets heated up due to conduction current and dielectric losses due to polarization.

The conductivity of the material increases with increase in temperature and a condition of instability is reached when the heat generated exceeds the heat dissipated by the material and the material breaks down.

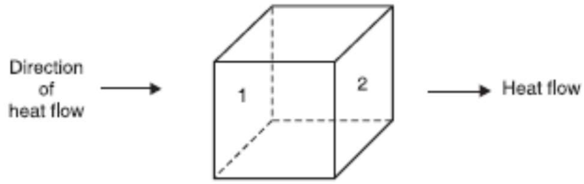
Fig below. Shows various heating curves corresponding to different electric stresses as a function of specimen temperature.

Assuming that the temperature difference between the ambient and the specimen temperature is small, Newton's law of cooling is represented by a straight line.



Thermal stability or instability of different fields

The test specimen is at thermal equilibrium corresponding to field E_1 at temperature T_1 as beyond that heat generated is less than heat lost. Unstable equilibrium exists for field E_2 at T_2, and for field E_3 the state of equilibrium is never reached and hence the specimen breaks down thermally.



In order to obtain basic equation for studying thermal breakdown, let us consider a small cube within the dielectric specimen with side Δx and temperature difference across its faces in the direction of heat flow (assume here flow is along x-direction) is ΔT. Therefore, the temperature gradient is

$$\frac{\Delta T}{\Delta x} = \frac{dT}{dx}$$

Let $\Delta x^2 = A$. The heat flow across face 1

$KA\,\frac{dT}{dx}$ joules

Heat flow across face 2

$$KA\,\frac{dT}{dx} = KA\,\frac{d}{dx}(\frac{dT}{dx})\Delta x$$

Here the second term indicates the heat input to the differential specimen. Therefore the heat adsorbed by the differential cube volume

$$\frac{KA\,\frac{d}{dx}\left(\frac{dT}{dx}\right)\Delta x}{\Delta V} = K\,\frac{d}{dx}\left(\frac{dT}{dx}\right)$$

The heat input to the block will be partly dissipated into the surrounding and partly it will raise the temperature of the block. Let CV be the thermal capacity of the dielectric, σ the electrical conductivity, E the electric field intensity.

The heat generated by the electric field = σE_2 watts, and suppose the rise in temperature of the block is ΔT, in time dt, the power required to raise the temperature of the block by ΔT is

$C_v\frac{dT}{dx}$ watts

Therefore $C_v\frac{dT}{dx} + K\,\frac{d}{dx}\left(\frac{dT}{dx}\right) = \sigma E^2$

Which thermal instability will reach and the dielectric will lose its insulating properties. However, unfortunately the equation can be solved in its present from CV, K and σ is all functions of temperature and in fact σ may also depend on the intensity of electrical field.

Therefore, to obtain solution of the equation, we make certain practical assumptions and we consider two extreme situations for its solution.

Case 1: Assume that the heat adsorbed by the block is very fast and heat generated due to the electric field is utilized in raising the temperature of the block and no heat is dissipated at is known as impulse thermal breakdown. The main equation reduces to

$$C_v \frac{dT}{dx} = \sigma E^2$$

The objective now is to obtain critical field strength E_c which will generate sufficient heat very fast so that above requirement is met, Let

$$E = \left(\frac{E_c}{t_c}\right) t$$

i.e the field is a ramp function

$$\sigma E^2 = C_v \frac{dT}{dt} = C_v \frac{dT}{dE} . \frac{dE}{dt}$$

$$\sigma = \sigma_0 e^{-\frac{u}{KT}}$$

Where K is the Boltzmann's constant and $\sigma_0$is the conductivity at ambient temperatureT_0

Substituting these values in the simplified equation, we have

$$\sigma_0 e^{-\frac{u}{KT}} E^2 = C_v \frac{dT}{dE} . \frac{dE}{dt}$$

$$\frac{dE}{dt} = \left(\frac{E_c}{t_c}\right)$$

therefore

$$\sigma_0 e^{-\frac{u}{KT}} E^2 = C_v \frac{dT}{dE} . \frac{E_c}{t_c}$$

$$\sigma_0 E^2 \frac{t_c}{E_c} dE = C_v \frac{dT}{e^{-\frac{u}{KT}}}$$

$$\frac{\sigma_0}{C_v} E^2 \frac{t_c}{E_c} dE = \frac{dT}{e^{-\frac{u}{KT}}}$$

$$\frac{\sigma_0}{C_v} \frac{t_c}{E_c} E^2 dE = dT\, e^{+\frac{u}{KT}}$$

integrate on both sides

$\frac{\sigma_0}{C_v}\frac{t_c}{E_c}\int_0^{E_c} E^2 dE = \int_{T_0}^{T_c} e^{+\frac{u}{KT}}\ dT$The integral on left hand side

$$\frac{\sigma_0}{C_v}\frac{t_c}{E_c}\int_0^{E_c} E^2 dE = \frac{\sigma_0}{C_v}\frac{t_c}{3E_c}{E_c}^3$$

The integral on Right hand side

$$\int_{T_0}^{T_c} e^{+\frac{u}{KT}}\ dT = \frac{k}{u}e^{+\frac{u}{KT}}{T_0}^2$$

Where $T_c \ggg> T_0$

Therefore

$$E_c = \frac{3C_v}{\sigma_0 t_c}\frac{k{T_0}^2}{u}e^{+\frac{u}{KT}}$$

10. Explain the various mechanisms (processes) of electric breakdown in vacuum. (Dec-2008,May-2011, Dec-2013,May-2014)

The following mechanisms are:
(i) Field emission; (ii) Thermionic emission; (iii) Field and Thermionic emission; (iv) Secondary emission by positive ion bombardment; (v) Secondary emission by photons; and (vi) Pinch effect.

<u>Non-metallic Electron Emission Mechanism</u>

The pre-breakdown conduction current in vacuum normally originates from a nonmetallic electrode surface.

These are present in the form of insulating/semiconducting oxide layer on the surfaces or as impurities in the electrode material.

These micro inclusions present in the electrode surface can produce strong electron emission and significantly reduce the break down strength of the gap.

Even when a vacuum system is completely sealed off, the electrode surfaces may still get contaminated.

It has been observed that when glass is heated to 'its' working temperature for sealing the electrodes into a closed container, fluxes are vaporized from the glass which get deposited in the cool inner surfaces in the form of spherical particles up to a µm diameter .

Therefore, the surface of a sealed electrode may have on its surface contaminates e.g., sodium, potassium, boron aluminium and silicon.

When an electric field is applied across such electrodes the oxides adsorbates and dust particles, then undergo chemical changes e.g., oxides and adsorbates undergo chemical reactions which are initiated by photons, electrons and ions and thus these contaminants limit the maximum field intensity for the following reasons:

(i) The adsorbates and dust enhance the field emission of electrons.

(ii) The oxides adsorbates and dust particles enhance the secondary electron emission.

(iii) The oxides adsorbates and dust particles exhibit stimulated desorption of molecules and ions under the impact of electrons, protons or ions.

Due to these mechanism, there is increase in electron emission process and therefore, more electric field energy is converted into kinetic energy of electron and ions which leads to an increase in surface energy of the metal.

Thus, the electric strength of the gap may reduce to a level as low as 10 kV/ cm as compared to 104 kV/cm which is required for the field emission process.

Clump Mechanism

The vacuum breakdown mechanism based on this theory makes following assumption:

(i) A loosely bound particle known as clump exists on one of the electrode surfaces.

(ii) When a high voltage is applied between the two electrodes, this clump gets charged and subsequently gets detached from the mother electrode and is attracted by the other electrode.

(iii) The breakdown occurs due to a discharge in the vapour or gas released by the impact to the particle at the opposite electrode.

It has been observed that for a certain vacuum gap if frequent recurrent electric breakdowns are carried out, the withstand voltage of the gap increases and after certain number of breakdown, it reaches an optimum maximum value.

This is known as conditioning of electrodes and is of paramount importance from practical reasons. In this electrode conditioning, the micro-emission sites are supposed to have been destroyed.

Various methods for conditioning the electrodes have been suggested. Some of these are

(i) To treat the electrodes by means of hydrogen glow discharge. This method gives more consistent results.

(ii) Allowing the pre-breakdown currents in the gap to flow for some time or to heat the electrodes in vacuum to high temperature.

(iii) Treating the electrodes with repeated spark breakdown. This method is however quite time consuming.

The area of electrodes for breakdown of gases, liquids, solids or vacuum plays an important role. It has been observed that if the area of electrodes is increased for the same gap distance in uniform field, the breakdown voltages are reduced.

11. List the properties of composite dielectric and short term breakdown. (Dec-2008, May-2011)

(OR)

i)Discuss the important properties of composite dielectrics

ii)Discuss the various mechanisms of breakdown in composite dielectrics(Dec 2015)

Different dielectric materials can be in parallel with each other (air or SF_6 gas in parallel with solid insulation) or in series with one another.Such insulating systems are called as composite dielectrics.

Properties of composite Dielectric:(Dec 2015)

<u>Effect of multiple layer:</u>

- Different layers of dielectric have a higher dielectric strength than a single dielectric.
- Significant in having a wide variations of dielectric strength measured at different points on its surface.

<u>Effect of Layer Thickness:</u>

- Breakdown voltage increases with increase in layer thickness. Breakdown occurs at the interfaces and note at other layer in case of layered constructions.
- In case of insulating paper with layered construction, the thickness varies from point to point and the dielectric strength varies. Variation of thickness gives a rough surface which helps for better impregnation. Low thickness of paper causes breakdown.

<u>Investigations on composite Dielectrics:</u>

- Thickness of the solid dielectric.
- Dielectric constant of liquid and solid dielectric

<u>Effect of interfaces:</u>

- Pre-breakdown

- Breakdown strength.

<u>Breakdown mechanism in composite Dielectrics(Dec-14)(Dec 2015)</u>

They are two types of breakdown mechanism in composite dielectric they are.

- Short-term Breakdown.
- Long-term Breakdown.

<u>Short-Term Breakdown:</u>

When the applied electric field is high, failure may occur in seconds or even faster without damaging the insulating surface prior to breakdown is called as short-term breakdown.

When the applied voltage is very close to the breakdown voltage, breakdown of composite dielectric occurs due to discharges.

The discharges of given magnitude can enter the insulation from the surface and propagate rapidly into its volume under critical stress to cause breakdown.

Breakdown strength increases due to

- The presence of more electrons (bombarding particles) than positive ions.
- Local field intensifications due to
  - The presence of impurities.
  - Variations in the thickness of solid insulations.

<u>Long-Term Breakdown:</u>

Long term breakdown occurs due to aging of insulations from thermal process and partial discharges. Long term breakdown arise due to the following.

- Ageing and breakdown due to partial discharges.
- Ageing and breakdown due to accumulation of charges on insulator surfaces.

Ageing and break down due to partial Discharges:

In composite dielectric, gas filled cavities will be present within the dielectric or adjacent to the interface between the conductor and the dielectrics.

When voltage is applied to the dielectric, discharges takes place within gas filled cavities. These discharges are called as partial discharges.

Failure of composite dielectric occurs depends on:

- Geometry of the cavity.
- Nature of the dielectric.

The degree of ageing depends on discharge inception voltage. The discharge inception voltage depends on:

Permittivity of the dielectrics ε_r

Thickness of the cavity,g.

$$\therefore V_i = \left(\frac{E_g}{\varepsilon_r}\right)(t + \epsilon_r g) ----------------------\to (1)$$

Where E_g=breakdown strength of the cavity.

t=Thickness of dielectric.

Assume(g+t) is a constant, say C

Adding and subtracting g in equation (1),We get

$$V_i = \frac{E_g}{\varepsilon_r}(t + g + \varepsilon_r g - g)$$
$$= \frac{E_g}{\varepsilon_r}[(\varepsilon_r - 1)g + C] ----------------------(2)$$

Differentiating equation (2) with respect to g,we get

$$\frac{dV_i}{d_g} = \frac{(\varepsilon_{r-1})}{\varepsilon_r}E_g + \frac{\varepsilon_{r-1}}{\varepsilon_r}g\frac{dE}{dg} + \frac{c}{\varepsilon_r}\frac{dE}{dg}$$
$$= \frac{(\varepsilon_{r-1})}{\varepsilon_r}\left\{E_g + g\frac{dE}{dg} + \frac{C}{\varepsilon_r - 1}\frac{dE}{dg}\right\}$$
$$\frac{dV_i}{d_g} = \frac{(\varepsilon_{r-1})}{\varepsilon_r}\left\{E_g + \frac{dE}{dg}\left(g + \frac{C}{\varepsilon_r - 1}\right)\right\} -------------(3)$$

Where $E_g = Positive, \frac{dE}{dg} = Negativeorzero$

Assumptions:

- $E_g = \varepsilon_r . E$
- $\frac{E_g(max)}{E_g} = 1$

Where E=Applied electric field

Paschen's curve can be used to explain breakdown of the gas gap when these assumptions are valid. When the voltage is applied, the breakdown of gas in the cavity occurs, and discharge progresses.

This discharge cause rise in temperature and pressure of gas. This causes decrease in the extinction voltage levels and erosion of cavity occurs.

Conclusions:

V_i decreases as cavity depth increases and follows Paschen's curve.
E<2 V_i, erosion of cavity occurs but breakdown will not takes place and the life of insulating is long.
E> 2 V_i, erosion and break down takes place due to ageing.

Aging and breakdown due to accumulation of charges on insulator surfaces:

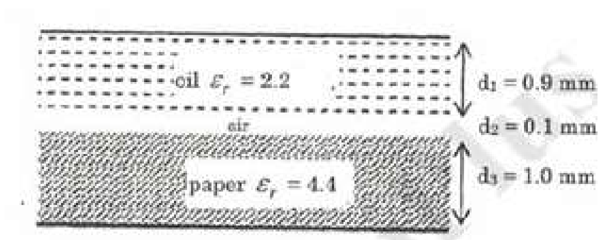
When electric field is applied to the composite dielectric, discharge occurs due to the charges (Electron or positive ions) gets deposited on the solid insulator surface.

These charges stays for a long durations (ays or weeks).this accumulation of charges increases the conductivity and increases the discharged magnitudes which causes damage to the dielectric surface. The discharge increases as the life of the insulation increases.

For clean surface,V_i value depends on on:

- Nature of dielectric
- Size of dielectric
- Shape of Dielectric

12.A certain dielectric can be considered to be represented by the equivalent circuit shown in figure.1.What is the maximum voltage that can be applied across the dielectric, If partial discharges in air to be avoided? State any assumption made(April/May 2015)



Permittivites of dielectric:K_1, K_2, K_3

$E_i = \frac{\sigma}{\varepsilon_0 K_1}$

Where i=1,2,3 and maximum applied voltage across each dielectric is represented by E_1,E_2,E_3, ε_0 - is the permittivity of free space,σ-charge density i.e charge per unit area

Assume $\sigma = 10^{-7} coloumb/m^2$

$E_1 = \frac{\sigma}{\varepsilon_0 K_1} = \frac{10^{-7}}{2.2\times 8.854\times 10^{-12}}$=5133.7 v/m

$E_2 = \frac{\sigma}{\varepsilon_0 K_2} = \frac{10^{-7}}{1\times 8.854\times 10^{-12}}$=11294.3 v/m

$E_3 = \frac{\sigma}{\varepsilon_0 K_3} = \frac{10^{-7}}{4.4\times 8.854\times 10^{-12}}$=2566.8 v/m

Total voltage across dielectric $\Delta V = E_1 d_1 + E_2 d_2 + E_3 d_3$

Where d_1,d_2,d_3 are thickness of the dielectrics

$\Delta V = 5133.7\times 0.9\times 10^{-3} + 11294.3 \times 0.1 \times 10^{-3} + 2566.8 \times 1 \times 10^{-3}$

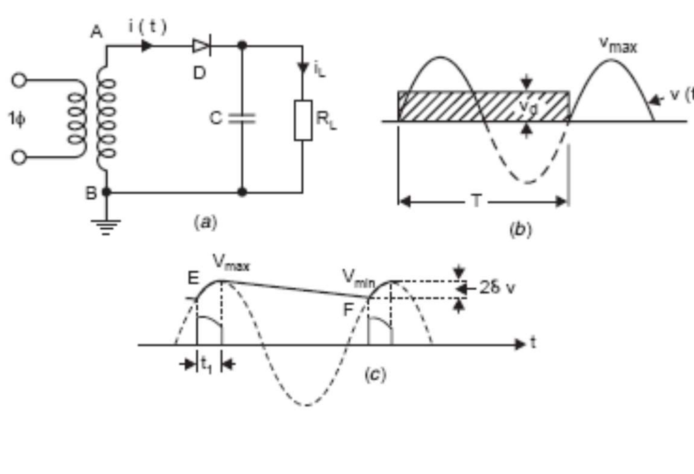
$\Delta V = 4.620+1.129+2.5668$

$\Delta V = 8.3158$ V

UNIT-3

1. Explain any one method of voltage multiplier circuits.(M/J-2012,N/D-2004,M/J-2011)

- The simplest circuit for generation of high direct voltage is the half wave rectifier shown in Fig. Here RL is the load resistance and C the capacitance to smoothen the d.c. output voltage.
- If the capacitor is not connected, pulsating d.c. voltage is obtained at the output terminals whereas with the capacitance C, the pulsation at the output terminal are reduced.
- Assuming the ideal transformer and small internal resistance of the diode during conduction the capacitor C is charged to the maximum voltage V_{max}during conduction of the diode D.
- Assuming that there is no load connected, the d.c. voltage across capacitance remains constant at V_{max}whereas the supply voltage oscillates between $+V_{max}$and during negative half cycle the potential of point A becomes $-V_{max}$and hence the diode must be rated for $2V_{max}$.
- This would also be the case if the transformer is grounded at A instead of B as shown in Fig. below. Such a circuit is known as voltage doublerdue to Villard for which the output voltage would be taken across D. This d.c. voltage, however, oscillates between zero and $2V_{max}$and is needed for the Cascade circuit.



- If the circuit is loaded, the output voltage does not remain constant at V_{max}. After point E.
- The supply voltage becomes less than the capacitor voltage, diode stops conducting. The capacitor can not discharge back into the a.c. system because of one way action of

the diode. Instead, the current now flows out of C to furnish the current I_L through the load.

- While giving up this energy, the capacitor voltage also decreases at a rate depending on the time constant CR of the circuit and it reaches the point F corresponding to V_{min}.
- Beyond F, the supply voltage is greater than the capacitor voltage and hence the diode D starts conducting charging the capacitor C again to V_{max} and also during this period it supplies current to the load also.
- This second pulse of $i_p(i_c + i_l)$ is of shorter duration than the initial charging pulse as it serve mainly to restore into C the energy that C meanwhile had supplied to load. Thus, while each pulse of diode current lasts much less than a half cycle, the load receives current more continuously from C.
- Assuming the charge supplied by the transformer to the load during the conduction period t, which is very small to be negligible, the charge supplied by the transformer to the capacitor during conduction equals the charge supplied by the capacitor to the load. Note that $i_c >> i_L$. During one period T = 1/f of the a.c voltage, a charge Q is transferred to the load RL and is given as

$$Q = \int_T iL(t)dt = \int_T \frac{V_{RL}(t)}{RL} dt = \pi = \frac{I}{f}$$

Where I is the mean value of the d.c output $iL(t)$ and $V_{RL}(t)$ the d.c. voltage which includes a ripple as shown in Fig.2.1. This charge is supplied by the capacitor over the period T when the voltage changes from V_{max} to V_{min} over approximately period T neglecting the conduction period of the diode. Suppose at any time the voltage of the capacitor is V and it decreases by an amount of dv over, the time dt then charge delivered by the capacitor during this time is

$$d_Q = Cd_v$$

Therefore, if voltage changes from V_{max} to V_{min} the charge delivered by the capacitor.

$$\int dQ = \int_{V_{max}}^{V_{min}} Cd_v = -C(V_{max} - V_{min})$$

Or the magnitude of charge delivered by the capacitor

$$Q = C(V_{max} - V_{min})$$

Using equation (2.2)

$$Q = 2\delta VC$$

Therefore, $2\delta VC = \pi$

Or

$$\delta V = \frac{\pi}{2C} = \frac{1}{2fC}$$

- The above Equation δV shows that the ripple in a rectifier output depends upon the load current and the circuit parameter like *f* and *C*. The product *fC* is, therefore, an important design factor for the rectifiers.

- The higher the frequency of supply and larger the value of filtering capacitor the smaller will be the ripple in the d.c. output.

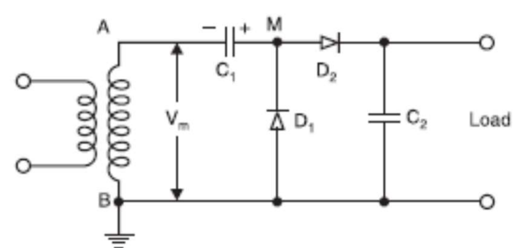
The single phase half-wave rectifier circuits have the following disadvantages:

(i) The size of the circuits is very large if high and pure d.c. output voltages are desired.

(ii) The H.T transformer may get saturated if the amplitude of direct current is comparable with the nominal alternating current of the transformer.

- It is to be noted that all the circuits considered here are able to supply relatively low currents and therefore are not suitable for high current applications such as HVDC transmission.
- When high d.c. voltages are to be generated, voltage doubler or cascaded voltage multiplier circuits are used. One of the most popular doublercircuit due to Grimacer is shown in Fig below.
- Suppose B is more positive with respect to A and the diode D1 conducts thus charging the capacitor C1 to $V_{max}$with polarity During the next half cycle terminal A of the capacitor C1 rises to $V_{max}$and hence terminal M attains a potential of 2 V_{max}. Thus, the capacitor C_2 is charged to 2 V_{max}through D_2. Normally the voltage across the load will be less than 2 V_{max}depending

upon the time constant of the circuit *C*2*RL*.



voltagedoubler circuit

2. Explain with neat diagram the n-stage Cockcroft-Walton circuit. Derive an expression for total ripple content in output voltage and hence deduce the condiction for optimum number of stages (A/M-2008,N/D-2007,DEC-2013,May-2014,Dec-14).

The multistage single phase cascade circuit of the Cockroft- Walton circuit.

No Load Operation:

- The portion ABM’MA is exactly indentical to Greinarcher voltage doubler circuit and the voltage across C becomes 2Vmax when M attains a voltage 2Vmax.
- During the next half cycle when B becomespositive with respect to A, potential of M falls and,therefore, potential of N also falls becoming lessthan potential at M′ hence C_2 is charged through D_2.

- Next half cycle A becomes more positive andpotential of M and N rise thus charging C'_2 through D'_2. Finally all the capacitors C'_1, C'_2, C'_3, C1, C_2,and C_3 are charged. The voltage across the columnof capacitors consisting of C_1, C_2, C_3, keeps onoscillating as the supply voltage alternates.
- Thiscolumn, therefore, is known as oscillating column. However, the voltage across the capacitances C_1, C_2, C_3, remains constant and is known as smoothening column.
- The voltages at M′, N′, and O′ are 2 V_{max}4 $V_{max}$and 6 V_{max}. Therefore, voltageacross all the capacitors is 2 V_{max}except for $C_1$where it is V_{max}only. The total output voltage is 2n V_{max} where n is the number of stages.
- Thus, theuse of multistage arranged in the manner shown enables very high voltage to be obtained. The equalstress of the elements (both capacitors and diodes) used is very helpful and promotes a modular designof such generators.

Generator Loaded: When the generator is loaded, the output voltage will never reach the value 2n Vmax. Also, the output wave will consist of ripples on the voltage. Thus, we have to deal with two quantities, the voltage drop ΔV and the ripple δV.

Suppose a charge q is transferred to the load per cycle. This charge is q = I/f = IT. The charge comes from the smoothening column, the series connection of C'_1, C'_2, C'_3,. If no charge were transferred during T from this stack via D_1, D_2, D_3, to the oscillating column, the peak to peak ripple would merely be

But in practice charges are transferred.

$$2\delta V = \pi \sum_{n=0}^{n} \frac{1}{c_i{}'}$$

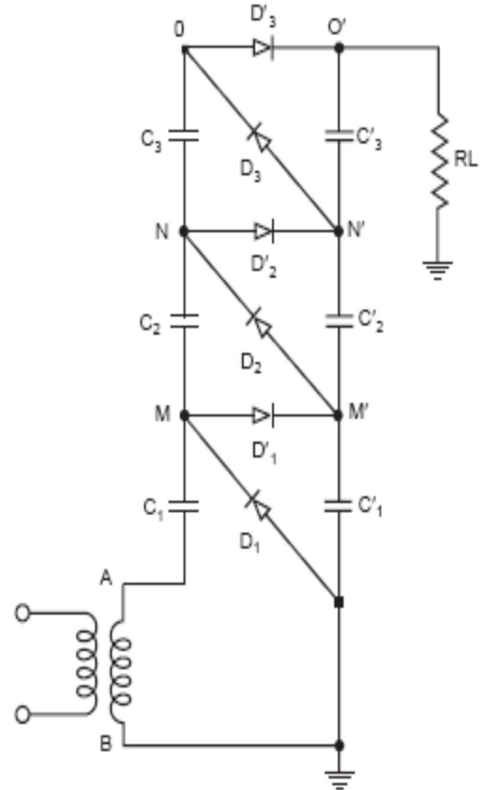
For n-stage circuits, the total ripple will be

$$2\delta V = \frac{1}{f}\left[\frac{1}{c_i{}'} + \frac{2}{c'_{in-1}} + \frac{3}{c'_{n-2}} + \cdots + \frac{n}{c'_1}\right]$$

$$\delta V = \frac{1}{2f}\left[\frac{1}{c_i{}'} + \frac{2}{c'_{in-1}} + \frac{3}{c'_{n-2}} + \cdots + \frac{n}{c'_1}\right]$$

From equation above it is clear that in a multistage circuit the lowest capacitors are responsible for most ripple and it is, therefore, desirable to increase the capacitance in the lower stages. However, this is objectionable from the view point of High Voltage Circuit where if the load is large and the load voltage goes down, the smaller capacitors (within the column) would be overstressed. Therefore, capacitors of equal value are used in practical circuits *i.e.,* $C'_n = C'_n - 1 = C'1 = C$ and the ripple is given as

$$\delta \text{v} = \frac{In(n+1)}{2fc * 2}$$



- It is to be noted that in general it is more economical to use high frequency and smaller value of capacitance to reduce the ripples or the voltage drop rather than low frequency and high capacitance.
- Cascaded generators of Cockroft-Walton type are used and manufactured world wide these days. A typical circuit is shown in Fig above. In general a direct current upto 20 mA is required for high voltages between 1 mv and 2 mv. In case where a higher value of current is required, symmetrical
- Cascaded rectifiers have been developed. These consist of mainly two rectifiers in cascade with a common smoothing column. The symmetrical cascaded rectifier has a smaller voltage drop and also a smaller voltage ripple than the simple cascade.
- The alternating current input to the individual circuits must be provided at the appropriate high potential; this can be done by means of isolating transformer. Fig shows a typical cascaded rectifier circuit.

Ripple in cascaded voltage multiplier circuit derivation :

Let f = Supply frequency.

Q = Charge transferred in each cycle.

I_1 = Load current from the rectifier.

t_1 = Conduction period of rectifier.

t_2 = Non – Conduction period of rectifier.

δv = Ripple voltage (peak to peak).

$I_1 = \frac{dq}{dt} = \frac{q}{t_2}$

Since $t_1 << t_2$ and $t_1 + t_2 = \frac{1}{f}$; $t_2 = \frac{1}{f}$

Also q = C_2 δv

$\delta v = \frac{q}{C_2} = \frac{I_1 t_2}{C_2} = \frac{I_1}{f C_2}$

Mean voltage drop from $2V_{max} = \frac{I_1}{f} [\frac{1}{C_1} + \frac{2}{C_2}]$

Let C_2 , $C_{2,}$……………, C_{2n} be the capacitance = C.

Let q be the change transferred from C_{2n} to the load.

Ripple at the capacitance C_{2n} will be $\frac{I_1}{fC}$.

Ripple at the capacitance $C_{2n-2} = \frac{2I_1}{fC}$

. .

Ripple at the capacitance $C_2 = \frac{nI_1}{fC}$

For n stages, Total Ripple (δv) = $\frac{I_1}{fC}$ [1+2+3…………+n]

$= \frac{I_1}{fC} [\frac{n(n+1)}{2}]$

Average ripple = $\frac{Total\ ripple}{2}$

$= \frac{\delta v}{2} = \frac{I_1}{4f}$ (n) (n+1)

Ripple contribution is more due to the lowest capacitances C_1, C_2, C_3, C_4, etc. Ripple can be reduced if the capacitances of these capacitors is increases proportionately i.e., C_1, C_2 are made nC,

$C_3, C_4$are made (n-1)C and so on.

Therefore, Total ripple = $\frac{nI_1}{fC}$

Where, n = Number of stages.

Percent ripple = % ripple = $\frac{\delta v\ X\ 100}{nV_{max}}$

Determination of Optimum Number of Stages

Change in voltage ΛV is caused due to the ripple (δv).

Let $C_1, C_2, \ldots\ldots\ldots, C_n$ = C

Capacitance C_{2n} *is charged to* V_{max} - Total ripple

$$= 2V_{max}\frac{nI_1}{fC}$$

Similarly Capacitance $C_{2n-1}$is charged to $2V_{max}$-$\frac{2n\ _1}{fC} - \frac{(n-1)I_1}{fC}$

Capacitance V_2 is charged to $2V_{max}$- $\frac{2nI_1}{fC}$ - $\frac{2(n-1)I_1}{fC}$ -$\frac{2X\ _1}{fC} + \frac{I_1}{fC}$

Therefore, Voltage drop across C_{2n} $(\Lambda V_{2n}) = \frac{nI_1}{fC}$

Voltage drop across C_{2n-1} $(\Lambda V_{2n-2}) = \frac{I_1}{fC}$ [2n + (n - 1)]

Voltage drop across C_2 $(\Lambda V_2) = \frac{I_1}{fC}$ [2n + 2(n – 1)+………+ 2 – 1]

Total Voltage drop = $\Lambda V_{2n} + \Lambda V_{2n-2}$………….. ΛV_2

$$= \frac{I_1}{fC}\left[\sum_1^n 2n^2 - \sum_1^n n\right]$$

$$= \frac{I_1}{fC}\left[2.\frac{n(n+1)(2n+1)}{6} - \frac{n(n+1)}{2}\right]$$

$$= \frac{I_1}{fC}\left[\frac{n(n+1)}{2}\left[\frac{4n+2}{3} - 1\right]\right]$$

$$= \frac{I_1}{fC}\left[\frac{n(n+1)(4n-1)}{6}\right]$$

$$= \frac{I_1}{fC}\left[\frac{2n^3}{3} + \frac{n^2}{2} - \frac{n}{6}\right]$$

For the number of stages n ≥ 4, We may neglect the n^2 and n terms, because small compared to that of n^3 term.

$$\Lambda V = \frac{I_1}{fC}\left[\frac{2n^3}{3}\right] \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3.1)$$

$$\%\text{Regulation} = \frac{\Lambda V}{2nV_{max}} \text{ X } 100$$

To determine optimum value of n, differentiate equation (3.1) with respect to n, we get

$$2V_{max} = \frac{I_1}{fC}\left[2.\frac{3n^2}{3}\right]$$

$$n^2 = \frac{V_{max}}{I_1}\text{fC}$$

$$n_{optimum} = \sqrt{\frac{fC\ V_{max}}{I_1}}$$

Design details:

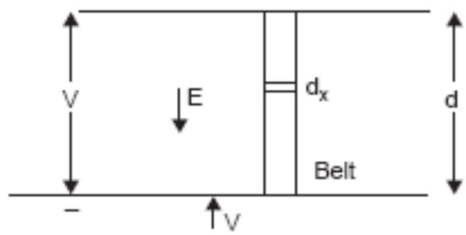
Production of voltage = 10KV to 2MV

Current = 10KV to 100mA

Frequency = 10 kHz

3.Discuss with neat diagram the Van-de Graff generator.(M/J-2012,A/M-2005,N/D-2008,2015,M/J-2009,M/J-2012 (A/M-2011,MAY-2013&2014)

- In electromagnetic generators, current carrying conductors are moved against the electromagnetic forces acting upon them.
- In contrast to the generator, electrostatic generators convert mechanical energy into electric energy directly.
- The electric charges are moved against the force of electric fields, thereby higher potential energy is gained at the cost of mechanical energy. The basic principle of operation is explained with the help of Fig below.



- An insulated belt is moving with uniform velocity v in an electric field of strength E (x). Suppose the width of the belt is b and the charge density σ consider a length dx of the belt, the charge dq= σbdx.

The forced experienced by this charge (or the force experienced by the belt)

$$dF = Ed_q = E\sigma bd_x$$

$$F = \sigma b \int E\, d_x$$

Normally the electric field is uniform

$$F = \sigma bv$$

The power required to move the belt

$$= Force \times velocity$$

$$= F_v = \sigma bV_v$$

Now current

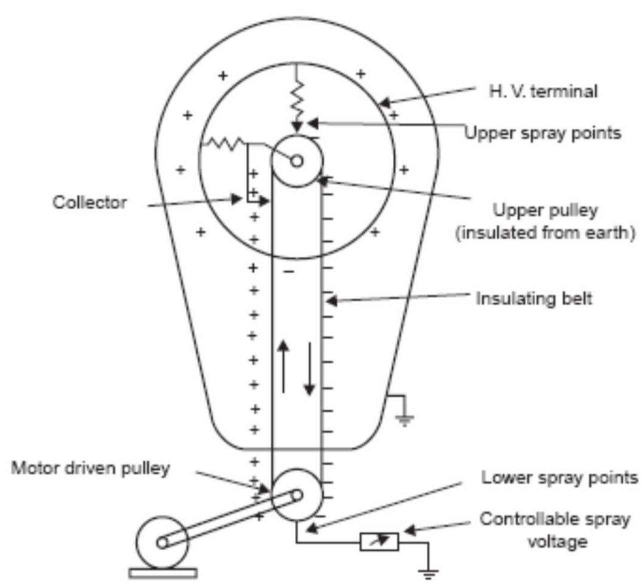
$$I = \frac{d_q}{d_t} = \sigma bV_v \frac{d_x}{d_t} = \sigma b$$

The power required to move the belt

$$P = F_v = \sigma b V_v = VI$$

Assuming no losses, the power output is also equal to VI

- Fig below shows belt driven electrostatic generator is called VandeGraff generator.
- An insulating belt is run over pulleys. The belt, the width of which may vary from a few cms to meters is driven at a speed of about 15 to 30 m/sec, by means of a motor connected to the lower pulley.
- The belt near the lower pully is charged electro statically by an excitation arrangement. The lower charge spray unit consists of a number of needles connected to the controllable d.c. source (10 kV–100 kV) so that the discharge between the points and the belt is maintained.
- The charge is conveyed to the upper end where it is collected from the belt by discharging points connected to the inside of an insulated metal electrode through which the belt passes.
- The entire equipment is enclosed in an earthed metal tank filled with insulating gases of good dielectric strength viz. SF6 etc.
- So that the potential of the electrode could be raised to relatively higher voltage without corona discharges or for a certain voltage a smaller size of the equipment will result.
- Also, the shape of the H.T electrode should be such that the surface gradient of electric field is made uniform to reduce again corona discharges, even though it is desirable to avoid corona entirely.
- An isolated sphere is the most favorable electrode shape and will maintain a uniform field E with a voltage of $E_r$where r is the radius of the sphere.



- As the h.t. electrode collects charges its potential rises. The potential at any instant is given as $V = q/C$ where q is the charge collected at that instant.
- It appears as though if the charge were collected for a long time any amount of voltage could be generated. However, as the potential of electrode rises, the field set up by the electrode increases and that may ionise the surrounding medium and, therefore, this would be the limiting value of the voltage. In practice, equilibrium is established at a terminal voltage which is such that the charging current

$$I = C\frac{dv}{dt}$$

equals the discharge current which will include the load current and the leakage and corona loss currents.

- The moving belt system also distorts the electric field and, therefore, it is placed within properly shaped field grading rings. The grading is provided by resistors and additional corona discharge elements.
- The collector needle system is placed near the point where the belt enters the h.t. terminal.
- A second point system excited by a self-inducing arrangement enables the down going belt to be charged to the polarity opposite to that of the terminal and thus the rate of charging of the latter, for a given speed, is doubled.
- The self inducing arrangement requires insulating the upper pulley and maintaining it at a potential higher than that of the h.t. terminal by connecting the pulley to the collector needle system.
- The arrangement also consists of a row of points (shown as upper spray points in diagram) connected to the inside of the h.t. terminal and directed towards the pulley above its points of entry into the terminal.
- As the pulley is at a higher potential (positive), the negative charges due to corona discharge at the upper spray points are collected by the belt.
- This neutralizes any remaining positive charge on the belt and leaves an excess of negative charges on the down going belt to be neutralized by the lower spray points.
- Since these negative charges leave the h.t. terminal, the potential of the h.t. terminal is raised by the corresponding amount.

The advantages of the generator are:

(*i*) Very high voltages can be easily generated

(*ii*) Ripple free output

(*iii*) Precision and flexibility of control

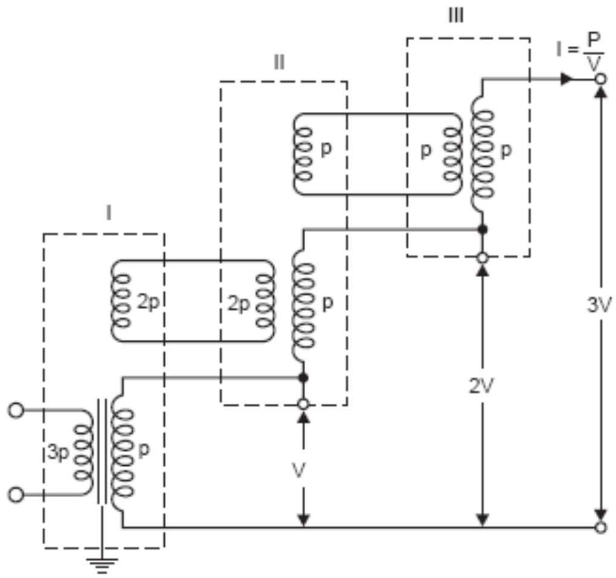
The disadvantages are:

(*i*) Low current output

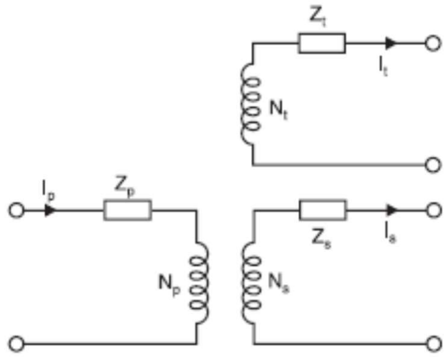
(*ii*) Limitations on belt velocity due to its tendency for vibration. The vibrations may make it difficult to have an accurate grading of electric fields.

4. Describe the cascade transformer connection to generate high alternating voltage. (A/M-2005, A/M-2008,MAY-2013,DEC-2013)

- For voltages higher than 400 KV, it is desired to cascade two or more transformers depending upon the voltage requirements.With this, the weight of the whole unit is subdivided into single units and, therefore, transport and erection becomes easier.
- Also, with this, the transformer cost for a given voltage may be reduced, since cascaded units need not individually possess the expensive and heavy insulation required in single stage transformers for high voltages exceeding 345 kV.
- It is found that the cost of insulation for such voltages for a single unit becomes proportional to square of operating voltage.Fig shows a basic scheme for cascading three transformers. The primary of the first stage transformer is connected to a low voltage supply.
- A voltage is available across the secondary of this transformer. The tertiary winding (excitation winding) of first stage has the same number of turns as the primary winding, and feeds the primary of the second stage transformer.
- The potential of the tertiary is fixed to the potential V of the secondary winding as shown in Fig below.The secondary winding of the second stage transformer is connected in series with the secondary winding of the first stage transformer, so that a voltage of 2V is available between the ground and the terminal of secondary of the second stage transformer.
- Similarly, the stage-III transformer is connected in series with the second stage transformer. With this the output voltage between ground and the third stage transformer, secondary is 3V.
- it is to be noted that the individual stages except the upper most must have three-winding transformers. The upper most, however, will be a two winding transformer.
- Fig below shows metal tank construction of transformers and the secondary winding is not divided. Here the low voltage terminal of the secondary winding is connected to the tank. The tank of stage-I transformer is earthed.
- The tanks of stage-II and stage-III transformers have potentials of V and 2V, respectively above earth and, therefore, these must be insulated from the earth with suitable solid insulation.
- Through h.t. bushings, the leads from the tertiary winding and the h.v. winding are brought out to be connected to the next stage transformer.



- However, if the high voltage windings are of mid-point potential type, the tanks are held at 0.5 V, 1.5 V and 2.5 V, respectively.
- This connection results in a cheaper construction and the high voltage insulation now needs to be designed for $V/2$ from its tank potential.
- The main disadvantage of cascading the transformers is that the lower stages of the primaries of the transformers are loaded more as compared with the upper stages.
- The loading of various windings is indicated by
- P in Fig. For the three-stage transformer, the total output VA will be $3VI = 3P$ and, therefore, each of the secondary winding of the transformer would carry a current of $I = P/V$.
- The primary winding of stage-III transformer is loaded with P and so also the tertiary winding of second stage transformer. Therefore, the primary of the second stage transformer would be loaded with $2P$. Extending the same logic, it is found that the first stage primary would be loaded with P.
- Therefore, while designing the primaries and tertiaries of these transformers, this factor must be taken into consideration.The total short circuit impedance of a cascaded transformer from data for individual stages can be obtained. The equivalent circuit of an individual Stage.
- Here *Zp, Zs,* and *Zt,* are the impedances associated with each winding. The impedances are shown in series with an ideal 3-winding transformer with corresponding number of turns *Np, Ns* and *Nt.*
- The impedances are obtained either from calculated or experimentally-derived results of the three shortcircuit tests between any two windings taken at a time.



➢

Let *Zps*= leakage impedance measured on primary side with secondary short circuited and tertiary open.

Zpt= leakage impedance measured on primary side with tertiary short circuited and secondary open.

Zst= leakage impedance on secondary side with tertiary short circuited and primary open.

If these measured impedances are referred to primary side then

*Zps = Zp+ Zs, Zpt= Zp+ Zt*and *Zst= Zs+ Zt*

Solving these equations, we have

$Z_p=(Z_{ps}+Z_{pt}-Z_{st})/2$,$Z_s=(Z_{ps}+Z_{st}-Z_{pt})/2$

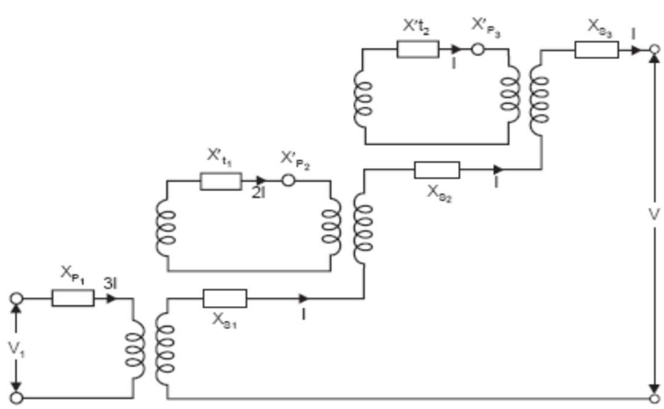
And $Z_t=(Z_{pt}+Z_{st}-Z_{ps})$

Assuming negligible magnetizing current, the sum of the ampere turns of all the windings must be zero.

$N_pI_p-N_sI_s-N_tI_t=0$

Assuming lossless transformer, we have

$Z_p=jX_p$, $Z_s=jX_s$ *and* $Z_t=jX_t$



5.Explain the principle of operation of resonant transformer.(N/D-2008)

- The equivalent circuit of a single-stage-test transformer along with its capacitive load is shown in Fig. Here L_1 represents the inductance of the voltage regulator and the transformer primary, Lthe exciting inductance of the transformer, $L2$ the inductance of the transformer secondary and C the capacitance of the load.

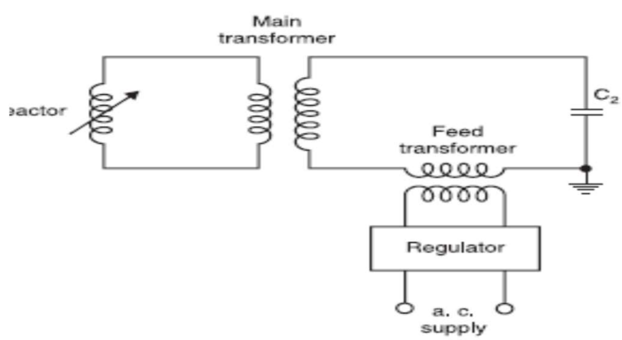
- Normally inductance L is very large as compared to $L1$ and $L2$ and hence its shunting effect can be neglected. Usually the load capacitance is variable and it is possible that for certain loading, resonance may occur in the circuit suddenly and the current will then only be limited by the resistance of the circuit and the voltage across the test specimen may go up as high as 20 to 40 times the desired value.

- Similarly, presence of harmonics due to saturation of iron core of transformer may also result in resonance.

- Third harmonic frequencies have been found to be quite disastrous. With series resonance, the resonance is controlled at fundamental frequency and hence no unwanted resonance occurs.

- The development of series resonance circuit for testing purpose has been very widely welcome by the cable industry as they faced resonance problem with test transformer while testing short lengths of cables. In the initial stages, it was difficult to manufacture continuously variable high voltage and high value reactors to be used in the series circuit and therefore, indirect methods to achieve this objective were employed.

- Below diagram shows a continuously variable reactor connected in the low voltage winding of the step up transformer whose secondary is rated for the full test voltage. $C2$ represents the load capacitance.



- If N is the transformation ratio and L is the inductance on the low voltage side of the transformer, then it is reflected with $N2\ L$ value on the secondary side (load side) of the transformer.

- For certain setting of the reactor, the inductive reactance may equal the capacitive reactance of the circuit, hence resonance will take place. Thus, the reactive power requirement of the supply becomes zero and it has to supply only the losses of the circuit.

- However, the transformer has to carry the full load current on the high voltage side. This is a disadvantage of the method.

- The inductor are designed for high quality factors $Q = \omega L / R$. The feed transformer, therefore, injects the losses of the circuit only. It has now been possible to manufacture high voltage continuously variable reactors 300 kV per unit using a new technique with split iron core. With this, the testing step up transformer can be omitted as shown in below.
- The inductance of these inductors can be varied over a wide range depending upon the capacitance of the load to produce resonance.

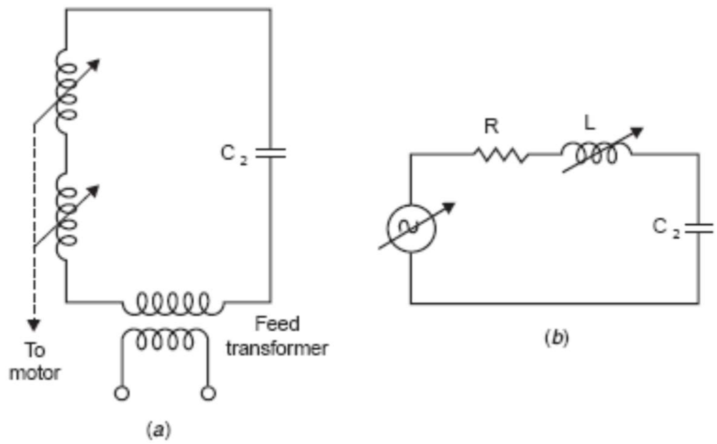


Fig above (*b*) represents an equivalent circuit for series resonance circuit. Here *R* is usually of low value. After the resonance condition is achieved, the output voltage can be increased by increasing the input voltage.

The feed transformers are rated for nominal current ratings of the reactor. Under resonance, the output voltage will be

$V_o = V/R\omega C_2$

Where V is the supply voltage.

Since at resonance

$\omega L = 1/\omega C_2$

Therefore $V_o = V\omega L/R = VQ$

where *Q* is the quality factor of the inductor which usually varies between 40 and 80. This means that with $Q = 40$, the output voltage is 40 times the supply voltage.

It also means that the reactive power requirements of the load capacitance in kVA is 40 times the power to be provided by the feed transformer in KW. This results in a relatively small power rating for the feed transformer.

The following are the advantages of series resonance circuit.

(i) The power requirements in KW of the feed circuit are (kVA)/Q where kVA is the reactive power requirements of the load and Q is the quality factor of variable reactor usually greater than 40. Hence, the requirement is very small.

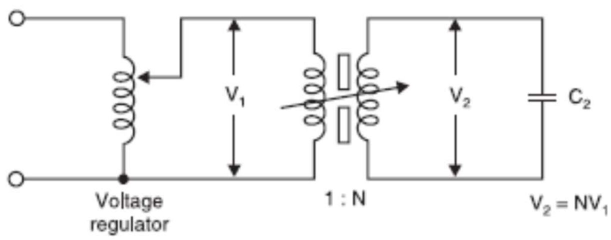
(ii) The series resonance circuit suppresses harmonics and interference to a large extent. The near sinusoidal wave helps accurate partial discharge of measurements and is also desirable for measuring loss angle and capacitance of insulating materials using Schering Bridge.

(iii) In case of a flashover or breakdown of a test specimen during testing on high voltage side, the resonant circuit is detuned and the test voltage collapses immediately. The short circuit current is limited by the reactance of the variable reactor. It has proved to be of great value as the weak part of the isolation of the specimen does not get destroyed. In fact, since the arc flash over has very small energy, it is easier to observe where exactly the flashover is occurring by delaying the tripping of supply and allowing the recurrence of flashover.

(iv) No separate compensating reactors (just as we have in case of test transformers) are required. This results in a lower overall weight.

(v) When testing SF6 switchgear, multiple breakdowns do not result in high transients. Hence, no special protection against transients is required.

(vi) Series or parallel connections of several units is not at all a problem. Any number of units can be connected in series without bothering for the impedance problem which is very severely associated with a cascaded test transformer. In case the test specimen requires large current for testing, units may be connected in parallel without any problem.



Here the variable reactor is incorporated into the high voltage transformer by introducing a variable air gap in the core of the transformer. With this connection, variation in load capacitance and losses cause variation in input current only. The output voltage remains practically constant. Within the units of single stage design, the parallel resonant method offers optimum testing performance.

6. Explain with neat diagram MARX circuit and its operations. (A/M-2011,A/M-2008,M/J-2009,A/M-2011)

(OR)

Starting from The Basic MARX Circuit Develop The Circuit Of A Morden Multi-Stage Impulse Generater And Explain Its Operation. Discuss On The Significance Of Various Parameter (N/D2007,N/D-2007,DEC-2013,N/D-2015)

In order to obtain higher and higher impulse voltage, a single stage circuit is inconvenient for the following reasons:

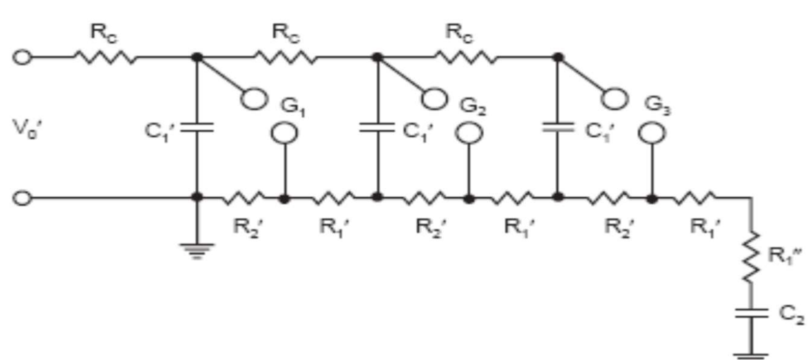
(i) The physical size of the circuit elements becomes very large.

(ii) High d.c. charging voltage is required.

(iii) Suppression of corona discharges from the structure and leads during the charging period is difficult.

(iv) Switching of vary high voltages with spark gaps is difficult.

- Multiplier circuit which is commonly used to obtain impulse voltages with as high a peak value as possible for a given d.c. charging voltage.
- Depending upon the charging voltage available and the output voltage required a number of identical impulse capacitors are charged in parallel and then discharged in series, thus obtaining a multiplied total charging voltage corresponding to the number of stages.
- Fig below shows a 3-stage impulse generator circuit due to Marx employing 'b' circuit connections. The impulse capacitors C1 are charged to the charging voltage V0 through the high charging resistors Rcin parallel.
- When all the gaps G break down, the C1′ capacitances are connected in series so that C2 is charged through the series connection of all the wave front resistances R1′ and finally all C1′ and C2 will discharge through the resistors R2′ and R1′.
- Usually Rc>>R2 >>R1. If in Fig below the wave tail resistors R2′ in each stage are connected in parallel to the series combination of R1′, G and C1′, an impulse generator of type circuit 'a' is obtained.
- In order that the Marx circuit operates consistently it is essential to adjust the distances between various sphere gaps such that the first gap G1 is only slightly less than that of G2 and so on.
- If is also necessary that the axes of the gaps G be in the same vertical plane so that the ultraviolet radiations due to spark in the first gap G, will irradiate the other gaps. This ensures a supply of electrons released from the gap electrons to initiate breakdown during the short period when the gaps are subjected to over voltages.



The wave front control resistance can have three possible locations

(i) entirely within the generator

(ii) entirely outside the generator

(iii) partly within and partly outside the generator.

The first arrangement is unsatisfactory as the inductance and capacitance of the external leads and the load form an oscillatory circuit which requires to be damped by an external resistance.

The second arrangement is also unsatisfactory as a single external front resistance will have to withstand, even though for a very short time, the full rated voltage and therefore, will turn out to be inconveniently long and would occupy much space.

A compromise between the two is the third arrangement as shown in Fig. below and thus both the "space economy" and damping of oscillations are taken care of.

It can be seen that Fig below can be reduced to the single stage impulse generator. After the generator has fired, the total discharge capacitance $C1$ may be given as,

$$\frac{1}{c'_n}\sum^{n}\frac{1}{c'_1}$$

The equivalent front resistance

$$R_1 = \sum^{n} R'_1 + R''_2$$

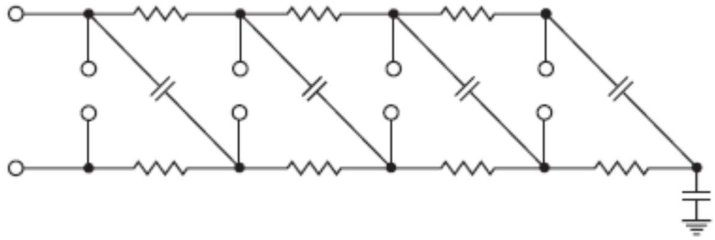
And the equivalent tail control resistance

$$R_2 = \sum^{n} R'_2$$

Where n is the number of stages

where the load is earthed during the charging period, without the necessity for an isolating gap. The impulse output voltage has the same polarity as the charging voltage is case of Marx circuit,

it is reversed in case of Goodlet circuit. Also, on discharge, both sides of the first spark gap are raised to the charging voltage in the Marx circuit but in case of Goodlet circuit they attain earth potential.

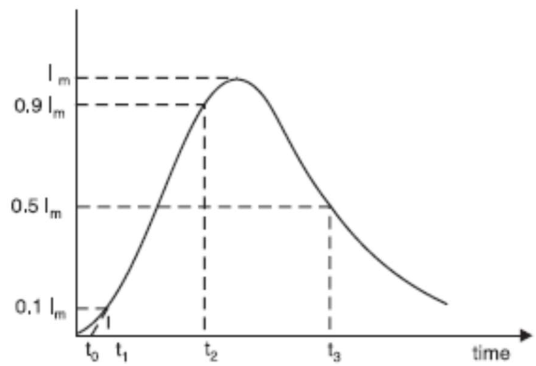


7. Draw and explain the circuits of producing impulse wave.(N/D-2004, N/D-2007,MAY-2013)

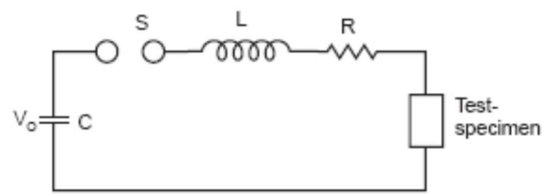
(OR)

Explain in detail the methods of switching surge generation from impulse generator and from power transformer.(M/J-2012,A/M-2011,M/J-2014)

The impulse current wave is specified on the similar lines as an impulse voltage wave. A typical impulse current wave is shown graph High current impulse generators usually consist of a large number of capacitors connected in parallel to the common discharge path.



The equivalent circuit of the generator is shown in Fig below and approximates to that of a capacitance C charged to a voltage V_0 which can be considered to discharge through an inductance L and a resistance R. In practice both L and R are the effective inductance and resistance of the leads, capacitors and the test objects.



After the gap S is triggered, the laplace transform current is given as

$$I(s) = \frac{V_0}{s}\frac{1}{R + SL + {}^{1}/_{cs}}$$

$$= \frac{V}{L}\frac{1}{S^2 + {}^{R}/_{LS}\, {}^{1}/_{LC}}$$

$$= \frac{V}{L}\frac{1}{(S+\alpha)^2 + \omega^2}$$

Where

$\alpha = \frac{R}{2L}$and$\omega = \left(\frac{1}{LC} - \frac{R^2}{4L^2}\right)^{\frac{1}{2}}$

$$or$$

$$\omega = \frac{1}{\sqrt{LC}}\left(1 - \frac{R^2 c}{4L}\right)^{\frac{1}{2}} = \frac{1}{\sqrt{LC}}(1 - V^{2)\frac{1}{2}}$$

Where

$$V = \frac{R}{2}\sqrt{\frac{C}{L}}$$

Take the inverse laplace we have the current

$$i(t) = \frac{V}{\omega L} e^{-\alpha t} \sin \omega t$$

For current i(t) to be maximum $\frac{di(t)}{dt}$=0

$\frac{di(t)}{dt} = \frac{V}{\omega L}[\omega e^{-\alpha t} \cos \omega t - \alpha e^{-\alpha t} \sin \omega t]$=0

$= \frac{V}{\omega L} e^{-\alpha t}[\omega \cos \omega t - \alpha \sin \omega t]$=0

Or

$$\frac{\omega}{\sqrt{\sigma^2 + \omega^2}} \cos \omega t - \frac{\alpha}{\sqrt{\sigma^2 + \omega^2}} \sin \omega t = 0$$

or

$$\sin \Theta \cos \omega t - \cos \Theta \sin \omega t = 0$$

or

$$\sin(\Theta - \omega t) = 0$$

or

$$\omega t = 0$$

or

$$t_{max} = \frac{\Theta}{\omega t}$$

Where t_{max} is the time when the first maximum value of current occurs and

$$\Theta = sin^{-1} \frac{\omega}{\sqrt{\sigma^2 + \omega^2}}$$

$$= sin^{-1} \frac{\omega}{\left[\frac{R_2}{4L^2}+\frac{1}{LC}-\frac{R^2}{4L^2}\right]^{\frac{1}{2}}}$$

$$= sin^{-1}\sqrt{LC}\omega$$

$$t_{max} = \frac{sin^{-1}\sqrt{LC}\omega}{\omega}$$

$$= \frac{sin^{-1}\sqrt{LC}\frac{1}{\sqrt{LC}}(1-V^2)^{\frac{1}{2}}}{\frac{1}{\sqrt{LC}}(1-V^2)^{\frac{1}{2}}}$$

$$t_{max}=\sqrt{LC}(1-V^2)^{\frac{-1}{2}}sin^{-1}(1-V^2)^{\frac{1}{2}} = \sqrt{LC}\,\frac{sin^{-1}(1-V^2)^{\frac{1}{2}}}{(1-V^2)^{\frac{1}{2}}}$$

Susbstuting the value of t=t_{max} in (3.25) the first maximum value of currents is given by

$$I_{max} = \frac{V_0\sqrt{LC}}{(1-V^2)^{\frac{1}{2}}L}\ Exp\left[-\frac{R\sqrt{LC}sin^{-1}(1-V^2)^{\frac{1}{2}}}{2L(1-V^2)^{\frac{1}{2}}}\right]$$

$$\sin\{\frac{(1-V^2)^{\frac{1}{2}}}{\sqrt{LC}}\sqrt{LC}(1-V^2)^{\frac{1}{2}}sin^{-1}(1-V^2)^{\frac{1}{2}}\}$$

$$= \frac{V_0}{(1-V^2)^{\frac{1}{2}}}\sqrt{\frac{C}{L}}\ \ Exp\left[\frac{-Vsin^{-1}(1-V^2)^{\frac{1}{2}}}{(1-V^2)^{\frac{1}{2}}}\right]\sin\{sin^{-1}(1-V^2)^{\frac{1}{2}}\}$$

$$=V_0\sqrt{\frac{C}{L}\ Exp\left[\frac{-Vsin^{-1}(1-V^2)^{\frac{1}{2}}}{(1-V^2)^{\frac{1}{2}}}\right]}$$

Equation (3.26) can be rewritten an

$$I_{max} = V_0\sqrt{\frac{C}{L}f_{(v)}} = \sqrt{\frac{2W}{L}}f_{(v)}$$

where

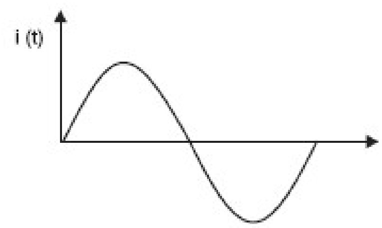
$$W = \frac{1}{2}CV^2$$

The initial energy stored by the generator

If R=0,V=0 then from equation (3.26) it is clear that

$$I = V_0\sqrt{\frac{C}{L}}\ and\ from\ equation$$

$$i(t) = V_0\sqrt{\frac{C}{L}}\sin\frac{t}{\sqrt{LC}}$$



Current response of circuit in

- From equation it is clear that for maximum value of current the inductance of the circuit should be low for a given initial energy W.
- The usual value of f (ν) without adding damping elements varies between 0.85 and 0.95. Unidirectional impulse can be produced by damping with additional resistance. However, this results in reduced peak value of current e.g.
- the value of the current during critical damping (R= 2√LC) is about 0.368 times its value when no damping (R = 0) is present. It has been found that an approximately unidirectional wave form can be obtained by the use of a non-linear damping resistance in the circuit with a reduction of $I_m$to only about 0.7 times and the V_0 √C L
- The effective inductance of the unit can be reduced by subdividing the capacitance C into groups of smaller units.

8. Explain With Neat Diagram The Triggering And Synchronization Of The Impulse Generator. (OR) EXPLAIN THE FUNCTION AND OPERATION OF TRIGATRON GAP. NOV/DEC-2015

Impulse generators are normally operated in conjunction with cathode ray oscillographs for measurement and for studying the effect of impulse waves on the performance of the insulations of the equipments.

- Since the impulse waves are of shorter duration, it is necessary that the operation of the generator and the oscillograph should be synchronized accurately and if the wave front of the wave is to be recorded accurately, the time sweep circuit of the oscillograph should be initiated at a time slightly before the impulse wave reaches the deflecting plates.

If the impulse generator itself initiates the sweep circuit of the oscillograph, it is then necessary to connect a delay cable between the generator or the potential divider and the deflecting plates of the oscilloscope so that the impulse wave reaches the plates at a controlled time after the sweep has been tripped.

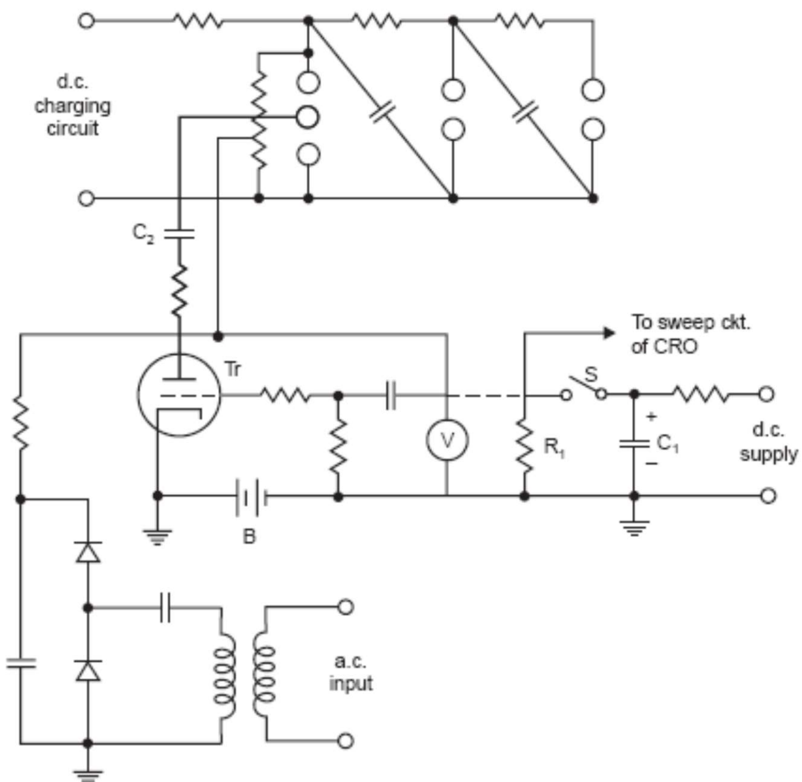
- However, the use of delay cable leads to inaccuracies in measurement. For this reason, some tripping circuits have been developed where the sweep circuit is operated first and then after a time of about 0.1 to 0.5 μ sec. the generator is triggered.

One of the methods involves the use of a three-sphere gap in the first stage of the generator as shown in Fig below .

- The spacing between the spheres is so adjusted that the two series gaps are able to withstand the charging voltage of the impulse generator. A high resistance is connected between the outer spheres and its centre point is connected to the control sphere so that the voltage between the outer spheres is equally divided between the two gaps.

- If the generator is now charged to a voltage slightly less than the breakdown voltage of the gaps, the breakdown can be achieved at any instant by applying an impulse of either polarity and of a peak voltage not less than one fifth of the charging voltage to the control sphere.

The operation is explained as follows. The switch *S* is closed which initiates the sweep circuit of the oscillograph. The same impulse is applied to the grid of the thyratron tube. The inherent time delay of the thyratron ensures that the sweep circuit begins to operate before the start of the high voltage impulse.



- A further delay can be introduced if required by means of a capacitance-resistance circuit R_1C_1. The tripping impulse is applied through the capacitor *C*2.

- During the charging period of the generator the anode of the thyratron tube is held at a positive potential of about 20 kV. The grid is held at negative potential with the help of battery *B* so that it does not conduct during the charging period.

- As the switch Sis closed, the trigger pulse is applied to the grid of the thyratron tube which conducts and a negative impulse of 20 kV is applied to the central sphere which triggers the impulse generator.

- Fig below shows a trigatron gap which is used as the first gap of the impulse generator and consists essentially of a three-electrode gap.

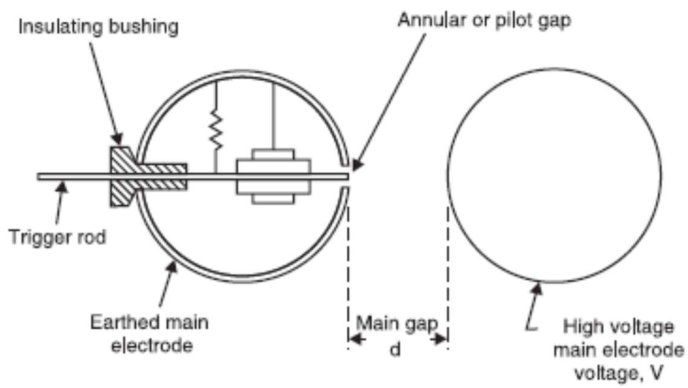
- The high voltage electrode is a sphere and the earthed electrode may be a sphere, a semi-sphere or any other configuration which gives homogeneous electric field. A small hole is drilled into the earthed electrode into which a metal rod projects.

- The annular gap between the rod and the surrounding hemisphere is about 1 mm. A glass tube is fitted over the rod electrode and is surrounded by a metal foil which is connected to the earthed hemisphere.

- The metal rod or trigger electrode forms the third electrode, being essentially at the same potential as the drilled electrode, as it is connected to it through a high resistance, so that the control or tripping pulse can be applied between these two electrodes.

- When a tripping pulse is applied to the rod, the field is distorted in the main gap and the latter breaks down at a voltage appreciably lower than that required to cause its breakdown in the absence of the tripping pulse.

- The function of the glass tube is to promote corona discharge round the rod as this causes photoionisation in the annular gap and the main gap and consequently facilitates their rapid breakdown.



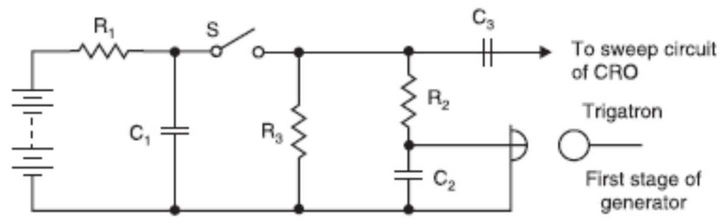
- For single stage or multi-stage impulse generators the trigatron gaps have been found quite satisfactory and these require a tripping voltage of about 5 kV of either polarity.

- The tripping circuits used today are commercially available and provide in general two or three tripping pulses of lower amplitudes. Fig below shows a typical tripping circuit. The capacitor C_1 is charged through a high

- Resistance R_1. As the remotely controlled switch S is closed, a pulse is applied to the sweep circuit of the oscillograph through the capacitor C_3.

- At the same time the capacitor C_2 is charged up and a triggering pulse is applied to the trigger electrode of the trigatron. The requisite delay in triggering the generator can be provided by suitably adjusting the values of R_2 and C_2.

- The residual charge on C_2 can be discharged through a high resistance $R3$. These days lasers are also used for tripping the spark gap.

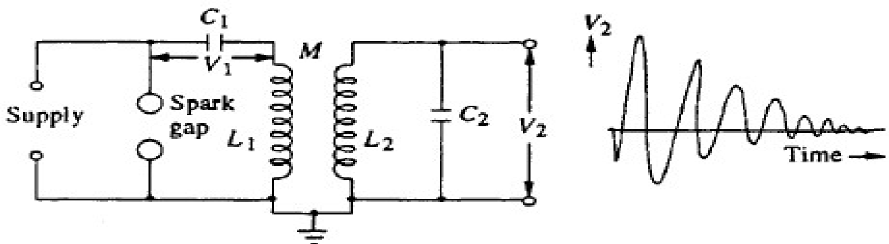


- The trigatron also has a phase shifting circuit associated with it so as to synchronise the initiation time with an external alternating voltage.

- Thus, it is possible to combine high alternating voltage tests with a superimposed impulse wave of adjustable phase angle. The trigatron is designed so as to prevent the overcharging of the impulse capacitors in case of an accidental failure of triggering. An indicating device shows whether the generator is going to fire correctly or not. An additional feedback circuit provides for a safe wave chopping and oscillograph release, independent of the emitted control pulse.

9. What is tesla coil? Derive an expression for damped high frequency oscillations obtained from a tesla coil. Give its advantage (Dec-14)

The commonly used high frequency resonant transformer is the Tesla coil, which is a doubly tuned resonant circuit shown schematically in Fig.. The primary voltage rating is 10 kV and the secondary may be rated to as high as 500 to 1000 kV. The primary is fed from a d.c. or a.c. supply through the condenser Ci. A spark gap G connected across the primary is triggered at the desired voltage *V* which induces a high self-excitation in the secondary



(a) Equivalent circuit (b) Output waveform

. The primary and the secondary windings ($L_1$and L_2) are wound on an insulated former with no core (air-cored) and are immersed in oil. The windings are tuned to a frequency of 10 to 100 kHz by means of the condensers $C_1$and C_2.
The output voltage *V* is a function of the parameters L_1, L_2 C_1, $C_2$and the mutual inductance *M*. Usually, the winding resistances will be small and contribute only for damping of the oscillations. The analysis of the output waveform can be done in a simple manner neglecting the winding resistances. Let the condenser C_1be charged to a voltage $V_1$when the spark gap is triggered. Let a current $i_1$flow through the primary winding *L1* and produce a current $i_2$through $L_2$and C_2
Then,

$$V_1 = \frac{1}{C_1}\int_0^t i_1\,dt + L_1\frac{di_1}{dt} + M\frac{di_2}{dt}$$

And

$$0 = \frac{1}{C_2}\int_0^{t_2} i_2\, dt + L_2 \frac{di_2}{dt} + M\frac{di_1}{dt}$$

The Laplace transformed equations for the above are $\frac{V_1}{s} = \left[L_1 s + \frac{1}{C_1 s}\right] I_1$ +MSI_2

And

$$0 = [MS]I_1 + \left[L_2 s + \frac{1}{C_2 s}\right] I_2$$

Where I_1 and $I_2$are the Laplace transformed values of $i_{1\,,}$ i_2 the output voltage V_1across the condenser C_2

$$V_2 = \frac{1}{C_2}\int_0^{t} i_2\, dt$$

Or transformed equation is

$$V_2(s) = \frac{I_2}{C_2(s)}$$

Where $V_2(s)$ is the Laplace transform ofV_2

The solution for V_2 from the above equation will be

$$N_2 = \frac{MV_1}{\sigma L_1 L_2 C_1}\frac{1}{'\Upsilon_{2^2} - '\Upsilon_{1^2}}[\cos{'\Upsilon_1 t} - cos{'\Upsilon_2 t}]$$

Where

$$\sigma^2 = 1 - \frac{M^2}{L_1 L_2} = 1 - K^2$$

K=coefficient of coupling between the winding L_1 and L_2

$$'\Upsilon_{1,2} = \frac{\omega_{1^2} + \omega_{2^2}}{2} + \sqrt{\left(\frac{\omega_{1^2} + \omega_{2^2}}{2}\right)^2 - \omega_{1^2}\omega_{2^2}(1 - k^2)}$$

$W_1 = \frac{1}{\sqrt{L_1 C_1}}andW_2 = \frac{1}{\sqrt{L_2 C_2}}$

The output waveforms is shown in Fig 6.13.6 The peak amplitude of the secondary voltage V_2 can be expressed as

V_{2max}= $V_2 e\sqrt{\frac{L_2}{L_1}}$

Where

$$e = \frac{2\sqrt{(1-\sigma)}}{\sqrt{(1+a)^2 - 4\sigma a}}$$

$$a = \frac{L_2 C_2}{L_1 C_1} = \frac{\omega_1{}^2}{\omega_2{}^2}$$

A more simplified analysis for the Tesla coil may be presented by considering that the energy stored in the primary circuit in the capacitance C_1 is transferred to C_2 via the magnetic coupling. If W_1 is the energy stored in C_1 and W_2 is the energy transferred to C_2 and if the efficiency of the transformer is T], then

$$W_1 = \frac{1}{2}\eta C_1 v_1{}^2 = (\frac{1}{2} C_2 v_2{}^2)$$

From which $V_2 = V_1 \sqrt{\frac{\eta C_1}{C_2}}$

It can be shown that if the coefficient of coupling *K* is large the oscillation frequency is less, and for large values of the winding resistances and AT, the waveform may become a unidirectional impulse. This is shown in the next sections while dealing with the generation of switching surges.

PROBLEM:1

A Cockcroft-Walton type voltage multiplier has eight stages with capacitances, all equal to 0.05 PF. The supply transformer secondary voltage is 125 kV at a frequency of 150 Hz. If the load current to be supplied is 5 mA, find *(a)* the percentage ripple, *(b)* the regulation, and *(c)* the optimum number of stages for minimum regulation or voltage drop. APRIL/MAY-2015

SOLUTION:

(a) Calculation of Percentage Ripple

The ripple voltage $\delta V = \frac{1}{fc}\frac{(n)(n+1)}{2}$

I=5mA, f=150Hz, C=0.05μF, and n=8,

$\delta V = \frac{5\times10^{-3}}{150\times0.05\times10^{-6}} \times \frac{8\times9}{2}$

% ripple$= \frac{\delta V \times 100}{2nV_{max}} = \frac{24\times100}{2\times125\times8}$

=1.2%

(b) ***Calculation of regulation***

Voltage drop, $\Delta V = \frac{1}{fc}\left(\frac{2}{3}n^3 + \frac{n^2}{2} - \frac{n}{6}\right)$

$= \frac{5\times10^{-3}}{150\times0.05\times10^{-6}}\left[\left(\frac{2}{3}\times 8^3\right) + \left(\frac{1}{2}\times 8\right)\right]$

=248 kV

Regulation $\left(\frac{V}{2nV_{max}}\right) = \frac{248}{2\times8\times125} = \frac{124}{1000}$

=12.4%

(c) **Calculation of optimum number of stages ($n_{optimum}$)**

Since n>5,

$$n_{optimum} = \sqrt{V_{max} f \frac{C}{I}}$$

$$= \sqrt{\frac{125 \times 150 \times 0.05 \times 10^{-6} \times 10^{+3}}{5 \times 10^{-3}}} = 13.69 = 14\, stages$$

PROBLEM:2

An impulse generator has eight stages with each condenser rated for 0.16microF and 125 kV. The load capacitor available is 1000 pF. Find the series resistance and the damping resistance needed to produce 1.2/50}is impulse wave. What is the maximum output voltage of the generator, if the charging voltage is 120kV? APRIL/MAY-2015

SOLUTION :

C_1 , the generator capacitance $=\frac{0.16}{8}$=0.02μF

C_2, the load capacitance =0.001μF

t_1, the time to front =1.2μs

$$= 3.0\, R_1 \frac{C_1 C_2}{C_1 + C_2} \times \frac{1}{3}$$

$$R_1 = 1.2 \times 10^{-6} \frac{0.021 \times 10^{-6}}{0.02 \times 0.001 \times 10^{-12}} \times \frac{1}{3}$$

$$= 420\Omega$$

t_2, time to tail = $0.7(R_1 + R_2)(C_1 + C_2)$

$$= 50 \times 10^{-6} s$$

Or, 0.7(420+R_2)$(0.021 \times 10^{-6)} = 50 \times 10^{-6} s$

$$R_2 = 2981\, \Omega$$

The d.c charging voltage for eight stages is

$$V=8 \times 120 = 960 kV$$

The maximum output voltage is

$$\frac{V}{R_1 C_2 (\alpha - \beta)} \left(e^{-\alpha t 1} - e^{-\beta t 1}\right)$$

Where

$$\alpha = \frac{1}{R_1C_2}\ \beta = \frac{1}{R_2C_1}\ and\ V\ is\ the\ d.c\ charging\ voltage,$$

Substituting for R_1C_1 and R_2C_2

$$\alpha = 0.7936 \times 10^{+6}$$

$$\beta = 0.02335 \times 10^{+6}$$

Maximum output voltage =932.6kV

10.HOW ARE THE WAVE FRONT AND WAVE TAIL TIME CONTROLLED IN IMPULSE GENERATOR CIRCUIT.(NOV-2015)

The most commonly used configurations for impulse generators are the circuits shown in Figs,6.15b and c. The advantages of these circuits are that the wave front and wave tail times are independently controlled by changing either R_1 and R_2 separately secondly the test objects which are mainly capacities in nature from part of C_2

For the configuration shown in fig 6.15 b the output voltage across C_2 is given by

$$V_0(t) = \frac{1}{C_2}\int_0^t i_2 dt$$

Performing Laplace transformation $\frac{1}{C_2 s} I_2(s) = V_0(s)$

Where $i_2$is the current throughC_2.

Taking the current through $C_1$and I_1 its transformed, value as $I_1(s)$,Taking the current through C_1 as i_1 and its transformed value as $I_1(s)$

$$I_2(s) = \left[\frac{R_2}{R_2 + \frac{1}{C_2 s}}\right] I_1(s)$$

$$I_1(s) = \frac{V}{S}\frac{1}{\frac{1}{C_1 s} + R_1 + \frac{R_2 \frac{1}{C_2 s}}{R_2 + \frac{1}{C_2 s}}}$$

Where

$\frac{R_2 \frac{1}{C_2 s}}{R_2 + \frac{1}{C_2 s}}$ Represents the impedance of the parallel combination of R_2 and C_2

Substution of $I_1(s)$ gives

$$V_0(s) = \frac{1}{C_1 s}\frac{R_2}{R_2 + \frac{1}{C_2 s}}\frac{V}{S}\frac{1}{\frac{1}{C_1 s} + R_1 + \frac{R_2\frac{1}{C_2 s}}{R_2 + \frac{1}{C_2 s}}}$$

After simplification and Rearrangement,

$$V_0(s) = \frac{V}{R_1 C_2}\left[\frac{1}{S^2 + \left(\frac{1}{C_1 R_1} + \frac{1}{C_2 R_2} + \frac{1}{C_2 R_1}\right)S + \frac{1}{C_1 C_2 R_1 R_2}}\right]$$

Hence, the roots of the equation,

$$S^2 + \left(\frac{1}{C_1 R_1} + \frac{1}{C_2 R_2} + \frac{1}{C_2 R_1}\right)S + \frac{1}{C_1 C_2 R_1 R_2}$$

And found from the relations

$$\alpha + \beta = -\left(\frac{1}{C_1 R_1} + \frac{1}{C_2 R_2} + \frac{1}{C_2 R_1}\right)$$

$$\alpha\beta = \frac{1}{C_1 C_2 R_1 R_2}$$

Taking inverse transform of $V_0(s)$ gives

$$V_0(s) = \frac{1}{R_1 C_2(\alpha - \beta)}[\exp(-\alpha t) - \exp(-\beta t)]$$

Usually $\frac{1}{C_1 R_1}$ and $\frac{1}{C_2 R_2}$ will be much smaller compared to $\frac{1}{R_1 C_2}$

Hence, the roots may be approximated as

$\alpha = \frac{1}{R_1 C_2}$ And $\beta = \frac{1}{R_2 C_1}$

Following a similar analysis, it may be shown that the output waveform for the circuit configuration of fig.5.15c will be

$$V_0(t) = \frac{V C_1 R_2 \alpha\beta}{\beta - \alpha}[\exp(-\alpha t) - \exp(-\beta t)]$$

Where α and β are the roots of the Eq(6.19). The approximate values of α and β given by Eq.(6.21) are valid for this circuits also.

The equivalent circuits given in fig 6.15d is a combination of the configurations of fig. 6.15b and fig.6.15c. The resistance R_1 is made into two parts and kept on either side of R_2 to give greater flexibility for the circuits.

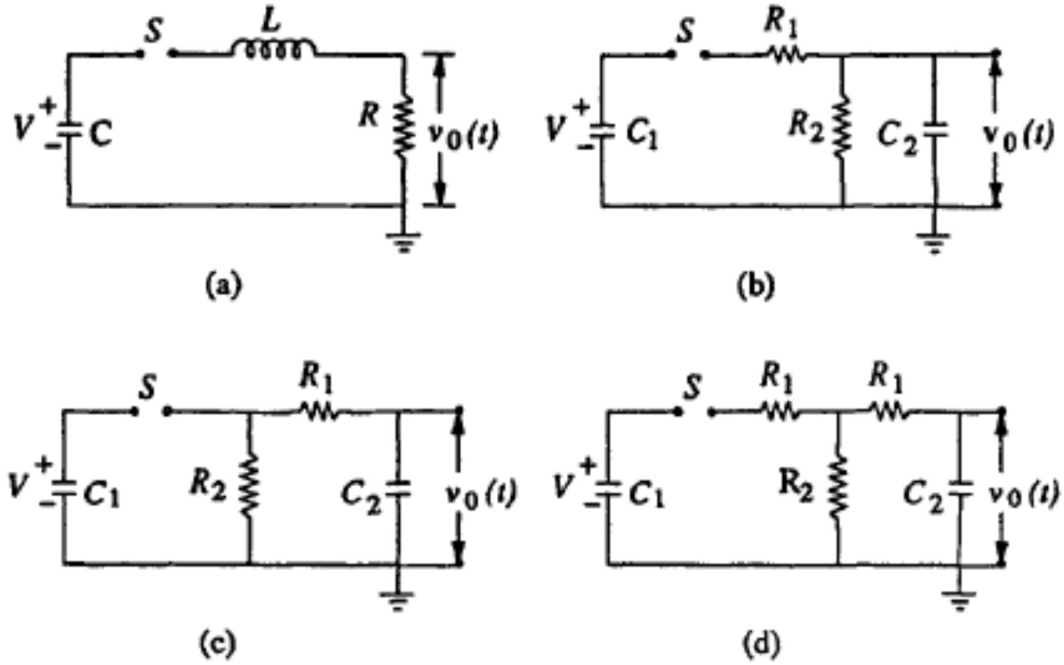


Fig. 6.15 Circuits for producing impulse waves

UNIT-4

1. ***Explain briefly different types of DC voltage measurements?NOV- 2011,May-2013,2015 (OR)***

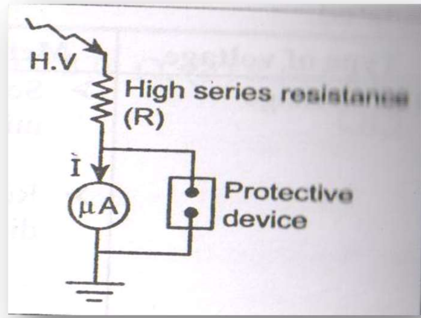
Describe the construction, principle of operation of a generating voltmeter and give its application and limitations.(May-2014)

DC voltage measurements types:

- Series resistance micro ammeter.
- Resistance potential divider.
- Generating voltmeters.
- Sphere and other spark gaps.

High ohmic series resistance with micro ammeters:

- A very high resistance i.e., few hundreds of mega ohms is connected in series with a micro ammeter (μA) is shown.
- A protective device like paper gap, a neon glow tube or zener diode with a suitable series resistance is connected across the micro-ammeter. It is used to protect the meter against high voltage (H.V) occurs due to the failure of high series resistance R or flashover.



<u>The resistance value of R is chosen such that:</u>

- ✓ A current of 1 to 10 μA is allowed for one full-scale deflection.
- ✓ It consists of large number of wire wound resistors in series.
- ✓ To provide corona free termination.
- ✓ Temperature coefficient < 10^{-4} /·C , so element is made up of carbon-alloy.
- ✓ To maintain very good temperature stability. So, resistance chain is placed in airtight, transformer oil filled PVC tube for 100 kV operations.

<u>Limitations in series resistance design:</u>

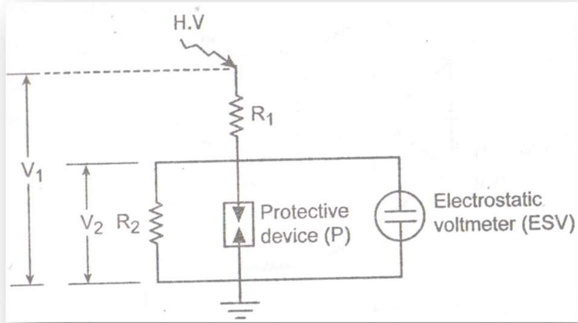
- ✓ Power dissipation and source loading
- ✓ Temperature effects and long time stability.
- ✓ Voltage dependence of resistive elements.
- ✓ Sensitivity to mechanical stresses.

<u>Operation:</u>

- Current I flowing through resistance R is measured using micro ammeter.
- Voltage or the source V=IR
- If any overvoltage or flashover occurs, the protective device will come into action to bypass the current.
- Series resistance meters can operate up to 500kV (D.C)
- Accuracy = ±0.2%

<u>ii)Resistance potential dividers:</u>

A resistance potential divider for D.C. voltage measurement with an electrostatic voltmeter as shown in fig



Let V_2 be the d.c. voltage across resistance R_2 (low voltage)

We know, $V_2 = v_1 * \frac{R_2}{R_{1+R_2}}$

High voltage magnitude, $V_1 = \frac{R_{1+R_2}}{R_2} . V_2$

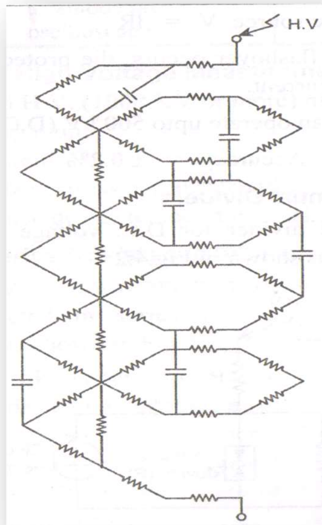
<u>Sudden voltage changes occur during transient period due to:</u>

- ✓ Switching operation
- ✓ Flashover of test objects.
- ✓ Damage may occur to the diverter elements due to stray capacitance across the elements and due to ground capacitance.

<u>Transient voltages can be avoided by:</u>

- ✓ Connecting voltage controlling capacitor across the element.
- ✓ Corona free termination,

For linearizing transient potential distribution, a series resistor is connected with a parallel capacitor as shown



The potential divider accuracy corresponding to the voltage is given in the table

Voltage	Accuracy
Upto 100 Kv	0.05 %
Upto 300 Kv	0.1 %
Upto 500 Kv	0.5 %

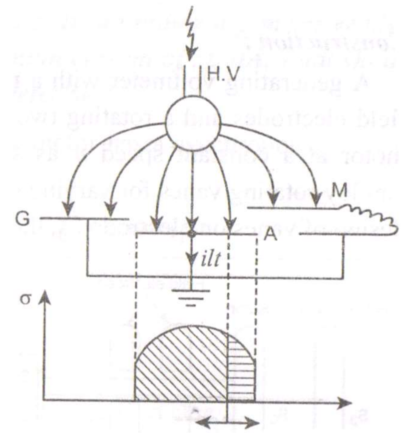
iii)Generating voltmeter:

- ✓ In H.V. D.C. measurement, the generating principle is used when source loading is not permitted or when direct connection to the high voltage source is to be avoided
- ✓ A generating voltmeter is a variable capacitor electrostatic voltage generator which generates current proportional to the voltage to be measured.
- ✓ It provides loss free measurement of D.C. and A.C. voltages.
- ✓ It is driven by a synchronous motor and does not absorb power or energy from the voltage measuring source.

Principle of operation:

- ✓ High voltage electrode excites the electrostatic field within a highly insulating medium (gas or vacuum) and ground potential.
- ✓ The earthed electrodes are subdivided into a sensing or pick-up electrode (A), guard electrode (G) and movable electrode (M), all are kept at same potential. Every field line ending at these electrodes binds free charges.

✓ For measuring purpose, surface area of electrode A is considered. Let q be the charge stored.



$$i = \frac{dq}{dt} = \frac{d(VC)}{dt}$$

$$= V.\frac{dC}{dt} + C.\frac{dV}{dt}$$

Consider the electrode M is fixed or for D.C. voltage,

$$\frac{dV}{dt} = 0; i = V\frac{dC}{dt}$$

If the capacitance C varies between limits C_0 and $(C_0 + C_m)$, then

$$C = C_0 + C_m \sin \omega t$$

$$i = V\frac{dC}{dt} = V \,.\, \mathrm{Cm} \cos \omega t \times \omega$$

$$= V \,.\, C_m\, \omega \cos \omega t = i_m \cos \omega t$$

Where, $i_m = V \,.C_m\, \omega$,

$$I_{r.m.s} = \frac{V\mathrm{Cm}\;\omega}{\sqrt{2}}$$

If the capacitance varies linearly with time and reaches its peak value C_m in time $\frac{Tc}{2}$ and vice versa.

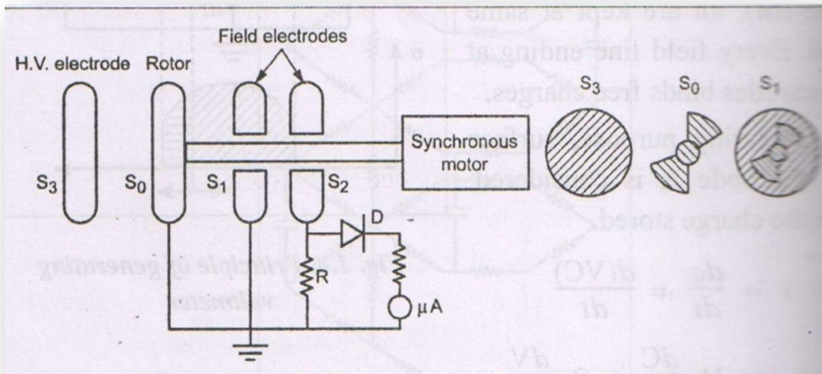
$i = V.\, C_m \,.\, f = V.\, C_m \,.\frac{2}{60}\, n = \frac{n}{30} V.\, C_m$

[let n r.p.m be the synchrounous speed , $T_c = \frac{60}{n}$]

Construction:

- A generating voltmeter with a rotating cylinder consists of two exciting field electrodes and a rotating two pole rotor (S_0) driven by a synchronous motor at a constant speed n as shown.

- Generating voltmeters employ rotating vanes for varying capacitance between S_2 and S_3.By proper design of vanes on electrodes S_0, the capacitance can be varied.H.V. source is connected to a disc electrode S_3 and is kept at a fixed distance from all other electrodes.



Operation:

- ✓ The generated A.C. current through the resistance R is rectified by using diode and read by a moving coil micro ammeter. If the current is small, an amplifier may be used before the current is measured.
- ✓ This instrument is calibrated using potential divider or sphere gap.
- ✓ Generating voltmeters can be used to measure wide range of voltages.

Advantages:

- ✓ Scale is linear and extension of voltage is easy.
- ✓ It can measure wide range of voltages.
- ✓ Source leading is zero.
- ✓ There is no direct connection to H.V. electrode.

Limitations:

- ✓ Need calibration.
- ✓ Careful construction is needed.
- ✓ Any disturbances due to position and mounting of the electrodes make the calibration invalid.

2) ***Explain briefly different types of AC voltage measurement?APR-MAY 2011,May-2013***

(or)

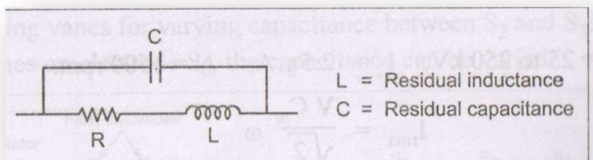
With neat sketch explain in detail the various methods used to measure the RMS and peak values of high AC voltages? APRIL/MAY-2015

i) Series impedance Voltmeter :

Problems Involved in Pure resistance Used for A.C. Voltage Measurement

- Power losses more.
- Variations of resistance vary the temperature. So it is problem.
- Residual inductance of the resistance gives rise to an impedance different from its ohmic resistance.

A simplified lumped parameter equivalent circuit of a high ohmic resistance R is given in Fig.



R+j$X_L$is connected in parallel with -jX_C.

$$Z = \frac{(R+j\omega L)X\frac{1}{j\omega C}}{R+j\omega L+\frac{1}{j\omega C}} = \frac{R+k\omega L}{1-\omega^2 LC+j\omega CR}$$

If ωL and $\omega C$are small compared to R.

$$Z = \frac{R+j\omega L}{1+j\omega C}$$

Multiplying by complex conjugate of the denominator to the numerator and denominator, we get

$$Z = \frac{R+j\omega L}{1+J\omega C}\frac{(1-j\omega C\ \ )}{(1-j\omega C\ \ )}$$

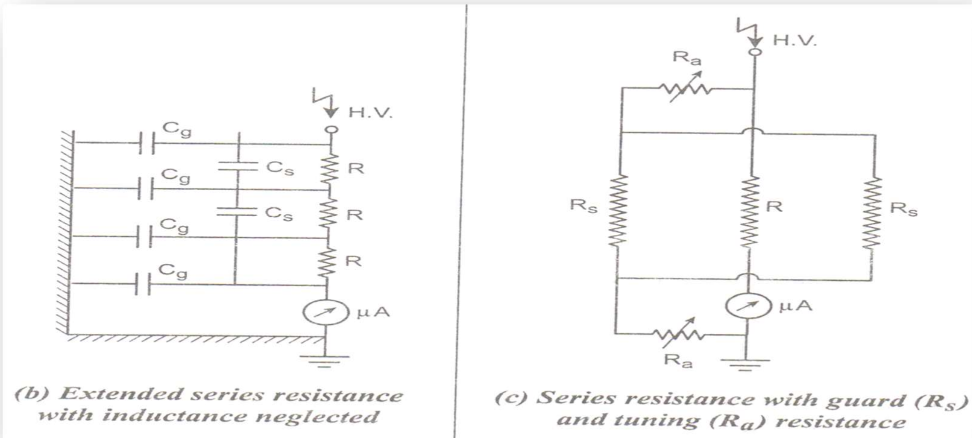
$$= \frac{R+j\omega L-j\omega R^2C+\omega^2 RLC}{1+\omega^2 R^2C^2}$$

$$= R[\ 1 + \frac{j\omega L}{R} - j\omega CR\ ] = R\ [\ 1 + j\ (\frac{\omega L}{R} - \omega CR)\ ]$$

Phase angle = tan Φ = $\frac{\omega L}{R} - \omega CR$

Extended Series Resistance Voltmeter:

The extended series resistance neglecting inductance is as shown in Fig b



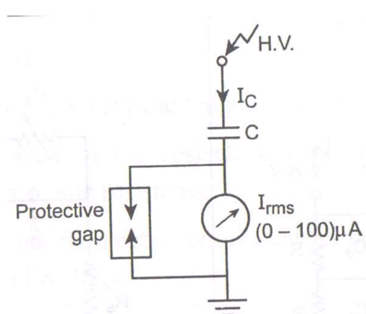
(b) Extended series resistance with inductance neglected

(c) Series resistance with guard (R_s) and tuning (R_a) resistance

- ✓ For calculating the effective resistance, the resistor unit can be taken as the equivalent circuit of transmission line and neglecting inductance. The ground capacitance C_g or stray capacitance influences current flowing in the unit, so the meter reading has error.
- ✓ The series resistance with guard and tuning resistance is as shown in Fig in c
- ✓ Stray and ground capacitance effects can be removed by shielding the resistor R by a second surrounding spiral R_s. $R_s$is connected across R and does not contribute the current through the instrument.
- ✓ Tuning resistance R_a is tuned to adjust the shielding resistor end potentials with respect to the actual measuring resistor. Therefore minimum phase angle can be provided between shield and the measuring resistors.

Series Capacitance Voltmeter:

A series capacitor is used instead of a resistor for A.C. high voltage measurements as shown in Fig.



Let C be the capacitance of the series capacitor.

Let V be the applied A.C. high voltage.

Let ω be the angular frequency.

If A.C. voltages are not pure sinusoidal, it contains harmonics. If an A.C. voltage contains harmonics, error in the measurement occurs due to changes in series impedance.

$V_{RMS} = \sqrt{V_1^2 + V_2^2 + \cdots \ldots \ldots \ldots \ldots + V_n^2}$

Where, V_1 = RMS value of fundamental.

V_2 = RMS value of second harmonic.

V_3 = RMS value of third harmonic.

V_n= RMS value of n^{th} harmonic.

The currents due to V_1, V_2 , ………,V_n are

$I_1 = \omega C V_1$

$I_2 = 2\ \omega\ C\ V_2$

$I_n = n\ \omega\ C V_n$

$I_{rms} = \omega\ C\ \sqrt{V_1^2 + (\ 2V_2)^2 + \ \ldots (nV_n)^2}$

$I_{rms} = \omega\ C \sqrt{V_1^2 + \ 4V_2^2 + \ \ldots \ldots . + n^2 V_n^2}$

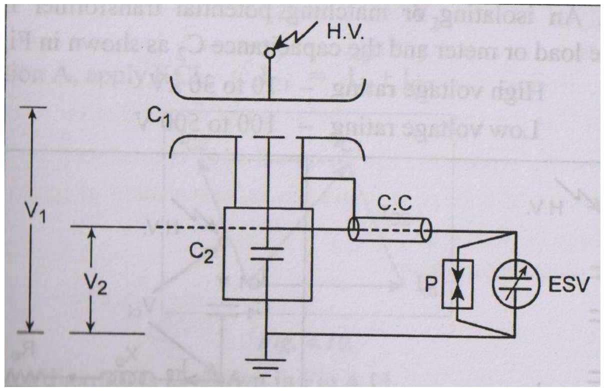
- ✓ Series capacitance voltmeters were used with cascade transformers for measuring rms values upto 1000KV.
- ✓ A series capacitance was formed between high voltage terminal of the transformer and ground. A rectifies ammeter is used as an indicating instrument, which reads rms value of high voltage A.C.

ii)Capacitance Potential Divider:

Capacitance potential divider can be used to eliminate errors due to harmonics with an electrostatic voltmeter or a high impedance meter. It requires high impedance meter like electrostatic voltmeter.

Construction:

A standard compressed air or condensed gas is used for C_1 and the large value capacitor C_2 has insulating media lime mica, paper, etc. C_1 is a three terminal capacitor and is connected to C_2 through a shielded cable. If long cable is connected, the capacitance value is taken into account. To avoid stray capacitance, C_2 is shielded in a box. A protective device is connected across electrostatic voltmeter. Capacitance potential divider is as shown in Fig.



Operation:

- When high voltage source is applied, it can be measured using electrostatic voltmeter. Some drop in voltage occurs due to the capacitanceC_1, C_2, and also the capacitance of the cable and wire.
- Applied voltage V_1can be calculated from the electrostatic voltmeter V_2 reading as,

  $V_{1=} V_2 \left[\frac{C_1 + C_2 + C_m}{C_1}\right]$

Where, C_m = Capacitance of meter and cable.

C_1 = Standard compressed gas h.v.

C_2 = Standard low voltage condenser.

V_2 = Meter rating.

P = Protective gap   C.C = Connecting cable.

Capacitance Voltage Transformer (CVT):

Capacitance voltage transformer is a device used in power system to measure voltages. It consists of capacitor divider with a suitable matching or isolating potential transformer tuned for resonance condition.

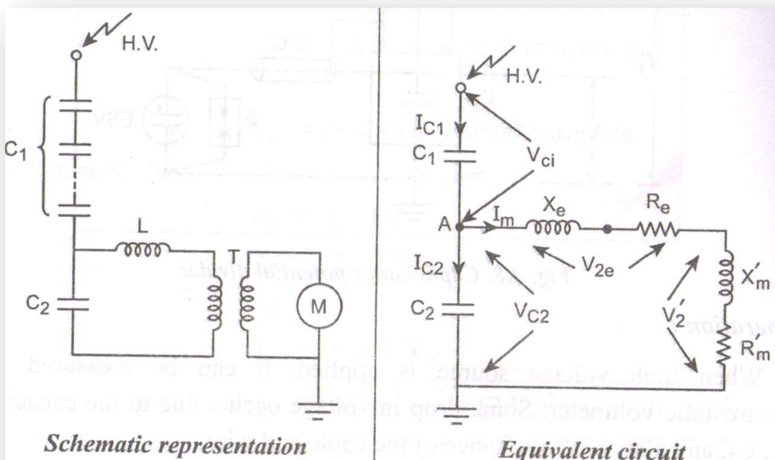
It can be connected to low impedance devices like a pressure coil of wattmeter or a relay coil. It can supply a load of few volt amperes.

Construction:

Capacitance divider has two sections C_1 and C_2, C_1 is made up of few units of high voltage condensers and has the total capacitance of about 1000 pico farad. An isolating or matching potential transformer is connected between the load or meter and the capacitance C_2 as shown in Fig.

High voltage rating – 10 to 30 KV

Low voltage rating – 100 to 500 V



Operating:

Choke L is connected to the primary side of potential transformer used to bring resonance condition or purely resistive by tuning.

Resonance condition is, $X_L = X_C$

$$\omega(L + L_T) = \frac{1}{\omega(C_1 + C_2)}$$

Where L = Inductance of the choke.

L_T = Equivalent inductance of the transformer referred to H.V. side.

Phasor Diagram:

The meter is taken as a resistive load and X'_m is neglected.

Let V'_2 be the voltage across the meter.

$V'_2 = I_m R'_m$

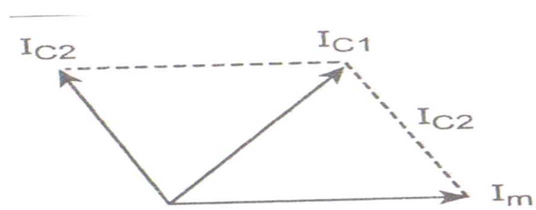
$V_{C2} = V'_2 + V_{2n} = V'_2 + I_m\ (R_e +\ X_e\ )$

Where R_e , X_e is the resistance and leakage reactance of P.T.

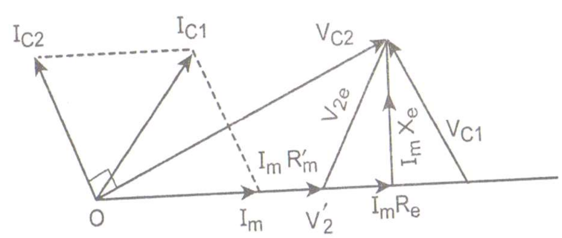
Input voltage V_1= V_{C1} + V_{C2} and inphase with V'_2.

Voltage ratio, a= $\frac{V_1}{V_2} = \frac{V_{C1}+ V_{2e}+ V'_2}{V'_2}$

At junction A, apply KCL, $\underset{I_{C1}}{\rightarrow} = \vec{I}_{C1} = \vec{I}_m + \vec{I}_{C2}$



The vector diagram is as shown in Fig.



Draw reference line V'_2. Mark $V'_2 = I_m R'_m$neglecting $i_m X'_m$. From V'_2, mark $I_m R_e$ in the same line. Draw perpendicular line for $I_m X_e$. Join from 0 gives V_{C2} by 90°. The vector sum of $I_m and I_{C2}$gives I_{C1}. From V_{C2}, draw perpendicular line for I_{C1}, which is V_{C1}i.e., I_{C1} leads $V_{C1}$by 90°.

Advantages:

- Design is simple.
- Installation is easy.
- CVT can be used as a voltage measuring device for meters.

- In power line carrier communications, CVT can be used.
- It provides isolation between H.V. terminal and low voltage metering. So it can be used for relaying purposes.
- Voltage distribution is independent of frequency.

Disadvantages:

- Voltage ratio is susceptible to temperature variations.
- In the presence of capacitance and choke, the problem of ferro resonance occurs in power system.

iii) Electrostatic Voltmeter:

Principle:

If the electric field is produced by the voltage V between a pair of parallel plate disc electrodes, the force F on an area A of the electrode, for which the field gradient E is the same across the area and perpendicular to the surface.

Attractive force between the

$$\text{Parallel plate electrodes } F = \left|\frac{-\partial W}{\partial s}\right|$$

$$= \left|\frac{\partial}{\partial s}\left(\frac{1}{2}CV^{2}\right)\right|$$

$$= \left|\frac{1}{2}V^{2}\frac{\partial C}{\partial s}\right| \quad = \left|\frac{1}{2}V^{2}\frac{\partial}{\partial s}\left(\frac{\varepsilon_{0}A}{d}\right)\right|$$

$$= \frac{1}{2}\varepsilon_{0}V^{2}\frac{A}{d^{2}}$$

V = Applied voltage between plates.

C = Capacitance between the plates

A = Area of cross section of the plates

D = Distance between the plates

ε_0 = Permittivity of the insulating medium.

Since the two plates are oppositely charged, there is attraction force between them.

Measured of voltage = Mean of the force

$$= \frac{1}{T}\int_0^T F(t).dt = \frac{1}{T}\int_0^T \frac{1}{2}\varepsilon_0 \frac{V^2(t)A}{d^2} dt$$

$$= \frac{1}{2}\varepsilon_0 \frac{A}{d^2}.\frac{1}{T}\int V^2(t)dt = \frac{1}{2}\varepsilon_0 \frac{A}{d^2} V_{rms}^2$$

In electrostatic voltmeters, one of the plates is fixed and the other is movable. The force on the plate can be measured by:

- Suspension of moving electrodes on one arm of a balance.
- Suspension of the moving electrode on a spring.
- Pendulous suspension of the moving electrode.
- Torsonal suspension of the moving electrode.

For high voltage measurements, a small displacement of one of the electrodes by a fraction of a millimeter to a few millimeters is sufficient.

As F∝ V_{rms}^2 , The meter can be used to measure both A.C. and D.C. voltages.

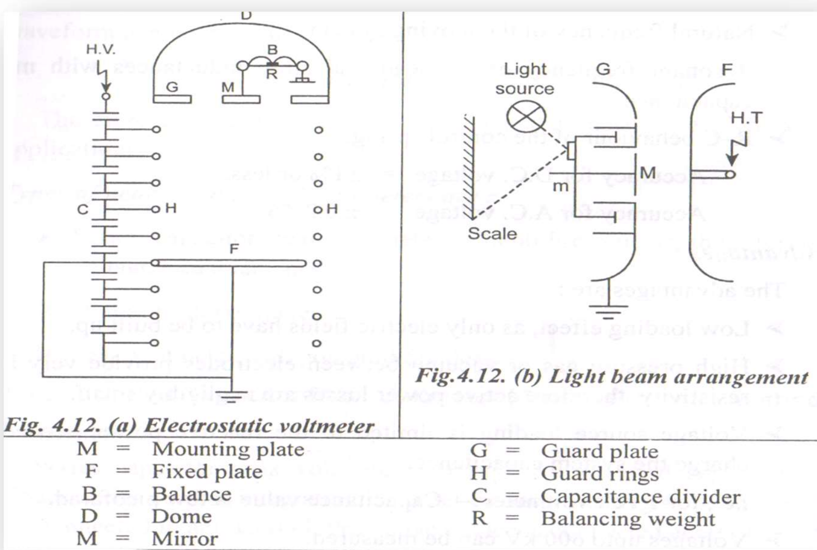


Fig. 4.12. (a) Electrostatic voltmeter

Fig.4.12. (b) Light beam arrangement

M = Mounting plate
F = Fixed plate
B = Balance
D = Dome
M = Mirror
G = Guard plate
H = Guard rings
C = Capacitance divider
R = Balancing weight

Construction:

Absolute electrostatic voltmeter is as shown in Fig. (a).

It consists of parallel plate disc electrodes. The moving disc M forms the central core of the guard ring G, which has the same dimension as that of fixed plate F. The guard rings are used to make the electric field uniform in the central region and to avoid corona. The controlling torque is provided by a balancing weight (B). The cap or dome D encloses a balance and a moving.

Operation:

The balance beam carries a mirror which reflects a beam of light. The movement of the moving electrode is amplified through optical arrangement as shown in Fig. (b)

To measure the given voltage with precision, the disc diameter is to be increased, and the gap distance between the electrodes is to be minimized. As the gap distance is more, the uniformity of electric field is maintained by guard rings H placed between electrodes F and M by using capacitance divider (C).

The upper frequency limit for A.C. application is determined from:

- Natural frequency of the moving system.
- Resonant frequency of the lead and stray inductances with meter capacitance.
- R-C behavior of the control spring.

Accuracy for D.C. voltage = $\pm 1\%$ or less.

Accuracy for A.C. voltage = $\pm 0.25\%$

Advantages:

The advantages are:

- Low loading effect, as only electric field have to be built up.
- High pressure gas or vacuum between electrodes provide very high resistivity, therefore active power losses are negligibly small.
- Voltage source loading is limited to the reactive power needed to charge the system capacitance.

i.e., for 1 volt voltmeter – Capacitance value is few picofarad.

- Voltages upto 600KV can be measured.

Disadvantages:

For a constant distance d, F $\propto V_{rms}^2$, the sensitivity is small. This can be overcome by varying the gap distance d in appropriate steps.

Restriction of electrostatic voltmeters:

- ✓ For D.C. voltage measurements, the electrostatic voltmeters compete with resistor voltage dividers or measuring resistors, as the very high impedance is not necessary

- ✓ For A.C. voltage measurements, the R.M.S. value is either of minor importance for dielectric testing or capacitance voltage dividers. Thus use of electrostatic voltmeters is restricted.

3) Explain briefly various types of peak reading voltmeters?

Necessity of peak value instrument for an AC waveform

In sinusoidal waveform,

Peak value of an A.C. waveform = RMS value * $\sqrt{2}$

But to obtain the maximum dielectric strength of insulating solids, the waveform is not sinusoidal.

Peak value RMS value $\neq * \sqrt{2}$

Therefore a separate peak value instrument is needed in high voltage applications.

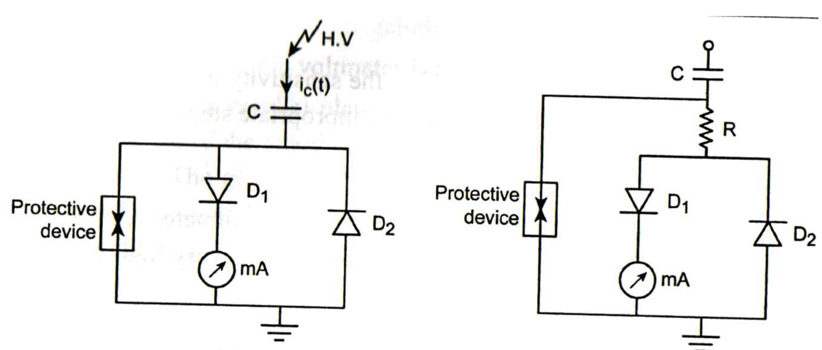
Types of peak reading A.C. voltmeters are:

- Series capacitor peak voltmeter (Chubb- Frotscue method for peak voltage measurement.)
- Digital peak voltmeter.
- Peak voltmeter with potential dividers.

i) Explain Series capacitor peak voltmeter (Chubb- Frotscue method for peak voltage measurement.(Dec-14)

Construction:

Series capacitor peak voltmeter consists of a standard capacitor, two diodes and a current integrating ammeter as shown in fig The diodes are connected in antiparallel.Protective device is connected across the diode to protect the equipment.



(a) (b)

Operation:

When a sinusoidal voltage source is connected to a capacitor, charging current proportional to the voltage to be measured flows is given by,

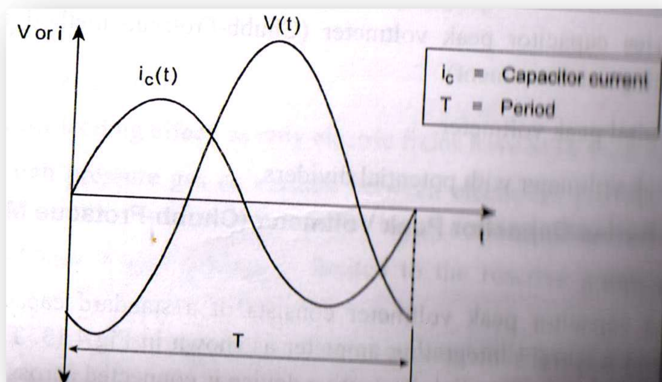
$I = C\int_0^t V dt = j\omega CV$

Where ω= angular velocity,

V= rms value of voltage.

I = D.C. current read by the mili ammeter

- During positive half cycle, diode D_2 conducts and during negative half cycle, diode D_1 conducts and ;used to rectify the A.C. current.
- Wave form is suitable sinusoidal A.C. only
- i.e., both half cycles are symmetrical and equal. Ammeter reads the mean value of current and voltage drop across the diodes (1 v for Si) can be neglected.



- When the waveform is not sinusoidal, the peak value may occur more than once in a half cycle as shown.
- Standard A.C. voltages for testing should not have any harmonics.
- But A.C. voltages for testing should have pre-discharge currents, causing very short duration voltage drops which introduce error in meter reading.
- This problem can be overcome by introducing a damping resistance R in series with capacitor and diode circuit as shown.

% Error due to resistance $\frac{\Delta V}{V} = \frac{V - V_m}{V}$ = (1- $\left(1 - \frac{1}{1+\omega^2 C^2 R^2}\right)$

Where, V = actual value.

V_m = measured value.

Errors occur due to:

- Imperfect rectifiers,
- Non-sinusoidal voltage, waveform, etc.

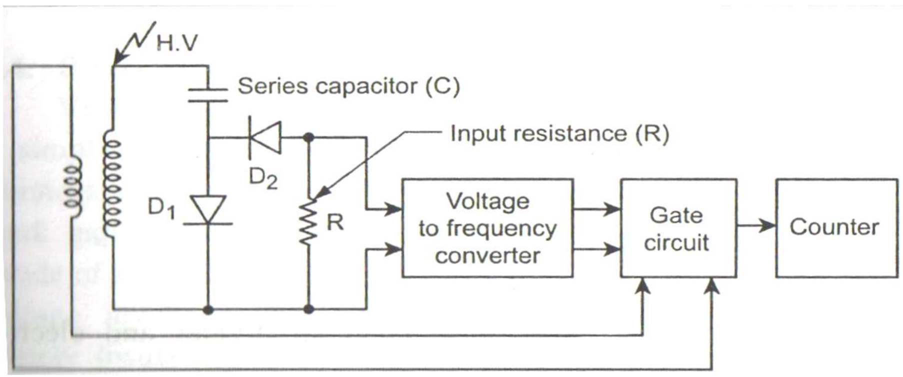
Advantages:

When sinusoidal waveform is used, the measurement is accurate and used for the calibration of the other peak voltage measuring devices.

ii)Digital peak voltmeter:

Construction:

- ✓ A digital peak voltmeter is as shown.in fig.
- ✓ A.C. voltage is given to the capacitor and diode circuit. Then output of the rectifier is a voltage signal proportional to the rectified charging current and is given to the voltage to frequency converter.
- ✓ Now analog voltage signal is converted into a proportional medium frequency f_m.Then the output is given to gate circuit which was controlled by a.c. power frequency (f).The frequency $\frac{f_m}{f}$ is measured in gage circuit and is given to counter.
- ✓ The counter opens for an adjustable number of periods $\Delta t = \frac{P}{f}$Where, P = instrument constant.Number of impulse counted n = $\Delta t \,.\, f_m = \frac{P}{f} f_m$



Where,

Voltage to frequency conversion factor, A = $\frac{f_m}{R i_m} = \frac{f_m}{R\, 2\, V_{mfC}}$

$$= \frac{f_m}{f} \cdot \frac{1}{2\, R V_{mC}}$$

$$n = 2\ PC\ V_m\ A\ R$$

Where, i_m = Rectified current through R

$= \frac{V_m}{X_c} = V_m\, 2\, \boldsymbol{\Pi} fC \propto 2\ V_m fC$

By choosing proper value of R and P, voltage can be measured immediately.

Accuracy < 0.35%

Merits:

- ✓ Scale in linear and extension
- ✓ Measure wide range
- ✓ Source loading is zero.

Demerits:

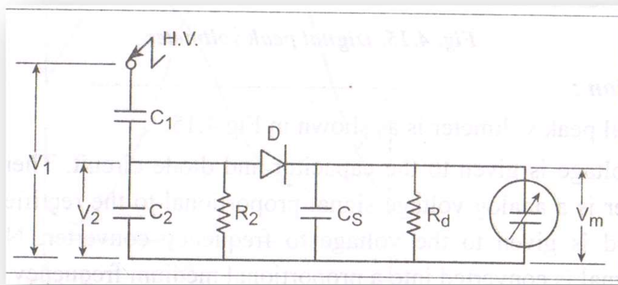
- ✓ Need calibrations

- ✓ Careful construction is needed

iii)Peak voltmeters with potential dividers:

- ✓ Peak voltmeter with a capacitance potential divider and electrostatic voltmeter is as shown in fig
- ✓ Diode D is used for rectification.The voltage across C_2 is used to charge the capacitor C_3.
- ✓ R_d is the discharge resistor used to permit the variation of V_m when V_2 is reduced.

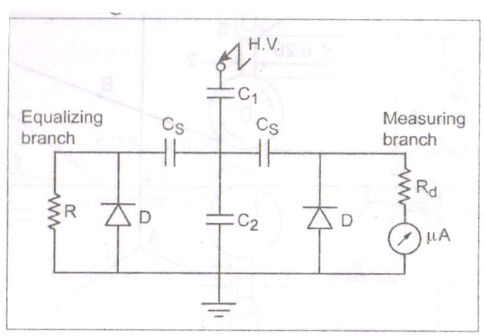
Electrostatic voltmeter is used as an indicating meter.



Voltage across the capacitor $C_s \propto$ Peak value to be measured.
Discharge time constant = $C_s R_d \approx 1$ to 10 sec
This gives discharge error, which depends on frequency of the supply.

Modified peak voltmeter

For compensating discharge error, the circuit can be modified as shown in fig
The indicating instrument used is microammeter.The circuit has equivalizing and measuring branches.



4)Explain various spark gap measurement of high D.C., A.C and impulse voltages (Peak values)?NOV-DEC 2011,May-2013,DEC-2013,Dec-14,15

- ✓ Spark gaps insulated by atmospheric air can be used to measure the amplitude of a voltage above 10 kV.Voltage level can be determined by a fast transition from either completely insulating or still higher insulating state of a gap to the high conducting arc state.

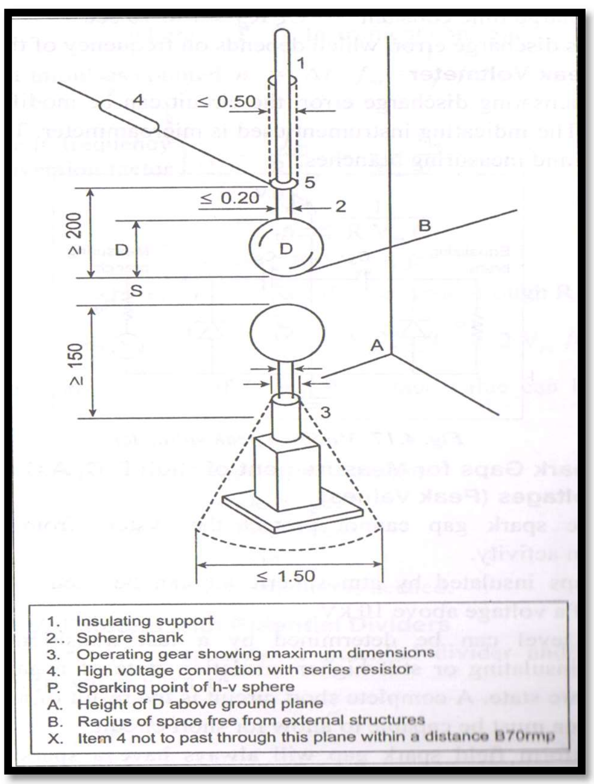
- ✓ A complete short circuit is the result of a spark and the voltage source must be capable to allow for short circuit.
- ✓ **A** uniform field spark gap will always have a spark over voltage within a known tolerance under constant atmospheric conditions.
- ✓ Measurements are reliable only for the certain gap configuration.
- ✓ Accuracy is less.

Advantages:

- High reliability
- Simplicity.
- More accurate if electronic circuits are applied for measurements.

i)Sphere gap measurements:

Sphere gaps are used for the measurement of voltage (D.C, A.C, impulse) and radio frequency A.C. peak voltage if the distance of the gap is known.A spark over voltage 30 kV (peak) at 1 cm spacing in air at 20°C and 760 torr pressure occurs for a sphere gap.



Construction:

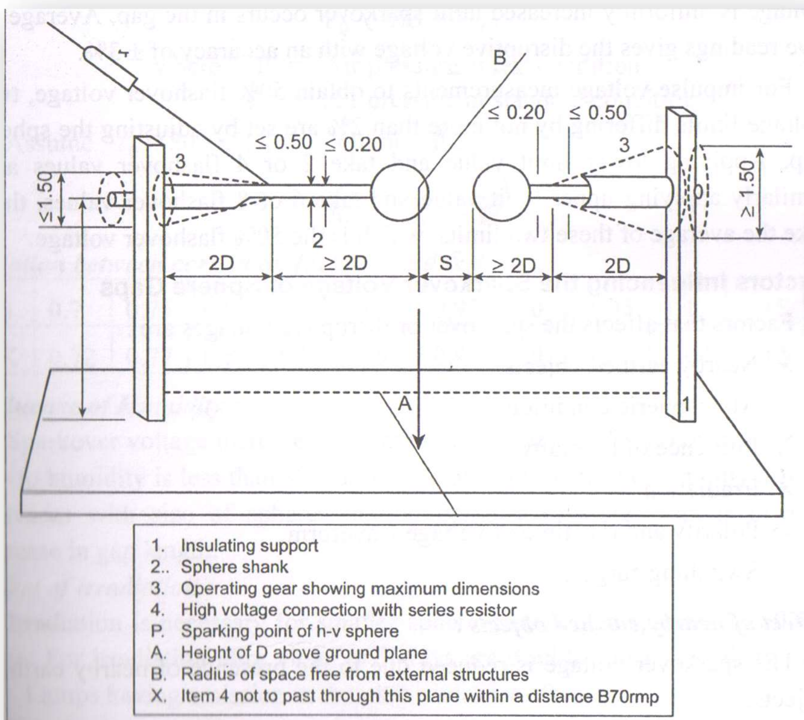
- Sphere gaps are arranged either vertically with lower sphere grounded or horizontally with both spheres connected to the source and one sphere grounded.Spheresare made us of copper, aluminum or brass.
- Spheres have identical size and shape, uniform surface, free from dust smooth

- Sphere gaps are made with two metal spheres of identical diameters with their shanks, operating gear, and insulator support dimensions are as shown in fig

- A series resistance is connected outside the shanks at a distance of 2D away form sparking point to limit the breakdown current and to suppress unwanted oscillations I n the source voltage when breakdown occurs.

- Value of resistance = 0.1 to 1 MΩ for D.C and A.C power frequency voltages.

- Value of resistance ≯500Ω for impulse voltage.



Sphere shanks should be in line and the shanks of the high voltage sphere should be free from sharp edges or corners.

Diameter of shank ≯0.2D

Irradiation of sphere gap is needed when measurements of voltages < 50 kV made with sphere gaps of 10 cm diameter of less. Irradiation may be obtained from a quartz tube mercury vapor lamp of 40 W rating.

Working:

- The voltage to be measured is applied between the two spheres and the distance of spacing S between them gives a measure of the spark over voltage.
- The ability to respond to peak values of voltages, if the duration of the peak region is not too short in time (1 – 3 μsec).
- This lag time is required for an electron to initiate electron avalanche and streamer breakdown to form spark.The gap distance is provided in such a way that no predischarge or corona occurs before breakdown.
- For D.C. voltage and A.C. peak voltage measurements, the applied voltage is uniformly increased until spark over occurs in the gap.Average of five readings gives the disruptive voltage with an accuracy of ±3%
- For impulse voltage measurements to obtain 50% flashover voltage, two voltages limits differing by not more than 2% are set by adjusting the sphere gap.

- Applying lower limit value and take 2 or 4 flashover values and similarly applying upper limit value and take 6 or 8 flashover values, then take the average of these two limits, which is the 50 flashover voltages.

Factors influence with the spark over voltage of sphere gaps:(NOV/DEC-15)

Factors that affects the spark over or disruptive voltages are(Dec-14)

- Nearby earthed objects.
- Atmospheric conditions.
- Influence of humidity.
- Irradiation.
- Polarity and rise time of voltage waveform.
- Switching surges.

Effects if nearby earthed objects:

The spark over voltage is reduced due to the presence of nearby earthed objects.

Voltage reduction ΔV = m log $\left(\frac{B}{D}\right)$ + C

Where, B= diameter of earthed enclosing cylinder.

D = diameter of the spheres.

S = gap distance between spheres.

m, C = constants.

For $\frac{S}{D} \leq 0.5$, $\frac{B}{D} \geq 0.8$, percentage reduction = 2%

For $\frac{S}{D} = 1.0$, $\frac{B}{D} \geq 1.0$, percentage reduction = 3%

Reduction voltage is within accuracy limit when $\frac{S}{D} < 0.6$

Effect of atmospheric condition:

Actual air density during measurements differs due to temperature and pressure variations. So spark over voltage depends on air density factor.

Spark over voltage $V = K\ V_0$

Where, K = correction factor related to air density factor

V_0 = spark over voltage under standard temperature and pressure.

$\delta = \frac{P}{P_0}\left(\frac{273+\ t_0}{273+T}\right)$

Where, P = air pressure at test condition.

P_0 = air pressure at standard condition.

Assume $t_0 = 20℃$, $P_0 = 760$ torr, then

$\delta = \frac{P}{P_0}\left(\frac{293}{273+T}\right)$

Relation between correction factor K and δ:

δ	**0.7**	**0.75**	**0.8**	**0.85**	**0.9**	**0.95**	**1.0**	**1.05**	**1.1**	**1.15**
K	0.72	0.77	0.82	0.86	0.91	0.95	1.0	1.05	1.09	1.12

Influence of humidity:

Spark over voltage increases with humidity. Increase of spark over voltage due to humidity is less that 3%. So it may be neglected. The humidity effect increases with size of spheres, partial pressure of water vapour in air, increase in gap length.

Effect of irradiation:

Irradiation is necessary for smaller sphere gaps of gap spacing less than 1 cm. for irradiation ultra violet or X-rays are used to ionize the air int the gap.

Lamps having emission in the ultra violet are efficient.

Effect of polarity and waveform:

Spark over voltages of positive and negative impulse are different.

For D.C.,

Positive minus negative voltage $\ngtr$ 1% for gap length of 6.25 to 25 cm diameter..

For impulse of $\frac{1}{50}\mu s$ waveform, Positive minus negative voltage = 8% for gap length < 2 cm diameter

Wave front and wave fail duration of the waveforms influence the spark over voltage. Sphere gap measurements are not used where

Wave front <0.5 μs and wave fail < 5 μs

Switching surges:

Spark over voltages was varied by switching surges.

ii) Uniform Field Electrode Spark Gaps(DEC-2013)

Uniform field spark gaps are used upto a voltage of 600 kv. We could not say that the sparking always takes place along the uniform field.

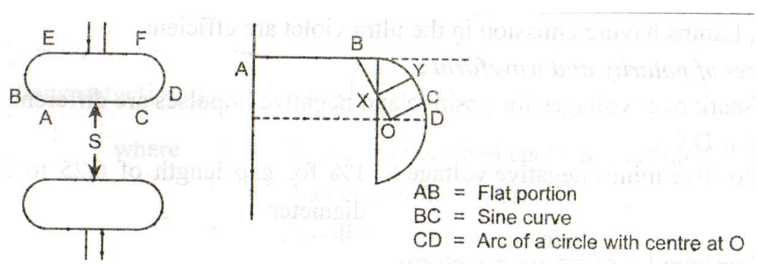
Rogowaski presented a design and the spark over voltage in a uniform field is given by,

$$V = As + B\int s$$

Where, A,B = Constants.

s = Gap spacing in cm.

Typical uniform field spark gap is as shown in Fig



For T = 25℃ , pressure = 260 torr, A = 24.4, B = 7.5.

$$V = 24.4\delta S + 7.5\int \delta S$$

According to Bruce, uniform field spark gaps are used for 140, 280 and 420 KV respectively.

Spark over voltage $V = 6.66\int \delta S + 24.55 + 0.41(0.1\ e - 1)\delta S$

Where, δ = Air density factor.

e = Vapour pressure of water in air.

Advantages:

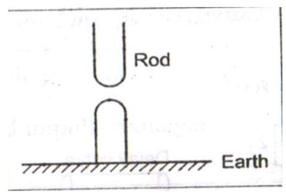
- No influence of nearby earthed objects.
- No polarity effect.

Disadvantages:

- Very accurate mechanical finish of the electrode is required. Otherwise measurement is not accurate.
- Two electrodes are properly aligned in parallel.
- Dust or greeze influences erratic breakdown of the gap.
- Accuracy is less.

iii)Rod Gaps

Rod gaps are used to measure peak value of impulse voltage and power frequency. The rod gap is as shown in Fig



For 50% flashover voltage, the procedure is same as that of sphere gap.

For T = 25°C , Pressure = 760 torr

Breakdown voltage, V = δ(A + Bs)4$\sqrt{5.1\,X10^{-2}(h + 8.65)}$ KV

Where, A = 20KV for positive polarity.

= 15KV for negative polarity.

B = 5.1KV/cm

H = Absolute humidity in gm/m^3(4 to 20)

Accuracy is about $\pm$2% for this method.

5)Explain with neat diagram various Impulse Voltage Measurements Using Voltage Dividers or Potential Dividers?(DEC-2013)

Discuss and compare the performance of resistance capacitance and mixed R-C potential divider for measurement of impulse voltage.(May-2014)

Give the schematic arrangement of an impulse potential divider with an oscilloscope connected for measuring impulse voltages. Explain the arrangement used to minimize errors.NOV/DEC-2015

What are the requirements of a digital storage oscilloscope for impulse and high frequency measurements in HV test circuits?NOV/DEC-15

Potential or voltage dividers are used to measure impulse voltages or high frequency A.C. or fast rising transient voltage measurements.

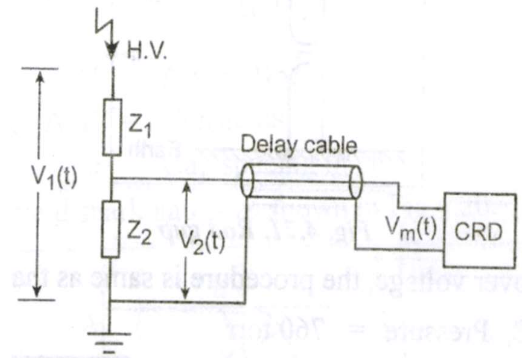
Types of potential divider circuit

- Resistive
- Capacitive

- Mixed

i)General Potential Divider:

The schematic diagram of potential divider with a delay cable and oscilloscope is as shown in Fig..$Z_1$is resistor or a series of resistors in the resistance potential divider or series of capacitors in the case of capacitive potential divider or combination of both. The low voltage arm of the divider is connected to a fast recording oscillograph or a peak reading instrument through a delay cable.



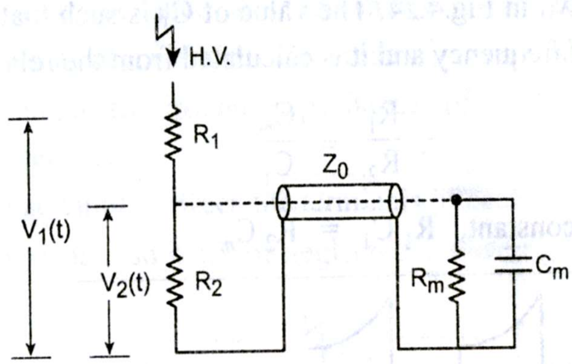
$Z_2$is a resistor or a capacitor or R – C impedance depends on the type. Each element has self resistance or capacitance. The resistive elements have residual inductances, stray capacitance to ground and terminal to terminal capacitances.

Errors arise due to the following elements are:

- Residual inductance in the element.
- Stray capacitance.
- Impedance.
- Parasitic oscillations due to lead and cable inductance and capacitance of high voltage terminal to ground.

Resistance Potential Divider for very Low Impulse Voltages and Fast Rising Pulses:

It consists of two resistances $R_1 and R_2$ in series ($R_1 \gg R_2$). The element R_2 is connected through the coaxial cable to the oscilloscope. The surge impedance of cable (Z_0) is connected in parallel with the input impedance of oscilloscope (R_M, C_m) as shown in Fig.



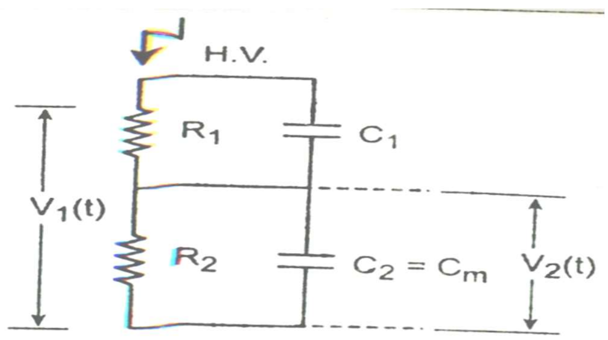
Attenuation factor or voltage ratio ‘a’ = $\frac{V_1(t)}{V_s(t)} = \frac{R_1 + R_2}{R_2} = 1 + \frac{R_1}{R_2}$

For high frequency and impulse voltages,

$$A = \frac{V_1}{V_2} = \frac{R_2 + R_1}{(R_2)//\frac{1}{j\omega C_m}} = \frac{\frac{R_2+R_1}{R_2}}{\frac{j\omega\ \ m}{R_2+\frac{1}{j\omega C_m}}}$$

$$= \frac{\frac{R_1 + R_1}{R_2}}{1+j\omega C_m R_2}$$

$$= 1 + \frac{R_1(1+j\omega C_m R_2)}{R_2}$$

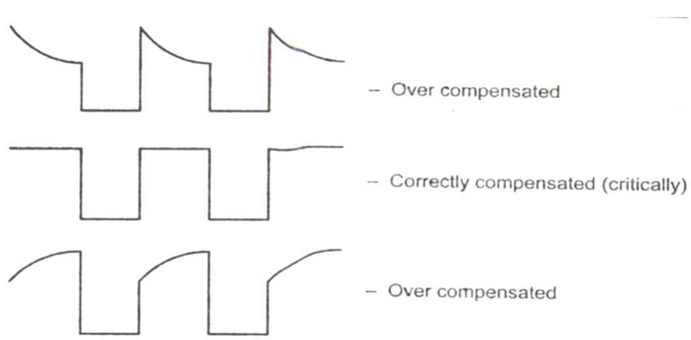


$$R_m > 1M\boldsymbol{\Omega}, C_m = 10\ to\ 50\ p.f$$

Value of ‘a’ depends on frequency. To avoid frequency dependence of ‘a’ , the divider is compensated by adding an additional capacitance C_1 across R_1as shown in Fig.. The value of C_1 is such that voltage divider is independent of frequency and it is calculated from the relation.

$$\frac{R_1}{R_s} = \frac{C_m}{C_1}$$

Time constant, $R_1\, C_1 = R_2 C_m$



The waveform of compensated divider is as shown in Fig.

Time constants of compensated divider $\tau = R_{eq}C_{eq}$

$$R_{eq} = \frac{R_1R_2}{R_1 + R_2}\ (R_1||R_2)$$

$$C_{eq} = C_1 + C_2$$

$\tau = R_{eq}C_{eq} = \frac{R_1R_2}{R_1 + R_2}(C_1 + C_m)$

If C_1> Correct compensation, τ is large.

An charging time is high, and exponential decay occurs as shown in Fig.

If charging time is high, an undershoot occurs with an exponential decay occurs as shown in fig.4.25(c).

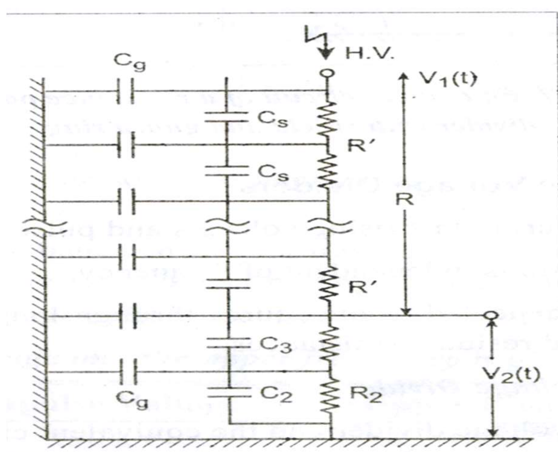
iii) Potential Dividers used for High Voltage Impulse Measurement:

For voltages above 100KV, single resistor R_1 cannot be used. So an equivalent distributed network with its terminal to ground capacitances and inter – sectional series capacitances as shown in Fig.4.26.

Resistor R_1 consists of n – resistors of value R'_1(i.e.,) R_1 = nR'_1.

C_g – Terminal to ground capacitance of each of the resistor elements R'_1.

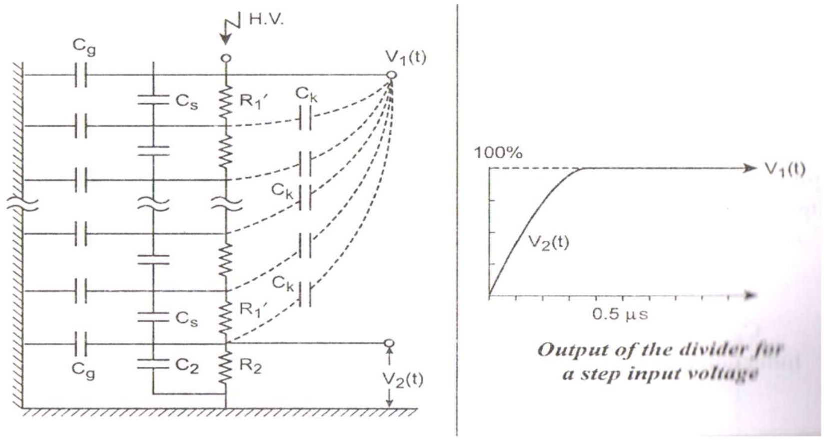
C_S - Capacitance between the terminals of each section Inductance is so small, so it can be neglected in the circuit.



It produces a non-linear voltage distribution along its length and acts like an R-C filter.

To make linear distribution along its length, and reduce distortion introduced by the divider, arrange guard rings at various elemental points and are shown in Fig.

C_h - Stray capacitance introduced between the high voltage lead and the guard element.



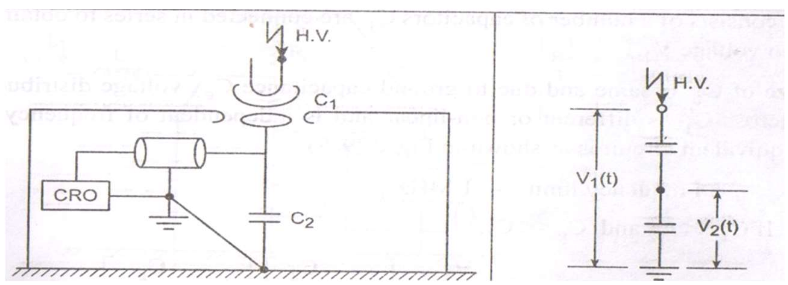
iv) Capacitance Voltage Dividers:

It is used for measuring fast rising voltages and pulses.

- Capacitance ratio is independent of frequency.
- Dividers are connected to the source through long leads which gives inductances and residual resistances.

a)Pure Capacitance Voltage Divider

Pure capacitance voltage divider and the equivalent circuit is as shown in Fig.



H.V. supply is given to the high voltage terminal. CRO is placed within the shielded screen surrounding capacitance C_2.

C_1 = Capacitance between H.V. terminal and test object.

C_2 = {Capacitance used + Lead capacitance + Capacitance of CRO + Ground capacitance

Voltage ratio 'a' $= \frac{V_1(t)}{V_2(t)} = \frac{C_1 + C_2}{C_1 C_2}$ X $C_2 = 1 + \frac{C_2}{C_1}$

$C_1\ inserieswith C_2;\ C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$

Advantages:

- The loading on the source is negligible.

Disadvantages

- A small disturbance in the location of C_2 or H.V. electrode or the presence of any stray object nearby changes the capacitance C_1, and hence the voltage ratio of the divider will be affected.

Impulse voltage range and the upper frequency is given in Table

Impulse Voltage	**Upper Frequency**
350KV	10MHz
Upto 100KV	200MHz

v) Capacitance voltage divider with distributed network:

Capacitance voltage divider with distributed network or string insulator unit structure is as shown in fig

C_1 consists of a number of capacitance are connected in series to obtain a given voltage V_1.

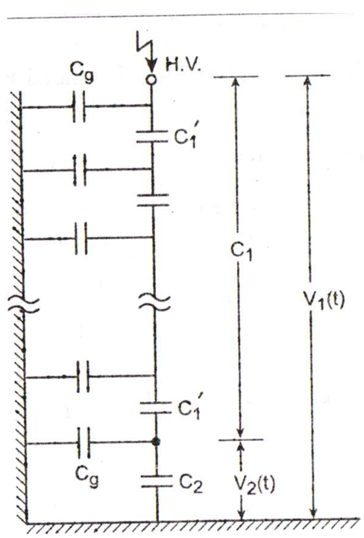
Size of C_1' is same and due to ground capacitance c_g, voltage distribution across is different or non-linear and is independent of frequency.

The equivalent circuit is as shown.

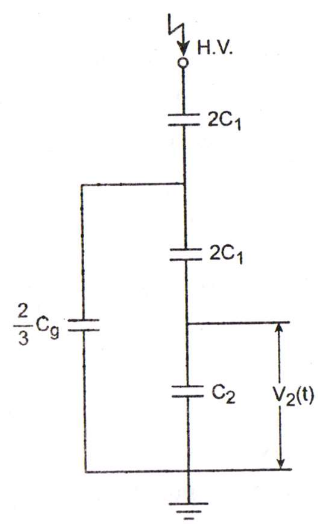
Frequency limit – 1MHz

If $C_1 << C_2$ and $C_g << C_1$

Voltage ratio $a = \frac{V_1}{V_2} = \left[1 + \frac{C_2}{C_1}\right]\left[1 + \frac{C_g}{6C_1}\right]$



(a)

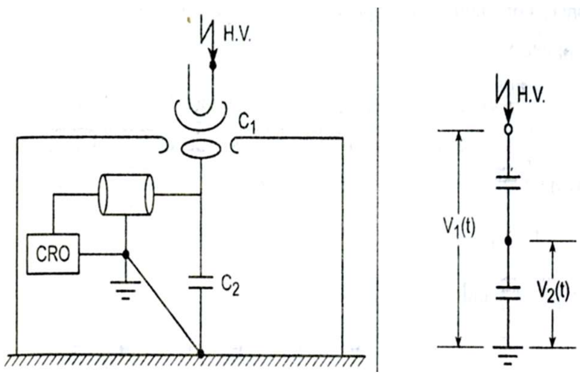


(b)

Vi) Field controlled voltage dividers:

To achieve uniform field in the neighborhood and along the divider, the electrostatic or capacitive field distribution of a shield or guard ring is placed over a resistive divider. This arrangement is used to measure high voltage.

The field controlled voltage divider with damping resistor is as shown. The shield has cone like structure.



Oscillations will be produced due to R_2 together with the lead inductance and shunt capacitance.

Damping resistance R_d is used to reduce the oscillations. This type is constructed for measuring very high voltages up to 2 MV.

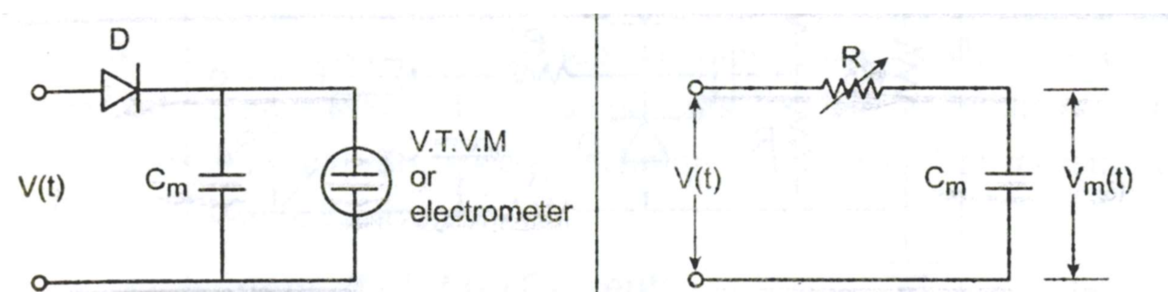
Response time < $30 * 10^{-9}$ sec

Advantages:

- The capacitance per unit length is small and hence loading effect is reduced.
- Response time is less and overshoot is reduced by using damping resistors.

Vii) Peak reading voltmeters for impulse voltages:

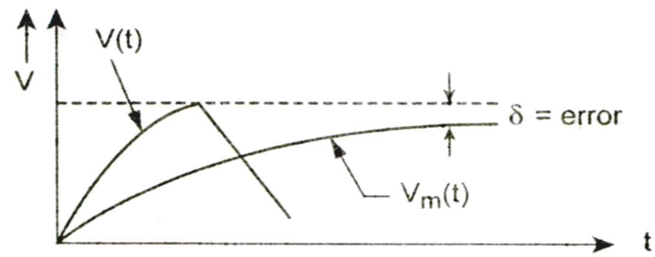
Peak reading voltmeters are used to measure Impulse voltage wave and routing impulse testing work. The wave shape of impulse voltage might be known or fixed by the source.Measuring instrument is connected to the low voltage side of the potential divider and the equivalent circuit is as shown.

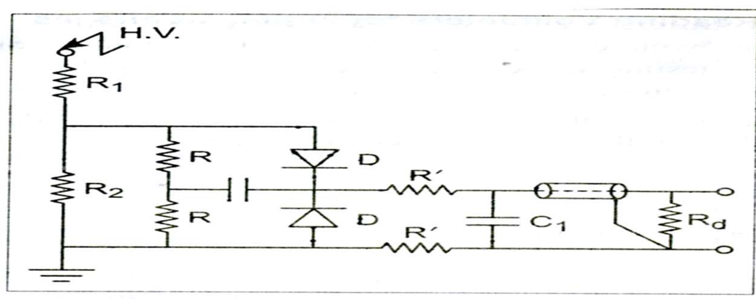


Basic circuit ***Equivalent circuit of basic circuit***

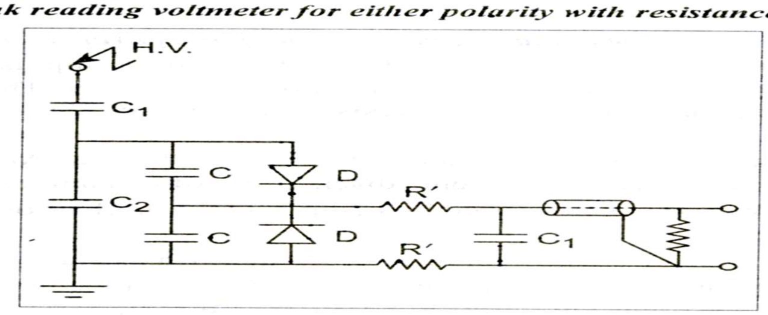
During positive half cycle, diode D conducts and a impulse voltageV(t) appears across the low voltage arm of the potential divider. The capacitor C_m charges to the peak value. Forward resistance of the diode is assumed to be finite.

During negative half cycle, diode D is reverse biased. Amplitude of the signal starts decreasing and prevents discharging of capacitor C_m.Now measured voltage < actual peak valueThe circuit can be modified using R-C network to measure peak voltage accurately. The error is as shown. The error can be estimated if the waveform is known.





(a) Peak reading voltmeter for either polarity with resistance divider



(b) Peak reading voltmeter for either polarity with a capacitive divider

To estimate the forward resistance of the diode is difficult, so meter can be calibrated by using oscilloscope.

For measuring peak reading for either polarity, we can use resistance potential divider or capacitive resistance as shown.

In this circuit, voltage of positive and negative polarity is transferred into a proportional positive measuring signal.

<u>Advantages:</u>

- Fast rising pulses or impulse waves can be measured.
- Capacitor is used to prevent the build-up of D.C. charge.
-

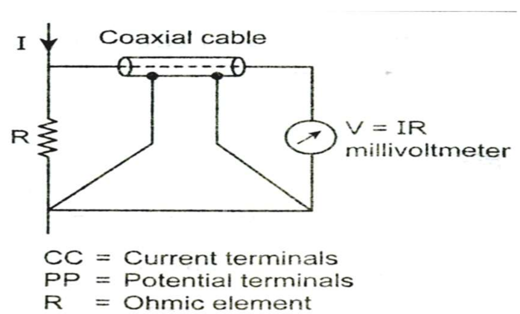
6) Write a shorts notes on *Measurement of high direct currents?* *MAY-2013*

There are two methods used to measure high direct currents. They are:

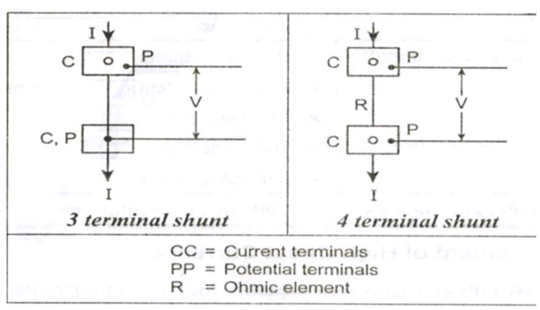
- Resistive shunts
- Hall generators

i) Resistive shunts:

Resistance shunts for high magnitude D.C measurement is shown High current whose magnitude is to be measured is passed through a resistive shunt of low ohmicvalue.The voltage drop across the shunt resistance is measured with the help of milli voltmeter, which is connected through a coaxial cable.



Value of shunt resistance = 10 μΩ to 13 μΩ depends on heating effect and loading effect.Voltage drop < 1 volt in power circuits.High current resistors are oil immersed type and are made as three or four terminal shunt as shown

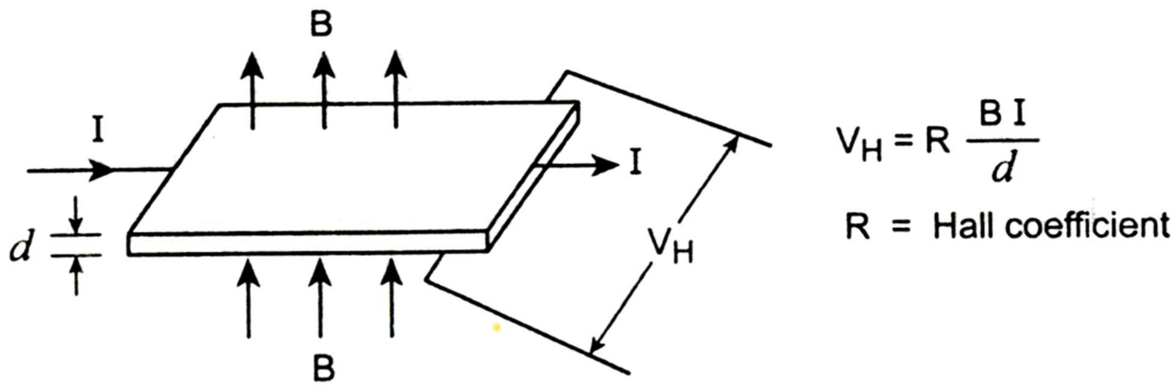


ii)Hall generator or D.C. measurements:

Hall effect is used for the measurements of high direct current as shown.

HALL EFFECT:

Whenever electric current flows through a metal plate placed in a magnetic field perpendicular to it, Lorenz force will deflect the electrons in the metal plate in a direction perpendicular to both the magnetic field and the flow of current. The change in displacement generates an e.m.f called the "Hall Voltage".



Hall voltage $V_H \alpha \frac{BI}{d}$

$V_H = R.\frac{BI}{d}$

Where, B= magnetic flux density,

I=Current,

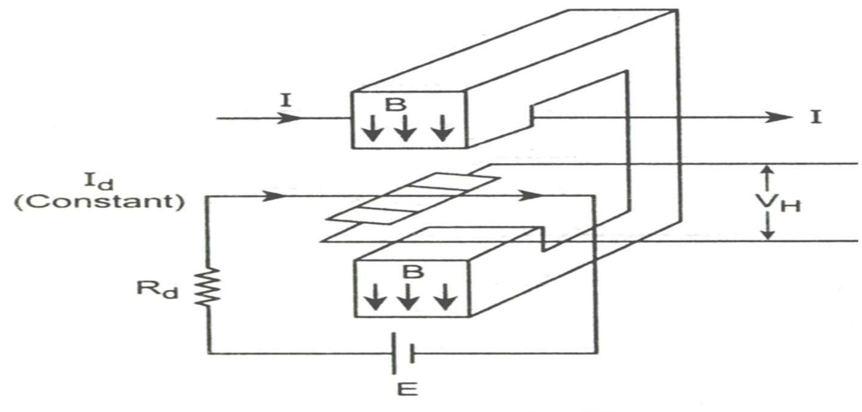
d=thickness of the metal plate,

R= hall coefficient.

Hall coefficient (R) depends on the material of the plate and temperature. Value of hall coefficient is very small for metals and high for semiconductor materials.

Construction of hall generators:

The D.C current which is to be measured is passed through the conductor. The conductor is wound on an iron cored magnetic circuit as shown. The magnetic circuit produces magnetic field in the air gap.



Magnetic field intensity, H=$\frac{1}{\delta}$

Where, δ = air gap distance or depth.

The hall element or metal plate is placed in the air gap formed by the iron core magnetic circuit. It is connected in series with resistor and a battery.A small d.c. current (I_d) is passed through this Hall element.
According to Faraday's law, whenever a current carrying conductor is placed in a magnetic field, an e.m.f. is induced in it.

The voltage or e.m.f. is developed across the hall element (V_H),

$V_H = R.\frac{BI}{d}$

R is the hall coefficient, which depends on the temperature and high magnetic field strengths and compensation provided for measuring high currents.

8)Write a shorts notes on Measurement of high power frequency alternating currents(A.C)?

Measurement of high power frequency current using current transformer:

Current transformers are normally used to measure high power frequency current, but it has some disadvantages.

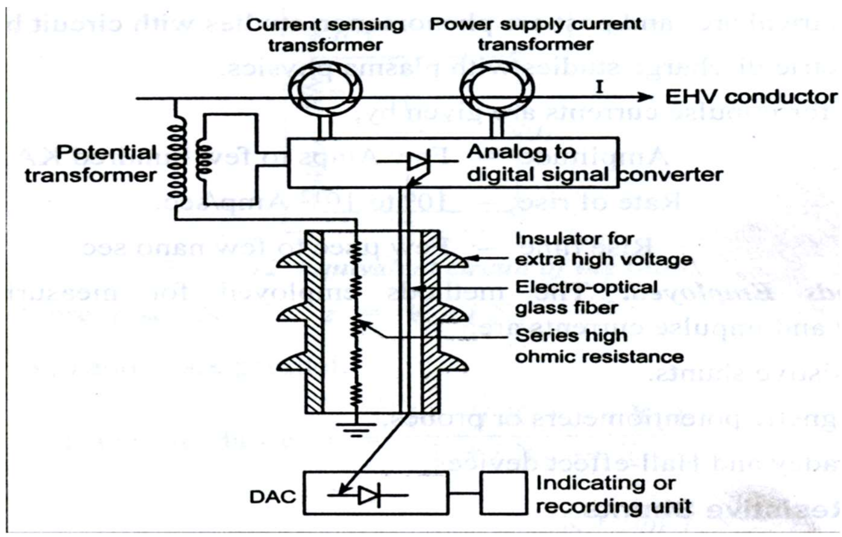
Disadvantages of using only current transformers:

- Current shunts involve unnecessary power loss.
- C.T. provides electrical isolation between H.V. and L.V. side of current transformers in power systems.
- Current transformers used for extra high voltage systems are kept at very high voltages with respect to the ground.

- So, we are using current transformer with electro-optical technique for measuring high alternating currents.

Current transformer with electro-optical signal converter for EHV system:

Current transformer with electro-optical signal converter for EHV system consists of current sensing transformer, power supply current transformer, potential transformer, analog-digital signal converter, and electro optical glass fiber, digital to analog converter as shown.



Operation:

- A voltage signal proportional to the measuring current is passed though the EHV conductor.Current transformer is used in the power circuit to stop down the current to a very low value.
- Potential transformer is used in the power circuit to step down the voltage to a very low value (measurable value).EHV conductor acts as primary side of current transformer. Potential transformer primary is connected between the EHV conductor and the ground through high series resistance.
- The secondary side of current transformers and potential transformers (power to signal converter) are given to the analog to digital converter which converts the analog signal into digital signal.
- This digital signal is given to the digital to analog converter converts the digital signal into analog signal. This analog signal is given to the recording unit.
- Accuracy = ±5% at rated current

9) Write a shorts notes on Measurement of high frequency and impulse currents?

Amplitude and waveform of high frequency and impulse current is necessary because of:

- Impulse currents occur during lightning discharge which causes severe faults.
- Electrical arcs and post arc phenomenon studies with circuit breakers.
- Electric discharge studies with plasma physics.

Range of impulse currents are given by,

Amplitude- Few Amps to few hundred KA.

Rate of rise- 10^6 to 10^{12} Amp/sec.

Rise time- Few µ sec to few nano sec.

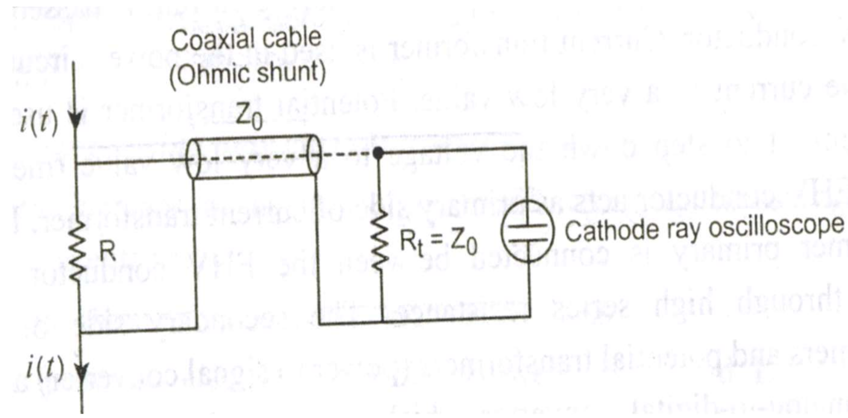
Methods Employed:

The methods employed for measuring high frequency and impulse currents are:

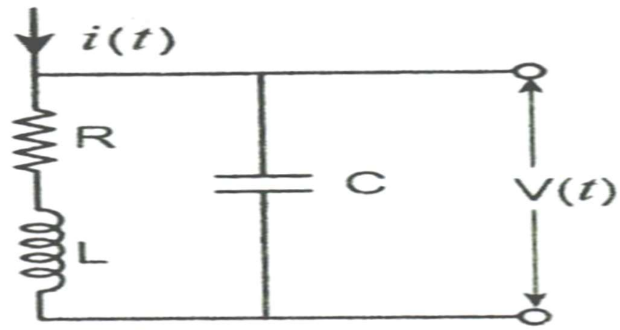
- Resistive shunts.
- Magnetic potentiometers or probes.
- Faraday and hall- effect devices.

i) Resistive shunts:

- The high impulse current which is to be measured is passed through a low ohmic pure resistance as shown.



- The current passed through the low resistance shunt element R produces a voltage drop R i(t) across it.The voltage signal generated is transmitted to a cathode ray oscilloscope through a coaxial cable of surge impedance z_0.
- The oscilloscope end is terminated by a resistance z_0 which is equal to the internal resistance to avoid reflections.The resistance element has a residual inductance L and a terminal capacitance C and the corresponding equivalent circuit as shown.



R and L are in series.

$z = R + j\,X_L$

$(R + j\,X_L)$ and C are parallel.

Total impedance, $z = \frac{(R + j\,XL)(-jXc)}{R + j\,XL - Xc}$

(or) $V(t) = z\ \ i(t) = \frac{(R+j\omega L)\frac{1}{j\omega C}}{R+j\omega L+\frac{1}{j\omega C}}\ i(t)$

$= \frac{R+j\omega L}{1+(j\omega)^2 LC+j\omega RC} * i(t)$

Taking Laplace transform on both sides, we get

$V(s) = \frac{(R+Ls)}{1+LCs^2+RCs} I(s)$

Where, s= complex frequency,

$s = j\omega$

Value of L and C become significant for a frequency above 1 MHz.

Resistance value= 10 μΩ to few milliohm. (Value can determine by thermal capacity and heat dissipation of the shunt)

Voltage drop = usually about a few volts

When the value of C is neglected, then

$V(s) = (R+Ls)\ I(s)$

Accuracy = 1 to 10%

Voltage drop is usually about a few volts.

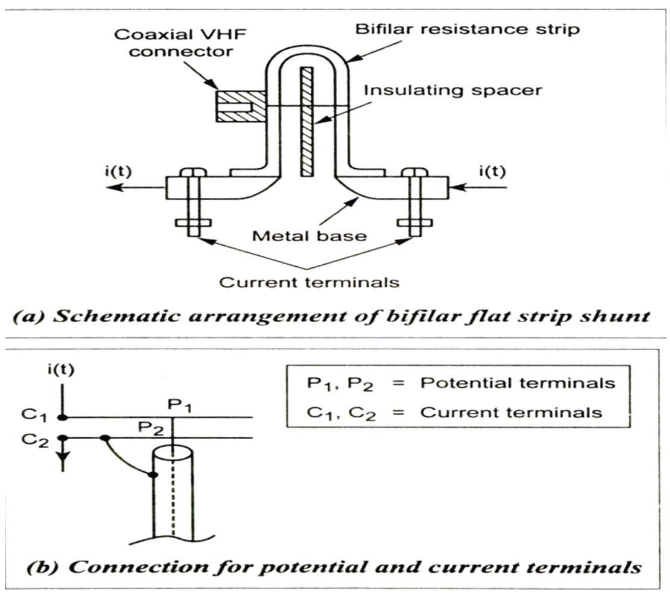
For better frequency response of the shunt, the stray inductance and capacitance should be as small as possible.

<u>To reduce stray effects, the resistance shunt is designed as follows:</u>

- Bifilar flat strip design.
- Coaxial tube or park's shunt design.
- Coaxial squirrel cage design

<u>a)Bifilar flat strip shunt:</u>

- The bifilar flat shunt design as shown. It consists of resistor elements which are wound in opposite directions and folded back.The both ends are insulated by Teflon, or other high quality insulation. The ultra high frequency voltage signal is collected by a coaxial connector.



(a) Schematic arrangement of bifilar flat strip shunt

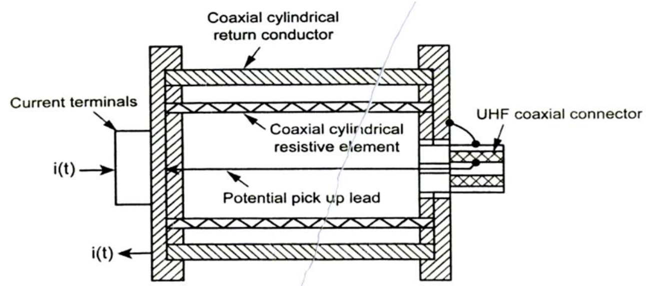
(b) Connection for potential and current terminals

Disadvantages:

- Shunt element is affected by stray inductance.
- Potential leads are linked to a small part of the magnetic flux generated by the current which is to be measured.

To overcome this, coaxial tabular shunts are used.

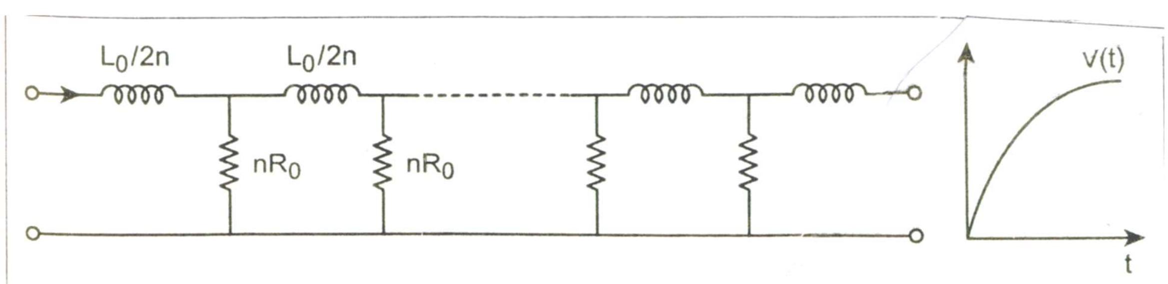
b)**Coaxial tubular or park's shunt:** The coaxial ohmic shunt arrangement as shown.



- Current is passed through the pick-up point or an inner cylinder or resistive element and is made to return through an outer case or outer conducting cylinder.The outer conducting cylinder is made up of copper or brass.
- The space between the inner and the outer cylinder is filled with air and acts as a pure insulator. The voltage drop across the resistive element is measured between the pick-up point and the outer case.
  - ✓ Maximum frequency limit: 1000 MHz.
  - ✓ Response time: few nano sec.

Upper frequency limit is governed by the skin effect in the resistive element (when A.C. is passed through the resistive element, the concentration of alternating current near the outer surface is called as skin effect)

The equivalent circuit is as shown.



Inductance $L_0 = \frac{\mu\ dI}{2\pi}$

Where, n = number of sections per unit length

$\mu = \mu_0\mu_r$

$\mu_0 = 4\pi * 10^{-7}$

d = thickness of the cylindrical tube,

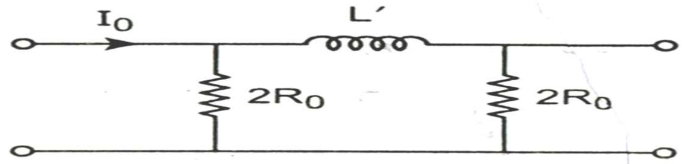
l= length of the cylindrical tube,

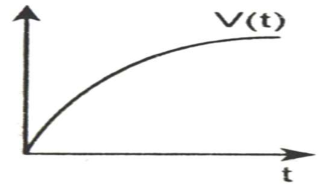
r= radius of the cylindrical tube.

Effective resistance R= $\frac{V(t)}{I_0}$

Where, R_0 = d.c. resistance

The simplified equilavalent circuit is as shown.





The step response and the corresponding frequency response is as shown

Rise time, T = 0.237 $\frac{\mu d^2}{\rho}$

Skin depth, d = $\frac{1}{\sqrt{\pi f \mu \sigma}}$

Where, σ= conductivity of material.

f = frequency.

Bandwidth, B = $\frac{1.46\,R}{L_0} = \frac{1.46\,\rho}{\mu d^2}$

Where, ρ = resisticity.

Maximum current = 200 kA

Rate of rise of current $\frac{di}{dt}$ = 5 * 10^{10} A/s

Induced voltage < 50V

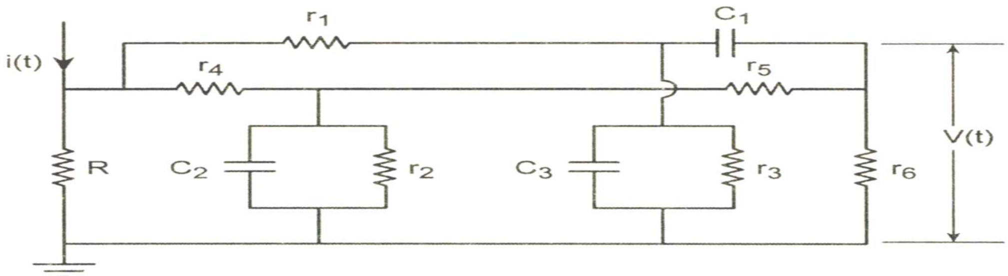
Voltage drop across the shunt = 100 V

In post arc current measurements, tubular shunts are not suitable. Due to heat dissipation, skin effect occurs**.**

c) Squirrel cage shunts:

The equivalent circuit of squirrel cage shunts as shown,

- To overcome the problem of heat dissipation and skin effect, the resistive cylinder is replaced by thick rods or strips. This construction is similar to that of the rotor of double cage induction motor. So, it is called as squirrel cage shunt.
- Squirrel cage shunts are high ohmic shunts which can dissipate large energy. The step response of squirrel cage shunt is large.Therefore, compensating network is used in conjunction with the shunt to improve frequency response.



R = Shunt resistance

r_1 to r_6 = Resistors in compensating double T Network

C_1 to C_3 = Capacitors in compensating double T-network

10) Explain with nean diagram various Measurement techinique of high impulse currents? (DEC-13)

Explain with neat diagram of Rogowskicoils ,the principle of operation for measurement of high impulse current (Dec-14)

<u>i) Magnetic potentiometers (Rogowski coils):NOV-DEC 2010</u>

Principle: when a coil is wound surrounding a current carrying conductor, the voltage is induced in the coil.

Voltage induced in the coil is V(t) = M $\frac{di(t)}{dt}$

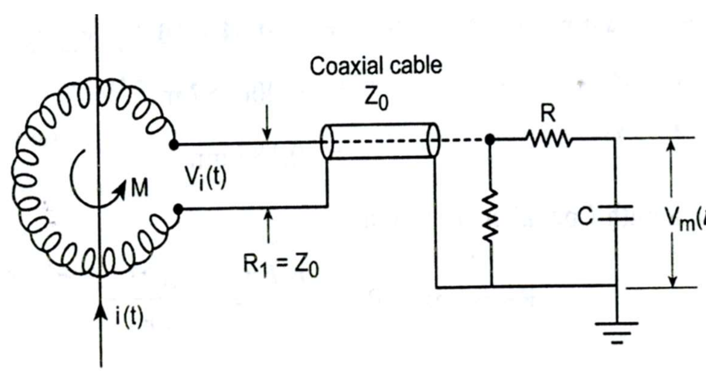
Where M= mutual inductance between the conductor and the coil.

I(t) = current flowing through the conductor.

Construction:

The coil is wound on a non-magnetic former of toroidal shape and is placed surrounding the current carrying conductor.

- To reduce the leakage reactance, the coil is wound crosswire.
- To get enough signals induced, the number of turns on the coil is chosen to be large.



Z_0 = Coaxial cable of surge impedance Z_0

R, C = Integrating circuit

The rogowski coil with integrating circuit is as shown,

Output voltage $V_m(t) = \frac{1}{RC}\int_0^t V_i\ (t) = \frac{1}{RC}\int_0^t M.\frac{di(t)}{dt}$ …(1)

Where RC = time constant of the integrating circuit

Integrating equation (1), we get

$V_m(t) = \frac{M}{CR}\ i(t)$

Voltage signal ∝ current to be measured

For higher frequency above 100 MHz, the response is affected by,

- Capacitance per unit length along the coil.
- Skin effect.
- Electromagnetic interference.

For ultra high frequency measurement, miniature probes with response time are nano sec and made up of few turns of copper strips are used.

ii)Magnetic links:

Magnetic links are used for the measurement of peak value of impulse currents but it is not used to give impulse wave shape.

Construction:

- Magnetic link consists of steel strips having high retentivity and are arranged on a circular wheel. These strips are used for the measurement of peak value of impulse current because it has the property of permanent magnetism for a current pulse of 0.5/5 sec is same as that caused by a D.C. current of same value.

Operation:

- The strips were kept at a known distance from the current carrying conductor and placed parallel to it.The peak value of current is measured by measuring the permanent magnetism.
- By increasing the number of strips for accurate measurement of peak value.

Uses:

Estimating the lightning current on the transmission lines and towers.

ii) Hall generators:

Hall Effect is used to measure very high impulse current.

Hall voltage $\propto \frac{BI}{d}$

$V_H = R\,\frac{BI}{d}$

- Hall voltage developed is directly proportional to the current.
- Whenever electric current flows through a metal plate placed in a magnetic field perpendicular to it, a force will deflect the electrons In a direction perpendicular to both magnetic field and current.

Bandwidth = 50 MHz

<u>iv)Faraday generator or magneto optic method:</u>

Principle: Faraday Effect:

When a linearly polarized light beam passes through a transparent crystal in the presence of a magnetic field, the plane or polarization of the light beam undergoes rotation. These rotation of plane of polarization Is proportional to the current.

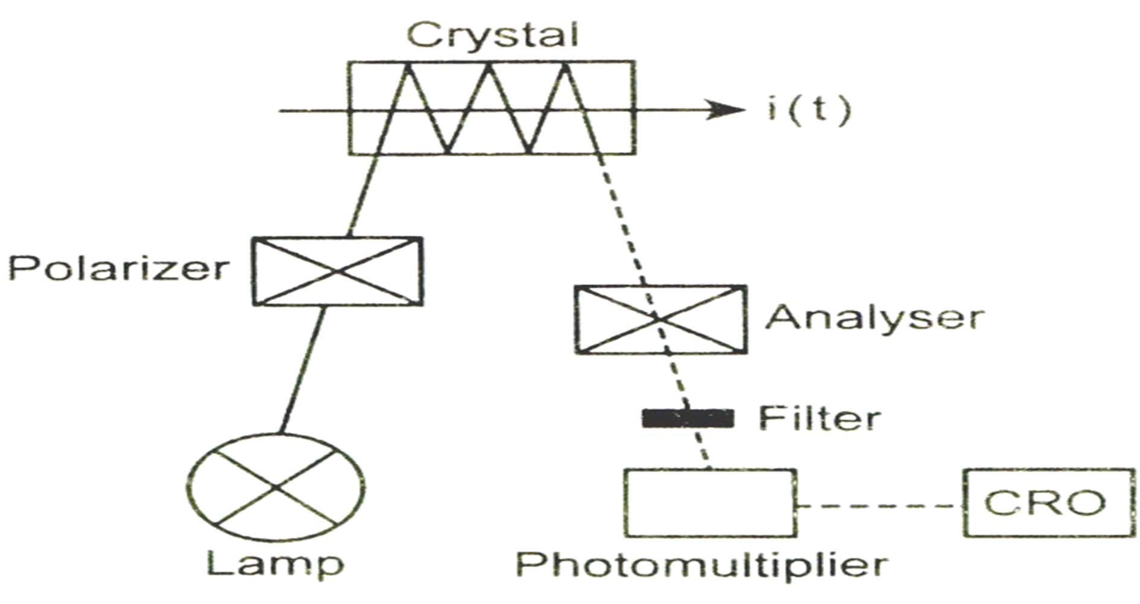
Angle of rotation ∝ B l

Angle of rotation = VB l

Where, V= constant of the crystal depends on the wavelength of the light,

B= magnetic flux density,

l = length of the crystal



Construction and operation:

- A stabilized light source (lamp) emits beam of light. These beams of light are felt on the crystal though a polarizer.
- The crystal is placed parallel to the magnetic field produced by the current i(t). Due to faraday's effect, light beam undergoes rotation of its plane of polarization.
- The beam is now passed through the analyzer, then filtered by using filter to allow only monochromatic light and is passed to the CRO through photo-multiplier.
- By seeing the output display of oscillograph, the current can be measured.
- This device cannot be operated for D.C. circuits.

Advantages:

- ➢ No electric connection between the source and the device.
- ➢ No thermal problems even for large currents of several kA.
- ➢ No insulation problem arises for EHV system, because signal transmission is through optical system.

UNIT-5

1.What are the different tests conducted on insulator? Explain any one of them. (MAY/JUNE-2009, MAY/JUNE -2013,2015,DEC-2013)

Arrangement of Insulators for Test:

- ➢ String insulator unit should be hung by a suspension eye from an earthed metal cross arm.
- ➢ The test voltage is applied between the cross arm and the conductor hung vertically down from the metal part on the lower side of the insulator unit.
- ➢ Suspension string with all its accessories as in service should be hung from an earthed metal cross arm. The length of the cross arm should be at least 1.5 times the length of the string being tested and should be at least equal to 0.9 m on either side of the axis of the string.
- ➢ No other earthed object should be nearer to the insulator string then 0.9 m or 1.5 times the length of the string whichever is greater.
- ➢ A conductor of actual size to be used in service or of diameter not less than 1 cm and length 1.5 times the length of the string is secured in the suspension clamp and should lie in a horizontal plane.
- ➢ The test voltage is applied between the conductor and the cross arm and connection from the impulse generator is made with a length of wire to one end of the conductor.

- For higher operating voltages where the length of the string is large, it is advisable to sacrifice the length of the conductor as stipulated above. Instead, it is desirable to bend the ends of the conductor over in a large radius.

- For tension insulators the arrangement is more or less same as in suspension insulator except that it should be held in an approximately horizontal position under a suitable tension (about 1000 Kg.).

- For testing pin insulators or line post insulators, these should be mounted on the insulator pin or line post shank with which they are to be used in service. The pin or the shank should be fixed in a vertical position to a horizontal earthed metal cross arm situated 0.9 m above the floor of the laboratory.

- A conductor of 1 cm diameter is to be laid horizontally in the top groove of the insulator and secured by at least one turn of tie-wire, not less than 0.3 cm diameter in the tie-wire groove.

- The length of the wire should be at least 1.5 times the length of the insulator and should over hang the insulator at least 0.9 m on either side in a direction at right angles to the cross arm. The test voltage is applied to one end of the conductor.

High voltage testing of electrical equipment requires two types of tests:
(i)Type tests,
(ii)Routine test.

Type tests involves quality testing of equipment at the design and development level i.e. samples of the product are taken and are tested when a new product is being developed and designed or an old product is to be redesigned and developed whereas the routine tests are meant to check thequality of the individual test piece. This is carried out to ensure quality and reliability of individual test objects.

Various types of overhead line insulators are:

- ✓ Pin type
- ✓ Post type
- ✓ String insulator unit
- ✓ Suspension insulator string
- ✓ Tension insulator.
- ✓ High voltage tests include
- ✓ Power frequency tests and
- ✓ Impulse tests.

These tests are carried out on all insulators:

- ✓ 50% dry impulse flash over test.
- ✓ Impulse withstand test.
- ✓ Dry flash over and dry one minute test.
- ✓ Wet flash over and one minute rain test.
- ✓ Temperature cycle test.
- ✓ Electro-mechanical test.
- ✓ Mechanical test.
- ✓ Porosity test.

- ✓ Puncture test.
- ✓ Mechanical routine test.

(i) 50% dry impulse flash over test:

- ✓ The test is carried out on a clean insulator mounted as in a normal working condition. An impulse voltage of 1/50µsec. wave shape and of an amplitude which can cause 50% flash over of the insulator, is applied, i.e.of the impulses applied 50% of the impulses should cause flash over.
- ✓ The polarity of the impulse is then reversed and procedure repeated. There must be at least 20 applications of the impulse in each case and the insulator must not be damaged. The magnitude of the impulse voltage should not be less than that specified in standard specifications.

ii)Impulse withstand test :

- ✓ The insulator is subjected to standard impulse of 1/50 µsec. wave of specified value under dry conditions with both positive and negative polarities.
- ✓ If five consecutive applications do not cause any flash over or puncture, the insulator is deemed to have passed the impulse withstand test. If out of five, two applications cause flash over, the insulator is deemed to have filed the test.

iii)Dry flash over and dry one minute test :

- ✓ Power frequency voltage is applied to the insulator and the voltage increased to the specified value and maintained for one minute.
- ✓ The voltage is then increased gradually until flash over occurs. The insulator is then flashed over at least four more times, the voltage is raised gradually to reach flash over in about 10 seconds.
- ✓ The mean of at least five consecutive flash over voltages must not be less than the value specified in specifications.

(iv) Wet flash over and one minute rain test :

- ✓ If the test is carried out under artificial rain, it is called wet flash over test. The insulator is subjected to spray of water of following characteristics:
- ✓ Precipitation rate: 3 ±10% mm/min.
- ✓ Direction: 45° to the vertical
- ✓ Conductivity of water: 100 micro Siemens ±10%
- ✓ Temperature of water ambient +15°C the insulator with 50% of the one-min.
- ✓ rain test voltage applied to it, is then sprayed for two minutes, the voltage raised to the one minute test voltage in approximately 10 sec. and maintained there for one minute.
- ✓ The voltage is then increased gradually till flash over occurs and the insulator is then flashed at least four more times, the time taken to reach flash over voltage being in each case about 10 sec. The flash over voltage must not be less than the value specified in specifications.

(v) Temperature cycle test :

- ✓ The insulator is immersed in a hot water bath whose temperature is 70° higher than normal water bath for Tminutes.

- ✓ It is then taken out and immediately immersed in normal water bath for T minutes. After Tminutes the insulator is again immersed in hot water bath for Tminutes.
- ✓ The cycle is repeated three times and it is expected that the insulator should withstand the test without damage to the insulator or glaze. Here T = (15 + W/1.36) where Wis the weight of the insulator in kgs.

(vi) Electro-mechanical test :

- ✓ The test is carried out only on suspension or tension type of insulator. The insulator is subjected to a 2½ times the specified maximum working tension maintained for one minute.
- ✓ Also, simultaneously 75% of the dry flash over voltage is applied. The insulator should withstand this test without any damage.

(vii) Mechanical test :

- ✓ This is a bending test applicable to pin type and line-post insulators. The insulator is subjected to a load three times the specified maximum breaking load for one minute.
- ✓ There should be no damage to the insulator and in case of post insulator the permanent set must be less than 1%. However, in case of post insulator, the load is then raised to three times and there should not be any damage to the insulator and its pin.

(viii) Porosity test:

The insulator is broken and immersed in a 0.5% alcohol solution of fuchsin under a pressure of 13800 kN/m^2 for 24 hours. The broken insulator is taken out and further broken. It should not show any sign of impregnation.

(ix) Puncture test:

- ✓ An impulse over voltage is applied between the pin and the lead foil bound over the top and side grooves in case of pin type and post insulator and between the metal fittings in case of suspension type insulators. The voltage is 1/50 μsec.

- ✓ wave with amplitude twice the 50% impulse flash over voltage and negative polarity. Twenty such applications are applied. The procedure is repeated for 2.5, 3, 3.5 times the 50% impulse flash over voltage and continued till the insulator is punctured.

- ✓ The insulator must not puncture if the voltage applied is equal to the one specified in the specification.

(x) Mechanical routine test :

- ✓ The string in insulator is suspended vertically or horizontally and a tensile load 20% in excess of the maximum specified working load is applied for one minute and no damage to the string should occur.

2. What are the different tests conducted on cable? Explain any one of them. (May/June-2012, May/June-2013,DEC-2013)

- ➢ The cable sample has to be carefully prepared for performing various tests especially electrical tests.

- This is essential to avoid any excessive leakage or end flashovers which otherwise may occur during testing and hence may give wrong information regarding the quality of cables.
- The length of the sample cable varies between 50 cms to 10 m. The terminations are usually made by shielding the ends of the cable with stress shields so as to relieve the ends from excessive high electrical stresses.

A cable is subjected to following tests:

- ✓ Bending tests.
- ✓ Loading cycle test.
- ✓ Thermal stability test.
- ✓ Dielectric thermal resistance test.
- ✓ Life expectancy test.
- ✓ Dielectric power factor test.
- ✓ Power frequency withstand voltage test.
- ✓ Impulse withstand voltage test.
- ✓ Partial discharge test.

(i) ***Bending tests:*** It is to be noted that a voltage test should be made before and after a bending test. The cable is bent round a cylinder of specified diameter to make one complete turn. It is then unwound and rewound in the opposite direction. The cycle is to be repeated three times.

(ii) Loading cycle test :A test loop, consisting of cable and its accessories is subjected to 20 load cycles with a minimum conductor temperature 5°C in excess of the design value and the cable is energized to 1.5 times the working voltage. The cable should not show any sign of damage.

(iii) Thermal stability test: After test as at (ii), the cable is energized with a voltage 1.5 times the working voltage for a cable of 132 kV rating (the multiplying factor decreases with increases in operating voltage) and the loading current is so adjusted that the temperature of the core of the cable is 5°C higher than its specified permissible temperature. The current should be maintained at this value for six hours.

(iv) Dielectric thermal resistance test: The ratio of the temperature difference between the core and sheath of the cable and the heat flow from the cable gives the thermal resistance of the sample of the cable. It should be within the limits specified in the specifications.

(v) Life expectancy test: In order to estimate life of a cable, an accelerated life test is carried out by subjecting the cable to a voltage stress higher than the normal working stress. It has been observed that the relation between the expected life of the cable in hours and the voltage stress is given by

$$g = \frac{K}{n\sqrt{t}}$$

where*K* is a constant which depends on material .
nis the life index depending again on the material.

(vi) Dielectric power factor test:

- ✓ High Voltage Schering Bridge is used to perform dielectric power factor test on the cable sample. The power factor is measured for different values of voltages *e.g.* 0.5, 1.0, 1.5 and 2.0 times the rated operating voltages.
- ✓ The maximum value of power factor at normal working voltage does not exceed a specified value (usually 0.01) at a series of temperatures ranging from 15°C to 65°C. The difference in the power factor between rated voltage and 1.5 times the rated voltage and the rated voltage and twice the rated voltage does not exceed a specified value.
- ✓ Sometimes the source is not able to supply charging current required by the test cable, a suitable choke in series with the test cable help sin tiding over the situation.

(vii) Power frequency withstand voltage test :

- ✓ Cables are tested for power frequency a.c. and d.c. voltages. During manufacture the entire cable is passed through a higher voltage test and the rated voltage to check the continuity of the cable.
- ✓ As a routine test the cable is subjected to a voltage 2.5 times the working voltage for 10 min without damaging the insulation of the cable. HV d.c. of 1.8 times the rated d.c. voltage of negative polarity for 30 min.
- ✓ is applied and the cable is said to have withstood the test if no insulation failure takes place.

viii) Impulse withstand voltage test:

- ✓ The test cable is subjected to 10 positive and 10 negative impulse voltage of magnitude as specified in specification, the cable should withstand 5 applications without any damage.
- ✓ Usually, after the impulse test, the power frequency dielectric power factor test is carried out to ensure that no failure Occurred during the impulse test.

(ix) Partial discharge test:

- ✓ Partial discharge measurement of cables is very important as it gives an indication of expected life of the cable and it gives location of fault, if any, in the cable.
- ✓ When a cable is subjected to high voltage and if there is a void in the cable, the void breaks down and a discharge takes place. As a result, there is a sudden dip in voltage in the form of an impulse.
- ✓ This impulse travels along the cable as explained in detail in Chapter VI. The duration between the normal pulse and the discharge pulse is measured on the oscilloscope and this distance gives the location of the void from the test end of the cable.
- ✓ However, the shape of the pulse gives the nature and intensity of the discharge.
- ✓ In order to scan the entire length of the cable against voids or other imperfections, it is passed through a tube of insulating material filled with distilled water.
- ✓ Four electrodes, two at the end and two in the middle of the tube are arranged. The middle electrodes are located at a stipulated distance and these are energized with high voltage.
- ✓ The two end electrodes and cable conductor are grounded. As the cable is passed between the middle electrodes, if a discharge is seen on the oscilloscope, a defect in this part of the cable is stipulated and hence this part of the cable is removed from the rest of the cable.

3. What are the test conducted on circuit breaker and isolator? Explain any one method for each.(may/june-2012,Dec-14)

An Equipment when designed to certain specification and is fabricated, needs testing for its performance. The general design is tried and the results of such tests conducted on one selected breaker and are thus applicable to all others of identical construction. These tests are called the type tests. These tests are classified as follows:

1. ***Short circuit tests:***
   - ✓ Making capacity test.
   - ✓ Breaking capacity test.
   - ✓ Short time current test.
   - ✓ Operating duty test

2. Dielectric tests:

(i) Power frequency test:

- ✓ One minute dry withstand test.
- ✓ One minute wet withstand test.

(ii) Impulse voltage dry withstand test.

3. Thermal test:

4. Mechanical test:

- ✓ Once a particular design is found satisfactory, a large number of similar C.Bs. are manufactured for marketing. Every piece of C.B. is then tested before putting into service. These tests are known as routine tests.
- ✓ With these tests it is possible to find out if incorrect assembly or inferior quality material has been used for a proven design equipment. These tests are classified as
  - operation tests,
  - Millivoltdrop tests,
  - (iii)power frequency voltage tests at manufacturer's premises, and
  - power

Frequency voltage tests after erection on site. We will discuss first the type tests. In that also we will discuss the short circuit tests after the other three tests.

Dielectric Tests:

- ✓ The general dielectric characteristics of any circuit breaker or switchgear unit depend upon the basic design i.e. clearances, bushing materials, etc. upon correctness and accuracy in assembly and upon the quality of materials used. For a C.B.
- ✓ These factors are checked from the viewpoint of their ability to

Withstand over voltages at the normal service voltage and abnormal voltages during lightning or other phenomenon.

The test voltage is applied for a period of one minute between

- phases with the breaker closed,
- phases and earth with C.B. open,
- Across the terminals with breaker open.

- ✓ With this the breaker must not flash over or puncture. These tests are normally made on indoor switchgear. For such C.Bs the impulse tests generally are unnecessary because it is not exposed to impulse voltage of a very high order.
- ✓ The high frequency switching surges do occur but the effect of these in cable systems used for indoor switchgear are found to be safely withstood by the switchgear if it has

withstood the normal frequency test. Since the outdoor switchgear is electrically exposed, they will be subjected to over voltages caused by lightning.

- ✓ The effect of these voltages is much more serious than the power frequency voltages in service. Therefore, this class of switchgear is subjected in addition to power frequency tests, the impulse voltage tests.

- ✓ The test voltage should be a standard 1/50 μsec wave, the peak value of which is specified according to the rated voltage of the breaker.

- ✓ A higher impulse voltage is specified for non-effectively grounded system than those for solidly grounded system. The test voltages are applied between

(i) Eachpole and earth in turn with the breaker closed and remaining phases earthed,

(ii) Between all terminals on one side of the breaker and all the other terminals earthed, with the breaker open.

- ✓ The specified voltages are withstanding values i.e.the breaker should not flash over for 10 applications of the wave.
- ✓ Normally this test is carried out with waves of both the polarities. The wet dielectric test is used for outdoor switchgear.
- ✓ In this, the external insulation is sprayed for two minutes while the rated service voltage is applied; the test overvoltage is then maintained for
- ✓ 30 seconds during which no flash over should occur.

The effect of rain on external insulation is partly beneficial, insofar as the surface is thereby cleaned, but is also harmful if the rain contains impurities

Thermal Tests:

- ✓ These tests are made to check the thermal behaviour of the breakers. In this test the rated current through all three phases of the switchgear is passed continuously for a period long enough to achieve steady state conditions.
- ✓ Temperature readings are obtained by means of thermocouples whose hot junctions are placed in appropriate positions. The temperature rise above ambient, of conductors, must normally not exceed 40°C when the rated normal current is less than 800 amps and 50°C if it is 800 amps and above.
- ✓ An additional requirement in the type test is the measurement of the contact resistances between the isolating contacts and between the moving and fixed contacts.
- ✓ These points are generally the main sources of excessive heat generation. The voltage drop across the breaker pole is measured for different
- ✓ values of d.c. current which is a measure of the resistance of current carrying parts and hence that of contacts.

Mechanical Tests:

- ✓ A C.B. must open and close at the correct speed and perform such operations without mechanical failure. The breaker mechanism is, therefore, subjected to a mechanical endurance type test involving repeated opening and closing of the breaker.
- ✓ B.S. 116: 1952 requires 500 such operations without failure and with no adjustment of the mechanism. Some manufacture feel that as many as 20,000 operations may be reached before any useful information regarding the possible causes of failure may be obtained.
- ✓ A resulting change in the material or dimensions of a particular component may considerably improve the life and efficiency of the mechanism.

Short Circuit Tests:

These tests are carried out in short circuit testing stations to prove the ratings of the C.Bs. Before discussing the tests it is proper to discuss about the short circuit testing stations.
There are two types of testing stations;

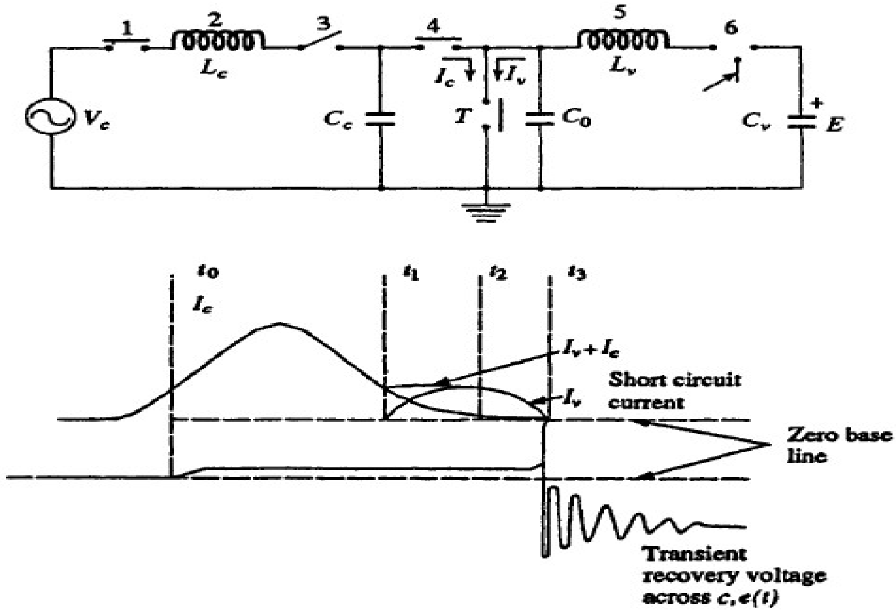
(i) field type,

(ii) Laboratory type.

In case of field type stations the power required for testing is directly taken from a large power system.
The breaker to be tested is connected to the system. Whereas this method of testing is economical for high voltage C.Bs. it suffers from the following drawbacks:
1. The tests cannot be repeatedly carried out for research and development as it disturbs the whole network.
2. The power available depends upon the location of the testing stations, loading conditions, installed capacity, etc.
3. Test conditions like the desired recovery voltage, the RRRV etc. cannot be achieved conveniently. In case of laboratory testing the power required for testing is provided by specially designed generators. This method has the following advantages:
1. Test conditions such as current, voltage, power factor, restriking voltages can be controlled accurately.
2. Several indirect testing methods can be used.
3. Tests can be repeated and hence research and development over the design is possible.
The limitations of this method are the cost and the limited power availability for testing the breakers.

Synthetic Tests

Synthetic Testing of Circuit Breakers Due to very high interrupting capacities of circuit breakers, it is not economical to have a single source to provide the required short circuit and the rated voltage. Hence, the effect of a short circuit isobtained as regards to the intensity of the current and the recovery voltage as a combination of the effects of two sources, one of which supplies the a.c. current and the other the high voltage. of comparatively high voltage of small current capacity. A schematic diagram of a synthetic testing station is shown in Fig.



With the auxiliary breaker (3) and the test breaker (T) closed, the closing of the making switch (1) causes the current to flow in the test circuit breaker. At some instant say *to,* the test circuit breaker (T) begins to operate and the master circuit breaker (1) becomes ready to clear the generator circuit. At some times *t.* just before the zero of the generator current, the trigger gap (6) closes and the higher frequency current from the discharging capacitor *Cv*also flows through the arc. At time ^, when the generator Cv which has the required rate of change of current at its zero flowing in the test circuit breaker. At the zero of this current/full test voltage will be available. The closing of gap (6) would be a little earlier in time than shown in Fig. 10.4, but it has been drawn as shown for clarity at current zeros. It is important to see that the high-current source is disconnected and a high-voltage source applied with absolute precision (by means of an auxiliary circuit breaker) at the instant of circuit breaking.

4. Explain the method of impulse testing of high voltage transformer. What is the procedure adopted for locating the failure?(may-2011,Dec-14,15)

- ✓ Transformer is one of the most expensive and important equipment in power system. If it is not suitably designed its failure may cause a lengthy and costly outage.
- ✓ Therefore, it is very important to be cautious while designing its insulation, so that it can withstand transient over voltage both due to switching and lightning.
- ✓ The high voltage testing of transformers is, therefore, very important and would be discussed here.
- ✓ Other tests like temperature rise, short circuit, open circuit etc. are not considered here. However, these can be found in the relevant standard specification.

<u>Partial Discharge Test:</u>

- ✓ The test is carried out on the windings of the transformer to assess the magnitude of discharges.
- ✓ The measurements are to be made at all the terminals of the transformer and it is estimated that if the apparent measured charge exceeds 104 picocoulombs, the discharge magnitude is considered to be severe and the transformer insulation should be

so designed that the discharge measurement should be much below the value of 104 pico-coulombs.

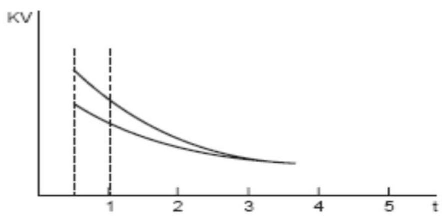
Impulse Testing of Transformer:

- ✓ The impulse level of a transformer is determined by the breakdown voltage of its minor insulation (Insulation between turn and between windings), breakdown voltage of its major insulation (insulation between windings and tank) and the flash over voltage of its bushings or a combination of these.

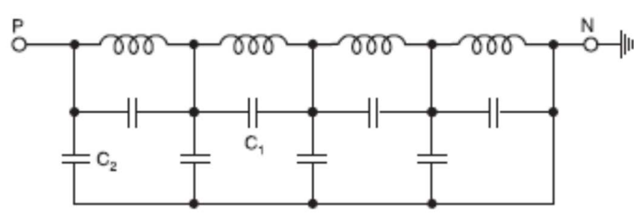
- ✓ The impulse characteristics of internal insulation in a transformer differ from flash over in air in two main respects.

- ✓ Firstly the impulse ratio of the transformer insulation is higher (varies from 2.1 to 2.2) than that of bushing (1.5 for bushings, insulators etc.). Secondly, the impulse breakdown of transformer

KV



- ✓ Volt time curve of typical major insulation in transformer insulation in practically constant and is independent of time of application of impulse voltage. Figshows that after three micro seconds the flash over voltage is substantially constant.
- ✓ The voltage stressbetween the turns of the same winding and between different windings of the transformer dependsupon the steepness of the surge wave front.
- ✓ The voltage stress may further get aggravated by the pilingup action of the wave if the length of the surge wave is large. In fact, due to high steepness of the surgewaves, the first few turns of the winding are overstressed and that is why the modern practice is toprovide extra insulation to the first few turns of the winding. Fig below shows the equivalent circuit of a transformer winding for impulse voltage.



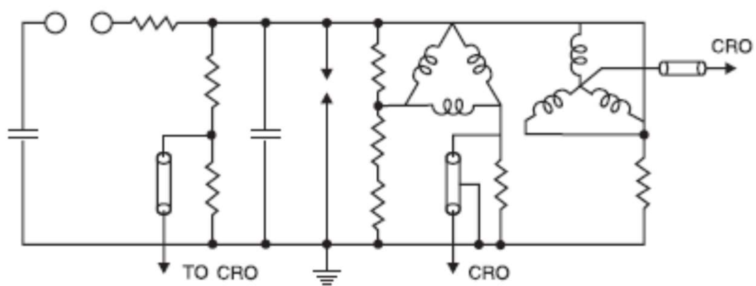
Equivalent circuit of a transformer for impulse voltage
Here C_1 represents inter-turn capacitance
C_2 capacitance between winding and the ground(tank).

- ✓ In order that the minor insulation will be able to withstand the impulse voltage, the winding issubjected to chopped impulse wave of higher peak voltage than the full wave.
- ✓ This chopped wave isproduced by flash over of a rod gap or bushing in parallel with the transformer insulation. The choppingtime is usually 3 to 6 micro seconds.
- ✓ While impulse voltage is applied between one phase andground, high voltages would be induced in the secondary of the transformer. To avoid this, the secondary windings are short-circuited and finally connected to ground.
- ✓ The short circuiting, however, decreases the impedance of the transformer and hence poses problem in adjusting the wave front and wave tail timings of wave. Also, the minimum value of the impulse capacitance required is given by

$$Co = \frac{\mathrm{P} * 10\text{^}8}{\mathrm{Z} * \mathrm{V}\text{^}2} microfarad$$

whereP= rated MVA of the transformer
Z = per cent impedance of transformer.
V = rated voltage of transformer.

Fig. bellow shows the arrangement of the transformer for impulse testing. CRO forms an integral part of the transformer impulse testing circuit. It is required to record to wave forms of the applied voltage and current through the winding under test.



Arrangement for impulse testing of transformer

<u>Impulse testing consists of the following steps:</u>

  - o Application of impulse of magnitude 75% of the Basic Impulse Level (BIL) of the transformer under test.
  - o One full wave of 100% of BIL.
  - o Two chopped wave of 115% of BIL.
  - o One full wave of 100% BIL
  - o One full wave of 75% of BIL.
- ✓ During impulse testing the fault can be located by general observation like noise in the tank or smoke or bubble in the breather. If there is a fault, it appears on the Oscilloscope as a partial of complete collapse of the applied voltage.
- ✓ Study of the wave form of the neutral current also indicated the type of fault. If an arc occurs between the turns or form turn to the ground, a train of high frequency pulses are seen on the oscilloscope and wave shape of impulse changes.
- ✓ If it is a partial discharge only, high frequency oscillations
- ✓ are observed but no change in wave shape occurs.

- ✓ The bushing forms an important and integral part of transformer insulation. Therefore, its impulse flash over must be carefully investigated. The impulse strength of the transformer winding is same for either polarity of wave whereas the flash over voltage for bushing is different for different polarity. The manufacturer, however, while specifying the impulse strength of the transformer takes into consideration the overall impulse characteristic of the transformer.

DETECTION AND LOCATION OF FAULT DURING IMPULSE TESTING(NOV-2015)

The fault in a transformer insulation is located in impulse tests by any one of the following methods.

General observations: The fault can be located by general observations like noise in the tank or smoke or bubbles in breather.

Voltage oscillogrammethod : Fault or failure appears as a partial or complete collapse of the applied voltage wave. Figure 10.14 gives the typical waveform. The sensitivity of this method is low and does not detect faults which occur on less than 5% of the winding.

Neutral current method : In the neutral current method, a record of the impulse current flowing through a resistive shunt between the neutral and ground point is used for detecting the fault. The neutral current oscillogram consists of a high frequency oscillation, a low frequency disturbance, and a current rise due to reflections from the ground end of the windings. When a fault occurs such as arcing between the turns or from turn to the ground, a train of high frequency pulses similar to that in the front of the impulse current wave are observed in the oscillogram and the waveshape changes.

If the fault is local, like a partial discharge, only high frequency oscillations are observed without a change of waveshape. The sensitivity of the method decreases, if other windings not under test are grounded.

Transferred surge current method: In this method, the voltage across a resistive shunt connected between the low voltage winding and the ground is used for fault location. A short high frequency discharge oscillation is capacitively transferred at the event of failure and is recorded. Hence, faults at a further distance from the neutral are also clearly located. The waveshape is distorted depending on the location and type of fault, and hence can be more clearly detected. After the location of the fault, the type of fault can be observed by dismantling the winding and looking for charred insulation or melted parts on the copper winding. This is successful in the case of major faults. Local faults or partial discharges are self healing and escape observation.

5.Explain the power frequency voltage test withstand test on a 66kv insulator.(nov/dec-2007apr,may-2008)

Power frequency overvoltages:

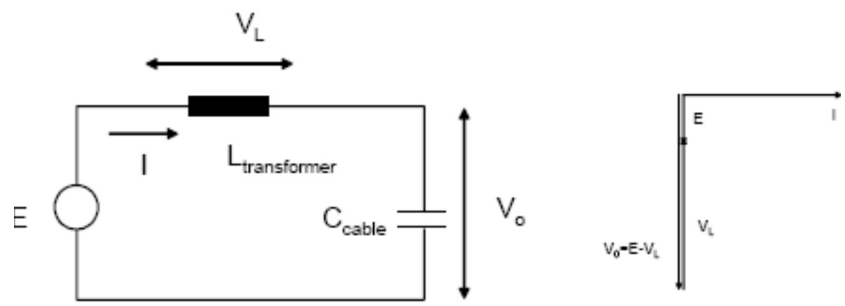
As shown in Table below power system apparatus are specified to operate at Um, which is usually about 5% higher than the nominal operating voltage. There are, however, circumstances where temporary over voltages (TOV's) as high as 50% of the nominal voltage may occur. These over voltages are extremely destructive due to their relatively long duration, as is clear from Table below Temporary over voltages are usually caused or triggered by some abnormal event on the power system. There are a variety of such causes and some are summarised in Table below

Type	Description

Earth fault occurrence	Voltage increase due to method of neutral grounding.
Load rejection	Ferranti effect Generator loss of load
Line energizing and autoreclosing Resonance effects	Travelling waves, trapped charge
Resonance effects	Resonance at fundamental frequency or harmonic frequency. Non-linear resonance between line capacitance and transformer magnetising reactance

Load rejection:

The disconnection (shedding) of a large load leads to voltage increases on the system as the series resistive and reactive voltage drops disappear. The capacitance of an unloaded cable, in combination with a transformer or generator inductance may lead to an increase of the voltage at the end of the line, if the cable capacitance and the series inductance are in near resonance, the output voltage can be much higher than the input voltage, as can be seen in the phasor diagram.



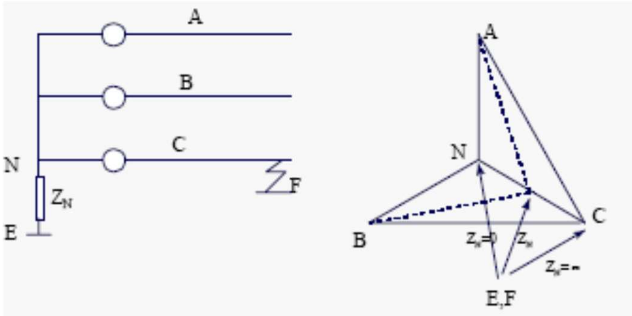
This phenomenon is known as the Ferranti effect and can also be explained, using a distributed parameter model of a transmission line, resulting in the following equation:

$V_0/V_1=1/COS\ (\beta l)$

with V_0 and V_1 the sending end and receiving end voltages of the line, respectively, l the line length and β the phase constant of the line (usually 6° per km).

Earth fault occurrence: the effect of neutral earthing:

If a ground fault occurs in a network with a non earthed neutral, the healthy phases will adopt a √3 times higher voltage until the fault is cleared. If the system is earthed through an impedance, the overvoltage depends on the transformer neutral earthing impedance, as indicated in Fig.



Earth Fault on Phase C

A system is classed as an effectively earthed system if $R_0/X_0 < 1$ and $X_0/X_1 < 3$, where:
R_0: zero sequence resistance
X_0: zero sequence reactance
X_1: positive sequence reactance
The overvoltage factor for earth faults (whereby the voltage prior to the fault occurrence has to be multiplied) is given by:

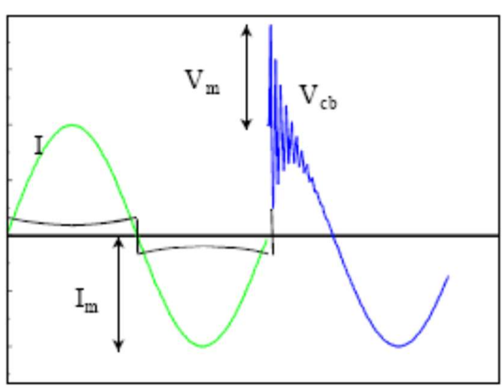
$$K = \sqrt{3}\,\frac{\sqrt{1 + Xo/X1 + (Xo/X1)^2}}{2 + Xo/X1}$$

In the above equation it was assumed that the system resistance can be ignored.

<u>Switching overvoltages:</u>

A power system contains a large number of capacitances (mainly the line shunt capacitances and compensation capacitors) and inductances (e.g. transformer leakage inductances). During disturbances transients occur in the form of damped oscillations. Typical examples are:
- Fault clearing
- Transformer magnetising current
- Capacitance switching
- Energizing of unloaded transmission lines,travelling waves.

- ✓ Only the interruption of fault currents will be dealt with here. Consider the power system in Fig below. Sinusoidal fault current flows, only limited by the reactance L.
- ✓ When the circuit breaker interrupts the fault current at the current zero the voltage across the circuit breaker must recover to follow the supply voltage. The high frequency recovery voltage across the open circuit breaker contacts adds to the power frequency voltage and introduces additional stresses of the insulation of the power system components as is shown in Fig.



- ✓ Clearly, a peak voltage as high as $2V_m$may appear across the circuit breaker and thus also on the equipment, connected to the system.
- ✓ The magnitude of the resulting overvoltage, should the current be "chopped" before the zero crossing, may be estimated by noting that the energy oscillates between Land Cduring the high frequency transient. For example, if the current is "chopped" at the current peak value, I_m, the energy in,

$$L,\ W_L=LI_m^2/2$$

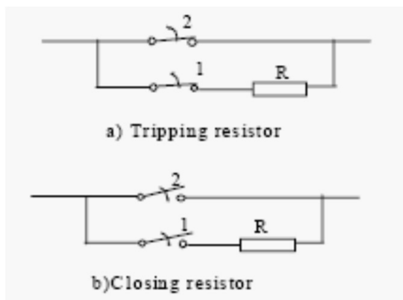
Is transferred to C(ignoring losses), during the first cycle of the transient. The energy in the capacitor is:

$$W_C=Cv_m^2/2$$

Equating $W_L$and W_C, it follows that the maximum voltage across C is:

$$V_m=\sqrt{(L/C)}I_m$$

Closing and tripping resistors that are inserted in parallel with the main circuit breaker gap for a short time during tripping, may effectively reduce switching over voltages as is shown in Figure.



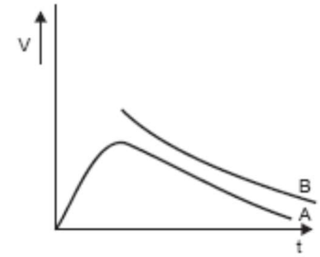
The tripping resistors drain trapped charge from the line, while closing resistors damp oscillations that occur on energizing a line.

6. Explain different aspects of insulation design and insulation co-ordination adopted for EHV systems.(APR/MAY-2011,NOV-2015)

What are volt-time curves? Explain the procedure for constructing volt-time curves with neat sketch. Give its significance in power system studies. (May-2014)

<u>Insulation coordination and overvoltage protection:</u>

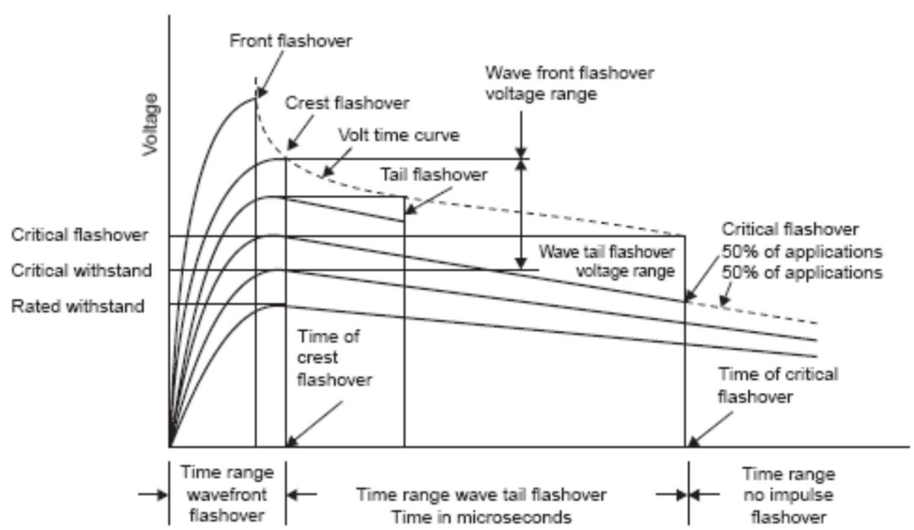
- ✓ Insulation coordination means the correlation of the insulation of the various equipments in a power system to the insulation of the protective devices used for the protection of those equipments against overvoltages. In a power system various equipments like transformers, circuit breakers, bus supports etc.
- ✓ have different breakdown voltages and hence the volt-time characteristics. In orderthat all the equipments should be properly protected it is desired that the insulation of the various protective devices must be properly coordinated. The basic concept of insulation coordinationis illustrated in Fig. below.



- ✓ Curve *A* is the volt-time curve of the protective device and *B* the volt-time curve of the equipment to be protected. Fig above shows the desired positions of the volt-time curves of the protecting device and the equipment to be protected.
- ✓ Thus, any insulation having a withstand voltage strength in excess of the insulation strength of curve *B* is protected by the protective device of curve *A*.The 'volt-time curve' expression will be used very frequently in this chapter. It is, therefore, necessary to understand the meaning of this expression.

<u>Volt-Time Curve:</u>

- ✓ The breakdown voltage for a particular insulation of flashover voltage for a gap is a function of both the magnitude of voltage and the time of application of the voltage.
- ✓ The volt-time curve is a graph showing the relation between the crest flashover voltages and the time to flashover for a series of impulse applications of a given wave shape. For the construction of volt-time curve the followingprocedure is adopted.
- ✓ Waves of the same shape but of different peak values are applied to the insulation whose volt-time curve is required. If flashover occurs on the front of the wave, the flashover point gives one point on the volt-time curve. The other possibility is that the flashover occurs just at the peak value
- ✓ of the wave;
- ✓ this gives another point on the *V*-*T* curve. The third possibility is that the flashover occurs on the tail side of the wave. In this case to find the point on the *V*-*T* curve, draw a horizontal line from the peak value of this wave and also draw a vertical line passing through the point where the flashovertakes place.
- ✓ The intersection of the horizontal and vertical lines gives the point on the *V*-*T* curve. This procedure is nicely shown in Fig below.



- ✓ The overvoltages against which coordination is required could be caused on the system due to system faults, switching operation or lightning surges.
- ✓ For lower voltages, normally upto about 345 kV, over voltages caused by system faults or switching operations do not cause damage to equipment insulation although they may be detrimental to protective devices.
- ✓ Overvoltages caused by lightning are of sufficient magnitude to affect the equipment insulation whereas for voltages above 345 kV it is these switching surges which are more dangerous for the equipments than the lightning surges.
- ✓ The problem of coordinating the insulation of the protective equipment involves not only guarding the equipment insulation but also it is desired that the protecting equipment should not be damaged. To assist in the process of insulation coordination, standard insulation levels have been recommended. These insulation levels are defined as follows.

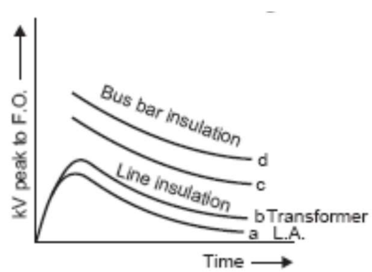
- ✓ Basic impulse insulation levels (BIL) are reference levels expressed in impulse crest voltage with a standard wave not longer than 1.2/50 μsec wave. Apparatus insulation as demonstrated by

- ✓ Suitable tests shall be equal to or greater than the basic insulation level.

The problem of insulation coordination can be studied under three steps:

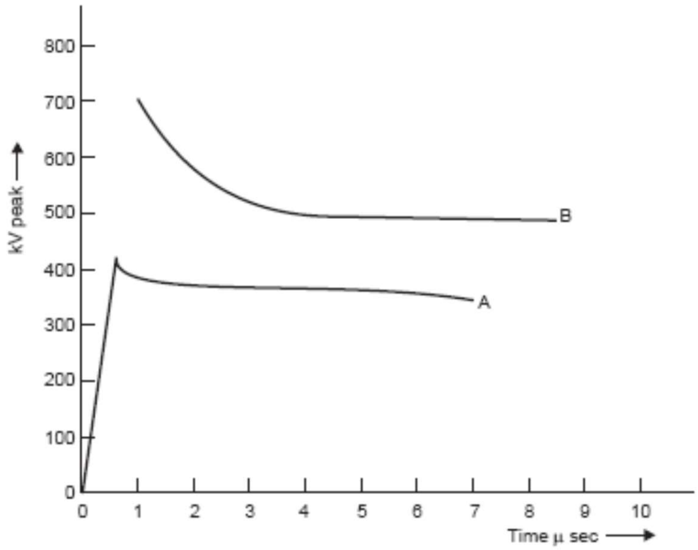
- ✓ Selection of a suitable insulation which is a function of reference class voltage (i.e., 1.05 × operating voltage of the system).
- ✓ The design of the various equipments such that the breakdown or flashover strength of all insulation in the station equals or exceeds the selected level as in Selection of protective devices that will give the apparatus as good protection as can be justified economically.

- ✓ The third column of the table gives the reduced insulation levels which are used for selecting insulation levels of solidly grounded systems and for systems operating above 345 kV where switching surges are of more importance than the lightning surges.
- ✓ At 345 kV, the the ratio of switching voltage to operating voltage is reduced by using the switching resistances between the C.B. contacts. For 500 kV it is has been possible to obtain this ratio as 2.0 and for 765 kV it is 1.7. With further increase in operating voltages, it is hoped that the ratio could be brought to 1.5. So, for switching voltages the reduced levels in third column are used *i.e.,* for 345 kV, the standard BIL is 1550 kV but if the equipment can withstand even 1425 kV or 1300 kV it will serve the purpose.



- ✓ The above Fig, gives the relative position of the volt-time curves of the various equipments in a substation for proper coordination.

- ✓ To illustrate the selection of the BIL of a transformer to be operated on a 138 kV system assume that the transformer is of large capacity and its star point is solidly grounded.
- ✓ The grounding is such that the line-to-ground voltage of the healthy phase during a ground fault on one of the phases is say 74% of the normal *L-L* voltage. Allowing for 5% overvoltage during operating conditions, the arrester rms operating voltage will be $1.05 \times 0.74 \times 138 = 107.2$ kV. The nearest standard rating is 109 kV. The characteristic of such a L.A. is shown in



- ✓ From the figure above the breakdown value of the arrester is 400 kV. Assuming a 15% margin plus 35 kV between the insulation levels of L.A. and the transformer, the insulation level of transformer should be at least equal
- ✓ to $400 + 0.15 \times 400 + 35 = 495$ kV. From Fig. 7.30 (or from the table the reduced level of transformer for 138 kV is 550 kV) the insulation level of transformer is 550 kV; therefore a lightning arrester of 109 kV rating can be applied
- ✓ It is to be noted that low voltage lines are not as highly insulated as higher voltage lines so that lightning surges coming into the station would normally be much less than in a higher voltage station because the high voltage surges will flashover the line insulation of low voltage line and not reach the station.
- ✓ The traditional approach to insulation coordination requires the evaluation of the highest overvoltages to which an equipment may be subjected during operation and selection of standardized value of withstand impulse voltage with suitable safety margin.
- ✓ However, it is realized that overvoltages are a random phenomenon and it is uneconomical to design plant with such a high degree of safety that they sustain the infrequent ones.
- ✓ It is also known that insulation designed on this basis does not give 100% protection and insulation failure may occur even in well designed plants and, therefore, it is desired to limit the frequency of insulation failures to the most economical value taking into account equipment cost and service continuity. Insulation coordination, therefore, should be based on evaluation and limitation of the risk of failure than on the prior choice of a safety margin.

- ✓ The modern practice, therefore, is to make use of probabilistic concepts and statistical procedures especially for very high voltage equipments which might later on be extended to all cases where a close adjustment of insulation to system conditions proves economical. The statistical methods even though laborious are quite useful.

7. Discuss the various tests carried out in a surge arrester at high voltage laboratories.(May-2014)

To ensure safe operation and an appropriate lifetime of surge arresters, type and routine tests are to be performed. The most important standards covering type and routine testing of surge arresters.

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Type tests

Surge arrester type tests demonstrate the general ability of an arrester design to withstand the electrical, mechanical, thermal and environmental stresses which might occur within the lifetime of a surge arrester. These test are performed once on a certain number of samples and are to be repeated when significant changes of the arrester design are introduced. Apart from test on arrester units (e.g. short circuit test), certain tests on complete arresters (e.g. artificial pollution test) have to be performed.

Routine tests

Surge arrester routine tests are performed on every single arrester unit in order to ensure the correct manufacturing and assembly of the arrester. Thus, routine testing is an important part of the quality assurance system of every manufacturer of surge arresters. As per IEC 60099-4, th

- Insulation withstand test-- Demonstrates the ability of the arrester housing to withstand voltage stresses under dry and wet conditions
- Residual voltage test-- Demonstrates the protective level of the arrester.
- Long duration current impulse withstand test --Demonstrates the ability of the resistor elements to withstand dielectric and energy stresses without puncture or flashover
- Operating duty test-- Demonstrates the thermal stability of the arrester under defined conditions
- Short circuit test --Demonstrates the ability of the arrester to withstand short circuit currents without violent shattering of the housing. For polymer housed arresters this test also demonstrates the ability self-extuingish any fire caused by the arc
- Test of arrester disconnections'-- Usually not applicable for surge arresters for SC banks and HVDC stations, since disconnectors are virtually not used
- Artificial pollution test for porcelain housed multi unit arresters-- Evaluation of the temperature rise of the internal parts due to a non-linear and transient voltage grading caused by the pollution layer on the surface of the arrester housing Usually only applicable for "A" and "D" arresters of HVDC stations, generally not for SC arresters
- Internal partial discharge test-- Measures the internal partial discharge rate
- Seal leak rate test-- Demonstrates the gas and water tightness of the complete system.
- Current distribution test-- for multi column arrester Determination of the current through each column of parallel resistors
- Bending moment test-- Demonstrates the ability of the arrester to withstand the values for bending loads claimed by the manufacturer
- Environmental tests-- Demonstrates that the sealing mechanism and the metal parts of the arrester are not impaired by environmental

8. EXPLAIN THE TYPES OF BUSHING.

I. Types of Bushings

High-voltage bushings for use on transformers and breakers are made in several principal types, as follows:

A. **Composite Bushing**.- A bushing in which insulation consists of two or more coaxial layers of different insulating materials.

B. **Compound-Filled Bushing**.- A bushing in which the space between the major insulation (or conductor where no major insulation is used) and the inside surface of a protective weather casing (usually porcelain) is filled with a compound having insulating properties.

C. **Condenser Bushing.-** A bushing in which cylindrical conducting layers are arranged coaxially with the conductor within the insulating material. The length and diameter of the cylinders are designed to control the distribution of the electric field in and over the outer surface of the bushing. Condenser bushings may be one of several types:

1. Resin-bonded paper insulation;
2. Oil-impregnated paper insulation; or
3. Other.

D. Dry or Unfilled Type Bushing.- Consists of porcelain tube with no filler in the space between the shell and conductor. These are usually rated 25 kV and below.

E. Oil-Filled Bushing.- A bushing in which the space between the major insulation (or the conductor where no major insulation is used) and the inside surface of a protective weather casing (usually porcelain) is filled with insulating oil.

F. Oil Immersed Bushing.- A bushing composed of a system of major insulations totally immersed in a bath of insulating oil.

G. Oil-Impregnated PaperInsulated Bushing.- A bushing in which the internal structure is made of cellulose material impregnated with oil.

H. Resin-Bonded, PaperInsulated Bushing.- A bushing in which the major insulation is provided by cellulose material bonded with resin.

I. Solid (Ceramic) Bushing.- A bushing in which the major insulation Is provided by a ceramic or analogous material.

9.WITH NEAT DIAGRAM EXPLAIN THE VARIOUS HV TESTING'S CARRIED OUT ON BUSHINGS. APRIL/MAY-2015

POWER FREQUENCY TESTS

(a) ***Power Factor—Voltage Test***: In this test, the bushing is set up as in service or immersed in oil. It is connected such that the line conductor goes to the high voltage side and the tank or earth portion goes to the detector side of the high voltage Schcringbridge. Voltage is applied up to the line value in increasing steps and then reduced. The capacitance and power factor (or tan 5) are recorded at each step. The characteristic of power factor or tan 8 versus applied voltage is drawn. This is a normal routine test but sometimes may be conducted on percentage basis.

(b) ***Internal or Partial Discharge Test***: This test is intended to find the deterioration or failure due to internal discharges caused in the composite insulation of the bushing. This is done by using internal or partial discharge arrangement. The voltage versus discharge magnitude as well as the quadratic rate gives an excellent record of the performance of the bushing in service. This is now a routine test for high voltage bushings.

(c) ***Momentary Withstand Test at Power Frequency:***This is done as per the Indian Standard Specifications, IS: 2099, applied to bushings. The test voltage is specified in the specifications. The bushing has to withstand without flashover or puncture for a minimum time (~ 3Os) to measure the voltage. At present this test is replaced by the impulse withstand test.

(d) ***One Minute Wet Withstand Test at Power Frequency***: The most common and routine tests used for all electrical apparatuses are the one minute wet, and dry voltage withstand tests. In wet test, voltage specified is applied to the bushing mounted as in service with the rain arrangement as described earlier. A properly designed bushing has to withstand the voltage without flashover for one minute. This test really does not give any information for its satisfactory performance in service, while impulse and partial discharge tests give more information.

(e) ***Visible Discharge Test at Power Frequency***This test is intended for determining whether the bushing is likely to give radio interference in service, when the voltage specified in IS: 2099 is applied. No discharge other than that from the arcing horns or grading rings should be visible to the observers in a dark room. The test arrangement is the same as that of the withstand test, but the test is conducted in a dark room.

IMPULSE VOLTAGE TESTS

(a) ***Full Wave Withstand Test:***The bushing is tested for either polarity voltages as per the specifications. Five consecutive full waves of standard waveform are applied, and, if two of them cause flashover, the bushing is said to have failed in the test. If only one flashover occurs, ten additional applications are done. The bushing is considered to have passed the test if no flashover occurs in subsequent applications.

(b) ***Chopped Wave Withstand and Switching Surge Tests***The chopped wave lest is sometimes done for high voltage bushings (220 kV and 400 kV and above). Switching surge flashover test of specified value is now-a-days included for high voltage bushings. The tests are carried out similar to full wave withstand tests.

THERMAL TESTS

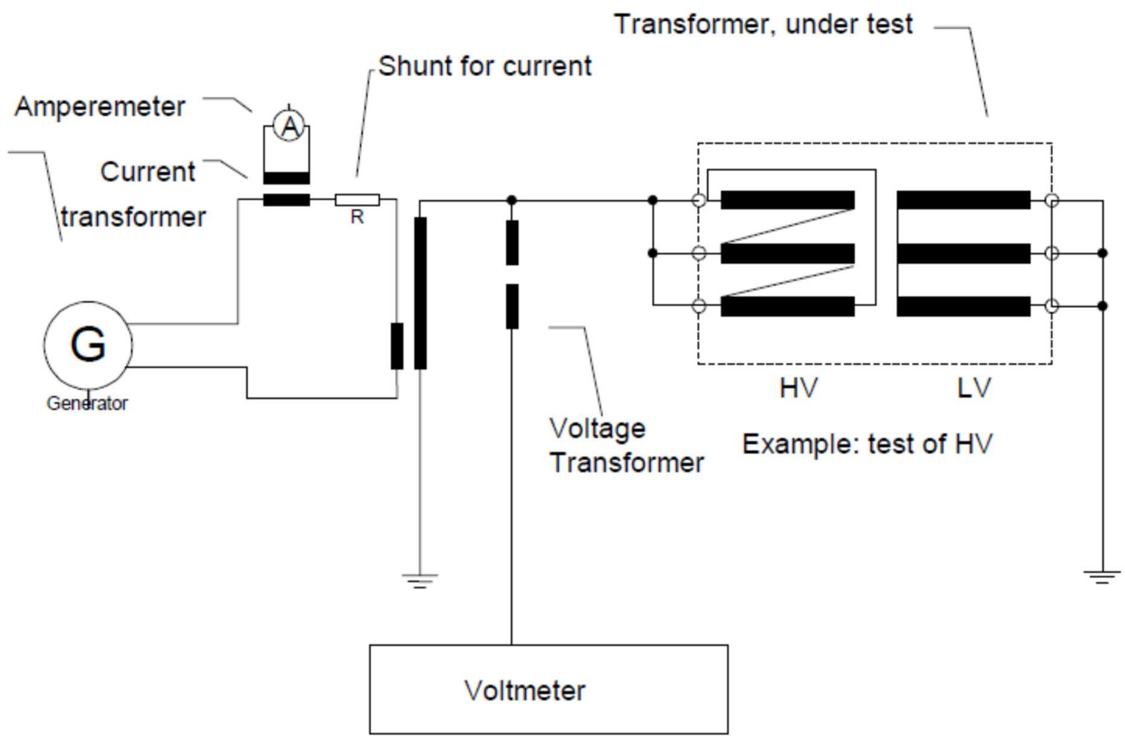
(a) ***Temperature Rise and Thermal Stability Tests:***The purpose of these tests is to ensure that the bushing in service for long does not have an excessive temperature rise and also does not go into the "thermal runaway" condition of the insulation used.Temperature rise test is carried out in free air with an ambient temperature below 4O^{0}C at a rated power frequency (50 Hz) a.c. current. The steady temperature rise above the ambient air temperature at any part of the bushing should not exceed 45^{0}C.
The test is carried out for such a long time till the temperature is substantially constant,
i.e. the increase in temperature rate is less than l°C/hr. Sometimes, the bushings have to be operated along with transformers, of which the temperature reached may exceed 8O^{0}C. This temperature is high enough to produce large dielectric losses and thermal instability. For high voltage bushings this is particularly important, and hence the thermal stability test is done for bushings rated for 132 kV and above. The test is carried out with the bushing immersed in oil at a maximum temperature as in service, and the voltage applied is 86% of the nominal system voltage. This is approximately *12* times the working voltage of the bushing and hence the dielectric losses are about double the normal value. The additional losses account for the conductor ohmic losses. It has been considered unnecessary to specify the thermal stability test for oil-impregnated paper bushings of low ratings; but for the large high voltage bushings
(1600 A, 400 kV transformer bushings, etc.), the losses in the conductor may be high enough to outweigh the dielectric losses. It may be pointed out here, that the thermal stability tests are type tests. But in the case of large sized high voltage bushings, it may be necessary to make them routine tests.

10.EXPLAIN IN SEQUENCE THE VARIOUS HIGH VOLTAGE TESTE BEING CARRIED OUT IN A POWER TRANSFORMER.APRIL/MAY-2015

1) *DIELECTRIC TESTS – SEPARATE-SOURCE VOLTAGE WITHSTAND TEST*

The single-phase applied voltage wave shape shall be approximately sinusoidal. The test must be performed at rated frequency. At the end of the test, the test voltage shall be rapidly reduced up to 1/3 the full voltage before disconnection. The full test voltage shall be applied for 60 seconds between the winding under test and all the remaining windings, magnetic core, frame and enclosure connected to earth. The test shall be performed on all the windings.The test is Successful if no failure occurs at full test voltage.

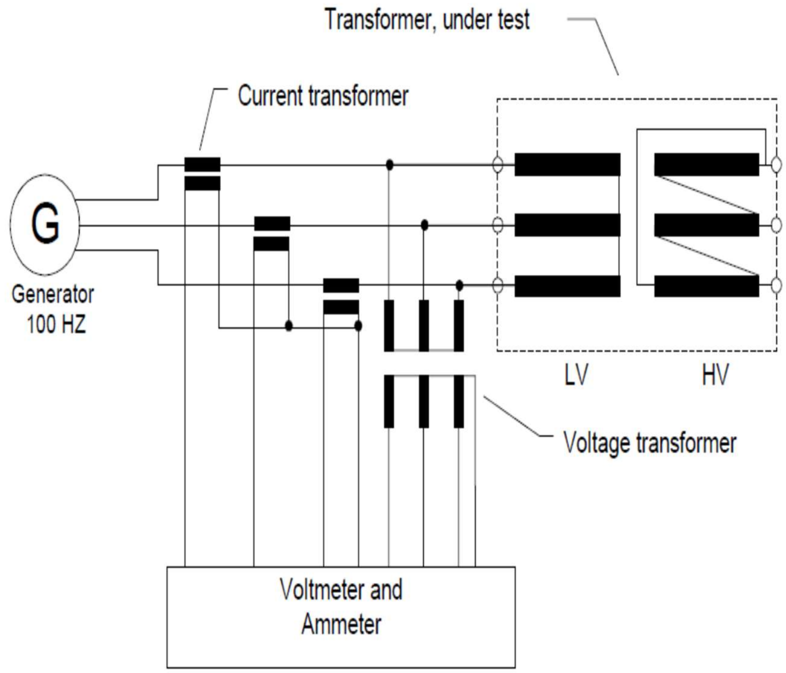
CONNECTION SCHEME:



2) *INDUCED VOLTAGE TEST*

The test voltage shall be twice the value corresponding to the rated voltage; it shall be applied between the terminals of the secondary windings, by maintaining the primary winding open. The duration of the test at full voltage shall be 60 s, and the frequency twice the rated value. The test shall start with a voltage lower than 1/3 the full test voltage, and it shall be quickly increased up to full value. At the end of the test, the voltage shall be rapidly reduced up to 1/3 the rated value before disconnection. The test is successful if no failure occurs at full test voltage.

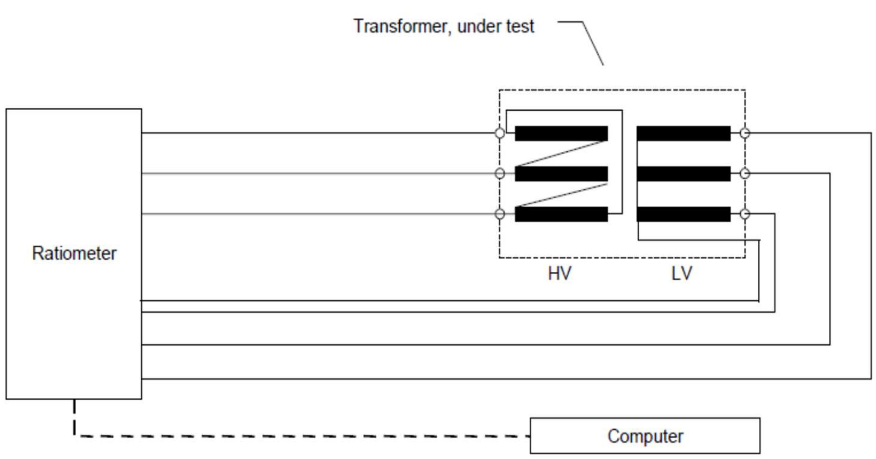
CONNECTION SCHEME:



3) *VOLTAGE RATIO MEASUREMENT AND CHECK OF POLARITIES AND CONNECTIONS*

Voltage ratio measurement and check of polarities and connections shall be performed on all tapchanger positions; the correspondence between the numbers assigned to the tappings and the ratings shall also be checked. Voltage ratio measurement shall be performed phase by phase between the terminals of corresponding windings. Voltage ratio measurement is carried out by use of potentiometric method.

CONNECTION SCHEME:

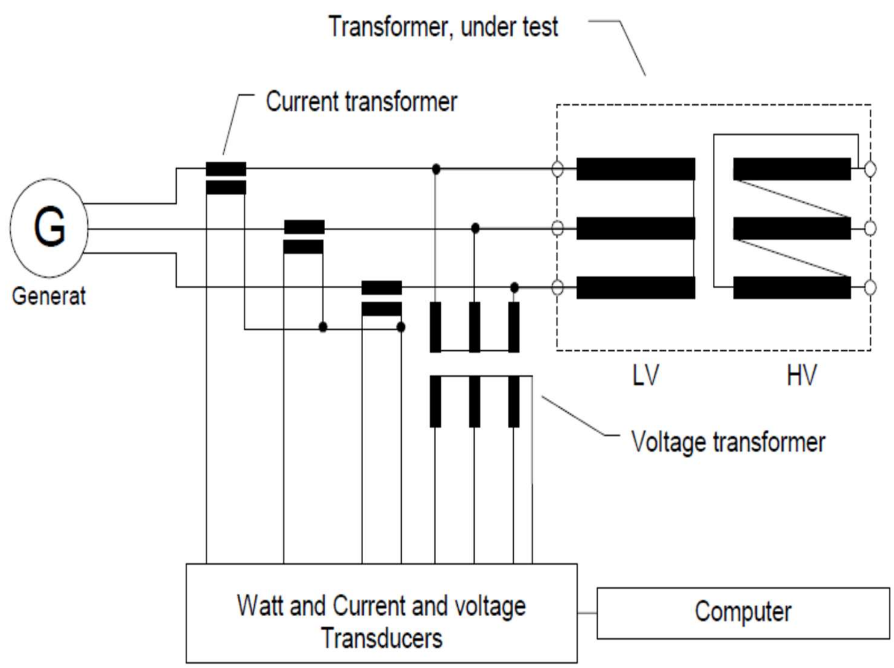


4) *NO-LOAD CURRENT AND NO-LOAD LOSS MEASUREMENT*

This test is performed by supplying LV windings at rated frequency and rated voltage. The wave shape shall be as nearly as possible of the sine-wave and the primary windings shall be open.

The frequency of the test shall not differ from the rated value more than ± 1%. No-load current and loss shall be measured as well as the mean value and the effective value of the voltage. If these two readings are equal, no correction shall be applied on the measurement of no-load loss; otherwise, no-load loss shall be referred to sine-wave condition in accordance with IEC Standards 60076-1. No-load current shall result as the average value of three readings performed by effective value ammeters. Three wattmeters shall be used to measure the power, by using instrument transformers and transducers when necessary.

CONNECTION SCHEME:



5) WINDING RESISTANCE MEASUREMENT

Winding resistance measurement shall be performed when the windings are at ambient temperature without supply for a time long enough to achieve this condition. The measurements shall be carried out in direct current between terminals according to the sequence U-V; V-W; WU.Ambient temperature shall also be measured. It shall result as the average value of three measurements performed by apposite thermal sensors.

HV winding resistance measurement

HV winding resistance measurement shall be performed by measuring simultaneously voltage and current. The voltmeter and ammeter must be connected as follows :

• voltmeter terminals must be connected beyond current cables;
• the current shall not exceed 10% of winding rated current;
• the measurement shall be carried out after voltage and current are stable.

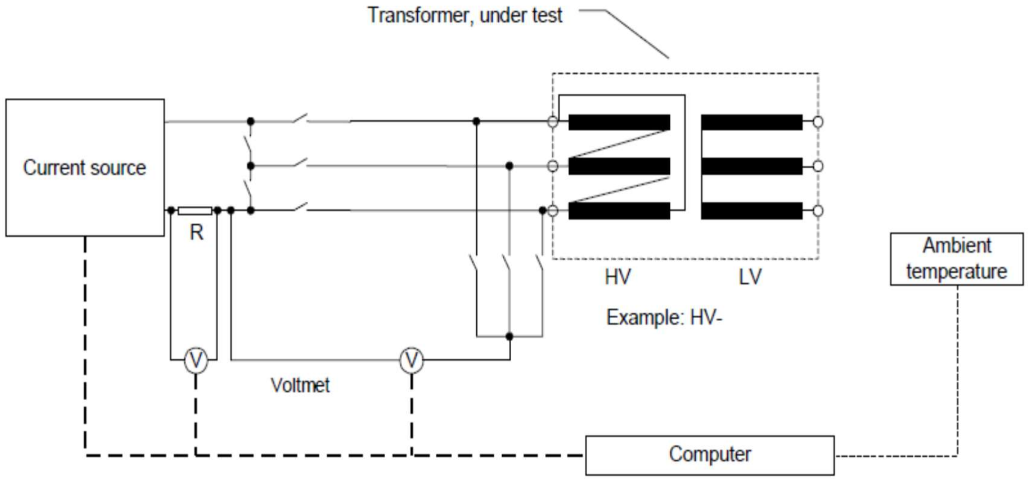
Unless otherwise agreed, the HV winding shall be connected on principal tapping.

LV winding resistance measurement

LV winding resistance measurement shall be performed by measuring simultaneously voltage and current. The voltmeter and ammeter shall be connected as follows :

• voltmeter terminals shall be connected beyond current cables;
• the current shall not exceed 5% of winding rated current;
• the measurement shall be carried out after voltage and current are stable.

CONNECTION SCHEME:

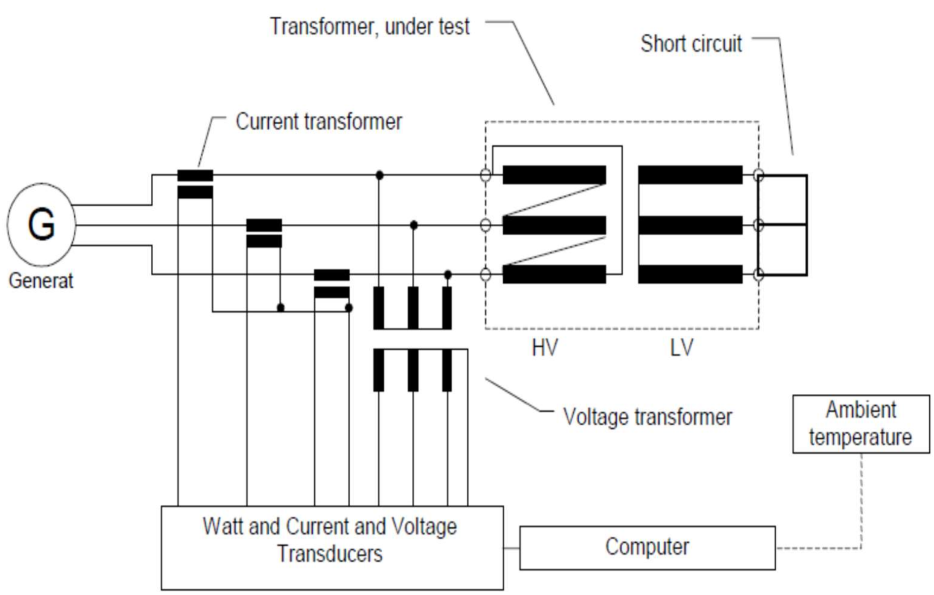


6) *SHORT-CIRCUIT IMPEDANCE AND LOAD LOSS MEASUREMENT*

Short-circuit impedance and load loss measurement shall be performed at rated frequency, by applying on the transformer primary windings (connected on principal tapping) a three –phase sine-wave voltage system. The secondary windings shall be short-circuited. Applied voltage, current and load loss shall be measured.

The frequency of the test shall not differ from the rated frequency more than ± 1%. In case the rated power is higher than 1000 kVA, load loss shall be measured by using three wattmeters, in order to reduce measurement uncertainties. When necessary, instrument transformers and transducers shall be used. The measured values shall be referred to rated current and then calculated at reference temperature. This temperature is the annual average ambient temperature (20°C) increased by the permissible temperature rise in accordance with the temperature class of the windings. IEC 60726 specify the permissible temperature rises on table no. 4. Beside, IEC 60076-1 give a complete explanation of how to perform the carries at rated current and at reference temperature.

CONNECTION SCHEME:

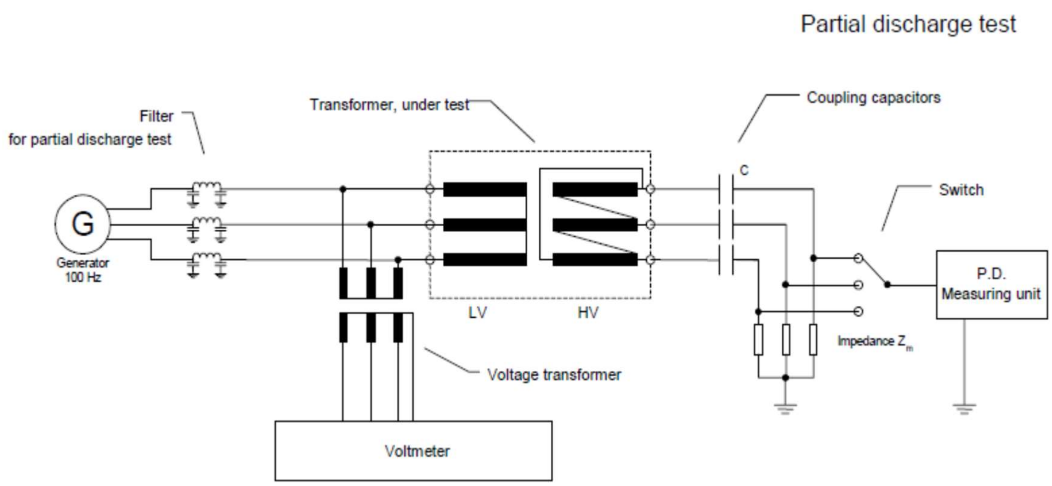


7) *PARTIAL DISCHARGE MEASUREMENT*

A basic measuring circuit for partial discharge test is shown in figure 2 , IEC Standards 60726.

The low-voltage windings shall be supplied from an alternate 100 Hz voltage source. The voltage shape shall be as nearly as possible of the sine-wave. Unless otherwise specified, a pre-stress voltage of 1,5 Um shall be induced for 30 s, followed without interruption by a voltage of 1,1 Um for three minutes, during which the partial discharge level shall be measured. The calibration of the measuring circuit is carried out by injecting simulated discharge pulses of 100pC at transformer terminals. Partial discharge measurement shall be carried out by use of an oscilloscope, in order to analise the developing of the ongoing phenomena. Test procedures must be in accordance with IEC Standards 60726. The test is successful if the partial discharge level is lower than 20 pC unless otherwise agreed between manufacturer and purchaser.

CONNECTION SCHEME:



(b) (i) Draw the cross-sectional view of a valve type lightning arrester and explain its operation with V-I characteristics . (8)

(ii) What are the requirements of a ground wire for protecting power conductors against direct lightning stroke? Explain how they are achieved in practice. (8)

12. (a) (i) Discuss the streamer theory of breakdown in gases. (8)

(ii) Explain the various mechanism of vacuum breakdown. (8)

Or

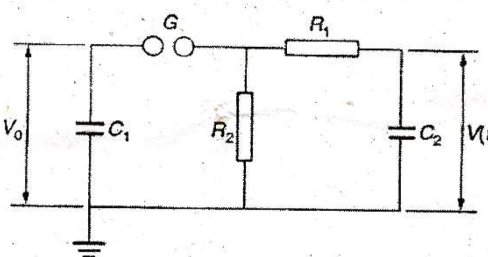
(b) Explain thermal breakdown mechanism in solid dielectrics. Derive an expression for critical thermal breakdown voltage (V_c) and critical electric field (E_c) for the same . State clearly the assumptions made. (16)

13. (a) (i) Explain the working of Cockroft-Walton voltage multiplier circuit under unloaded and loaded conditions. (8)

(ii) Derive an expression for total voltage drop and total ripple voltage of n-stage voltage multiplier circuit and hence deduce the condition for optimum number of stages. (8)

Or

(b) Give complete analysis of the given impulse circuit and derive the condition for physical realization of wavefront and wave tail resistances. (16)



14. (a) Describe the construction, principle of operation of a generating voltmeter and give its application and limitations. (16)

Or

(b) Discuss and compare the performance of resistance capacitance and mixed R- C potential dividers for measurement of impulse voltages. (16)

15. (a) (i) What are volt-time curves? Explain the procedure for constructing volt-time curves with neat sketch. Give its significance in power system studies. (10)

(ii) Explain the modern trends in the insulation design of EHV and UHV substations. (6)

Or

(b) Discuss the various tests carried out in a surge arrester at high voltage laboratories. (16)

Reg. No. :

Question Paper Code : 51445

B.E./B.Tech. DEGREE EXAMINATION, MAY/JUNE 2014.

Sixth Semester

Electrical and Electronics Engineering

EE 2353/EE 63/10133 EE 603 – HIGH VOLTAGE ENGINEERING

(Regulation 2008/2010)

(Common to PTEE 2353- High Voltage Engineering for B.E. (Part-Time) Fifth Semester-Electrical and Electronics Engineering-Regulation 2009)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — ($10 \times 2 = 20$ marks)

1. Draw the mathematical model for lightning discharges.
2. Classify the lightning strokes.
3. What are the factors which affect breakdown of gaseous dielectrics?
4. What is meant by Penning Effect?
5. What are the advantages of series resonant circuit?
6. Mention the necessity of generating high dc voltage.
7. Give the procedure for dc and ac peak voltage measurement using sphere gap.
8. What are different types of resistive shunts used for impulse current measurements?
9. How is impulse voltage withstand test conducted?
10. Distinguish between flash over and puncture.

PART B — ($5 \times 16 = 80$ marks)

11. (a) (i) Discuss the step by step procedure for constructing Bewley's Lattice Diagram with an example. (8)

(ii) Explain how are switching and power frequency over voltages controlled in power system. (8)

Or

(b) (i) Draw the cross-sectional view of a valve type lightning arrester and explain its operation with V-I characteristics. (8)

(ii) What are the requirements of a ground wire for protecting power conductors against direct lightning stroke? Explain how they are achieved in practice. (8)

12. (a) (i) Discuss the streamer theory of breakdown in gases. (8)

(ii) Explain the various mechanism of vacuum breakdown. (8)

Or

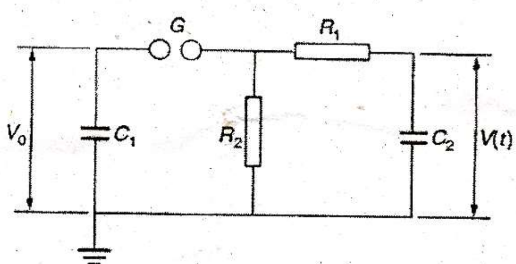
(b) Explain thermal breakdown mechanism in solid dielectrics. Derive an expression for critical thermal breakdown voltage (V_c) and critical electric field (E_c) for the same. State clearly the assumptions made. (16)

13. (a) (i) Explain the working of Cockroft-Walton voltage multiplier circuit under unloaded and loaded conditions. (8)

(ii) Derive an expression for total voltage drop and total ripple voltage of n-stage voltage multiplier circuit and hence deduce the condition for optimum number of stages. (8)

Or

(b) Give complete analysis of the given impulse circuit and derive the condition for physical realization of wavefront and wave tail resistances. (16)



14. (a) Describe the construction, principle of operation of a generating voltmeter and give its application and limitations. (16)

Or

(b) Discuss and compare the performance of resistance capacitance and mixed R- C potential dividers for measurement of impulse voltages. (16)

15. (a) (i) What are volt-time curves? Explain the procedure for constructing volt-time curves with neat sketch. Give its significance in power system studies. (10)

(ii) Explain the modern trends in the insulation design of EHV and UHV substations. (6)

Or

(b) Discuss the various tests carried out in a surge arrester at high voltage laboratories. (16)

Reg. No. :

Question Paper Code : 31405

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2013.

Sixth Semester

Electrical and Electronics Engineering

EE 2353/EE 63/10133 EE 603 — HIGH VOLTAGE ENGINEERING

(Regulation 2008/2010)

(Common to PTEE 2353 – High Voltage Engineering for B.E. (Part-Time) Fifth Semester – Electrical and Electronics Engineering – Regulation 2009)

Time : Three hours — Maximum : 100 marks

Answer ALL questions.

PART A — ($10 \times 2 = 20$ marks)

1. State the sources which determine the wave shape of switching surges.

2. Write down the causes of power frequency and its harmonic over voltages.

3. What are the properties required for a gaseous dielectric for HV applications?

4. What are commercial liquid dielectrics and how are they different from pure liquid dielectrics?

5. Define the front and tail times of an impulse wave.

6. What are the disadvantages of half wave rectifier circuit?

7. What is the effect of dust particles on the measurement using sphere gaps?

8. List out the limitations of generating voltmeters.

9. Define disruptive discharge voltage.

10. Mention the characteristics of the spray used in wet flashover test.

PART B — (5 × 16 = 80 marks)

11. (a) (i) What are the mechanisms by which lightning strokes develop and induce over voltages on over head power lines? (8)

(ii) Write short notes on ground rods as protective devices. (8)

Or

(b) What are the causes for switching and power frequency over voltages? How are they controlled in power systems?

12. (a) (i) Describe the various mechanisms of vacuum break down. (8)

(ii) What are treeing and trenching? Explain clearly the two processes in solid dielectrics. (8)

Or

(b) (i) Explain the various theories that explain break down in commercial liquid dielectrics. (8)

(ii) What is corona discharge? Explain clearly anode and cathode coronas. (8)

13. (a) Explain with neat sketches cockroft-walton voltage multiplier circuit. Explain clearly its operation when the circuit is

(i) unloaded and

(ii) loaded.

Or

(b) (i) Explain one method of controlled tripping of impulse generators. Why is controlled tripping necessary? (8)

(ii) What is a cascaded transformer? Explain why cascading is done? Describe with neat diagram, a 3 stage cascaded transformer. (8)

14. (a) (i) Discuss various methods of measuring high impulse currents. (8)

(ii) Describe the construction of uniform field spark gap and discuss its advantages and disadvantages for high voltage measurements. (8)

Or

(b) (i) What are the requirements of a sphere gap for measurement of high voltages? Discuss the disadvantages of sphere gap for measurements. (8)

(ii) Draw a simplified equivalent circuit of resistance potential divider and discuss its step response. (8)

15. (a) Describe the various tests to he carried out on a circuit breaker.

Or

(b) (i) Discuss the different aspects of insulation design and insulation co-ordination adopted for EHV systems. (8)

(ii) Explain the function of discharge device used in power capacitor and explain the test for efficacy of this device. (8)

Question Paper Code : 21405

B.E./B.Tech. DEGREE EXAMINATION, MAY/JUNE 2013.

Sixth Semester

Electrical and Electronics Engineering

EE 2353/EE 63/10133 EE 603 – HIGH VOLTAGE ENGINEERING

(Regulation 2008/2010)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — ($10 \times 2 = 20$ marks)

1. Mention the different kinds of over voltages.
2. What is stepped leader stroke?
3. What is meant by corona discharges?
4. What are electronegative gases?
5. Mention the specifications of the standard impulse voltage.
6. Give any two methods of switching surge generation in laboratory.
7. Define CVT.
8. Give the advantages of electrostatic voltmeter.
9. What are the different tests conducted on insulators?
10. What are type and routine tests?

PART B — ($5 \times 16 = 80$ marks)

11. (a) (i) Explain the mechanism of lighting strokes. (10)

(ii) Give the mathematical models for lightning discharges and explain them. (6)

Or

(b) (i) Explain causes of power frequency over voltages in power system.(8)

(ii) Give a brief note on protection of transmission lines using protection devices. (8)

12. (a) State the criteria for sparking potential and hence obtain the relation between sparking potential and (pd) values (Paschen's Law). Discuss on the nature of variations of sparking potential with (pd) values. (16)

Or

(b) Explain the breakdown mechanism involved in commercial liquid dielectrics. (16)

13. (a) (i) Explain the operation of basic impulse generator. (8)

(ii) Explain the cascaded transformer method of HVAC generation. (8)

Or

(b) Explain the operation of vande graff generator from the electrostatic principle. (16)

14. (a) (i) Explain the operation of the hall effect generator for measuring high DC currents. (8)

(ii) Discuss the factors influencing the spark over voltage on Sphere gaps. (8)

Or

(b) Tabulate the various methods of High AC and DC voltage and current measurements. (16)

15. (a) Explain the various tests conducted in high voltage insulators. (16)

Or

(b) Explain the tests conducted on high voltage cables. (16)

Reg. No. : | | | | | | | | | | | | |

Question Paper Code : 71511

B.E./B.Tech. DEGREE EXAMINATION, APRIL/MAY 2015.

Sixth Semester

Electrical and Electronics Engineering

EE 2353/EE 63/10133 EE 603 — HIGH VOLTAGE ENGINEERING

(Regulation 2008/2010)

(Common to PTEE 2353/10133 EE 603 – High Voltage Engineering for B.E. (Part-Time) Fifth Semester – Electrical and Electronics Engineering – Regulation 2009/2010)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. What are various abnormalities in a High Voltage system?

2. What are the characteristics of a lightning voltage?

3. What is Town-sends condition for Breakdown?

4. Define statistical time lag and formative time lag.

5. What are differences between a high voltage testing transformer and a power transformer?

6. What do you mean by tracking index?

7. What is the principle behind the operation of generating voltmeter?

8. Calculate the correction factors for atmospheric conditions, if the laboratory temperature is 37°C, the atmospheric pressure is 750 mmHg and the wet bulb temperature is 27°C.

9. What are called type tests?

10. What is BIL?

PART B — (5 × 16 = 80 marks)

11. (a) (i) Briefly describe a method of recording the occurrence of lightning in an overhead transmission line. (8)

(ii) Explain why a steep fronted surge waveform are more vulnerable to insulation. (8)

Or

(b) Briefly explain, with the aid of suitable diagrams, the statistical method of insulation co ordination.

12. (a) A certain dielectric can be considered to be represented by the equivalent circuit shown in figure 1. What is the maximum voltage that can be applied across the dielectric, if partial discharges in air to be avoided? State any assumptions made.

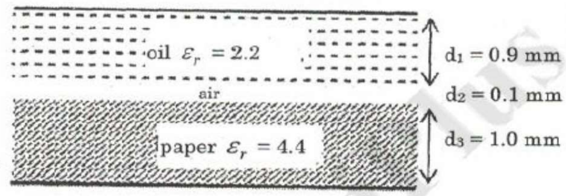


Figure. 1

Or

(b) From the fundamental principles, derive Townsend's criteria for the breakdown of gaseous dielectric medium.

13. (a) A Cockcroft – Walton type voltage multiplier has eight stages with capacitances equal to 0.05 μF. The supply transformer secondary voltage is 125 kV at a frequency of 150 Hz. If the load current to be supplied is 5 mA, find (i) the percentage ripple (ii) the regulation and (iii) the optimum number of stages for minimum regulation of voltage drop.

Or

(b) A six-stage impulse generator designed to generate the standard waveform (1.2/50 μs) has a per stage capacitance of 0.06 μF to be used to test transformers with an equivalent winding to earth capacitance of 1 nF. A peak output voltage of 550 kV is required for testing the transformer. The wavefront time is to be defined based on 30% and 90% values. With the aid of appropriate calculations select the values of the resistive elements in the circuit to produce the required waveform. State any assumptions made.

14. (a) Explain in detail the various techniques for the measurement of High DC voltages.

Or

(b) With neat sketch explain in detail the various methods used to measure the RMS and peak values of High AC voltages.

15. (a) With neat diagram explain the various HV testing's carried out on Insulators and Bushings.

Or

(b) Explain in sequence the various high voltage tests being carried out in a Power Transformer.

Reg. No. :

Question Paper Code : 21511

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2015.

Sixth Semester

Electrical and Electronics Engineering

EE 2353/EE 63/10133 EE 603 — HIGH VOLTAGE ENGINEERING

(Regulations 2008/2010)

(Common to PTEE 2353/10133 EE 603 – High Voltage Engineering for B.E. (Part–Time) Fifth Semester – Electrical and Electronics Engineering – Regulations 2009/2010)

Time : Three hours | Maximum : 100 marks

Answer ALL questions.

PART A — ($10 \times 2 = 20$ marks)

1. What are the factors that influence the lightning induced voltage on transmission line?

2. Why a simple spark gap cannot offer full protection against over voltages?

3. Name the various secondary ionization processes involved in gaseous dielectric breakdown.

4. What are electronegative gases? Give its significance.

5. How is the circuit inductance controlled and minimized in impulse current generator?

6. Mention the specification of impulse current as per Indian Standards.

7. What are the drawbacks of series resistance micro-ammeter technique in HVAC measurements?

8. How the stray effect of capacitance potential divider is minimized for impulse measurements?

9. Distinguish between flash over and puncture.

10. Define safety margin as applied to insulation co-ordination.

PART B — (5 × 16 = 80 marks)

11. (a) (i) What are the sources of switching surges? Explain the characteristics of switching surges with typical wave shapes. (10)

(ii) Discuss the various controlling methods of over voltages due to switching and power frequency. (6)

Or

(b) (i) A long transmission line is energized by a unit step voltage of 1.0 V at the sending end and is open circuited at the receiving end. Construct the Bewley Lattice diagram and obtain the value of the voltage at the receiving end after a long time. Take the attenuation factor $\alpha = 0.8$. (10)

(ii) Write a short note on ground rods as protective devices. (6)

12. (a) (i) Discuss the important properties of composite dielectrics. (6)

(ii) Discuss the various mechanism of breakdown in composite dielectrics. (10)

Or

(b) State why the very high intrinsic strength of a solid dielectrics is not fully realized in practice? Explain the different mechanisms by which breakdown occurs in solid dielectrics in practice. (16)

13. (a) (i) Explain the Marx circuit arrangement for multistage generator. How is the basic arrangements modified to accommodate the wave time control resistances? (10)

(ii) How are the wave front and wave tail time controlled in impulse generator circuit? (6)

Or

(b) (i) With a neat sketch, describe the construction and working of a Van de Graaff generator. (10)

(ii) Explain the functions and operation of a trigatron gap. (6)

14. (a) (i) Discuss the construction and vertical arrangement of sphere-gap. Explain the procedures for peak value measurement of high voltage DC, AC and impulse voltages using standard sphere gap. (10)

(ii) Explain the parameters and factors that influence the sphere-gap measurements. (6)

Or

(b) (i) Give the schematic arrangement of an impulse potential divider with an oscilloscope connected for measuring impulse voltages. Explain the arrangement used to minimize errors. (10)

(ii) What are the requirements of a digital storage oscilloscope for impulse and high frequency measurements in HV test circuits? (6)

15. (a) (i) Discuss with a circuit arrangements, the detailed procedure for conducting impulse voltage testing of HV power transformer. (8)

(ii) Explain the procedure adopted for detection and location of fault during impulse voltage testing. (8)

Or

(b) Explain the different aspects of insulation design and insulation coordination adopted for EHV systems. (16)

Reg. No. : | | | | | | | | | | | | |

Question Paper Code : 51445

B.E./B.Tech. DEGREE EXAMINATION, MAY/JUNE 2014.

Sixth Semester

Electrical and Electronics Engineering

EE 2353/EE 63/10133 EE 603 – HIGH VOLTAGE ENGINEERING

(Regulation 2008/2010)

(Common to PTEE 2353- High Voltage Engineering for B.E. (Part-Time) Fifth Semester-Electrical and Electronics Engineering-Regulation 2009)

Time : Three hours — Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Draw the mathematical model for lightning discharges.
2. Classify the lightning strokes.
3. What are the factors which affect breakdown of gaseous dielectrics?
4. What is meant by Penning Effect?
5. What are the advantages of series resonant circuit?
6. Mention the necessity of generating high dc voltage.
7. Give the procedure for dc and ac peak voltage measurement using sphere gap.
8. What are different types of resistive shunts used for impulse current measurements?
9. How is impulse voltage withstand test conducted?
10. Distinguish between flash over and puncture.

PART B — (5 × 16 = 80 marks)

11. (a) (i) Discuss the step by step procedure for constructing Bewley's Lattice Diagram with an example. (8)

(ii) Explain how are switching and power frequency over voltages controlled in power system. (8)

Or

(b) (i) Draw the cross-sectional view of a valve type lightning arrester and explain its operation with V-I characteristics . (8)

(ii) What are the requirements of a ground wire for protecting power conductors against direct lightning stroke? Explain how they are achieved in practice. (8)

12. (a) (i) Discuss the streamer theory of breakdown in gases. (8)

(ii) Explain the various mechanism of vacuum breakdown. (8)

Or

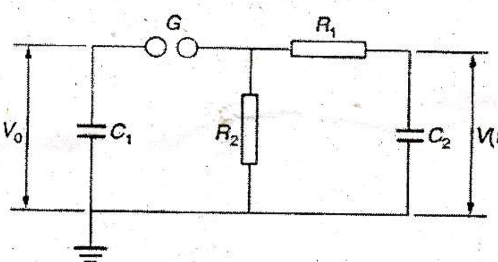
(b) Explain thermal breakdown mechanism in solid dielectrics. Derive an expression for critical thermal breakdown voltage (V_c) and critical electric field (E_c) for the same . State clearly the assumptions made. (16)

13. (a) (i) Explain the working of Cockroft-Walton voltage multiplier circuit under unloaded and loaded conditions. (8)

(ii) Derive an expression for total voltage drop and total ripple voltage of n-stage voltage multiplier circuit and hence deduce the condition for optimum number of stages. (8)

Or

(b) Give complete analysis of the given impulse circuit and derive the condition for physical realization of wavefront and wave tail resistances. (16)



14. (a) Describe the construction, principle of operation of a generating voltmeter and give its application and limitations. (16)

Or

(b) Discuss and compare the performance of resistance capacitance and mixed R- C potential dividers for measurement of impulse voltages. (16)

15. (a) (i) What are volt-time curves? Explain the procedure for constructing volt-time curves with neat sketch. Give its significance in power system studies. (10)

(ii) Explain the modern trends in the insulation design of EHV and UHV substations. (6)

Or

(b) Discuss the various tests carried out in a surge arrester at high voltage laboratories. (16)

Reg. No. :

Question Paper Code : 31405

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2013.

Sixth Semester

Electrical and Electronics Engineering

EE 2353/EE 63/10133 EE 603 — HIGH VOLTAGE ENGINEERING

(Regulation 2008/2010)

(Common to PTEE 2353 – High Voltage Engineering for B.E. (Part-Time) Fifth Semester – Electrical and Electronics Engineering – Regulation 2009)

Time : Three hours | Maximum : 100 marks

Answer ALL questions.

PART A — ($10 \times 2 = 20$ marks)

1. State the sources which determine the wave shape of switching surges.

2. Write down the causes of power frequency and its harmonic over voltages.

3. What are the properties required for a gaseous dielectric for HV applications?

4. What are commercial liquid dielectrics and how are they different from pure liquid dielectrics?

5. Define the front and tail times of an impulse wave.

6. What are the disadvantages of half wave rectifier circuit?

7. What is the effect of dust particles on the measurement using sphere gaps?

8. List out the limitations of generating voltmeters.

9. Define disruptive discharge voltage.

10. Mention the characteristics of the spray used in wet flashover test.

PART B — (5 × 16 = 80 marks)

11. (a) (i) What are the mechanisms by which lightning strokes develop and induce over voltages on over head power lines? (8)

(ii) Write short notes on ground rods as protective devices. (8)

Or

(b) What are the causes for switching and power frequency over voltages? How are they controlled in power systems?

12. (a) (i) Describe the various mechanisms of vacuum break down. (8)

(ii) What are treeing and trenching? Explain clearly the two processes in solid dielectrics. (8)

Or

(b) (i) Explain the various theories that explain break down in commercial liquid dielectrics. (8)

(ii) What is corona discharge? Explain clearly anode and cathode coronas. (8)

13. (a) Explain with neat sketches cockroft-walton voltage multiplier circuit. Explain clearly its operation when the circuit is

(i) unloaded and

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(b) (i) Explain one method of controlled tripping of impulse generators. Why is controlled tripping necessary? (8)

(ii) What is a cascaded transformer? Explain why cascading is done? Describe with neat diagram, a 3 stage cascaded transformer. (8)

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(ii) Describe the construction of uniform field spark gap and discuss its advantages and disadvantages for high voltage measurements. (8)

Or

(b) (i) What are the requirements of a sphere gap for measurement of high voltages? Discuss the disadvantages of sphere gap for measurements. (8)

(ii) Draw a simplified equivalent circuit of resistance potential divider and discuss its step response. (8)

15. (a) Describe the various tests to he carried out on a circuit breaker.

Or

(b) (i) Discuss the different aspects of insulation design and insulation co-ordination adopted for EHV systems. (8)

(ii) Explain the function of discharge device used in power capacitor and explain the test for efficacy of this device. (8)

Question Paper Code : 21405

B.E./B.Tech. DEGREE EXAMINATION, MAY/JUNE 2013.

Sixth Semester

Electrical and Electronics Engineering

EE 2353/EE 63/10133 EE 603 – HIGH VOLTAGE ENGINEERING

(Regulation 2008/2010)

Time : Three hours | Maximum : 100 marks

Answer ALL questions.

PART A — ($10 \times 2 = 20$ marks)

1. Mention the different kinds of over voltages.
2. What is stepped leader stroke?
3. What is meant by corona discharges?
4. What are electronegative gases?
5. Mention the specifications of the standard impulse voltage.
6. Give any two methods of switching surge generation in laboratory.
7. Define CVT.
8. Give the advantages of electrostatic voltmeter.
9. What are the different tests conducted on insulators?
10. What are type and routine tests?

PART B — ($5 \times 16 = 80$ marks)

11. (a) (i) Explain the mechanism of lighting strokes. (10)

(ii) Give the mathematical models for lightning discharges and explain them. (6)

Or

(b) (i) Explain causes of power frequency over voltages in power system. (8)

(ii) Give a brief note on protection of transmission lines using protection devices. (8)

12. (a) State the criteria for sparking potential and hence obtain the relation between sparking potential and (pd) values (Paschen's Law). Discuss on the nature of variations of sparking potential with (pd) values. (16)

Or

(b) Explain the breakdown mechanism involved in commercial liquid dielectrics. (16)

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(ii) Discuss the factors influencing the spark over voltage on Sphere gaps. (8)

Or

(b) Tabulate the various methods of High AC and DC voltage and current measurements. (16)

15. (a) Explain the various tests conducted in high voltage insulators. (16)

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Reg. No. : | | | | | | | | | | | | |

Question Paper Code : 21511

B.E./B.Tech. DEGREE EXAMINATION, NOVEMBER/DECEMBER 2015.

Sixth Semester

Electrical and Electronics Engineering

EE 2353/EE 63/10133 EE 603 — HIGH VOLTAGE ENGINEERING

(Regulations 2008/2010)

(Common to PTEE 2353/10133 EE 603 – High Voltage Engineering for B.E. (Part–Time) Fifth Semester – Electrical and Electronics Engineering – Regulations 2009/2010)

Time : Three hours | Maximum : 100 marks

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1. What are the factors that influence the lightning induced voltage on transmission line?

2. Why a simple spark gap cannot offer full protection against over voltages?

3. Name the various secondary ionization processes involved in gaseous dielectric breakdown.

4. What are electronegative gases? Give its significance.

5. How is the circuit inductance controlled and minimized in impulse current generator?

6. Mention the specification of impulse current as per Indian Standards.

7. What are the drawbacks of series resistance micro-ammeter technique in HVAC measurements?

8. How the stray effect of capacitance potential divider is minimized for impulse measurements?

9. Distinguish between flash over and puncture.

10. Define safety margin as applied to insulation co-ordination.

PART B — (5 × 16 = 80 marks)

11. (a) (i) What are the sources of switching surges? Explain the characteristics of switching surges with typical wave shapes. (10)

(ii) Discuss the various controlling methods of over voltages due to switching and power frequency. (6)

Or

(b) (i) A long transmission line is energized by a unit step voltage of 1.0 V at the sending end and is open circuited at the receiving end. Construct the Bewley Lattice diagram and obtain the value of the voltage at the receiving end after a long time. Take the attenuation factor $\alpha = 0.8$. (10)

(ii) Write a short note on ground rods as protective devices. (6)

12. (a) (i) Discuss the important properties of composite dielectrics. (6)

(ii) Discuss the various mechanism of breakdown in composite dielectrics. (10)

Or

(b) State why the very high intrinsic strength of a solid dielectrics is not fully realized in practice? Explain the different mechanisms by which breakdown occurs in solid dielectrics in practice. (16)

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(ii) How are the wave front and wave tail time controlled in impulse generator circuit? (6)

Or

(b) (i) With a neat sketch, describe the construction and working of a Van de Graaff generator. (10)

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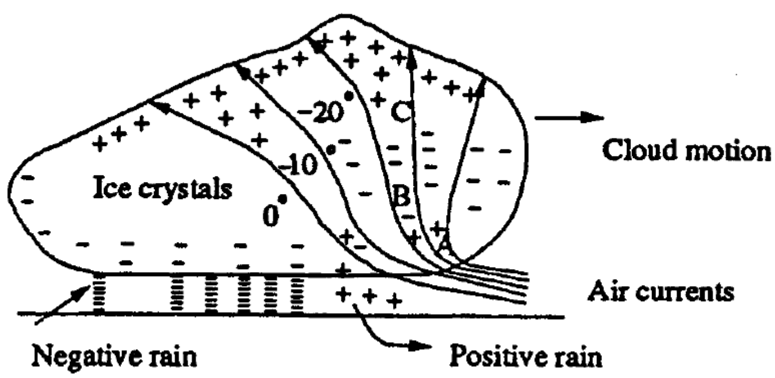
Or

(b) Explain the different aspects of insulation design and insulation coordination adopted for EHV systems. (16)

UNIT I

OVER VOLTAGES IN ELECTRICAL POWER SYSTEMS

PART – A

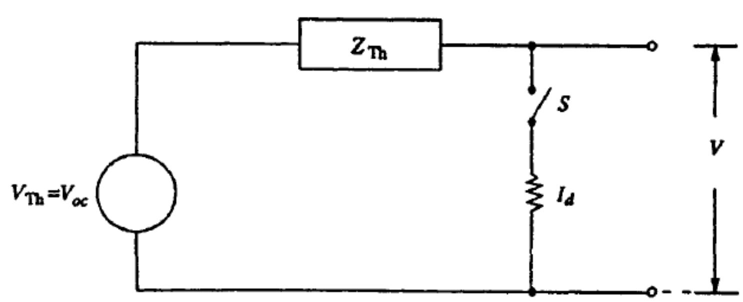
1.	**What are the different types of over voltages? (May 2013)(May 2015)** The different types of over voltages are, • Lightning over voltages(Natural causes) • Switching over voltages(system oriented causes) • Power frequency over voltages (temporary over voltage).
2.	**What are the various regions of the cloud according to Simpson's theory.** According to Simpson's theory, there are three regions named A, B and C. In region A, air velocity is high enough to break the falling raindrops causing a positive charge spray in the cloud and negative charge in the air. The spray is blown upwards, but as the velocity of air decreases, the positively charged water drops recombine with the larger drops and fall again. Thus, region A, eventually becomes predominantly positively charged, while region B above it, becomes negatively charged by air currents. In region C in the cloud, the temperature is low (below freezing point) and only ice crystals exist. 
3.	**What is back flashover? (Dec 2016)** When a direct lightning strike occurs on a tower, the tower has to carry huge impulse currents. If the tower footing resistance is considerable, the potential of the tower rises to a large value, steeply with respect to the line and consequently a flashover may take place along the insulator strings. This is

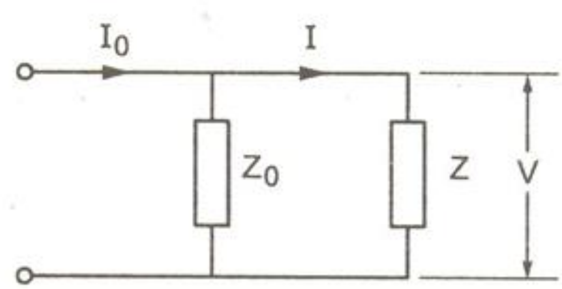
	known as back flashover
4.	**How are attenuation and distortion caused?** Attenuation is caused due to the energy loss in the line and distortion is caused due to the inductance and capacitance of the transmission line.
5.	**State the parameters and the characteristics of the lightning strokes. (May 2015)** The parameters and the characteristics of the lightning strokes are Amplitude of the current, the rate of rise, the probability distribution of them and the wave shapes of the lightning voltages and currents.
6.	**State the factors influence the lightning induced voltages on transmission lines.(Nov 2015)** a) Direct lightning stroke b) Electromagnetically induced over voltages due to lightning discharge taking place near the line, called 'side stroke'. c) Voltages induced due to atmospheric changes along the length of the line. d) Electrostatically induced voltages due to presence of charged clouds nearby. e) Electrostatically induced over voltages due to the frictional effects of small particles like dust or dry snow in the atmosphere or due to change in the altitude of the line.
7.	**State the attenuation and distortion of traveling waves. (Dec 2021)** As a travelling wave moves along a line, it suffers both attenuation and distortion. The decrease in the magnitude of the wave as it propagates along the line is called attenuation. The elongation or change of wave shape that occurs along the transmission line is called distortion.
8.	**What is a ground wire?**

	The Ground wire is a conductor that run parallel and above the main conductor of the transmission line supported on the same tower and earthed at every equally and regularly spaced towers. It is run above the main conductor of the line.
9.	**What is a protector tube?** Protector tube is one of the protection device used in transmission lines, which consists of a rod or spark gap together with an arc quenching device which extinguishes the current arc when the gaps breakover due to overvoltages.
10.	**Define Isokeraunic level (or) thunderstorm days. (May 2011, Dec 2016, Dec 2017, Apr 2019).** Thunderstorm Days (or) "Isokeraunic Level" which is defined as the number of days in a year when the thunder is heard or recorded in a particular location. Often it does not distinguish between the ground strokes and the cloud-to-cloud strokes.If a measure of ground flashover density (N_g) is obtained, then the number of ground flashovers can be computed from the TD level which is given by, N_g= (0.1 to 0.2) TD/strokes/km^2-year.
11.	**What is a surge arrester? (Nov 2018)** A surge arrester is a device used to protect electrical equipment from over-voltage transients caused by external (lightning) or internal (switching) events. Also called a surge protection device (SPD) or transient voltage surge suppressor (TVSS), this class of device is used to protect equipment in power transmission and distribution systems.
12.	**A transmission line surge impedance 250 ohms is connected to a cable of surge impedance of 50 ohms at the other end, if the surge of 400 kV travels along the line to the junction point, find the voltage build at the junction. (May 2011).** V”=V(2*Z_2/Z_1+Z_2), where V=400 kV , Z_1=250 ohms, Z_2=50 ohms V”=400,000*(2(50)/(250+50)), V”=133.33kV.
13.	**Define Lightning phenomenon. (Dec 2012)**

	Lightning phenomenon is defined as peak discharge in which charge accumulated in the cloud discharges into a neighboring cloud or on the ground. Lightning is a naturally occurring electrostatic discharge during which two electrically charged regions, both in the atmosphere or with one on the ground, temporarily equalize themselves, causing the instantaneous release of as much as one gigajoule of energy.
14.	**List some sources causing switching surges. (Dec 2012, May 2016, April 2018, Dec 2022)** ➢ De-energizing of transmission lines, cables, shunt capacitor, banks, etc. ➢ Disconnection of unloaded transformers, reactors, etc. ➢ Energization or reclosing of lines and reactive loads, ➢ Sudden switching off of loads. ➢ Short circuits and fault clearances. ➢ Resonance phenomenon like ferro-resonance, arcing grounds, etc.
15.	**What is stepped leader stroke? (May 2013)** Due to insufficient build of charge at the head of leader stroke comes to a halt after progressing about 50 meter and again after a short interval the streamer starts out repeating its performance with different branches by a series of jumps. It is called as stepped leader.
16.	**State the sources which determine the wave shape of switching surges. (Nov 2013)** ➢ De-energizing of transmission lines, cables, shunt capacitor, banks,etc. ➢ Disconnection of unloaded transformers, reactors, etc. ➢ Energization or reclosing of lines and reactive loads, ➢ Sudden switching off of loads. ➢ Short circuits and fault clearances. ➢ Resonance phenomenon like ferro-resonance, arcing grounds, etc.
17.	**Write down the causes of power frequency over voltages. (Nov 2013, Dec 2017, April 2018)**

	The main causes for power frequency and its harmonic over voltages are, ➢ Sudden loss of loads, ➢ Disconnection of inductive loads or connection of capacitive loads, ➢ Ferranti effect, unsymmetrical faults, and ➢ Saturation in transformer
18.	**Define : Corona Critical Disruptive Voltage (May 2017).** Critical Disruptive Voltage is defined as the minimum phase to neutral voltage required for the corona discharge to start.
19.	**What are the Protective devices used to protect power system equipment's against lightning? (May 2016, May 2017)** The protective devices used to protect power system equipment's against lightning are • Surge arresters • Protector tube • Ground wire • Expulsion gap
20.	**Classify the lightning strokes. (May 2014, Nov 2019)** ➢ Pilot streamer ➢ Stepped leader ➢ Return stroke ➢ Second charge center ➢ Dart Leader ➢ Heavy return streamer
21.	**Why a simple spark gap cannot offer full protection against overvoltages? (Nov 2015)** The sparkover voltage of a rod gap depends on the atmospheric conditions. There is no current limiting device provided so as to limit the current after sparkover, and hence a series resistance is often used. Without a series

	resistance, the sparking current may be very high and the applied impulse voltage suddenly collapses to zero thus creating a steep step voltage, which sometimes proves to be very dangerous to the apparatus to be protected, such as transformer or the machine windings.
22.	**What are the causes of overvoltages and its effects in power system? (Nov 2018)** There are two types of causes of over voltage in power system. ➢ Over voltage due to external causes: Lightning overvoltage ➢ Over voltage due to internal causes: Switching overvoltage and Power frequency over voltages. <u>Effects:</u> Over voltage tends to stress the insulation of the electrical equipment's and likely to cause damage to them when it frequently occurs. Over voltage caused by surges can result in spark over and flash over between phase and ground at the weakest point in the network, breakdown of gaseous/solid/ liquid insulation, failure of transformers and rotating machines.
23.	**Draw the equivalent circuit of surge diverter. (Apr 2019)**  Equivalent circuit of a surge diverter
24.	**What are the factors to be considered for the effective protection of transmission line using ground wire ? (Nov 2019)** The factors to be considered for the effective protection of transmission line using ground wire depends on the following factors.

	(i) Height of the ground wire above the ground (H)and the protection or shielding angle Θ_s (usually 30°). (ii) The shielding angle Θ_s=30° was considered adequate for tower heights of 30 m or less. The shielding wires may be one or more depending on the type of the towers used. But for EHV lines, the tower heights may be up to 50 m, and the lightning strokes sometimes occur directly to the line wires
25.	**Draw the mathematical model for lightning discharge. (Nov 2020)**  Where, I_0 be the lightning stroke current Z_0 be the source impedance Z be the object impedance
26.	**Define surge impedance of a line. (Dec 2022)** The square root of the ratio of line impedance (Z) and shunt admittance (Y) is called the surge impedance (ZC) of the line. Surge impedance $Z_C = \sqrt{\frac{Z}{Y}}$

PART – B (C401.1)

1.	What are the causes for switching and power frequency over voltages? How are they controlled in power system? **(May 2011, 2012, 2013,2014, Nov 2015, May 2016, May 2017, 2018, 2019, Nov 2019,2020,2021)**
2.	Explain with suitable figure the principles and functioning of (i) Expulsion Gap (ii) Protector Tube.**(May 2017)**
3.	Write short a note on (i) Rod gaps as protective devices (ii) Ground wires for

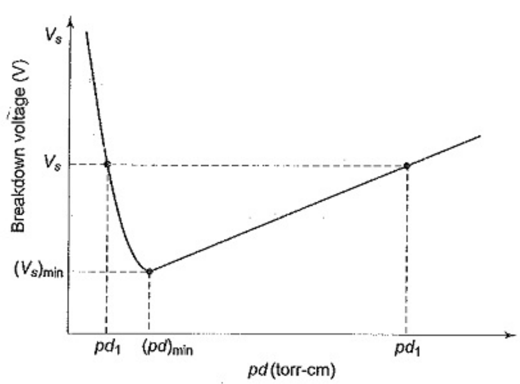
	protection of overhead lines.(iii) Ground rods as protective devices. **(Nov 2014, April 2018, Nov 2020)**
4.	What are the mechanisms by which lightning strokes develop and induce over voltages on overhead power lines? Give the mathematical models for lightning discharges and explain them.**(May 2013, Dec 2016, May 2016, Dec 2017, April 2018, Apr 2019)**
5.	Explain the different theories of charge formation in clouds. **(Dec 2012, May 2017, Dec 2017, Nov 2018, 2020)**
6.	An underground cable of inductance 0.150 mH/km and of capacitance 0.2 μF/km is connected to an overhead line having an inductance of 1.2 mH/km and capacitance of 0.006 μF/km. Calculate the transmitted and reflected voltage and current waves at the junction, if a surge of 200 kV travels to the junction, (i)along the cable, and (ii)along the overhead line. **(May 2011).**
7.	A long transmission line is energized by a unit step voltage 1.0 V at the sending end and is open circuited at the receiving end. Construct the Bewley lattice diagram and obtain the value of the voltage at the receiving end after a long time. Take the attenuation factor $\alpha = 0.8$. Discuss the step by step procedure for constructing Bewley's Lattice diagram with an example. **(Nov 2015, May 2016, Apr 2019)**
8.	What are the requirements of a ground wire for protecting power conductors against direct lightning stroke? Explain how they are achieved in practice. **(May 2014)**
9.	Explain the characteristics of switching surges with typical waveforms. Explain why a steep fronted surge waveform are more vulnerable to insulation? **(May 2015)**
10.	Explain the different method employed for the lightning protection of overhead lines? **(Dec 2016, Dec 2017, Nov 2018)**
11.	Cloud discharge 15 coulombs within 1.5 ms on to a transmission line during lightning. Estimate the voltage produced at the point of the stroke on the

	transmission line. (Assume surge impedance of line as 350 ohms) **(Nov 2018)**
12.	What is tower footing resistance? Discuss the two methods to reduce this resistance. **(Nov 2019)**
13.	A long transmission line is energized by a unit step voltage 1.0 V at the sending end and terminated through a resistance R. Construct the Bewley lattice diagram and obtain the value of the voltage at the receiving end after a long time. Take the attenuation factor $\alpha = 0.4$.**(Nov 2019)**
14.	Describe the various steps to draw the Bewley-Lattice diagram of successive reflections. **(Nov 2020).**
15.	Explain the refraction of traveling waves in power systems. **(Dec 2021)**
16.	Consider a long transmission line is energized by a unit step voltage 1.0V at the sending end and is terminated through a resistance R. Construct the Bewley lattice diagram and obtain the value of voltage at the receiving end after a long time. Also draw the voltage –time and current-time curves at the receiving end. Take reflection coefficient at receiving end is 0.4. **(Dec 2022)**
17.	Derive the expression for velocity of travelling waves on transmission line. **(Dec 2022)**

UNIT II DIELECTRIC BREAKDOWN

PART A (C401.2)

1.	**What is ionization?** The build-up of high currents in a breakdown is due to the process known as ionization in which electrons and ions are created from neutral atoms or molecules, and their migration to the anode and cathode respectively leads to high currents.The process of liberating an electron from a gas molecule with a simultaneous production of a positive ion is called ionization.
2.	**What is a Townsend's first ionization coefficient? (May 2017)** Townsend's first ionization coefficient is the average number of ionizing

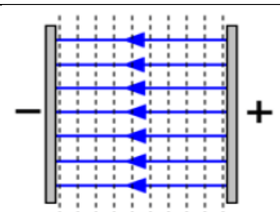
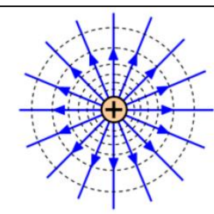
	collisions made by an electron per centimeter travel in the direction of the field.
3.	**What is a Townsend's secondary ionization coefficient?** The Townsend's secondary ionization coefficient is defined as the net number of secondary electrons produced per incident, positive ion, photon, excited particle or metastable particle.
4.	**What are electronegative gases? (May 2013, Nov 2015, Dec 2017)** The gases which are highest breakdown strength due to attachment of free electrons to neutral atoms or molecules to form negative ions, thus removing free electrons that would otherwise led to breakdown is called as electronegative gases.
5.	**State Paschen's law. (May 2011, May 2017, Nov 2018, Nov 2019, Dec 2022).** Paschen's law is an equation that gives the breakdown voltage, that is, the voltage necessary to start a discharge or electric arc, between two electrodes in a gas as a function of pressure and gap length. V=f(pd) The breakdown voltage of a uniform field gap is a unique function of the product of gas pressure p and gas length d for a particular gas and electrode material. This relation is known as Paschen's law.  *Breakdown voltage-pd curve (Paschen's law)*
6.	**What do you mean by 'Intrinsic strengths' of solid dielectric? (May 2011, Dec 2012)**

	When voltage is applied for a short time of the order of 10^{-8} , the electric strength of the solid material increases rapidly to an upper limit. This is called intrinsic strength.
7.	**Define treeing and tracking. (Dec 2012)** Treeing is the formation of a continuous conducting path across the surface of the insulation mainly due to surface erosion under voltage application. Insulation failure occurs when carbonized tracks bridge the distance between the electrodes. This phenomenon is called tracking**.**
8.	**What is meant by corona discharges? (May 2013, Nov 2020)** Corona discharge is an electrical discharge brought on by the ionization of a fluid surrounding a conductor, which occurs when the strength of the electric field exceeds a certain value. If the field is nonuniform, an increase in voltage will cause a corona discharge in the gas to appear at points with highest electric field intensity, which can be observed as a bluish luminescence.
9.	**What are the properties required for a gaseous dielectric for HV application? (Nov 2013)** Generally, the preferred properties of a gaseous dielectric for high voltage applications are, ➢ High dielectric strength ➢ Thermal stability and chemical inactivity towards materials of construction ➢ Non-flammable and physiological inertness, and environmentally non-hazardous ➢ Low temperature of condensation ➢ Arc extinguishing ability ➢ Good heat transfer ➢ Commercially available at moderate cost.
10.	**What are commercial liquid dielectrics and how are they different from pure liquid dielectrics? (Nov 2013)**

	➢ Pure liquids are those which are chemically pure and do not contain any other impurity even in traces of 1 in 10^9, and are structurally simple. Examples of such simple, pure liquids are n-hexane, n-heptane and other paraffin hydrocarbons. ➢ Commercial liquids which are insulating liquids like oils which are not chemically pure. ➢ Normally consist of mixtures of complex organic molecules which cannot be easily specified or reproduced in a series of experiments.
11.	**What is the Townsend's condition for breakdown? (May 2015, May 2016, April 2018)** Townsends breakdown criterion for gases is given by $\gamma(e^{\alpha d}-1) = 1$, where α, γ are the Townsends co-efficients. Normally $e^{\alpha d}$ is very large, hence the above equation reduces to $\gamma e^{\alpha d}=1$
12.	**What is meant by "Penning effect"? (May 2014)** Penning Effect is a form of chemi-ionization, an ionization process involving reactions between neutral atoms or molecules. The process is named after the Dutch physicist Frans Michel Penning who first reported it in 1927. The Penning effect is put to practical use in applications such as gas-discharge neon lamps and fluorescent lamps, where the lamp is filled with a Penning mixture to improve the electrical characteristics of the lamps.
13.	**What are the factors which affect the breakdown in gaseous dielectrics? (May 2014, Nov 2020)** If the applied voltage are large, the current flowing through the insulation increases very sharply and an electrical breakdown occurs. The factors which affect the breakdown in gaseous dielectrics are, ➢ Low dielectric strength ➢ Thermal and chemical instability ➢ Flammability and hazardous ➢ Bad heat transfer

14.	**Define statistical time lag and formative time lag. (May 2015, 2018)** The time which lapses between the application of the voltage sufficient to cause breakdown and the appearance of the initiating electron is called a statistical time lag of the gap. After the appearance of electron, a time (t_t) is required for the ionization process to develop fully to cause the breakdown of the gap. This time is called formative time lag(t_t).
15.	**What do you mean by tracking index?(May 2015)** The numerical value of voltage that initiates or causes the formation of a track in solid dielectric is called the "tracking index" and this is used to qualify the surface properties of dielectric materials.
16.	**Name the various secondary ionization process involved in gaseous dielectric breakdown. (Nov 2015)(Dec 2021)** The various secondary ionization process involved in gaseous dielectric breakdown are, • Electron emission due to positive ion impact • Electron emission due to photons • Electron emission due to metastable and neutral atoms.
17.	**What is ionization by collision? (Dec 2016)** The process of liberating an electron from a gas molecule with the simultaneous production of a positive ion is called ionization.In the process of ionization by collision, a free electron collides with a neutral gas molecule and gives rise to a new electron and a positive ion.
18.	**Define Gas law. (Dec 2016)** Boyle's Law is an ideal gas law where at constant temperature, the volume of an ideal gas is inversely proportional to its absolute pressure. There are couple of ways of expressing the law as an equation. The most basic is: $PV = k$ where P is pressure, V is volume, and k is a constant

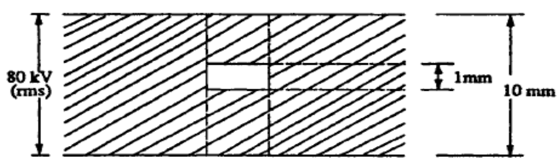
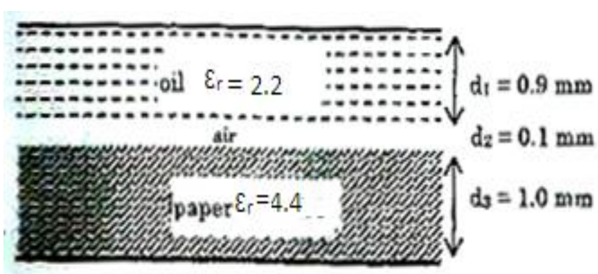
	The law may also be used to find the pressure or volume of a system when temperature is held constant: $P_i V_i = P_f V_f$ where P_i = initial pressure, V_i = initial volume, P_f = final pressure, V_f = final volume
19.	**Give the electrical properties that are essential in determining the dielectric performance of a liquid dielectric (May 2016)** A good liquid dielectric should have high dielectric strength, high thermal stability and chemical inertness against the construction materials used, non-flammability and low toxicity, good heat transfer properties, and low cost.
20.	**What is 'Burst Corona'? (Apr 2019)** On the high voltage conductors at high pressures there is a distinct difference in the visual appearance of the corona under positive and negative polarities of the applied voltage. Investigations with point-plane gaps in air showed that when point is positive, the corona current increases steadily with voltage. At sufficiently high voltage, current amplification increases rapidly with voltage, up to a current of about 10^{-7}A, after which the current becomes pulsed with repetition frequency of about 1 kHz composed of small bursts. This form of corona is called burst corona. The average current then increases steadily with applied voltage leading to breakdown.
21.	**State the properties of a composite dielectrics. (Apr 2019)** A composite dielectric generally consists of a large number of layers arranged one over the other. This is called "the layered construction" and is widely used in cables, capacitors and transformers. Three properties of composite dielectrics which are important to their performance are given below. (a) Effect of Multiple Layers (b) Effect of Layer Thickness (c) Effect of Interfaces.
22.	**Define uniform and non-uniform fields and give examples of each. (Nov 2018)**

	A uniform electric field is one whose magnitude and direction is same at all points in space and it will exert same force of a charge regardless of the position of charge in space. It is represented by parallel and evenly spaced lines. For example we find uniform Electric field between parallel plates of a capacitor. The equipotential surfaces (dotted lines) drawn normal to the field lines are also equidistance from each other. A non uniform electric field is one has either different magnitudes or different directions or both different in a given region of space. For example, the field due to a point charge, shown by radial lines. It depends inversely as square of distance from the point charge. The equipotential surfaces are also at unequal distances (closely spaced near the charge and farther separating as we move away from the charge). Field due to a dipole is also non uniform.  Uniform Field  Non-Uniform Field
23.	**How does long term breakdown occur in a composite dielectric ? (Nov 2019)** Long-term breakdown is also called the ageing of insulation. The occurrence of long term breakdown due to, (i) Ageing and breakdown due to partial discharges. (ii) Ageing and breakdown due to accumulation of charges on insulator surfaces.
24.	**What are the insulating materials used in power transformer ?(Nov 2020)** Majority of power transformers are oil filled transformers and they work with "class A" insulation with maximum permissible temperature of 105 degrees centigrade. The insulation consists mainly of (1) cellulose (wood) based insulation viz. paper and pressboard; and (2) mineral insulating liquid

	called transformer oil which works both as an insulating medium and as a coolant. The overall insulation can be termed as oil impregnated paper and pressboard.
25.	**List few effects of corona. (Dec 2021)** There is a hissing noise with violet glow phenomenon termed as corona effect which is commonly observed in high voltage transmission lines. The corona effects lead to high voltage drops and energy loss along with release of ozone gas.
26.	**What is pure liquid di-electrics? (Dec 2022)** Pure liquids are those which are chemically pure and do not contain any other impurity even in traces of 1 in 109, and are structurally simple. Examples of such simple, pure liquids are n-hexane, n-heptane and other paraffin hydrocarbons.

PART B (C401.2)

1.	What are the Electro negative gases? Why is the break down strength higher in these gases compared to that in other gases? Explain the streamer theory of break down in air at atmospheric pressure.**(May 2014,May 2016).**
2.	Discuss the various mechanisms of vacuum break down.**(May 2014,May 2016,May 2017, Dec 2017, Apr 2019, Nov 2020).**
3.	Explain the theories that explain break down in commercial liquid dielectrics and also Discuss the various properties of composite dielectrics. **(Nov 2013, Dec 2016,May 2016, May 2017, Dec 2017, Apr 2019, Nov 2020).**
4.	Explain the Townsends criterion for a spark. **(May 2011, May 2015, Dec 2016, April, Nov 2018, Dec 2022)**
5.	What do you understand by intrinsic strength of solid dielectrics? Explain different mechanisms by which breakdown occurs in solid dielectrics in practice.**(Nov 2015)**
6.	State the criteria for sparking potential and hence obtain the relation between

	sparking potential and (pd) values (Paschen's Law). Discuss on the nature of variations of sparking potential with (pd) values. **(May 2013)(Nov 2020)**
7.	Explain Thermal break down in solid dielectrics? Derive an expression for critical thermal breakdown voltage(Vc) and critical electric field (Ec) for the same. State clearly the assumption made. **(May 2014, Apr 2019)**
8.	Explain composite dielectrics and how the breakdown occurs in it. **(Dec 2012, Nov 2015,May 2016)**
9.	A solid dielectric specimen of dielectric constant of 4.0 shown in the figure has an internal void of thickness 1 mm. The specimen is 1 cm thick and is subjected to a voltage of 80 kV (rms). If the void is filled with air and if the breakdown strength of air can be taken as 30 k V (peak)/cm, find the voltage at which an internal discharge can occur. 
10.	A certain dielectric can be considered to be represented by the equivalent circuit shown in figure. What is the maximum voltage that can be applied across the dielectric, if partial discharges in air to be avoided? State any assumptions made. **(May 2015, 2018)** 
11.	Explain the breakdown mechanisms involving in solid dielectric breakdown**.** **(Nov 2018, Nov 2019, Nov 2020, Dec 2022)**
12.	List out the problems caused by corona discharges. **(Nov 2018, 2019)**
13.	Derive the Townsend's current growth equation in uniform gaseous dielectric field. (or) Derive the expression of current growth equation in a uniform field

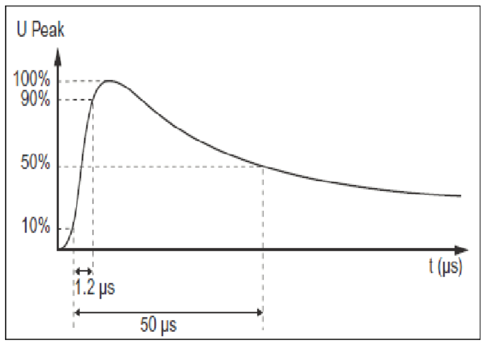
	due to Townsend's first and second ionization process and thereby deduce the condition for condition for gaseous dielectrics. **(Apr 2019,Nov 2019,2021)**
14.	In an experiment in a certain gas it was found that the steady state current is $5.5\text{x}10^{-8}$A at 8kV at a distance of 0.4 cm between the plane electrodes. Keeping the field constant and reducing the distance to 0.1 cm results in a current of $5.5\text{x}10^{-9}$A. Calculate Townsend's primary ionization coefficient α. In the above experiment, if the breakdown occurs calculate the value of γ when the gap distance is increased to 0.9 cm. **(Dec 2021)**
15.	What will be the breakdown strength of air for small gaps (1mm) and large gaps (20 cm) under uniform field conditions and standard atmospheric conditions?

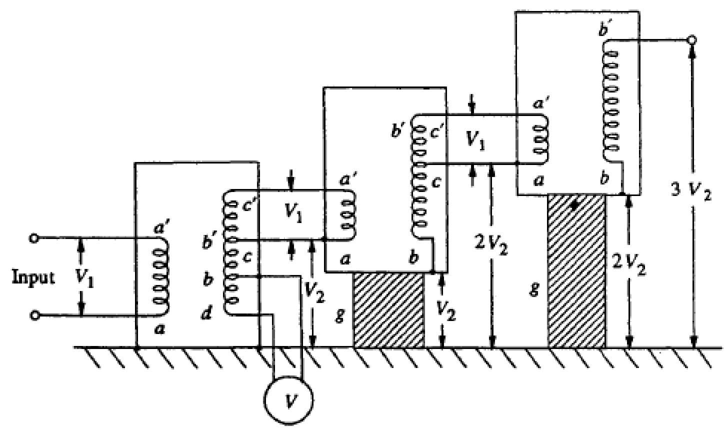
UNIT III GENERATION OF HIGH VOLTAGES AND HIGH CURRENTS

PART A(C401.3)

1.	**What does the selection of BIL level for lines depend?** The selection of BIL level for lines depend on various factors like • Atmospheric conditions, • Lightning activity, • Insulation • Pollution • Acceptable outage of the line.
2.	**What are the disadvantages of half wave rectifier circuit?(Nov 2013)** • Low dc output power and lower efficiency. • Higher ripple voltage & ripple current. • Higher ripple factor. • Low transformer utilization factor. • The input supply current waveform has a dc component which can result in dc saturation of the transformer core.
3.	**What are the classifications of high voltages?**

	The classifications of high voltages are, • High d.c. voltages • High a.c. voltages of power frequency. • High a.c. voltages of high frequency. • High transient or impulse voltages of very short duration such as lightning overvoltages • Transient voltages of longer duration such as switching surges.
4.	**What is regulation?** Voltage Regulation is a measure of change in the voltage magnitude between the sending and receiving end of a component, such as a transmission or distribution line. Voltage regulation describes the ability of a system to provide near constant voltage over a wide range of load conditions.
5.	**What is a tesla coil? (Dec 2016, Nov 2018)** The commonly used high frequency resonant transformer is the Tesla coil, which is a doubly tuned resonant circuit used for testing of electrical apparatus by generating switching surges and high frequency high voltage damped oscillations.
6.	**What are the uses of high frequency high voltage supply?** High frequency high voltage is used for testing of electrical apparatus for switching surges, high frequency high voltage damped oscillations are needed which need high voltage high frequency transformers.
7.	**What are the advantages of high frequency transformers for generating high AC voltage? (Nov 2020)** The advantages of high frequency transformers are, Saving in cost and size, pure sine wave output, uniform distribution of voltage across the winding coils due to subdivision of coil stack into number of units.
8.	**What is 'Trigatron gap'? What are its function? (May 2016, May 2017,2018)** A trigatron is a type of triggerable spark gap switch designed for high current and

	high voltage.Atrigatron has three electrodes. The heavy main electrodes are for the high current switching path, and a smaller third electrode serves as the trigger. During normal operation, the voltage between the main electrodes is somewhat lower than the breakdown voltage corresponding to their distance and the dielectric between them.
9.	**Mention the specifications of standard impulse wave. (May 2013, Nov 2015, Nov 2020, Dec 2022)** By defining the rise of front time and tail time 1.2/50µs, 1000 KV (standard value), fall time to 50% peak value of 50μs and a peak value of 1000 kV. 
10	**Explain Deltatron circuit. (Dec 2012, Dec 2016)** Deltatron is also called as cascaded modular voltage multipliers Circuits which is a combination of cockcroft walton type voltage multiplier with cascaded transformer dc rectifier is developed for very high voltages but limited output currents having high stability, small ripple factor and fast regulation. This type of circuit is called deltatron circuit
11	**What are drawbacks of single stage circuit for the generation of very high impulse voltage? (May 2011)** For higher voltage requirements, a single unit construction becomes difficult and costly due to insulation problems. Also Erection and transportation becomes difficult.
12	**Give some merits of vande Graff generator. (Dec 2012, Dec 2017)** ➢ Very high DC voltage can be generated easily. ➢ Ripple free output.

	➢ Precision and flexibility of control. ➢ Stability of voltage can be achieved with suitable stabilizing devices.
13	**What is a cascaded transformer? (May 2011).** The Cascade Transformer Connection units in which the first transformer is at the ground potential along with its tank. The second transformer is kept on insulators and maintained at a potential of V_2, the output voltage of the first unit above the ground. The high voltage winding of the first unit is connected to the tank of the second unit. The low voltage winding of this unit is supplied from the excitation winding of the first transformer, which is in series with the high voltage winding of the first transformer at its high voltage end. 
14	**Give any two methods of switching surge generation in laboratory. (May 2013)** ➢ By changing the tail time constants of impulse generator. ➢ By connecting primary and secondary windings of power transformer in series.
15	**Define the front and tail times of impulse wave.(Nov 2013, Dec 2017, 2018)** **Rise or Front time:** It is the time required for the response to raise from 10 to 90% of the final value at the very first instance. Rise time for standard impulse wave of 1.2/50 μ s,1000 kV = 1.2 μ s. **Fall or Tail time:** It is the time to reach 50% peak value of 50 μ s. Fall time for

	standard impulse wave of 1.2/50 μ s,1000 kV = 50% peak value of 50μ s.
16	**Mention the necessity of generating high dc voltage.(April 2014) (May 2016, 2018)** The generating high dc voltage is necessary for, ➢Research work in applied physics ➢Charging of impulse generators ➢Insulation tests on cables and capacitors ➢Rectifiers are used to get HVDC up to 100 kV and 100mA
17	**What are the advantages of series resonant circuit? (April 2014)** ➢It gives an output of pure sine wave. ➢Power requirements are less.(5 to 10% of total KVA required) ➢ No high-power arcing and heavy current surges occur if the test object fails, a resonance ceases at the failure of the test object. ➢Cascading is also possible for very high voltages. ➢Simple and compact test arrangement. ➢No repeated flashovers occur, in case of partial failure of test objects.
18	**How is the circuit inductance controlled and minimized in the impulse current generator?(Nov 2015)** If the series resistance *R*is increased, the wave front oscillations are damped, but the peak value of the voltage is also reduced. Thereby circuit inductance can be controlled and minimized in the impulse current generator.
19	**What is the principle of Marx circuit?** A bank of capacitors are charged in parallel and then discharged in series into a wave shaping network to produce a lighting impulse voltage, double exponential fast rising & slow decaying voltage.
20	**What is the necessity for generating high voltages?** In the fields of electrical engineering and applied physics, generating high voltages (d.c., a.c., and impulse) are necessary for several applications like, electon microscope, X rays, particle accelerators, electrostatic precipitators, testing of

<table>
<tr><td></td><td>power apparatus, insulation testing etc.,</td></tr>
<tr><td>21</td><td>

A tesla coil has a primary winding rated for 10 kV with 2 µF capacitance on primary side and 1 nF capacitance on secondary side. If the energy efficiency is 5 %, determine the output voltage. (Apr 2019)

The expression for output voltage is given by,

$$V_2 = V_1 \sqrt{\eta \frac{C_1}{C_2}}$$

$$V_2 = 10*10^3 \sqrt{0.05*\frac{2*10^{-6}}{1*10^{-9}}} = 100kV$$

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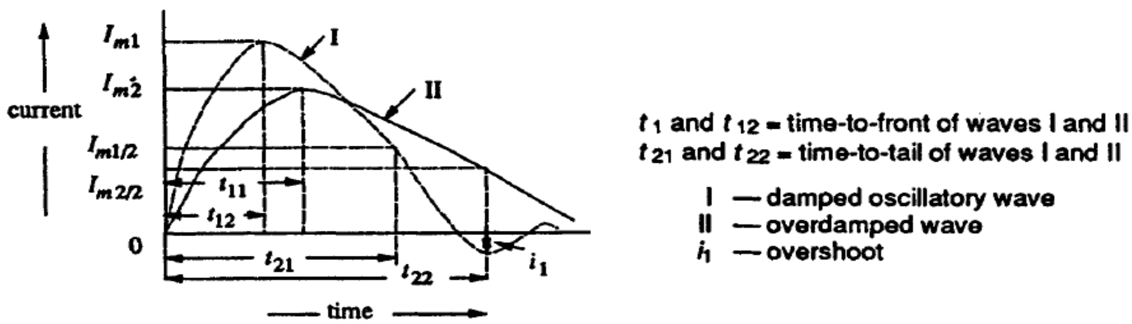
Show the types of impulse current waveforms. (Apr 2019)



Types of impulse current waveforms

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Why is controlled tripping necessary in a multistage impulse generator? (Nov 2019).

In large impulse generator, the spark gaps are generally sphere gaps or gaps formed by hemispherical electrodes. The gaps are arranged such that sparking of one gap results in automatic sparking of other gaps as overvoltage is impressed on the other. In order to have consistency in sparking, irradiation from an ultraviolet lamp is provided from the bottom to all the gaps. It is necessary to trip the generator at a predetermined time, the spark gaps may be mounted on a movable frame, and the gap distance is reduced by moving the movable electrodes closer.

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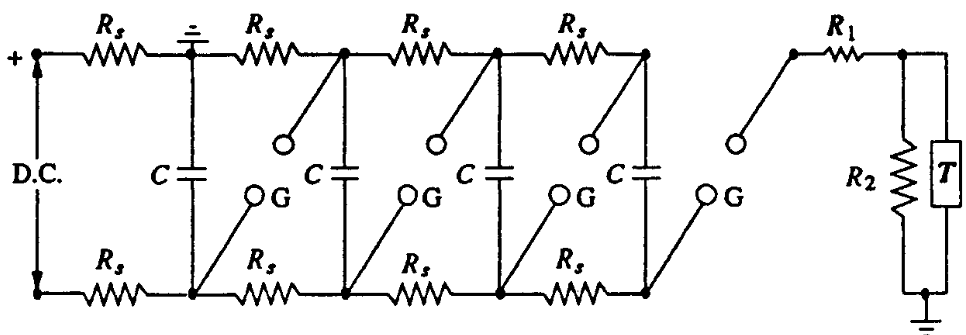
What are the advantages of cascaded transformer over two winding transformer for generating high AC voltages? (Nov 2019)

For test voltages higher than 400 KV, a single unit construction becomes difficult

</td></tr>
</table>

	and costly due to insulation problems. Moreover transportation and erection of large transformers become difficult. These drawbacks can be overcome by using cascaded transformer generating high AC voltages.
25	**Write down the formula to determine optimum number of stages for a cock-croftwalton voltage multiplier. (Dec 2021)** The formula to determine optimum number of stages for a cock-croft walton voltage multiplier is given by, $$n_{optimum} = \sqrt{\frac{V_{max} f C}{I}}$$ Where, I is the load current, V_{max} is the transformer secondary voltage, f is the frequency, C is the capacitance.
26	Draw the schematic diagram of Marx circuit arrangement for multistage impulse generator. **(Dec 2022)** 

PART B(C401.3)

1.	i) Mention the necessity of generating high DC voltages. ii) Describe with a neat sketch the working of a Van De Graff generator. What are the factors that limit the maximum voltage obtained? **(May 2013, Nov 2014, Dec 2016, May 2016, May 2017, Dec 2017, Nov 2018, Apr 2019, Nov 2020, Dec 2022).**
2.	What is the principle of operation of a resonant transformer? How is it advantages over the cascade-connected transformer? Explain the basic principle of operation of an electrostatic generator.**(May 2011, May 2016, 2018, 2021)**

3.	How are damped high frequency oscillation obtained from a Tesla coil? Explain.**(Dec 2012, Dec 2017)**
4.	Give the Marx circuit arrangement for multistage impulse generators. How is the basic arrangement modified to accommodate the wave time control resistances? **(May 2011, Nov 2015, Nov 2019, 2020).**
5.	A 100 kVA 250 V/200 kV feed transformer has resistance and reactance of 1% and 5% respectively. This transformer is used to test a cable at 400 kV at 50 Hz. The cable takes a charging current of 0.5 A at 400 kV. Determine the series inductance required. Assume 1% resistance of the inductor. Also determine input voltage to the transformer. Neglect dielectric loss of the cable. **(Nov 2020)**
6.	Discuss the circuits for producing impulse waves. **(Dec 2021)**
7.	A Cockcroft-Walton type voltage multiplier has eight stages with capacitances, all equal to 0.05 μF. The supply transformer secondary voltage is 125 kV at a frequency of 125 Hz. If the load current to be supplied is 4.5 mA, find (a) the percentage ripple, (b) the regulation, and (c) the optimum number of stages for minimum regulation or voltage drop.**(May 2011, May 2015, May 2017, Nov 2020)**
8.	Explain tripping and control of impulse generators with Trigatron gap arrangements. How are the wavefront and wave tail time controlled in impulse generator circuits?**(Dec 2012, Nov 2015, Nov 2018, 2020)**
9.	What is a cascaded transformer? Explain why cascading is done? Describe with neat diagram, a 3-stage cascaded transformer. **(Dec 2013, Apr 2019).**
10.	An impulse generator has 8 stages with each condenser rated for 0.16 microFarad and 125kv. The load capacitor available is 1000pf. Find the series resistance and the damping resistance needed to produce 1.2/50 microsecond impulse wave .What is the maximum output voltage of the generator if the charging voltage is 120 kV ?
11.	What are the essential parts of an impulse current generator? **(May 2016, April**

	2018)
12.	Explain the working principle of parallel resonant transformer. **(Apr 2019)**
13.	A ten-stage impulse generator has 0.250 μF condensers. The wave front and the wave tail resistances connected are 75 ohms and 2600 ohms respectively. If the load condenser is 2.5 nF, find the front and tail times of the impulse wave produced. **(Apr 2019)**
14.	Explain the principle of operation of resonant transformer for generating high alternating voltages. **(Nov 2019)**
15.	With a neat circuit diagram, explain any one method of generating switching surges in HV laboratory. **(Nov 2020, Dec 2022)**

UNIT IV - MEASUREMENT OF HIGH VOLTAGES AND HIGH CURRENTS

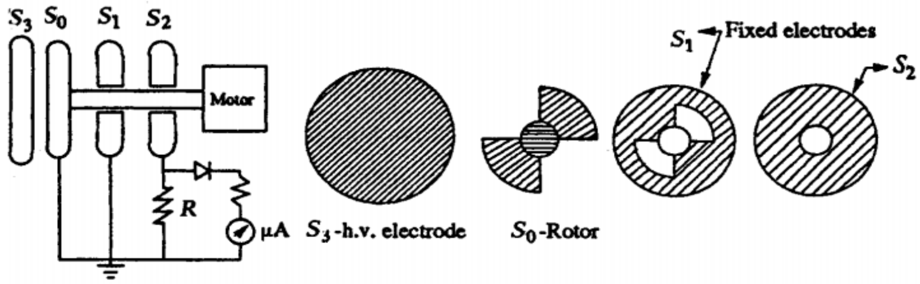
PART-A(C401.4)

1.	**Mention the techniques used in impulse current measurements. (Dec 2017, April 2014)** The techniques used in impulse current measurements are, <u>Resistive shunts:</u>(a) Bifilar flat strip design (b) coaxial tube or Park's shunt design, and (c) coaxial squirrel cage design. <u>Other techniques:</u>Hall generators, Faraday generators and current transformers
2.	**Mention the problems associated with bifilar strip shunt design.** The bifilar strip shunt suffers from stray inductance associated with resistance element and its potential leads are linked to a small part of the magnetic flux generated by the current that is measured.
3.	**Mention the different ways in which the stray effect is reduced in resistance shunt? (or) What are the different types of resistive shunts used for impulse current measurements? (Nov 2019)** The different ways in which the stray effect is reduced in resistance shunt are, ➢ Bifilar flat strip design ➢ Co-axial tube or park's shunt design

	➢ Co-axial squirrel cage design.
4.	**State the advantages of Sphere gaps.** They are used for voltage measurements. They are suitable for all types of waveforms from d.c to impulse voltages of short times. They are used for radio frequency a.c voltage peak measurements upto 1 MHz.
5.	**State the advantages of magnetic potential transformers.** The advantages of magnetic potential transformers are simple in construction and designed for any operating voltage by cascading the transformers. Potential transformers (PT) do not permit fast rising transient or high frequency voltages along with the normal supply frequency.
6.	**How is an electric field is measured?** It is measured by introducing a small fixed capacitance probe into the field area and measuring the induced charge on it. The magnitude of the electric field is simply defined as the force per charge on the test charge. $\text{Electric Field Strength} = \frac{\text{Force}}{\text{Charge}}$
7.	**Mention the devices used to measure the D.C electric field strength.** The devices used to measure the D.C electric field strength are, a)Variable capacitor probe b)Vibrating plate capacitor.
8.	**Give the advantages of generating voltmeters. (Apr 2019)** ✓ No source loading by the meter, ✓ No direct connection to high voltage electrode, ✓ Scale is linear and extension of range is easy, and ✓ A very convenient instrument for electrostatic devices such as Vande Graaff generator and particle accelerators.
9.	**Explain the porosity test on insulators.** The insulator is broken and immersed in a 0.5 % alcohol solution under a pressure of 13800 kN/sq.m for 24 hours. The broken insulator is taken out and

	further broken. It should not show any sign of impregnation.
10.	**Why is the cable meant for A.C system to be tested with DC supply?** Cables are tested for power frequency AC and DC voltages. During manufacture the entire cable is passed through a higher voltage test and the rated voltage to check the continuity of cable. High voltage dc of 1.8 times the rated dc voltage of negative polarity for 30 minutes is applied and cable is set to have no failure.
11.	**Define CVT. (May 2013)(Dec 2021)** CVT meant for capacitive voltage transformer. It is defined as the capacitive voltage transformer step-down the high voltage input signals and provide the low voltage signals which can easily measure through the measuring instrument. The Capacitive voltage transformer (CVT) is also called capacitive potential transformer
12.	**List some advantages of Faraday generator. (Dec 2012, Dec 2016)** ➢ There is no electric connection between the source and the device. ➢ No thermal problems even for large currents of several kilo amperes. ➢ There is no insulation problem, as the signal transmission is through an optical system.
13.	**Give the advantages of electrostatic voltmeter. (May 2013)** The electrostatic voltmeter is (i)compact and smaller in size (ii) it has high input impedance, therefore no need to have meter protection additionally (iii) the range of the meter can be easily changed by changing gap separation.
14.	**List out the limitations of generating voltmeters.(Nov 2013)(Dec2021)** ➢ Need calibration. ➢ Careful construction is needed. ➢ Any disturbance due to position and mounting of the electrodes make the calibration invalid.
15.	**What are the drawbacks of series resistance micro ammeter technique in HVAC measurements?(Nov 2015)**

	The drawbacks of this technique are (i)power dissipation and source loading, (ii) temperature effects and long time stability, (iii)voltage dependence of resistive elements, and (iv) sensitivity to mechanical stresses.
16.	**How the stray effect of capacitance potential divider is minimized for impulse measurements? (Nov 2015)** The stray effect of capacitance potential divider is minimized for impulse measurements by designing proper resistive shunt in the following manner to reduce the stray effects. *(a)* Bifilar flat strip design, *(b)* coaxial tube or Park's shunt design, and *(c)* coaxial squirrel cage design
17.	**What is the principle behind the operation of generating voltmeter?(May 2015, 2018)** A generating voltmeter is a variable capacitor electrostatic voltage generator which generates current proportional to the applied external voltage. The device is driven by an external synchronous or constant speed motor and does not absorb power or energy from the voltage measuring source.
18.	**What are the advantages of generating voltmeter? (Dec 2016)** The advantages of generating voltmeter are, i) No source loading by the meter, ii) No direct connection to the high voltage electrode, iii) Scale is linear and extension of range is easy, and iv) A very convenient instrument for electrostatic devices such as Van de Graaff generator and particle accelerators
19.	**Draw the schematic diagram of generating voltmeter. (May 2016)**

	
20.	**What are the advantages of digital techniques in high voltage measurements? (May 2016, Apr 2019)** Digital techniques are useful because it is easier to get an electronic device to switch into one of a number of known states than to accurately reproduce a continuous range of values.
21.	**What are the advantages of CVT measurements in HVAC ? (Dec 2017, 2018)** (i) Simple design and easy installation, (ii) Can be used both as a voltage measuring device for meter and relaying purposes and also as a coupling condenser for power line carrier communication and relaying. (iii) Frequency independent voltage distribution along elements as against conventional magnetic potential transformers which require additional insulation design against surges. (iv) Provides isolation between the high voltage terminal and low voltage metering.
22.	**For what measurement are Hall generators normally used? (Nov 2018)** The principle of the "Hall effect" is made use of in measuring very high direct currents. Hall generators can be used to measure current, power, position, number of revolutions and pressure as well as for multiplication of two input signals, for brushless DC motor control, as a contactless switch and applications in the automotive industry.
23.	**Give the requirements of an oscilloscope used for impulse and high**

	frequency high voltage requirements. (Nov 2019). The cathode ray oscilloscope for impulse work normally has input voltage range from 5 mV/cm to about 20 V/cm. In addition, there are probes and attenuators to handle signals up to 600 V (peak to peak). The bandwidth and rise time of the oscilloscope should be adequate. Rise times of 5 ns and bandwidth as high as 500 MHz may be necessary.
24.	**Why are the capacitive voltage dividers preferred for high AC voltage measurements ? (Nov 2020)** The capacitive voltage dividers can be used to eliminate errors due to harmonics with an electrostatic voltmeter or a high impedance meter. It requires high impedance meter like electrostatic voltmeter.
25.	**What are the requirements of a digital storage oscilloscope for impulse and high frequency measurement? (Nov 2020)** The requirements of a digital storage oscilloscope for impulse and high frequency measurement are acquisition memory, Analog to Digital Converter and Microprocessor for measurement purpose.
26.	**What is a mixed potential divider? How is it used for impulse voltage measurements? (Dec 2022)** Mixed potential dividers use R-C elements in series or in parallel. One method is to connect capacitance in parallel with each R'1 element and other method is to connect R and C in series. It can be measured using, (i) the shape of the voltage in the test arrangement should be transferred without any distortion to the L. V. side, (ii) simple determination of transfer behaviour should be ensured, and (iii) they should be suitable for multipurpose use, i.e. for use with a.c. power frequency voltages, switching impulse voltages as well as with lightning impulse voltages.
27.	**Enumerate the reason for using sphere type electrodes in HV measurement. (Dec 2022)** They are used for voltage measurements. They are suitable for all types of

	waveforms from d.c to impulse voltages of short times. They are used for radio frequency a.c voltage peak measurements upto 1 MHz.

PART B(C401.4)

1.	Explain with neat diagram the principle of operation of an electrostatic voltmeter. Discuss its advantages and limitations for high voltage measurements. **(May 2011,May 2016, Dec 2017, 2020,2021).**
2.	Draw the calibrated Low ohmic shunt and its equivalent circuit for high impulse current measurements. Explain the different types of resistive shunts with their characteristics and limitations**(May 2016, Nov 2020)**
3.	(i) Give the schematic arrangement of an impulse potential divider with an oscilloscope connected for measuring impulse voltages. Explain the arrangement used to minimize the errors. (ii) What are the requirements of a digital storage oscilloscope for impulse and high frequency measurement in HV test circuits? **(Nov 2015)**
4.	A Rogowski coil is to be designed to measure impulse currents of 10 kA having a rate of change of current of 10^{10}A/s. The current is read by a VTVM as a potential drop across the integrating circuit connected to the secondary. Estimate the values of mutual inductance, resistance, and capacitance to be connected, if the meter reading is to be 10 V for full-scale deflection. .**(May 2011, Nov 2018).**
5.	i) Enumerate digital peak voltmeter. **(Dec 2012, Dec 2016)** ii) What is CVT? Explain how CVT can be used for high voltage ac measurement. **(Dec 2016, Nov 2019)**
6.	Describe the construction, principle of operation of a Generating voltmeter and give its applications and limitations. **(May 2014, May 2017, Dec 2017, Nov 2019, Dec 2022).**
7.	A generating voltmeter has to be designed so that it can have a range from 20 to 200 kV DC If the indicating meter reads a minimum current of 2μA and

	maximum current of 25μA, what should the capacitance of the generating voltmeter be?Also calculate Irms if the capacitance value is 1.2pF and comment the results. **(Dec 2021)**
8.	Explain with neat diagram how a sphere gap can be used to measure the peak value of voltages. Explain the parameters and factors that influence the sphere gap measurement. **(Nov 2015, Dec 2016, May 2017, Apr 2019, Nov 2020, Dec 2022)**
9.	Explain in detail various techniques for the measurement of impulse voltages. **(May 2015, 2018, 2021)**
10.	With neat sketch, explain in detail the various methods used to measure the RMS and peak values of high AC voltages. **(May 2015, 2018)**
11.	A coaxial shunt is to be designed to measure an impulse current of 40kA. If the bandwidth of shunt is to be at east 10 MHz and if the voltage drop across the shunt should not exceed 50V. Find the ohmic value of the shunt and its dimensions.**(May 2017)**
12.	What are the various Digital techniques used in high voltage measurement and explain each types briefly. **(Nov 2018)**
13.	(i) Write short notes on Mixed R-C potential dividers. (ii) Explain the operation of Peak Reading Voltmeters for impulse voltages. **(Apr 2019)**
14.	With an equivalent circuit and its step response, discuss how are resistance, capacitance and mixed R-C potential dividers used for impulse voltage measurements. Explain the arrangement used to minimize the errors in each case. **(Nov 2019)**
15.	Explain the operation of a series capacitance voltmeter to measure high AC voltages. **(Nov 2020)**
16.	Explain how DC high voltage can be measured using series ammeter. **(Dec 2022)**

UNIT V - HIGH VOLTAGE TESTING & INSULATION COORDINATION

PART-A (C401.5)

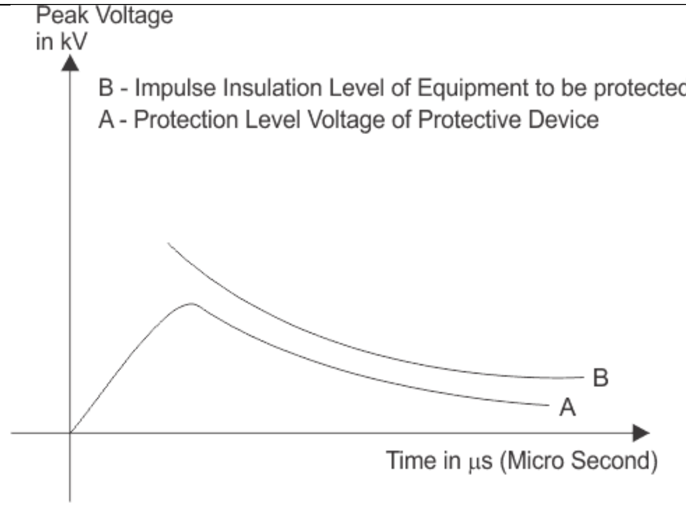
1.	**What is meant by Insulation Coordination? (Dec 2017, Nov 2018, Apr 2019)** Insulation coordination is the process of knowing the insulation levels of the power system components. In other words, it is the process of determining the insulation strength of the equipment. The internal and external insulation of the electrical equipment is exposed to continuous normal voltage and temporary abnormal voltage.
2.	**Define creepage distance.** Creepage distance is defined as the shortest distance on the contour of the external surface of the insulator unit or between two metal fittings on the insulator.
3.	**What is the importance of radio interference voltage measurements for extra high voltage power apparatus?** Many electrical apparatuses like transformers, line conductors, rotating machines, etc. produce unwanted electrical signals in the radio and high frequency (television band, microwave bands, etc.) ranges. These signals arise due to corona discharges in air, internal or partial discharges in the insulation, sparking at commutators and brush gear in rotating machines, etc. It is important to see that the noise voltages generated in the radio and other transmission bands are limited to acceptable levels, and hence the High Voltage Test on Radio interference voltage measurements are of importance.
4.	**What is an isolator.** An isolator is a disconnector or a mechanical switching device used for isolating a circuit or equipment from a source of power. An isolator is a mechanical switching device that, in the open position, allows for isolation of the input and output of a device.
5.	**Define withstand voltage.** It is defined as the Maximum voltage level that can be applied between circuits

	or components without causing a break down. The voltage which has to be applied to a test object under specified conditions in a withstand test is called the withstand voltage.
6.	**What is the function of surge arrester?** A surge arrester is a device to protect electrical equipment from over-voltage transients caused by external (lightning) or internal (switching) events. Also called a surge protection device (SPD) or transient voltage surge suppressor (TVSS), this class of device is used to protect equipment in power transmission and distribution systems. It is capable of discharging 10 to 20 KA of long duration surges and 100 to250 KA of short duration surge currents.
7.	**Mention the characteristics of the spray used in wet flashover test. (Nov 2013)** The characteristics of the spray are ✓ Precipitation rate : 3 ± 10% (mm/min) ✓ Direction : 45° to the vertical ✓ Conductivity of water : 100 micro Siemens ± 10% ✓ Water temperature : ambient ±15°C
8.	**Define partial discharge**.**(Dec 2012)** A partial discharge (PD) is an electrical discharge or spark that bridges a small portion of the insulation between two conducting electrodes. Partial Discharge can happen at any point in the insulation system, where the electric field strength exceeds the breakdown strength of that portion of the insulating material.
9.	**What is meant by circuit breaker.** A circuit breaker is an automatically operated electrical switch designed to protect an electrical circuit from damage caused by excess current from an overload or short circuit. Its basic function is to interrupt current flow after a fault is detected. Unlike a fuse, which operates once and then must be replaced,

	a circuit breaker can be reset (either manually or automatically) to resume normal operation.
10.	**How is impulse with-stand voltage test conducted? (April 2014)** This test is done by applying standard impulse voltage of specified value under dry conditions with both positive and negative polarities of the wave. If five consecutive waves do not cause a flashover or puncture, the insulator is deemed to have passed the test. If two applications cause flashover, the object is deemed to have failed. If there is only one failure, additional ten applications of the voltage wave are made. If the test object has withstand the subsequent applications, it is said to have passed the test.
11.	**Define 50% flashover voltage. (Dec 2016)(Dec 2021)** This is the voltage which has a probability of 50% flashover, when applied to a test object. This is normally applied in impulse tests in which the loss of insulation strength is temporary.
12.	**Define 100 % flash over voltage. (Dec 2021)** The voltage that causes a flashover at each of its applications under specified conditions when applied to test objects is specified as hundred per cent flashover voltage.
13.	**What are significance of power factor test? (May 2011).** High voltage schering bridge is used to perform dielectric power factor test on the cable sample. The power factor is measured for different values of voltages eg 0.5,1,1.5,2 times of rated operating voltages. The maximum value of power factor at normal working voltage does not exceed a specified voltage at a series of temperatures ranging from 15 to 65^0C .
14.	**What is the type and routine test? (May 2013 ,May 2015)** The type test is conducted on the sample to test the quality of the material with which the component is made. Routine test is conducted on the equipment or component periodically to check the deterioration in the quality during operation.

15.	**Define Disruptive discharge voltage.(Nov 2013, May 2016, Dec 2017)** It is defined as the voltage which produces the loss of dielectric strength of an insulation. It is that voltage at which the electrical stress in the insulation causes a failure, which includes the collapse of voltage and passage of current. In solids, this causes a permanent loss of strength, and in liquids or gases only temporary loss maybe caused. When a discharge takes place between two electrodes in a gas or a liquid or over a solid surface in air, it is called flashover. If the discharge occurs through a solid insulation it is called puncture.
16.	**What is BIL?(May 2015, Nov 2020)** BIL is an abbreviation for Basic Insulation Level. Insulation levels in electrical equipment are characterized by the withstand voltages used during the impulse test. It is defined as the minimum insulation impulse withstands voltage of any power equipment or apparatus. The BIL of a power system is usually chosen as 25% to 30% more than the protective level Offered by the protective devices.
17.	**Distinguish between flashover and puncture. (April 2014, Nov 2015, April 2018)** When a discharge takes place between two electrodes in a gas or a liquid or over a solid surface in air, it is called flashover. If the discharge occurs through a solid insulation it is called puncture.
18.	**What are the tests need to be conducted on the power transformer. (Dec 2016)** The tests conducted on the power transformer are basically Type tests and Routine tests. Some other tests are i) Induced overvoltage test ,ii) Partial discharge test,iii) Impulse voltage test
19.	**List out the various Electrical tests to be carried out for bushings. (May 2017, Nov 2018)** (i) Power Factor Test, (ii) Impulse Withstand Test, (iii) Chopped Wave and

	Switching Surge Test(iv) Partial Discharge Test
20.	**Define Air Density Correction factor. (May 2017, Dec 2022)** The electrical characteristics of the insulators and other apparatus are normally referred to the reference atmospheric conditions. Its alititude and temperature increases, the weight of the air decreases. To determine the actual amount of air being delivered through a system, air density correction factor is used which is given by, $d = \frac{0.289b}{273+t}$ for 20°C or, $\frac{0.296b}{273+t}$ for 27°C $b =$ atmospheric pressure in millibars, and $t =$ atmospheric temperature, °C.
21.	**Write the standard atmospheric conditions for HV testing as per the Indian Standard. (Apr 2019, Nov 2019)** The standard atmospheric conditions for HV testing as per the Indian Standard are: ● Temperature : 27^0C ● Pressure : 1013 millibars (or 760 torr) ● Absolute humidity : 17 gm/m^3
22.	**What are volt time curves? (Nov 2019)** In order for an insulation media to breakdown, the following requirements are needed: a) The existence of at least one free electron to start the ionization process. b) Enough voltage to cause ionization and avalanche formation. c) Enough time to complete the breakdown process.

	 Voltage - Time Curved Used for Insulation Coordination
23.	**How is salt-fog test conducted on insulators ? (Nov 2020)** In this test, the maximum normal withstand voltage is applied on the insulator and then artificial salt fog is created around the insulator by jets of salt water and compressed air. If the flashover occurs within one hour, the test is repeated with fog of lower salinity, otherwise, with a fog of higher salinity. The maximum salinity at which the insulator withstands three out of four tests without flashover is taken as the representative figure.
24.	**List few International and Indian standards related to High voltage testing of electrical power apparatus. (Dec 2021)** ❖ The Institute of Electrical and Electronics Engineers (IEEE). ❖ International Electrotechnical Commission (IEC). ❖ Bureau of Indian Standards (BIS). ❖ Indian Standard (IS).
25.	**Compare the withstand voltage and flashover voltage.** ❖ It is defined as the Maximum voltage level that can be applied between circuits or components without causing a break down. The voltage which has to be applied to a test object under specified conditions in a withstand test is called the withstand voltage. ❖ In electric power transmission, a flashover is an unintended high voltage

	electric discharge over or around an insulator, or sparking between two or more adjacent conductors. A flashover is an electric discharge over or around the surface of an insulator.

PART –B(C401.5)

1.	What are the different power frequency tests done on insulators? Mention the procedure for testing.
2.	What are the significance of power factor tests and partial discharge tests on bushings? How are they conducted in testing laboratory?
3.	Explain the various method of testing of high voltage transformers. Discuss in detail the dielectric power factor test, partial discharge test and Impulse testing of a HV transformer. **(May 2011, Nov 2015, May 2015, Dec 2016, May 2016, May 2017, 2018, 2019, Nov 2019,2021, Dec 2022).**
4.	Why is synthetic testing advantages over the other testing methods for short circuit tests? Give the layout for synthetic testing. **(May 2017)**
5.	Explain the importance of RIV measurements for EHV power apparatus. Explain, with a neat schematic diagram, one method of measuring RIV of Transmission line hardware.
6.	Discuss the different high voltage tests conducted on bushings. **(Dec 2012, May 2015, Nov 2020)**
7.	Explain the various tests conducted in high voltage insulators. **(May 2013, May 2014, May 2015, Nov 2018, Dec 2022)**
8.	Explain the various tests conducted in high voltage cables. **(May 2013, May 2014)**
9.	Describe the various tests to be carried out on a circuit breaker. **(Nov 2013,2016, 2020)**
10.	Explain the different aspects of insulation design and insulation co-ordination adopted for EHV systems. **(May 2011, Nov 2013, Nov 2015, May 2015, May**

	2016, May 2017, Apr2018, Dec 2017, Nov 2019)
11.	Explain the direct and synthetic testing of isolators and Circuit breakers in detail. **(Dec 2017, Apr 2019,2021)**
12.	Explain the different high voltage tests conducted on bushings. **(Nov 2018)**
13.	What is the significance of impulse tests? Briefly explains the impulse testing of insulators.
14.	With a neat diagram, explain the procedure of synthetic testing of circuit breakers. Also give its advantages over other testing methods for short circuit test. **(Nov 2019)**
15.	Discuss the arrangement, procedure and specification of water for conducting impulse voltage wet withstand test on insulator. **(Nov 2019)**
16.	Explain the following: **(Dec 2022)** ▪ Flashover voltage ▪ Withstand voltage ▪ Impulse voltage ▪ Creepage distance

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

GE3752 - TOTAL QUALITY MANAGEMENT

SEMESTER VII

REGULATIONS 2017

NOTES

&

QUESTION BANK

GE3752 TOTAL QUALITY MANAGEMENT L T P C 3 0 0 3

COURSE OBJECTIVES: •

Teach the need for quality, its evolution, basic concepts, contribution of quality gurus, TQM framework, Barriers and Benefits of TQM.

• Explain the TQM Principles for application.

• Define the basics of Six Sigma and apply Traditional tools, New tools, Benchmarking and FMEA.

• Describe Taguchi's Quality Loss Function, Performance Measures and apply Techniques like QFD, TPM, COQ and BPR.

• Illustrate and apply QMS and EMS in any organization.

UNIT I INTRODUCTION 9

Introduction - Need for quality - Evolution of quality - Definition of quality - Dimensions of product and service quality –Definition of TQM-- Basic concepts of TQM - Gurus of TQM (Brief introduction) -- TQM Framework- Barriers to TQM –Benefits of TQM.

UNIT II TQM PRINCIPLES 9

Leadership - Deming Philosophy, Quality Council, Quality statements and Strategic planning- Customer Satisfaction –Customer Perception of Quality, Feedback, Customer complaints, Service Quality, Kano Model and Customer retention – Employee involvement – Motivation, Empowerment, Team and Teamwork, Recognition & Reward and Performance Appraisal-- Continuous process improvement –Juran Trilogy, PDSA cycle, 5S and Kaizen - Supplier partnership – Partnering, Supplier selection, Supplier Rating and Relationship development.

UNIT III TQM TOOLS & TECHNIQUES I 9

The seven traditional tools of quality - New management tools - Six-sigma Process Capability- Bench marking - Reasons to benchmark, Benchmarking process, What to Bench Mark, Understanding Current Performance, Planning, Studying Others, Learning from the data, Using the findings, Pitfalls and Criticisms of Benchmarking - FMEA - Intent , Documentation, Stages: Design FMEA and Process FMEA. 222

UNIT IV TQM TOOLS & TECHNIQUES II 9

Quality circles – Quality Function Deployment (QFD) - Taguchi quality loss function – TPM – Concepts, improvement needs – Performance measures- Cost of Quality - BPR.

UNIT V QUALITY MANAGEMENT SYSTEM 9

Introduction-Benefits of ISO Registration-ISO 9000 Series of Standards-Sector Specific Standards - AS 9100, TS16949 and TL 9000-- ISO 9001 Requirements Implementation-Documentation- Internal Audits-Registration-ENVIRONMENTAL MANAGEMENT SYSTEM: Introduction—ISO 14000 Series Standards—Concepts of ISO 14001—Requirements of ISO 14001-Benefits of EMS. TOTAL: 45 PERIODS

COURSE OUTCOMES:

CO1: Ability to apply TQM concepts in a selected enterprise.

CO2: Ability to apply TQM principles in a selected enterprise.

CO3: Ability to understand Six Sigma and apply Traditional tools, New tools, Benchmarking and FMEA.

CO4: Ability to understand Taguchi's Quality Loss Function, Performance Measures and apply QFD, TPM, COQ and BPR.

CO5: Ability to apply QMS and EMS in any organization.

TEXT BOOK:

1. Dale H.Besterfiled, Carol B.Michna,Glen H. Bester field,MaryB.Sacre, HemantUrdhwareshe and RashmiUrdhwareshe, “Total Quality Management”, Pearson Education Asia, Revised Third Edition, Indian Reprint, Sixth Impression,2013.
2. REFERENCES: 1 Joel.E. Ross, “Total Quality Management – Text and Cases”,Routledge.,2017. 2. Kiran.D.R, “Total Quality Management: Key concepts and case studies, Butterworth – Heinemann Ltd, 2016. 3. Oakland, J.S. “TQM – Text with Cases”, Butterworth – Heinemann Ltd., Oxford, Third Edition, 2003. 4. Suganthi,L and Anand Samuel, “Total Quality Management”, Prentice Hall (India) Pvt. Ltd., 2006 .

UNIT I - INTRODUCTION

Introduction

TQM is defined as both philosophy and a set of guiding principles that represent the foundation of continuously improving organization. It is the application of quantitative methods and human resources to improve all the process within the organisation and exceed customer needs now and in the future.

Evolution of quality

Time	Events
Until 1960s	
Prior to the 20^{th}century	Quality is an art Demands overcome potential production An era of workmanship
F.Taylor 1900s	The scientific approach to management resulting in rationalization of work and its break down leads to greater need for standardization, inspection and supervision
Shewart 1930s	Statistical beginnings and study of quality control. In parallel, studies by R A Fisher on experimental design; the beginning of control charts at western Electric in USA
Late 1930s	Quality standards and approaches are introduced in France and Japan. Beginning of SQC, reliability and maintenance engineering
1942	Seminal work by Deming at the ministry of war in USA on quality control and sampling Working group setup by Juran and Dodge on SQC in US army Concepts of acceptance sampling devised
1944	Daodge and Deming carried out seminal research on acceptance sampling
1945	Founding of the Japan standard association
1946	Founding of the ASQC
1950	Visit of Deming in Japan at the invitation of K Ishikawa
1951	Quality assurance increasingly accepted
1954	TQC in Japan ; Book published 1956
1957	Founding of European organization for the control of quality
After 1960s	
1961	The Martin Co in USA introduces the zero defects approach while developing and

	producing Pershing Missiles. Quality motivation is starting in the US and integrated programmes begun
1962	Quality circles are started in Japan
1964	Ishikawa publishes book on Quality management
1970	Iskiawa publishes the book on the basics of quality circles and the concept of Total Quality is affirmed and devised in Japanese industries
1970 to 1980	Just – in –Time and quality become crucial for competitiveness. A large number of US and European corporations are beginning to appreciate the advance of Japan's industries. Taguchi popularizes the use of environmental design to design robust systems and products
1980+	Facing the rising sun challenge in quality management Development and introduction of FMSs and greater dependence on supplier contracts. Growth of economic based on quality control, information software packages
1990+	The management of quality has become a necessity that is recognized at all levels of management Increasing importance is given to off line quality management for the design of robust manufacturing processes and products. The growth of process optimization

QUALITY – DEFINITION

1. Predictable degree of uniformity and dependability at low cost and suited to the market - **Deming**

2. Fitness for use-**Juran**

3. Conformance to requirements - **Crosby**

4. Minimum loss imparted by a product to society from the time the product is shipped - T**aguchi**

5. A way of managing tile organization -**Feigenbaum**

6. Correcting and preventing loss, not living with loss - **Hosffin .**

7. The totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs – **ISO**

QUANITIFICATION OF QUALITY

$$Q = \frac{P}{E}$$

P=Performance E =Expectations

If Q is greater than 1.0, then the customer has a good feeling about the product or service.

DIMENSIONS OF MANUFACTURING (product) Quality

The various dimensions of product quality are:

All these nine dimensions can be clearly explained with the example of ***Android Phone.***

Performance - Primary product characteristics, such as signal strength, battery life

Features - Secondary characteristics, added features, such as remote control.

Conformance - Meeting specifications or industry standards, workmanship.

Reliability – Consistency of performance over time, average time for the unit to fail.

Durability – Useful life, includes repair

Service – Resolution of problems and complaints, ease of repair.

Response – Human-to-human interface, such as the courtesy of the dealer.

Aesthetics – Sensory characteristics, such as exterior finish

Reputation – Past performance and other intangibles, such as being ranked first

DIMENSIONS OF AND SERVICE QUALITY

Tangibles: Refers to a service's look or feel

Reliability: Refers to the dependability of the service providers and their ability to keep their promises.

Responsiveness: Refers to the reaction time of the service.

Assurance: Refers to the level of certainty a customer has regarding the quality of the service provided.

Empathy: Being able to understand the needs of the customer as an individual and meet the special requirements of the customer.

Others: Time, Timeliness, completeness, courtesy, consistency, accessibility, accuracy, competence, access, communication, credibility and security

<u>Basic concepts of TQM</u>

Total - M*ade up of the whole* **Quality**- D*egree of excellence a product or service provides*

Management- Act, A*rt or manner of handling, controlling, directing, etc...*

Why TQM:

1. A question of survival in the intense competitive environment
2. Increasing customer consciousness

DEFINITION:

1. TQM is the management approach of an organization, centered on quality, based on me participation of all its members and aiming at long-term success through customer satisfaction. and benefits to all members of me organization and to society.- **ISO**
2. TQM is an integrated organizational approach in delighting customers (both internal and external) by meeting their expectations on a continuous basis through every one involved with the organization working on continuous improvement in all products, services, and processes along with proper problem solving methodology - **INDIAN STATISTICAL INSTITUTE (ISI)**
3. TQM is a. people - focused management system that aims at continual increase in customer satisfaction at continually lower cost. TQM is a total system approach (not a separate area of program), and an integral part of high level strategy. It works horizontally across functions and departments, involving all employees, top to bottom, and exceeds backwards and forward to include the supply chain and the customer chain – **TOTAL QUALITY FORUM OF USA**

CHARACTERISTICS

1. Customer Oriented
2. Long term commitment for continuous improvement of all process
3. Team work
4. Continuous involvement of top management
5. Continuous improving at all levels and all areas of responsibility

BASIC CONCEPTS OF TQM:

1. Top management commitment
2. Focus on the customer – Both internal and external
3. Effective involvement and utilization of entire workforce
4. Continuous improvement
5. Treating suppliers as partners
6. Establishing performance measures for the processes

PRINCIPLES OF TQM:

1. Customers requirements - (both internal & external) must be met first time & every time
2. There must be agreed requirements, for both internal and external customers.
3. Everybody must be involved
4. Regular two way communication must be promoted
5. Identify the training needs and supply it to the employees
6. Top management commitment is must
7. A culture of continuous improvement must be established.
8. Emphasis should be placed on purchasing and supplier management.
9. Every job must add value
10. Eliminate waste & reduce total cost
11. There must be a focus on the prevention of problems.
12. Promote creativity
13. Performance measures are a must at all levels to meet objectives of quality.
14. Focus on team work.

Four Pillars of TQM house:

1.Problem solving discipline 2. Interpersonal skills 3. Team work 4. Quality improvement process.

PRINCIPLES OF TQM:

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CONTRIBUTIONS BY QUALITY GURUS

To fully understand the TQM movement, we need to look at the philosophies of notable individuals who have shaped the evolution of TQM. Their philosophies and teachings have contributed to our knowledge and understanding of quality today.

American Quality Gurus

1. Walter Shewhart (1920 -1940s)
2. W.Edeards Deming (post world war II through 1980s)
3. Joseph .M.Juran (post world war II through 1980s)
4. Philip Crosby (1980s)
5. Armand Feigenbaum (1970s -1980s)

Japanese Quality Gurus

1. Kaoru Ishikawa (post world war II through 1980s)
2. Genichi Taguchi (1960s – 1980s)
3. Shigeo Shingo (post world war II through 1980s)
4. Masaaki Imai (1980s)

Deming Contributions:

1. Deming's 14 points on route to quality
2. Deming (PDCA) cycle
3. Seven deadly diseases of mgt
4. System of profound knowledge

Deming's 14 points for Management:

1. **Create and publicize** to all employees the aims and purposes of the organization.

2. **Adopt the new philosophy** (of customer satisfaction, continuous improvement, defect prevention, management-labour cooperation, etc.).

3. **Stop dependence on inspection to achieve quality**. (Managers must understand how variation affects their processes and take steps to reduce the causes of variation.
Workers must take responsibility for their own work).

4. **End the practice of awarding business on the basis of price tag alone**. (Costs due to inferior materials/components increase costs in the later stages of production.
Suppliers themselves are part of the whole system and hence should be treated along-term partners).

5.**Improve constantly** and forever the system of production and service .(Aim for small, incremental, continuous improvements – not merely in the area of production but also covering transportation, maintenance, sales, service, administration, etc. – all areas of the organization).

6. **Institute training**. (Employees need the proper tools and knowledge to do a good job, and it is management's responsibility to provide these. Training not only improves quality and productivity, but also enhances workers' morale).

7. **Adopt modern methods of supervision and leadership**. (Managers, Supervisors should act as coaches, facilitators and not as policemen).

8. **Drive out fear**. (Fear in work manifests as fear of reprisal, fear of failure, fear of change, fear of the unknown. Fear encourages short-term, selfish thinking, not long term improvement for the benefit of all).

9. **Break down barriers between departments and individuals**. (Promote teamwork).

10. **Eliminate the use of slogans and exhortations**. (Workers cannot improve solely through motivational methods when the system in which they work constrains their performance. On the contrary, they will become frustrated, and their performance will decrease further).

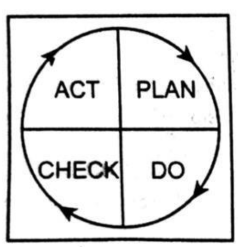
11. **Eliminate work standards, numerical quotas, and MBO**. (Numerical quotas reflect short-term perspectives and do not encourage long-term improvement. Workers may shortcut quality to reach the goal. The typical MBO system focuses on results, not processes, and encourages short-term behavior).

12. **Remove barriers to pride in workmanship**. (Treating workers as commodities; giving them monotonous jobs, inferior tools; performance appraisals, management assuming it is smarter than workers and not using the workers' knowledge and experience to the fullest extent).

13. **Encourage education and self-improvement for everyone**.

14. Take action to achieve the transformation. (The TQ philosophy is a major cultural change, and many firms find it difficult. Top management must take the initiative and include everyone in it).

Deming Cycle:



PLAN	what is needed
DO	it
CHECK	that it works
ACT	to correct problems or improve performance

The Deming cycle

CROSBY'S CONTRIBUTIONS

Philip Crosby, author of ***Quality is Free.*** Crosby emphasized meeting customer requirements by focusing on prevention rather than correction.

<u>His "Absolutes" are:</u>

(1) Quality is defined as conformance to requirements, not *goodness;*

(2) The system for achieving quality is prevention, not appraisal;

(3) The performance standard is zero defects, not *that's close enough;* and

(4) The measure of quality is the price of non-conformance, not indexes.

14 <u>Principles</u>

1. **Management commitment**, that is, top level management must be convinced and committed and communicated to the entire company.
2. **Quality improvement team** composed of department heads to oversee improvements.
3. **Quality measurement** is established for every activity.
4. **Cost of quality** is estimated to identify areas of improvement.
5. **Quality awareness** is raised among all employees.
6. **Corrective action** is taken.
7. **Zero defects** are planned for.
8. **Supervisor training** in quality implementation.
9. **Zero defects day is scheduled.**
10. **Goal setting** for individuals.
11. **Error causes are removed** by having employees informed management of problems.
12. **Recognition is given**, but it is non-financial, to those who meet quality goals.
13. **Quality councils** meet regularly.
14. **Do it all over again** (i.e., repeat steps one through thirteen).

Juran’s Contributions

It can be studied under the following topics:

1. Quality planning

– Establish quality goals.

– Identify who the customers are.

– Determine the needs of the customers.

– Develop product features that respond to customers' needs.

– Develop processes able to produce the product features.

– Establish process controls; transfer the plans to the process.

2. Quality control

– Evaluate actual performance.

– Compare actual performance with quality goals.

– Act on the difference.

3. Quality improvement

– Prove the need.

– Establish the infrastructure.

– Identify the improvement projects.

– Establish project teams.

– Provide the teams with resources, training, and motivation to:

. Diagnose the causes, and; . Stimulate remedies.

– Establish controls to hold the gains.

Meanwhile, Juran drew “a graph with time on the horizontal axis and cost of poor quality on the vertical axis”, to describe the zones an areas that belong to the parts of “Juran's Trilogy”. As depicted in Figure 3, the graph illustrate the three processes of the “Juran's Trilogy” are interrelated. The first zone is “quality planning”, that planners should find the requirements of customers by accurate information. Next zone is quality control planners have to design a proper process to produce the product/s accordant to the needs of customers. In the third zone of “Juran's Trilogy”, the planners turn the plans over to the operating forces: “You run the process, produce the product features, and meet the customers’ needs”

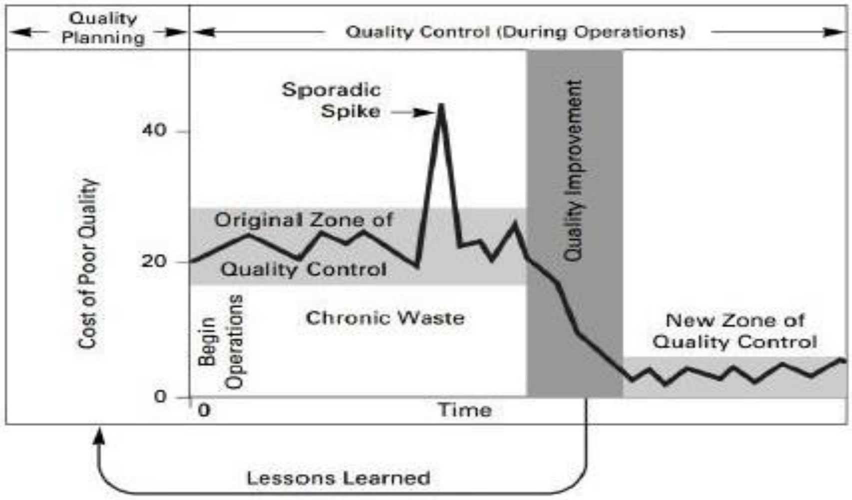


Figure 3: The Juran trilogy diagram [15]

He introduced "**Ten Steps to Quality Improvement**" for improving the satisfaction of customer, these steps are listed below

1. "Build awareness of the need and opportunity for improvement;
2. Set goals for improvement;
3. Organize to reach the goals (establish a quality council, identify problems, select projects, appoint teams, and designate facilitators);
4. Provide training;
5. Carry out projects to solve problems;
6. Report progress;
7. Give recognition;
8. Communicate results;
9. Keep score, and;
10. Maintain momentum by making annual improvement part of the regular systems and processes of the company".

Barriers to TQM Implementation

1. Lack of management commitment
2. Lack of faith in and support to TQM activities among management personnel
3. Failure to appreciate TQM as a cultural revolution. In other words, inability to change organizational culture
4. Misunderstanding about the concept of TQM
5. Improper planning

6. Lack of employees commitment
7. Lack of effective communication
8. Lack of continuous training and education
9. Lack of interest or incompetence of leaders
10. Ineffective measurement techniques and lack of access to data and results
11. Non-application of proper tools and techniques
12. Inadequate use of empowerment and teamwork

Potential Benefits of TQM

Tangible Benefits	Intangible Benefits
• Improved product quality • Improved productivity • Reduced quality costs • Increased market and customers • Increased profitability • Reduced employee grievances	• Improved employee participation • Improved teamwork • Improved working relationships • Improved customer satisfaction • Improved communication • Enhancement of job interest • Enhanced problem solving capacity • Better company image

QUALITY STATEMENTS

Three elements of quality statements are :

a. Vision statement,

b. Mission statement, and

c. Quality policy statement What is Vision Statement?

1. ***The vision statement*** is a short declaration of what on organization aspires to be tomorrow.
2. It is the ideal state that might never be reached; but on which one will work hard continuously to achieve. Successful visions provide a brief guideline for decision making.
3. The vision statement should be coined in such a way that the leaders and the employees working in the organization should work towards the achievements of the vision statement.
4. ***An example of a simple vision statement is :***

"To continuously enrich knowledge base of practitioners in mobility industry and institutions in the service of humanity". – Society of Automotive Engineers (SAE)

What is Mission Statement?

1. The mission statement, describes the function of the organization. It provides a clear statement of purpose for employees, customers, and suppliers.
2. ***The mission statement*** answers the following questions: who we are?; who are our customers? ; what we do?; and how we do it?
3. ***An example of a simple mission statement is :***

   "Concern for the ultimate customers – millions of customers Concern for the intermediate customers– the trade

   Concern for the suppliers – the sources of raw materials and ancillaries Concern for the employees – the most valued asset

   Concern for the competitors – wishing them well as healthy competition ultimately benefits the customers.

   Concern for the shareholders – the investing public Concern for the national aspiration – India's future!"

What is Quality Policy Statement?

The quality policy is a guide for everyone in the organization as to how they provide products and service to the customers.

It should be written by the CEO with feedback from the workforce and be approved by th
quality council.

A quality policy is a important requirement of ISO 9000 quality systems.

An example of a simple quality policy statement is:

"Xerox is a quality company. Quality is the basic business principle for Xerox. Quality means providing our external and internal customers with innovative products and services that fully satisfy their requirements. Quality is the job of every employee".

VISION STATEMENT

It is a short declaration of what an organization aspires to be tomorrow.

Example :

Disney Theme Park	-	Happiest place on earth
Polaroid	-	Instant photography

Successful visions provide a guideline for decision making

MISSION STATEMENT

It answers the following questions

- Who we are?
- Who are the customers?
- What we do?
- How we do it?

It describes the function of the organization. It provides a clear statement of purpose for employees, customers & suppliers

A simpler mission statement is

"To meet customers transportation and distribution needs by being the best at moving their goods on time, safely and damage free" - National Railways

QUALITY POLICY STATEMENT

It is guide for everyone in the organization as to how they should provide products and services to the customers.

Common characteristics are

- ✓ Quality is first among equals
- ✓ Meet the needs of the internal & external customers
- ✓ Equal or exceed competition
- ✓ Continuously improve the quality
- ✓ Utilize the entire workforce

Ex: Xerox is a quality company. Quality is the basic business principle for Xerox. Quality means providing our external and internal customers with innovative products and services that fully satisfy their requirements.

<u>Costs of quality</u>

Costs of quality are costs that occur because poor quality may exist or actually does exist. More specifically, quality costs are the total of the costs incurred by (1) investing in the prevention of nonconformance to requirements; (2) appraising a product or service for conformance to requirements; and (3) failure to meet requirements.

Quality costs are classified into three broad categories: prevention, appraisal, and failure costs.

Prevention Costs. These are costs that are incurred to prevent defects. Amounts spent on quality training programs, researching customer needs, quality circles, and improved production equipment are considered in prevention costs. Expenditures made for prevention will minimize the costs that will be incurred for appraisal and failure.

Appraisal Costs. These are costs incurred for monitoring or inspection; these costs compensate for mistakes not eliminated through prevention.

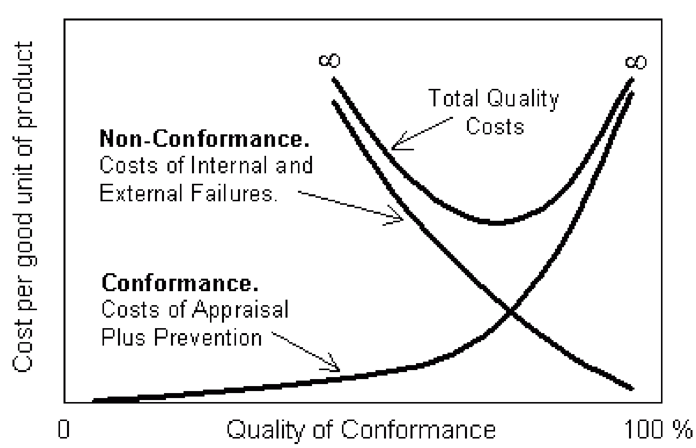
Failure Costs. These may be internal, such as scrap and rework costs and reinspection, or external, such as product returns due to quality problems, warranty costs, lost sales due to poor product performance, and complaint department costs.

There are two views concerning optimal quality costs:

1. Traditional view that uses an acceptable quality level.
2. World-class view that uses total quality control.

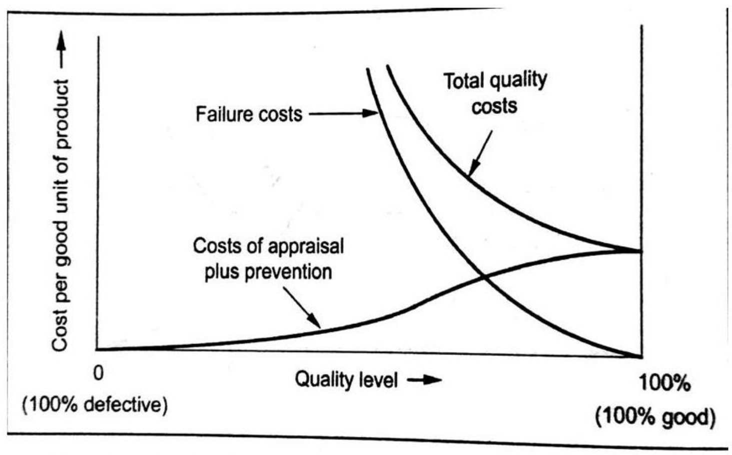
Optimal Distribution of Quality Costs: Traditional View.

The traditional approach uses an acceptable quality level (AQL) that permits a predetermined level of defective units to be produced and sold. AQL is the level where the number of defects allowed minimizes total quality costs. The reasoning of the traditional approach is that there is a tradeoff between failure costs and prevention and appraisal costs. As prevention and appraisal costs increase, internal and external failure costs are expected to decrease. As long as the decrease in failure costs is greater than the corresponding increase in prevention and failure costs, a company should continue increasing its efforts to prevent or detect defective units.



Optimal Distribution of Quality Costs: World-Class View.

The world-class view uses total quality control and views the optimal level of quality costs as the level where zero defects are produced. The zero-defects approach uses a quality performance standard that requires:



1. Prevention costs.
2. Appraisal costs.
3. Internal failure costs.
4. External failure costs.

In addition, each category of quality costs is expressed as a percentage of sales.

Performance reports:

There are four types of **performance reports** to measure a company's quality improvement.

They are:

Interim Quality Performance Report. It measures the progress achieved within the period relative to the planned level of progress for the period.

- ✓ **One-Year Quality Trend Report.** It compares the current year's quality cost ratio with the previous year's ratio. More specifically, it compares (1) the current year's variable quality cost ratio with the previous year's variable quality cost ratio, and the current year's actual fixed quality costs with the previous year's actual fixed quality costs.
- ✓ **Multiple-Period Quality Report.** It shows the overall trend of quality costs by category since the inception of the quality enhancement program. Once the quality-related activities are identified for each category, resource drivers can be used to improve cost assignments to individual activities. Root or process drivers can also be identified and used to help managers understand what is causing the cost of the activities.

The principal objective of reporting quality costs is to improve and facilitate managerial planning, control, and decision-making. Potential uses of quality cost information include:

- ❖ Quality program implementation decisions.
- ❖ Evaluation of the effectiveness of quality programs.
- ❖ Strategic pricing decisions; for example, improved reporting of quality costs might be used by managers to target specific quality costs for reductions. A reduction in quality costs might enable a firm to reduce its selling price, improve its competitive position, and increase market share.
- ❖ Inclusion of quality costs in cost-volume-profit analysis; for example, overlooking quality cost savings results in a higher break-even and possible rejection of a profitable project.

The control process involves comparing actual performance with quality standards. This comparison provides feedback that can be used to take corrective action, if necessary.

THE CUSTOMERS

- • The most important people in the business
- • Not dependent on the organization, but the organization depends on them.
- • Not an interruption to work but are the purpose of it.
- • Doing a favor when they seek business and not vice-versa.
- • A part of business, not outsiders and they are life blood of the business
- • People who come with their needs and jobs
- • Deserve the most courteous and attentive treatment.

TYPES OF CUSTOMERS

Internal Customer: The customer inside the company are called internal customers

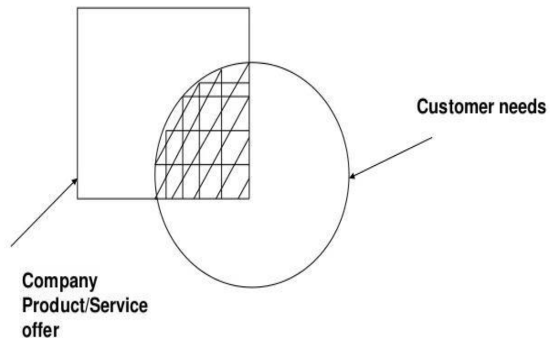
External Customers: An external customer is the one who used the product or service or who purchase the products or service or who influences the sale of the product or service.

CUSTOMER SATISFACTION

The Customer is the King - Emphasized by Today's Buyers Market. TQM's Purpose is meeting or exceeding customer expectations, so that the customers are delighted. The customer satisfactions must be the primary goal of any organization.

CUSTOMER SATISFACTION MODEL

Teboul's Model of customer satisfaction as shown in figure



From the above diagram it is understood that the company should strive for increasing the intersection portion i.e. Customer Satisfaction.

CUSTOMER COMPLAINTS (FEEDBACK)

Customer feedback must be continuously solicited and monitored to reduce the dissatisfied customers as much as possible.

CUSTOMER FEEDBACK OR CUSTOMER COMPLAINT IS REQUIRED

1. To discover customer dissatisfaction
2. To identify customer's needs
3. To discover relative priorities of quality
4. To compare performance with the competition
5. To determine opportunities, for improvement

TOOLS USED FOR COLLECTING CUSTOMER COMPLAINTS

• **Comment card** - Low cost method, usually attached to warranty card

• **Questionnaire** - Popular tool, costly and time consuming - by mail or telephone preferably multiple choice questions or a point rating system (1 to 5) or (1 to 10)

• **Customer Focus groups** - Meeting by a representative of the company with the group of customers. Imprint analysis is an emerging technique to obtain intrinsic feelings using customer meetings, word associations, discussion, relaxation techniques etc.

• **Phone -** Toll free Telephone numbers

• **Customer visits** - Visit customer's place of business.

• **Report cards** - Usually, send to customer on a quarterly basis.

• **The internet and computer** - It includes newsgroups, electronic bulletin board mailing lists,

• Employee feedback.

• **Mass Customization** - Capturing the voice of customers using data of what customer want instead of what customer is thinking about buying and manufacturing exact what they want.

SOLVE CUSTOMER COMPLAINTS

_ Complaints can be collected from all sources (letters, phone -calls, meetings and verb inputs)

_ Develop procedures for complaint resolution that includes empowering front-line personnel.

_ Analyze complaints, but understand that complaints do not always fit into new categories

_ Work to identify process and material variations and then eliminate the root cause.

_ When a survey response is received, a senior manager should contact the customer and strive to resolve the concern.

_ Establish customer satisfaction measures and constantly monitor them.

_ Communicate complaint information, as well as the result of all investigation solution, to all people in the organization. .

_ Provide a monthly complaint report to the quality council for their evaluation and needed, the assignment of process improvement teams.

_ Identify customer's expectations beforehand rather than afterward through complaint analysis.

CUSTOMER RETENTION.

More powerful and effective than customer satisfaction It is the process of retaining the existing customer care can be defined as every activity which occurs within the organization that ensures that the customer is not only satisfied but also retained.

SIGNIFICANCE OF CUSTOMER RETENTION

• 60% of organizations future revenue will come from existing customers

• 2% increase in customer retention has 10% decreases in operating cost.

• 96% of unhappy customers do not complain but 3 times likely to convey to other customers about their bad experience.

• 91% of unhappy customers never purchase goods and services from you.

• It costs 5 times more to attract the customer than retaining the existing customer.

• Customer retention creates customer loyalty and moves customer satisfaction to a next level called customer delight.

PRINCIPLES OF CUSTOMER/SUPPLIER RELATIONS

1. Both the customer and the supplier are fully responsible for the control of the quality
2. Both the customer and the supplier should be independent of each other and respect each other's independence.
3. The customer is responsible for providing the supplier with clear and sufficient requirements so that the supplier can know exactly what to produce.
4. Both the customer and the supplier should enter a contract with respect to quality, quantity, price, delivery method, and terms of payments.
5. The supplier is responsible for providing the quality that will satisfy the customer and submitting necessary related with customer's needs.
6. Both the customer and the supplier should decide the method to evaluate the quality of the product or service to satisfaction of both parties
7. Both the customer and the supplier should establish a settlement method in the contract.
8. Both the customer and the supplier should continually exchange information, sometimes using multifunctional teams, in order to improve the product or service quality.
9. Both the customer and the supplier should perform business activities such as procurement, production and inventory planning, and etc.
10. When dealing with business transactions, both the customer and the supplier should always have the best interest of the end user in mind.

SUPPLIER PARTNERSHIP

An organization (or customer) purchases its requirements, raw materials, components, and services, from supplier.

Better supplier's quality ➔ Better product's quality

A partnership between customer and supplier is one of the keys to obtaining high quality products and services. Customers and suppliers have the same goal –to satisfy the end user. They must work together as partners to maximize the return on investment because they have limited resources.

PARTNERING

Partnering is a long-term commitment between two or more organizations for the purpose of achieving specific business goals & objectives.

- The relationship is based upon trust, dedication to common goals and objectives.
- Benefits include:
    - Improved Quality,
    - Increased efficiency,
    - Lower cost,
    - Increased opportunity for innovation, &
    - Continuous improvement of products and services
- The three key elements of partnering are:
    - Long-term commitment.
    - Trust.
    - Shared vision.

SUPPLIER RATING

Supplier rating system is based on quality, delivery and other added services.

The objectives of a rating system are:

- To obtain an overall rating of supplier performance.
- To ensure communication with suppliers in the areas of quality, service, delivery and other desired measures.
- To provide supplier with a detailed and factual record of problems for corrective action.
- To enhance the relationship between the customer and the supplier.

UNIT II - TQM PRINCIPLES

LEADERSHIP

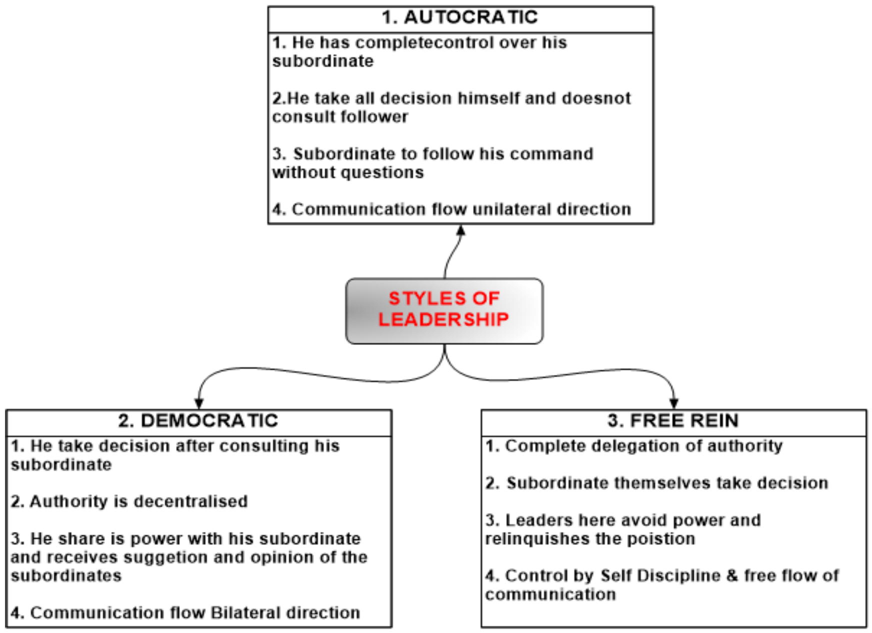


Fig. 1 Types of Quality leader

- "Leadership is lifting of organisation's visions to higher sights, the raising of organisation's performance to a higher standard, the building of organisation beyond its normal limitations."

CHARACTERISTICS OR BEHAVIOURS OF QUALITY LEADERS

1. The customers first:
    - ❖ Clarity in thought
    - ❖ Primary importance to both internal and external customer needs
    - ❖ Leaders actively listen on customer opinion on the value of product / service
2. Value people:
    - ❖ Leaders have trust and confidence in their performance of their subordinates
    - ❖ They monitor, appraise and recognize subordinate performance
3. Build supplier partnership:
    - ❖ Leaders clarify quality to suppliers, audit their capabilities, give feedback, discuss improvement and support them where need
4. Empower people:
    - ❖ Leaders train and coach rather than direct supervising

5. Demonstrate involvement/commitment:

- ❖ Continually demonstrate commitment to quality achievement

6. Strive for excellence:

- ❖ Leader emphasizes continuous improvement rather than maintenance.

7. Curiosity

- ❖ Willingness to learn quality policy to all involved

8. Improve communication:

- ❖ Leader continually improves communication establish channels of communication which are reliable and accessible in every one organisation

9. Promote teamwork:

- ❖ Leader promotes multidisciplinary teamwork, create involvement & active participation of everyone.

10. Benchmark continuously:

- ❖ Continuously do benchmarking and create new learning effects through innovation

11. Establish system: Quality:

- ❖ Quality leaders establish organisational systems to support quality effort

12. Encourage collaboration:

- ❖ Leaders encourage collaboration rather than competition.

ROLE OF TQM LEADERS

- ➢ To study and investigate the TQM concepts and issues.
- ➢ To set clear quality policies and provide challenging tasks.
- ➢ To establish 'priority of quality' and 'customer satisfaction' as the basic policy and determine the long-term goals.
- ➢ To bring a cultural charge required for the TQM effort.
- ➢ To establish the TQM vision for the future and communicate to all involved.
- ➢ To become coaches and cheer leaders for encouraging and supporting the managers during the transition phase of the transformation change.
- ➢ To stimulate employees to be involved.
- ➢ To teach employees to realise that the company's interest and their interest are geared into one another.
- ➢ To uphold norms and values, and let it be known.

- To attend TQM training programmes.
- To create coordination and harmony among and within departments.
- To monitor whether quality improvement programs are conducted as planned.

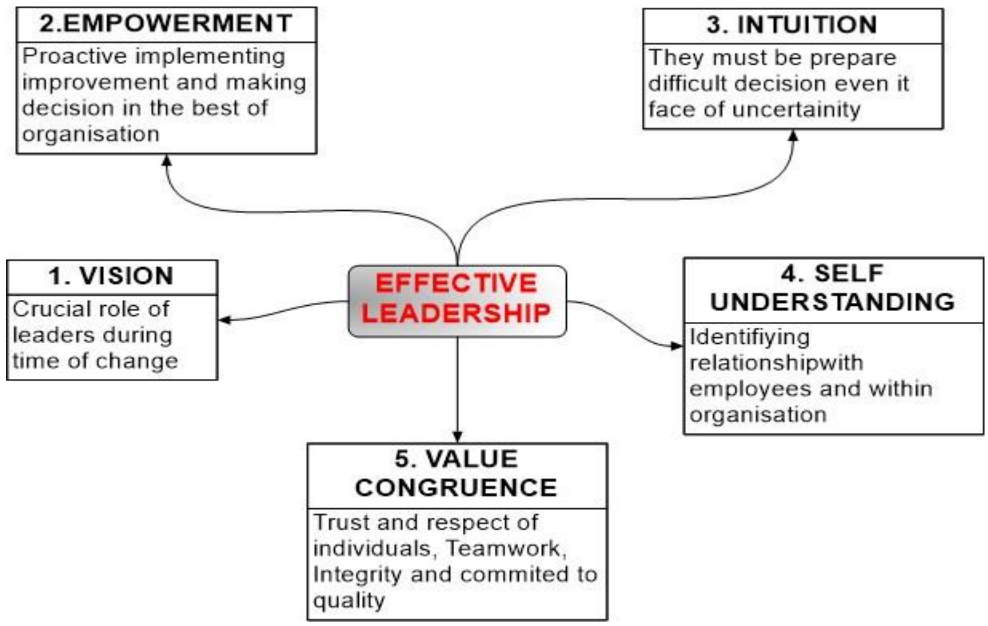


Fig. 2 Qualities of a leader

STRATEGIC QUALITY PLANNING

- Strategic quality plans and business plans are inseparable.
- No organization can survive for long without placing a core emphasis on quality.
- The time horizon for strategic planning is three to ten years and short term planning is one year.
- Both long-term and short-term require goals and objectives.
- Goals and objectives are derived from organizational Mission/Vision statement.
- Quality should be used as key Mission statement and strategic option.

QUALITY STATEMENT

- Quality Statements are established by the Quality council to provide overall direction for achieving the total quality culture.
- Three elements of quality statements are:
  - 1. Vision Statement
  - 2. Mission Statement, and
  - 3. Quality policy statement

- Effective leader communicates the values of the organization to their employees by translating the vision and mission into day–to–day activities.

VISION STATEMENT

A well-written vision statement, regardless of the type of organization, has the following characteristics:

- Is easily understood by all stakeholders
- Is briefly stated, yet clear and comprehensive in meaning
- Is challenging, yet attainable.
- Is lofty, yet tangible
- Is capable of stirring excitement for all stakeholders
- Is capable of creating unity of purpose among all stakeholders
- Is not concerned with numbers
- Sets the tone for employees.

MISSION STATEMENT

- The mission statement, is usually one paragraph, describes the function of the organization. It provides a clear statement of purpose for employees, customers, and suppliers.
- The mission statement answers the following questions: who we are? Who are the customers? What we do?; and how we do it?
- A well conveyed mission statement defines the fundamental, unique purpose that sets a company apart from other firms of its type and identifies the scope of the company's operations in terms of products offered and markets served.

  Together, a vision and mission statements provide a common agreed-upon direction for the entire organization. The direction can be used as a basis for daily decision making.

STRATEGIC PLANNING

Strategic Planning can be defined as the process of deciding on objectives of the organization, on changes on these objectives, on the resource used to attain these objectives and on the policies that are to govern the acquisition, use and disposition of these resources

- It sets the long-term direction of the organisation in which it wants to proceed in future.

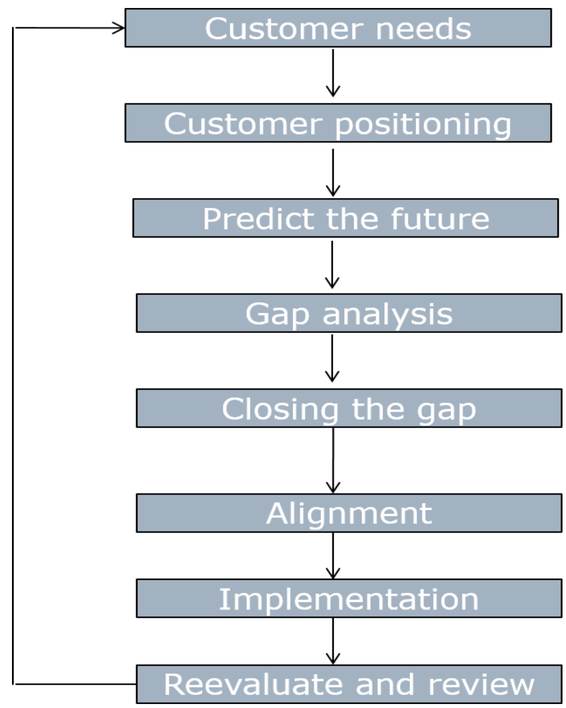


Fig. 3 Strategic Planning Cycle

Types of Strategic Planning

S.No	Traditional strategic planning	Strategic quality planning
1	Focus is not defined	Focus is on customer
2	Focus is on products	Focus is on process
3	Leader – lack of understanding – critical to success	Leader determines critical to success
4	Goals and objectives result oriented	Goals and objectives process & result oriented
5	No alignment exist	Alignment exists
6	Improvement activities – within functional areas	Improvement activities – both within and across functional area

EMPLOYEE INVOVLEMENT

The heart of the TQM is the concept of intrinsic motivation involvement in decision making. Total involvement from every individual at all level is very must.

Why involvement?

- Market is changing
- Competition is emerging at global level.
- Every employee is regarded as a unique human being and each employee is involved in helping the organisation meet its goals.
- By involving **employees, empowering and bringing them into decision making process** the opportunity is provided for continual process improvement
- Their ideas, expert knowledge potential, experience and creative thoughts of employees, promote quality and productivity.

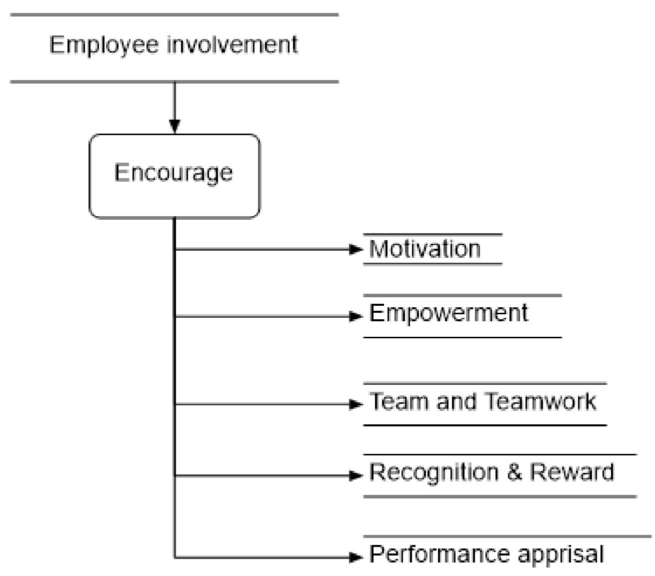


Fig. 4 Types of Encouragements

EMPLOYEE MOTIVATION

- Motivation means a process of **stimulating people** to accomplish **desired goals**.
- It is lead to **success of organisation**; however, it is **difficult** to understand because **human nature is quite complex.**
- Important function of motivation
    1. Job performance(ability)
    2. Productivity (skills)
    3. Job satisfaction
    4. Employee extension

EMPOWERMENT

- Involving people in decision related to their **work is essential for good management**
- Empowerment refers to a process where by an individual's belief in **his or her self- efficiency is enhanced**.
- Empowered should not be confused with delegation or job enrichment

TEAM AND TEAM WORK

- Team are group of people **working towards the common goals**
- Team work is the **cumulative sum of action of the team, during which each person in the team subdues one's individual desires and opinions, to satisfy the objectives or goals of the group.**

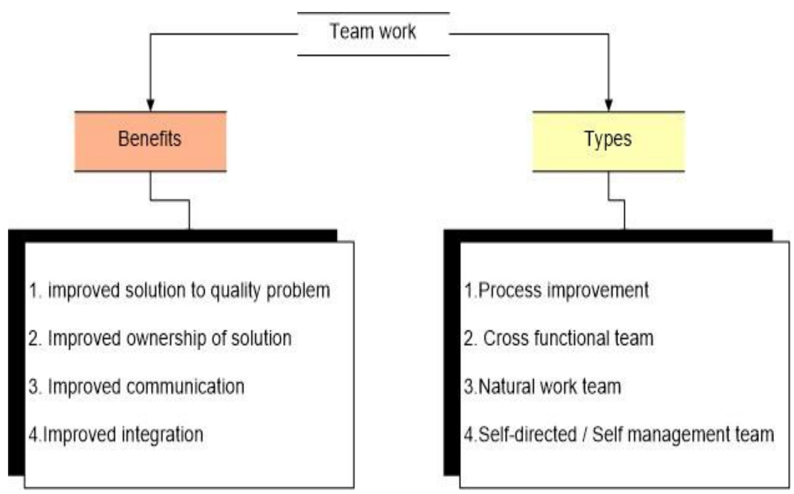


Fig 5. Team Work

WHY AND HOW - TEAM WORK?

1. Many procedures are so complicated that **one member cannot have through knowledge on entire process**
2. According to **synergy principle** the whole is greater than the sum of its constituents
3. The team members develop mutual respect and appreciation with each other which enables them to do **jobs better – team spirit.**

STAGES OF TEAM DEVELOPMENT

Forming stage (start-up)

- members go through a process of defining their collective task, agreeing on individual roles and responsibilities

- **Stroming (conflict)**

  Deciding on the plan of action.

  There is frustration and disagreement on issues of leadership, power, control and influence.

- **Norming (Teamwork)**

  Stage things begin to settle down and stabilize conflict and issues are resolved

  Disagreements are negotiated

  Strong bonds from within the group

- **Performing (achievement)**

  This is the maturing stage. Members have strong loyalty to the team and to one another

  This performance is high

  Members work together in constructive ways to achieve common goals

- **Transforming (change)**

  In this last change the team may add or lose members. It may have a new mission or break up entirely

RECOGNITION AND REWARD

Recognition

- Recognition is a process whereby management shows acknowledgement of an employee's outstanding performance,
- Recognition is a form of employee positive motivation. Recognition of employees is highly essential as people find themselves in a accepted and winning role.
- To sustain employee's interest and to propel them towards continuous improvement, it is essential to recognise the people. This acknowledgement may be of financial, psychological or both in nature.

Reward

- Reward is a tangible one, such as increased salaries, commissions, cash bonus, gain sharing, etc., to promote desirable behaviour.

Why should we recognize the Employees?

The employee’s effort towards the improvement should be recognised for many reasons.

- Recognition is essential to: improve employees morale.

- show the company's appreciation for better performance.

- create satisfied workplace.

- create highly motivated workplace.

- reinforce' behavioural patterns.
- stimulate creative efforts.

Table 1 Types of rewards

Intrinsic Rewards	Extrinsic Rewards
Celebrations to acknowledge achievement of quality improvement goals	Profit sharing
Formal suggestion system available for individuals to make quality improvement suggestions	Gain sharing
Developmental based performance appraisals.	Employee security
Quality based promotions.	Compensation time

PERFORMANCE APPRAISAL

- The purpose of the performance appraisals is to let employees know how they evaluate and provide a basis for promotions, salary increment, and counselling.
- The appraisal should bring out strengths and weaknesses, as well as how performance can be improved.
- Performance appraisal is a systematic and objective assessment or evaluation of performance and contribution of an individual.
- It is a systematic and objective way of judging the relative worth of an employee in performing his task.
- It is the systematic, periodic and an impartial rating of an employees excellence in matters pertaining to his present job and his potential for a better job.

Need for Performance Appraisal

The purpose of performance appraisal is:

- To identify employees for salary revision, promotion, transfer, demotion.
- To take an organisational of inventory people, skills and potential for comparing it with its needs.
- To determine training and development needs of the employees.
- To motivate employees by providing feedback on their performance levels.
- To know personal strengths and weaknesses of different individuals.
- To establish a basis for research and reference for personnel decisions in future.

- To guide the individual to plan job and personal objectives and to help him in career planning.
- To validate the selection procedures.
- To improve communication in an organisation.

CONTINUATION PROCESS IMPROVEMENT

We must strive to achieve perfection by continuously improving the business and Production process. We continuously improve by

Fig. 7 Lamp example for Continuous Improvement

- Viewing all work as a process, it is associated with production or business activities,
- Making all our processes effective, efficient and adaptable,
- maintaining constructive dissatisfaction with the present level of performance,
- Eliminating waste and rework wherever it occurs.
- Eliminating non conformities in all phases of every one's work, even if the increment of
- improvement is small.
- Using bench marking to improve competitive advantage
- Innovating to achieve break thoroughly
- Holding gains so there is no regression

- In corporating lessons learned into future activities.
- Using technical tools such as statistical process control (SPC), experimented design, bench marking, quality function deployment (QFD). etc.

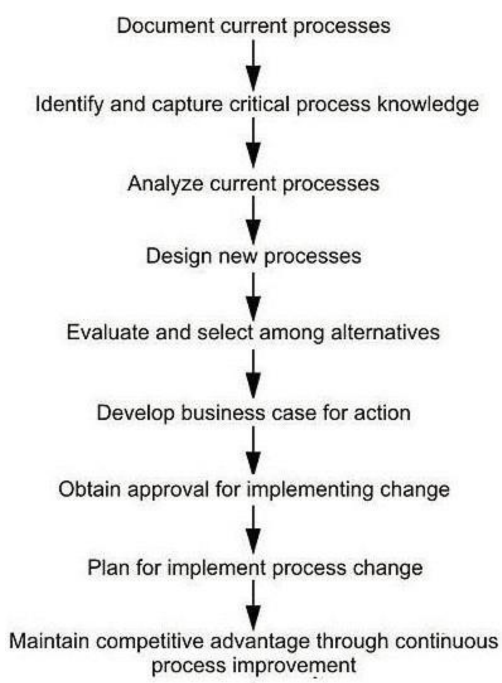
Continuous process improvement is designed to utilize the resource of the organization to achieve a quality-driven culture.

KAIZEN

'Kai' and 'zen' in Japanese, mean change for good. It indicates the philosophy that defines management's role in continuously encouraging and implementing small improvements involving every person.

Kaizen, also known as continuous improvement, is a **long-term approach** to work that systematically seeks to achieve small, incremental changes in processes in order to improve efficiency and quality.

It is the principle of continual improvement whereby the process is made more effective, efficient, controllable and adaptable. Improvements are achieved with little expense, and with less sophisticated equipment or techniques. It concentrates on simplification by splitting the complex processes into their sub-processes and then improving upon them.



Limits and Risks-Kaizen Principles:

Kaizen is a tool that has to be used in a business environment which has long-term goals. Using the Kaizen principle need not resolve a particular problem completely and immediately. Thus, to implement the Kaizen philosophy, the practitioners need to be patient. Thus, the Kaizen principle is not meant for everyone.

The 5 W and 1 H of Kaizen

Who?	What?	Where?
1. Who does it? 2. Who is doing it? 3. Who should be doing it? 4. Who else can do it? 5. Who else should do it? 6. Who is doing 3-Mus?	1. What to do? 2. What is being done? 3. What should be done? 4. What else can be done? 5. What else should be done? 6. What 3-Mus are being done?	1. Where to do it? 2. Where is it done? 3. Where should it be done? 4. Where else can it be done? 5. Where else should it be done? 6. Where are 3-Mus being done?
When?	**Why?**	**How?**
1. When to do it? 2. When is it done? 3. When should it be done? 4. What other time can it be done? 5. What other time should it be done? 6. Are there any time 3-Mus?	1. Why does he do it? 2. Why do it? 3. Why do it there? 4. Why do it then? 5. Why do it that way? 6. Are there 3-Mus in the way of thinking?	1. How to do it? 2. How is it done? 3. How should it be done? 4. Can this method be used in other areas? 5. Is there any other way to do it? 6. Are there any 3-Mus in the method?

The PDSA Cycle

The basic Plan-Do-Study-Act (PDSA) cycle was first developed by Shewhart and then modified by Deming.

The four steps in the cycle are exactly as stated.

1. First, plan carefully what is to be done?
2. Next, carryout the plan (do it)?
3. Third, study the results. Did the plan work as intended or were the results different?
4. finally, act on the results by identifying what worked as planned and what didn't?

Using the knowledge learned, develop an improved plan and repeat the cycle.

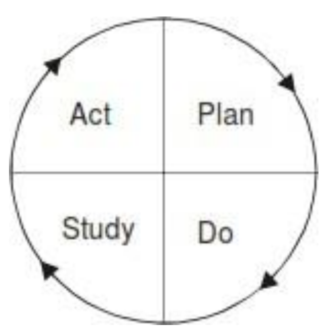


Fig. 8 PDSA Cycle

5S PRINCIPLE

- SEIRI – Organisation/Sort out
- SEITON – Orderliness/Systemize
- SEISO – The Cleaning/Shining
- SEIKETSU – STANDARDIZE
- SHITSUKE - Sustain/Discipline

Seiri

Decide what you need

Remove unnecessary clutter

All tools, gauges, materials, classified and then stored

Remove items which are broken, unusable or only occasionally used

Seiton

Once you have eliminated all the unneeded items

Now turn to the left-over items

Seiso

Create a spotless workplace

Identify and eliminate causes of dirt and grime – remove the need to clean

Sweep, dust, polish and paint

Seiketsu

Generate a maintenance system for the first three

Develop procedures, schedules, practices

Continue to assess the use and disposal of items

Regularly audit using checklists and measures of housekeeping

Real challenge is to keep it clean

Shitsuke

Means inoculate courtesy & good habits

Driving force behind all 5S

Deming’s point number 1: Constancy of purpose

Make it a way of life

Part of health and safety

Involve the whole workforce

Develop and keep good habits

Advantages of 5S

Health and Safety is ensured

Machine maintenance

Quality

Productivity

Lean Manufacturing

Time saving

Quick retrieval

Accidents & mistakes minimized

Increases space

Creates workplace ownership

UNIT - III TQM TOOLS AND TECHNIQUES

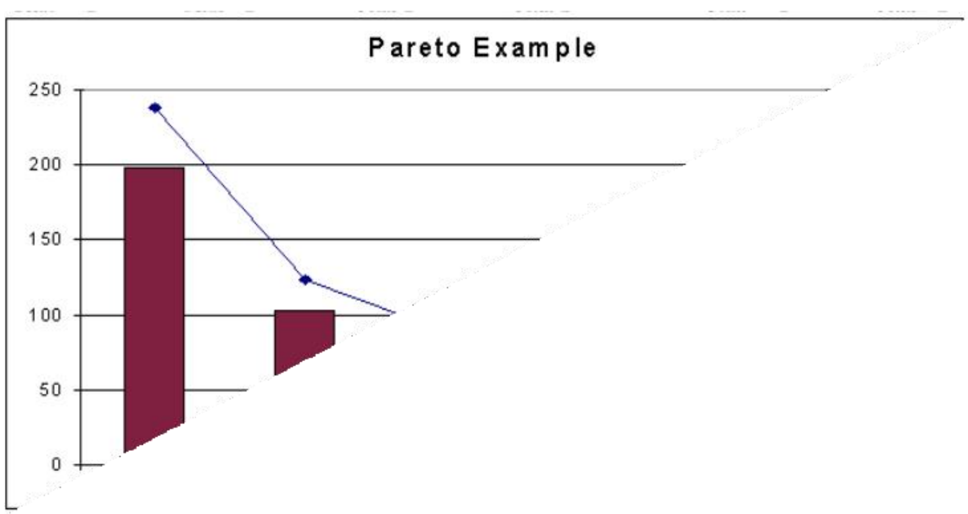
THE SEVEN TRADITIOAL TOOLS OF QUALITY OR STATISTICAL PROCESS CONTROL:
Statistical process control (SPC) is the application of statistical methods to the monitoring and control of a process to ensure that it operates at its full potential to produce conforming product. Under SPC, a process behaves predictably to produce as much conforming product as possible with the least possible waste.

Seven Tools:

- Pareto Diagram
- Process Flow Diagram
- Cause and Effect diagram
- Check sheets
- Histogram
- Scatter diagram
- Control charts

1. PARETO DIAGRAM:

- The Pareto diagram is a graphical overview of the process problems, in ranking order of the most frequent, down to the least frequent, in descending order from left to right.
- Thus, the Pareto diagram illustrates the frequency of fault types.
- Using a Pareto, you can decide which fault is the most serious or most frequent offender.
- The basic underlying rule behind Pareto's law is that in almost every case, 80% of the total problems incurred are caused by 20% of the problem cause types; such as people, machines, parts, processes, and other factors related to the production of the product.
- Therefore, by concentrating on the major problems first, you can eliminate the majority of your problems.
- The few items that have the largest amount of occurrence is your more frequent problem, than are the many items that only happen once in a while. This is called the "vital few over the trivial
- Many "rule.
- Quite often, once you cure several of the "big hitters" you also eliminate some of the smaller problems at the same time.

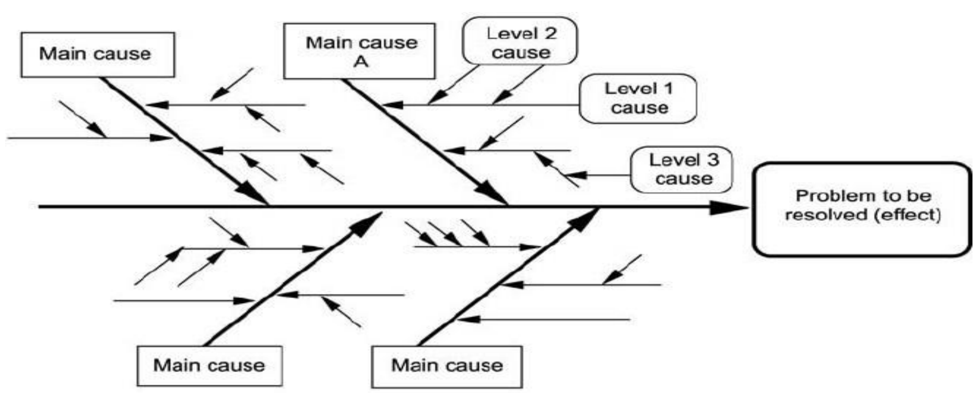


2. PROCESS FLOW DIAGRAM:

- A process flow diagram (PFD) is a diagram commonly used in engineering to indicate the general flow of plant processes and equipment.
- The PFD displays the relationship between major equipment of a plant facility and does not show minor details such as piping details and designations.
- For many products and services it may be useful to construct a process flow diagram.
- These diagrams show the flow of the product and service as it moves through various processing operations.
- The diagram makes it easy to visualize the entire system, identify potential trouble spots and locate control activities.
- It answers the question “Who is the next customer”?
- Improvements can be made by changing, reducing, combining or eliminating steps.

3. CAUSE AND EFFECT DIAGRAM:

- A C&E diagram is a picture composed of lines and symbols designed to represent a meaningful relationship between an effect and its causes.
- It is also referred to as fishbone diagram because of its shape.
- For every effect, there are likely to be numerous causes.
- In C&E diagram the effect is on the right side and causes on the left.
- The first step in the construction of a C&E diagram is for the project team to identify the effect or quality problem.
- It is placed on the right side of a large piece of a paper by the team leader.
- Next the major causes are identified and placed on the diagram.
- The minor causes require brainstorming by the project team.



Source: TQM Tools (2006)

4. CHECK SHEETS:

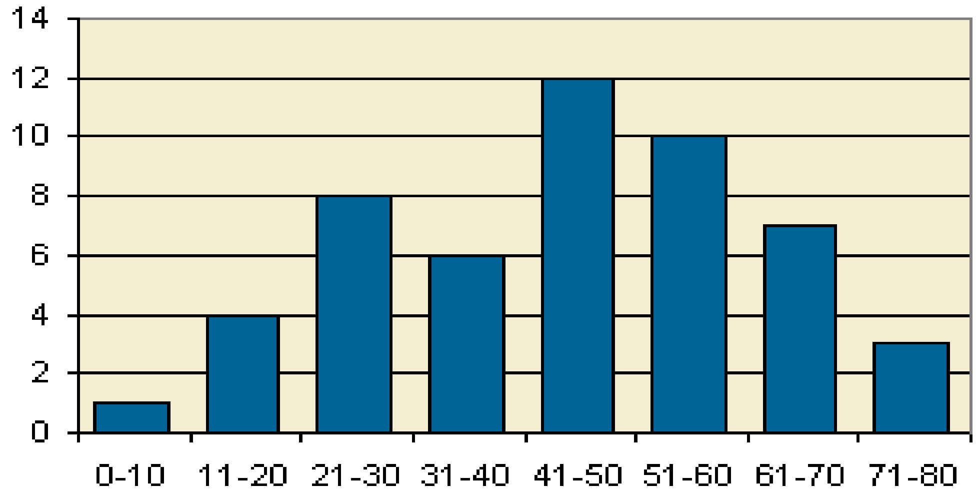
- The check sheet is a simple document that is used for collecting data in real-time and at the location where the data is generated.
- The document is typically a blank form that is designed for the quick, easy, and efficient recording of the desired information, which can be either quantitative or qualitative. When the information is quantitative, the check sheet is sometimes called a tally sheet.
- A defining characteristic of a check sheet is that data is recorded by making marks ("checks") on it.
- A typical check sheet is divided into regions, and marks made in different regions have different significance.
- Data is read by observing the location and number of marks on the sheet.

Arun Bakery

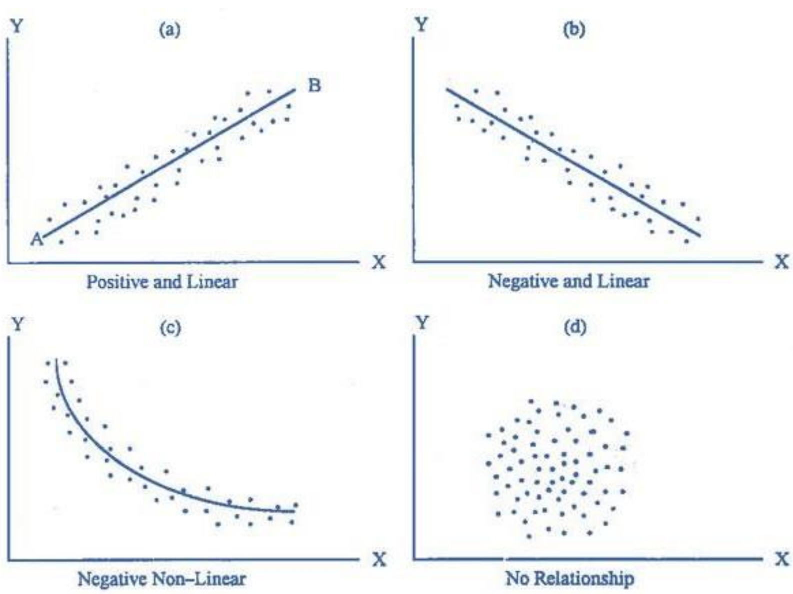
Complaint type	Tally	Total
Packaging	LH1 LH1	8
Quality	LH1 LH1 LH1	13
Foreign material	1111	4
Infestation	111	3
Others	11	2

5. HISTOGRAM:

- A graphical representation, similar to a bar chart in structure, that organizes a group of data points in to user-specified ranges.
- The histogram condenses a data series into an easily interpreted visual by taking many data points and grouping them into logical ranges or bins.
- Histograms are commonly used in statistics to demonstrate how many of a certain type of variable occurs within a specific range. For example, a census focused on the demography of a country may use a histogram of how many people there are between the ages of 0 and 10, 11 and 20, 21 and 30, 31 and 40, 41 and 50 etc.



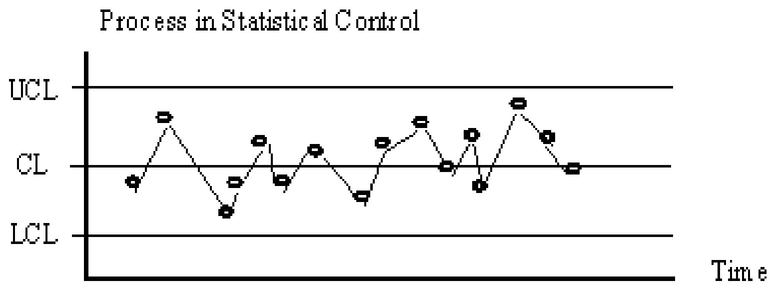
6. SCATTER DIAGRAM:



- A scatter diagram is a tool for analyzing relationships between two variables.
- One variable is plotted on the horizontal axis and the other is plotted on the vertical axis.
- The pattern of their intersecting points can graphically show relationship patterns.
- Most often a scatter diagram is used to prove or disprove cause-and-effect relationships.

7) CONTROL CHART:

- A statistical tool to determine if a process is in control.



CONTROL CHARTS FOR VARIABLES AND ATTRIBUTES

VARIABLE CONTROL CHARTS

1. Deal with items that can be measured.

Example

1) Weight

2) Height

3) Speed

4) Volume

Types:

• X chart: deals with a average value in a process

• R chart: takes into count the range of the values

• MA chart: take into count the moving average of a process

ATTRIBUTE CONTROL CHART

Control charts that factor in the quality attributes of a process to determine if the process is performing in or out of control.

Types:

• P chart - a chart of the percent defective in each sample set.

• C Chart - a chart of the number of defects per unit in each sample set.

• U Chart - a chart of the average number of defects in each sample set.

Reasons for using Control Charts:

• Improve productivity

• Make defects visible

• Determine what process adjustments need to be made

• Determine if process is “in” or “out of control

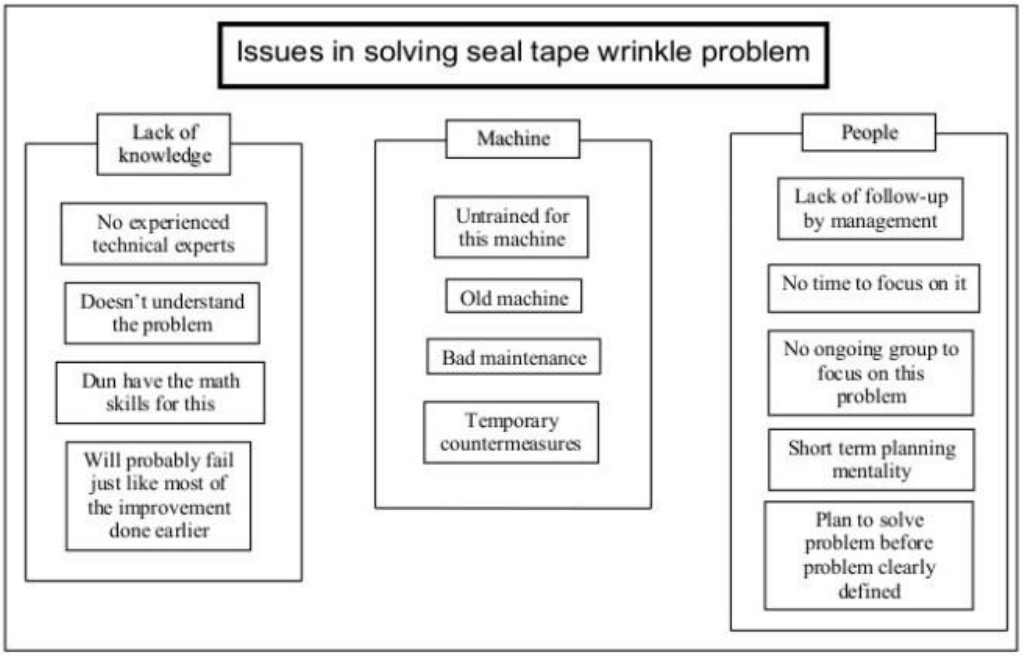
SEVEN NEW MANAGEMENT TOOLS

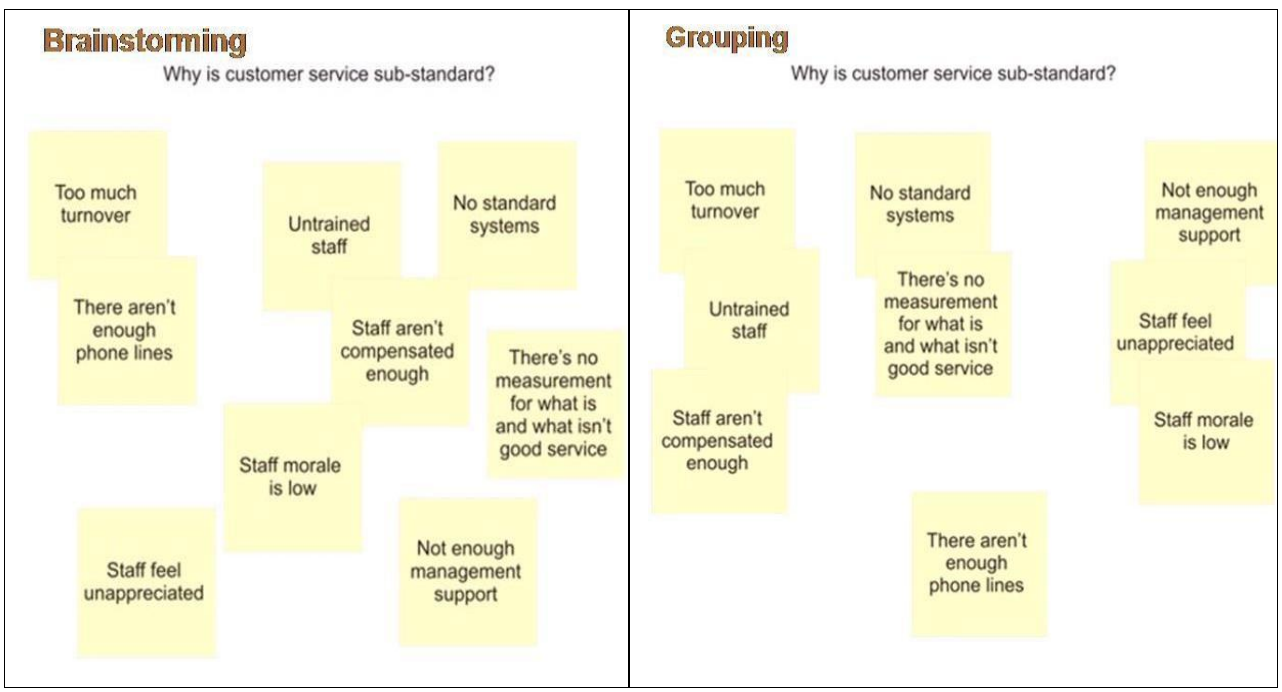
The seven new management tools are:

1. Affinity Diagram
2. Interrelationship Digraph
3. Tree Diagram
4. Matrix Diagram
5. Prioritization Matrices
6. Process Decision Program Chart (PDPC)
7. Activity Network Diagram

1. Affinity Diagram:

- This tool takes large amounts of disorganized data and information and enables one to organize it into groupings based on natural relationships
- This diagram allows the team to creatively generate a large number of issues/ideas and then logically group them for problem understanding and possible break through solution.
- The procedure is to state the issue in a sentence, brainstorming using short sentences on self-adhesive notes, post them for the team to see, sort ideas in to logical groups and create concise descriptive headings for each group.
- Large groups should be divided in two smaller groups with appropriate headings.
- Notes, that stand alone could become headers or placed in a miscellaneous category.
- Affinity diagrams encourage team creativity, break down barriers, facilitate breakthroughs and stimulate ownership of the process.


Issues in solving seal tape wrinkle problem
Lack of knowledge
No experienced technical experts
Doesn't understand the problem
Dun have the math skills for this
Will probably fail just like most of the improvement done earlier
Machine
Untrained for this machine
Old machine
Bad maintenance
Temporary countermeasures
People
Lack of follow-up by management
No time to focus on it
No ongoing group to focus on this problem
Short term planning mentality
Plan to solve problem before problem clearly defined


Brainstorming
Why is customer service sub-standard?
Too much turnover
Untrained staff
No standard systems
There aren't enough phone lines
Staff aren't compensated enough
There's no measurement for what is and what isn't good service
Staff morale is low
Staff feel unappreciated
Not enough management support
Grouping
Why is customer service sub-standard?
Too much turnover
Untrained staff
Staff aren't compensated enough
No standard systems
There's no measurement for what is and what isn't good service
There aren't enough phone lines
Not enough management support
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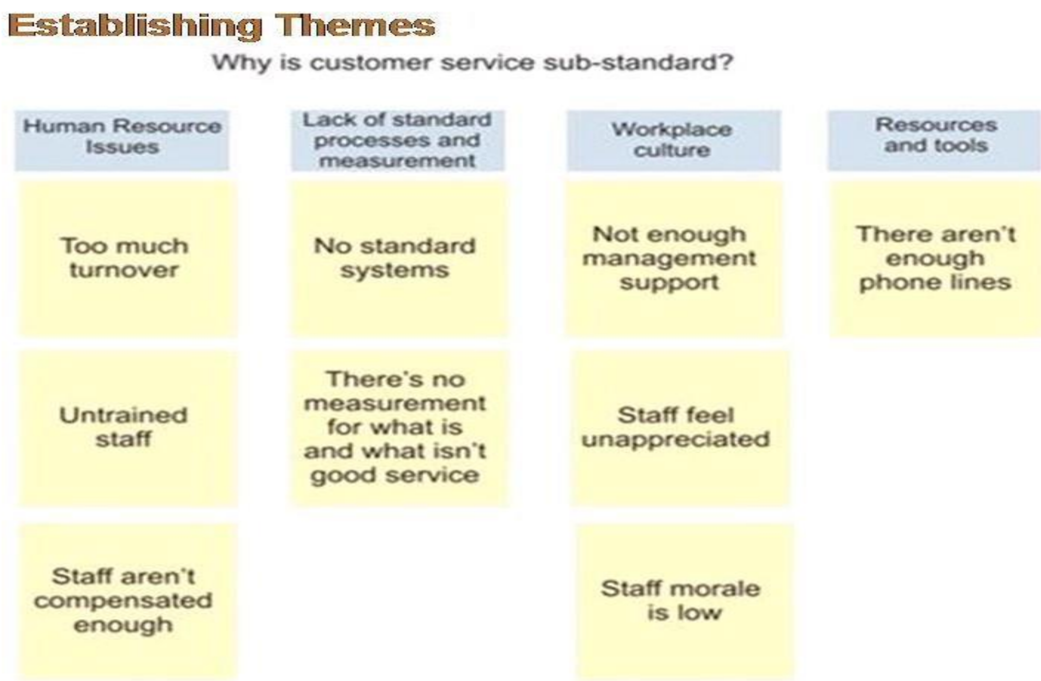
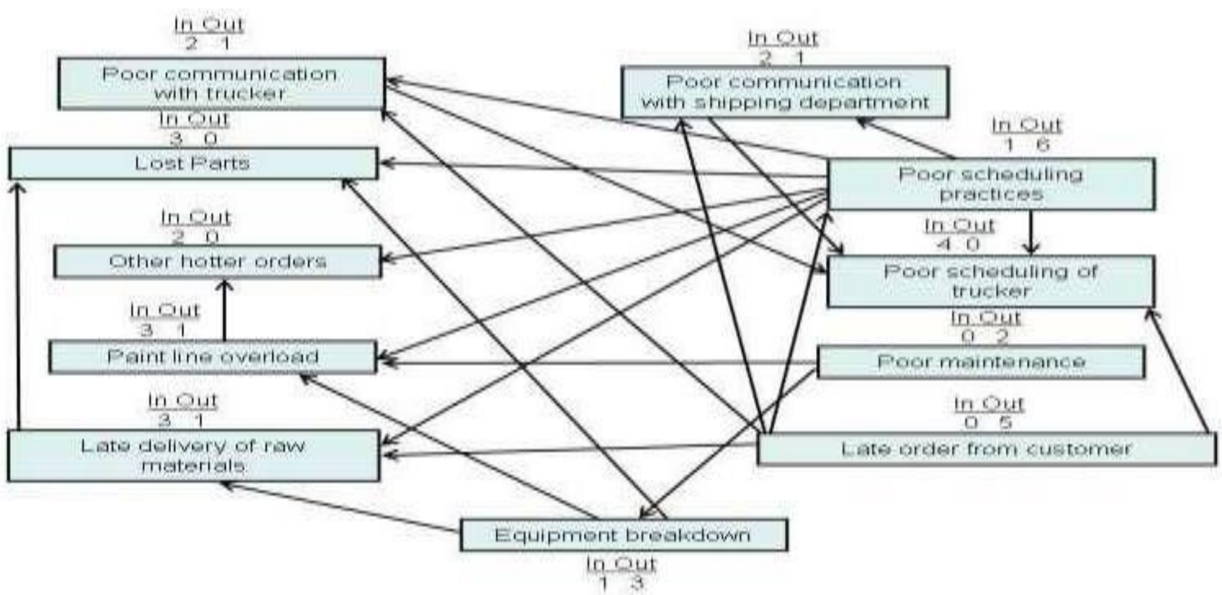


2. Interrelationship Digraph:

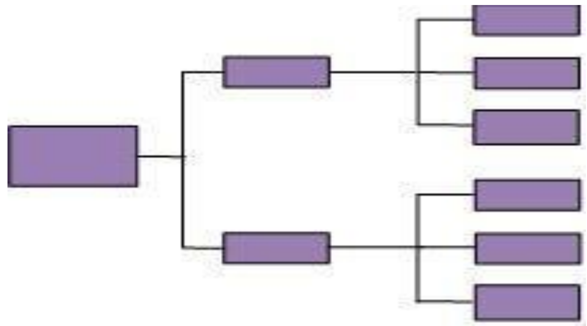
- This tool displays all the interrelated cause-and-effect relationships and a factor involved in a complex problem and describes desired outcomes.
- The process of creating an interrelationship digraph helps a group analyze the natural links between different aspects of a complex situation.
- The interrelationship diagraph clarifies the interrelationship of many factors of a complex situation.



- It allows the team to classify the cause and effect relationships among all the factors so that the key drivers and outcomes can be used to solve the problem.
- A relationship diagram allows a team to identify root causes from subjective data, systematically explores cause and effect relationship, encourages member to think multi directionally and develops team harmony and effectiveness
- A concern with a high number of output arrows is a driver or key cause. A key cause affects a large number of other items. The above diagram shows the following key causes:
- Poor scheduling practices' (6 outgoing arrows),
- Late order from customer' (5 outgoing arrows), and
- Equipment breakdown (3 outgoing arrows).
- A concern with a large number of input arrows is affected by a large number of other concerns. Thus, it could be a source of a quality or performance metric. 'Poor scheduling of the trucker' has 4 input arrows.

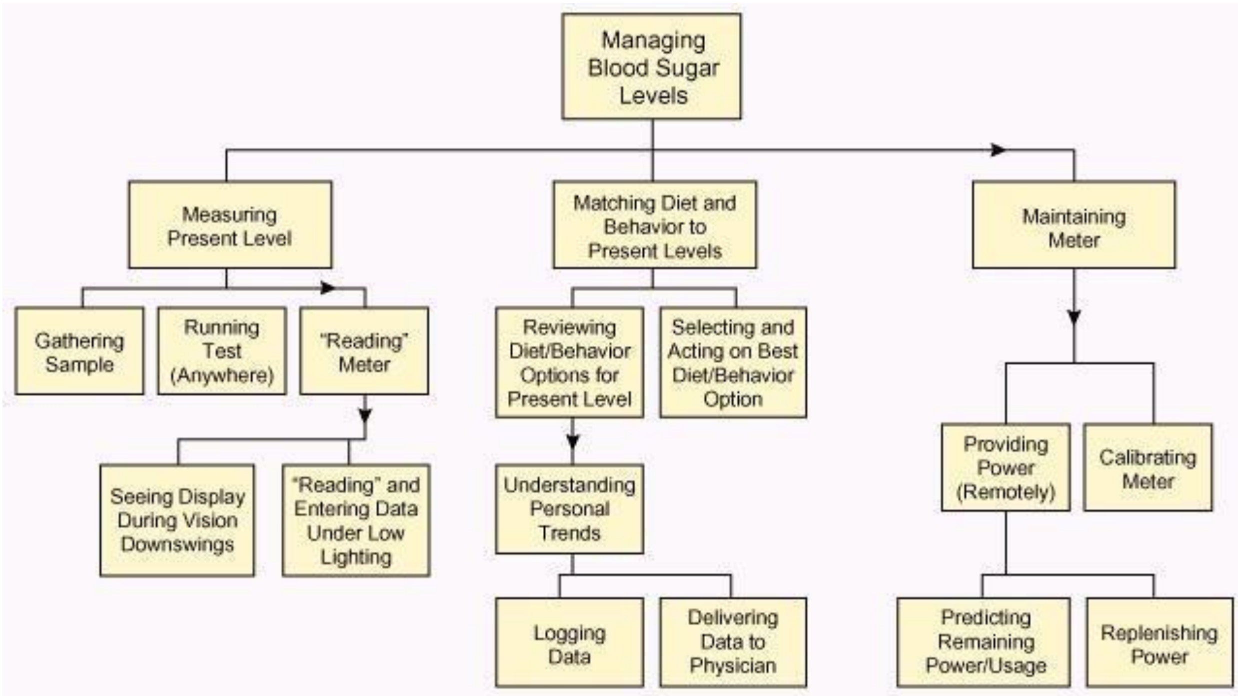
3. Tree Diagram:

- This tool is used to break down broad categories into finer and finer levels of detail
- This tool is used to reduce any broad objective in to increasing levels of detail in order to achieve the objective.
- The procedure is to first choose an action oriented objective statement from the interrelation ship diagram, affinity diagram, and brainstorming.
- Second using brainstorming chooses the major headings.
- The third step is to generate the next level by analyzing the major headings.
- Ask "What needs to be addressed to achieve the objective? Repeat this question at each level.
- Three levels below the objective are usually sufficient to complete the diagram and make appropriate assignments.
- The diagram should be reviewed to determine if these actions will give the results anticipated or if something has been missed.
- The tree diagram encourages team members to think creatively, makes large projects manageable and generates a problem solving atmosphere.



4. Matrix Diagram:

- The matrix diagram allows individuals or teams to identify, analyze and rate the relationship among twoor more variables.
- QFD is the best example of the use of matrix diagram.
- There are 5 standard formats
- L-Shaped(2 Variables)
- T-Shaped(3Variables)
- Y-Shaped(3Variables)
- C-Shaped(3 Variables)
- X-Shaped(4 Variables)
- The procedure for the diagram is to first select the factors affecting a successful plan.
- Select the appropriate format Eg: L-Shaped
- Next step is to determine the relationship symbols



- Any symbols can be adopted provided the diagram contains a legend.
- Numerical values are sometimes associated with the symbol as we have seen in QFD.
- The last step is to complete the matrix by analyzing each cell and inserting the appropriate symbol.
- The matrix diagram clearly shows the relationship of the two variables.
- It encourages the team to think in terms of relationships, their strength and any patterns.

Legend	
Soft-skills training	
√	Course attended
Social club attendance	
◎	More than 70%
○	30% to 70%
△	Less than 30%

Measures are over past three years

Soft-skills courses							Social clubs					
Assertiveness	Team building	Negotiation	Listening skills	Group working	People in Purchasing dept.	Yrs. of service	Chess	Football	Photography	Pool	Swimming	Tennis
√	√				Michael Jordan	2		◎		△	△	
√		√	√		Richie Valens	6	○		○	△		
	√				Dawn Simmons	10	△				◎	△
					Eleri Mair	4						△
		√			Dave Morgan	3	△					
	√		√		Cynthia Place	6			◎			
√					Geraint Morgan	3		○				
√	√		√	√	Heledd Eluned	11	◎		○	△		◎
					Gwen Uki	9		○				
	√				Bella Bumpps	6			◎		○	

5. Prioritization Matrices:

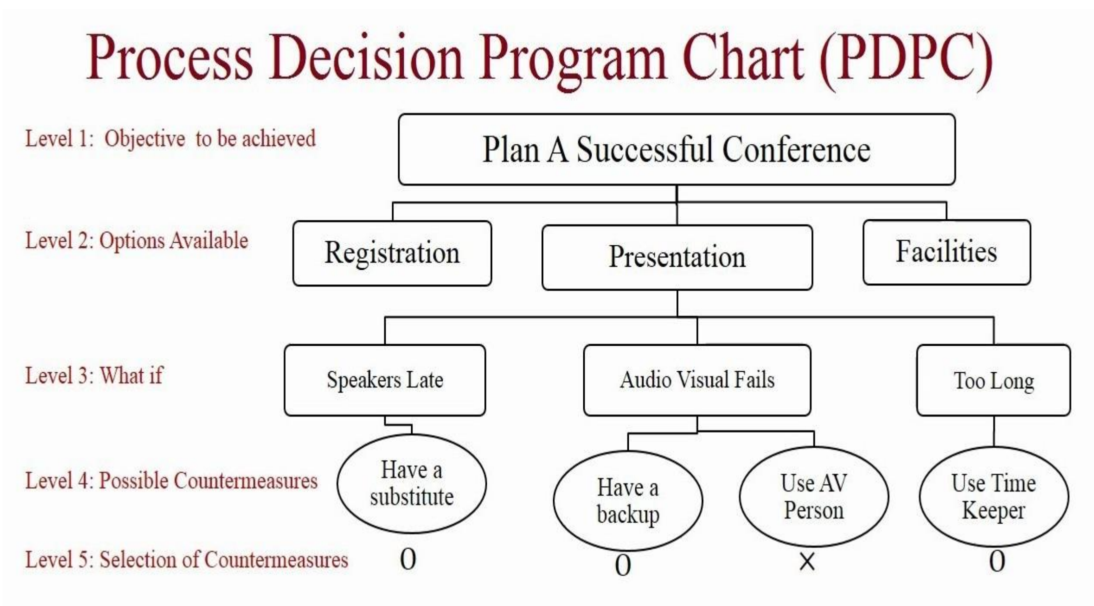
- This tool is used to prioritize items and describe them in terms of weighted criteria.

- It uses a combination of tree and matrix diagramming techniques to do a pair-wise evaluation of item sand to narrow down options to the most desired or most effective.
- This tool prioritizes issues, tasks and characteristics based on weighted criteria.
- Once prioritized effective decisions can be made.

Prioritization Matrix				
Issue	*Frequency*	*Importance*	*Feasibility*	*Total*
No appointments for the afternoon	5	0	0	5
Delays in registration	6	1	5	12
Incomplete laboratory	9	11	6	26
Not enough materials for the lab	3	0	0	3
Broken down ambulance	0	3	0	3
Long waiting time	7	14	15	36
Disrespect of patients	4	6	10	20

6. Process Decision Program Chart (PDPC):

- PDPC helps to avoid surprises and identifies possible counter measures.
- The procedure starts with the team stating the objective.
- The objective here is to plan a successful conference.
- This activity is followed by the first level which has the conference activities of registration,

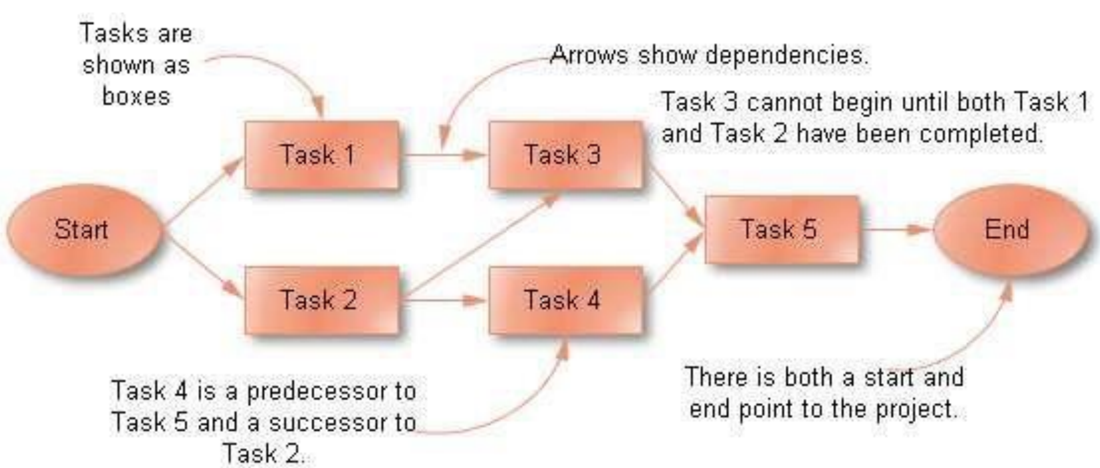


- Presentation and facilities.

- Only the presentation activity is discussed here.
- In some cases a second level of detailed activities may be used.
- Next the team brainstorms to determine what could go wrong with the conference and these are shown in “What if” level.
- Countermeasures are brainstormed and placed in a balloon in the last level.
- The last step is to evaluate the counter measures and select the optimal ones by placing an O underneath.
- Place an X under those that are rejected.
- PDPC should be used when the task is new or unique, complex or potential failure has great risks.
- This tool encourages team members to think about what can happen to a process and how counter measures can be taken.

7. Activity Network Diagram:

- A project network is a graph (flow chart) depicting the sequence in which a project's terminal elements are to be completed by showing terminal elements and their dependencies.
- The work breakdown structure or the product breakdown structure shows the "part-whole" relations. In contrast, the project network shows the "before-after" relations.
- The most popular form of project network is activity on node, the other one is activity on arrow.
- The condition for a valid project network is that it doesn't contain any circular references.
- Project dependencies can also be depicted by a predecessor table. Although such a form is very inconvenient for human analysis, project management software often offers such a view for data entry.
- An alternative way of showing and analyzing the sequence of project work is the design structure matrix.



SIX SIGMA

- **Six Sigma** is a business management strategy originally developed by Motorola, USA in 1986. Six Sigma seeks to improve the quality of process outputs by identifying and removing the causes of defects (errors) and minimizing variability in manufacturing and business processes.
- It uses a set of quality management methods, including statistical methods, and creates a special infrastructure of people within the organization ("Black Belts", "Green Belts", etc.) who are experts in these methods.
- Each Six Sigma project carried out within an organization follows a defined sequence of steps and has quantified financial targets (cost reduction and/or profit increase). A six sigma process is one in which99.99966% of the products manufactured are statistically expected to be free of defects (3.4 defects per million).

SIX SIGMA IS SEVERAL THINGS

• A statistical basis of measurement: 3.4 defects per million opportunities

• A philosophy and a goal: as perfect as practically possible

• A methodology

• A symbol of quality

SIGMA VALUES

Sigma Level	% Good	PPM/DPMO
2	95.45	45500
3	99.73	2700
4	99.9937	63
5	99.999943	0.57
6	99.9999998	0.002

METHODS:

- Six Sigma projects follow two project methodologies inspired by Deming's Plan-Do-Check-Act Cycle.
- These methodologies, composed of five phases each, bear the acronyms DMAIC and DMADV.

- **DMAIC** is used for projects aimed at improving an existing business process.
- **DMADV** is used for projects aimed at creating new product or process designs. DMAIC
- **The DMAIC project methodology has five phases:**
- **Define** the problem, the voice of the customer, and the project goals, specifically.
- **Measure** key aspects of the current process and collect relevant data.
- **Analyze t**he data to investigate and verify cause-and-effect relationships. Determine what the relationships are, and attempt to ensure that all factors have been considered. Seek out root cause of the defect under investigation.
- **Improve** or optimize the current process based upon data analysis using techniques such as design of experiments, poka yoke or mistake proofing, and standard work to create a new, future state process. Set up pilot runs to establish process capability.
- **Control** the future state process to ensure that any deviations from target are corrected before they result in defects. Implement control systems such as statistical process control, production boards, visual workplaces, and continuously monitor the process.

DMADV or DFSS

The DMADV project methodology, also known as DFSS ("**D**esign **F**or **S**ix **S**igma"), features five phases:

- **Define** design goals that are consistent with customer demands and the enterprise strategy.
- **Measure** and identify CTQs (characteristics that are **C**ritical **to Q**uality), product capabilities, production process capability, and risks.
- **Analyze** to develop and design alternatives, create a high-level design and evaluate design capability to select the best design.
- **Design** details, optimize the design, and plan for design verification. This phase may require simulations.

- **Verify** the design, set up pilot runs, implement the production process and hand it over to the process owner(s).

IMPLEMENTATION:

Six Sigma identifies several key roles for its successful implementation.

- ***Executive Leadership*** includes the CEO and other members of top management. They are responsible for setting up a vision for Six Sigma implementation. They also empower the other role holders with the freedom and resources to explore new ideas for breakthrough improvements.
- ***Champions*** take responsibility for Six Sigma implementation across the organization in an integrated manner. The Executive Leadership draws them from upper management. Champions also act as mentor's to Black Belts.
- ***Master Black Belts***, identified by champions, act as in-house coaches on Six Sigma. They devote 100% of their time to Six Sigma. They assist champions and guide Black Belts and Green Belts. Apart from statistical tasks, they spend their time on ensuring consistent application of Six Sigma across various functions and departments.
- ***Black Belts*** operate under Master Black Belts to apply Six Sigma methodology to specific projects. They devote 100% of their time to Six Sigma. They primarily focus on Six Sigma project execution, whereas Champions and Master Black Belts focus on identifying projects/functions for Six Sigma.
- ***Green Belts*** are the employees who take up Six Sigma implementation along with their other job responsibilities, operating under the guidance of Black Belts. Some organizations use additional belt colors, such as *Yellow Belts*, for employees that have basic training in Six Sigma tools and generally participate in projects and 'white belts' for those locally trained in the concepts but do not participate in the project team.

BENCHMARKING

Definition:

- Benchmarking is a systematic method by which organization can measure themselves against the best industry practices.
- It provides superior performance by providing an organized framework through which organizations learn how the "best in class" do things, understand how these best practices differ from their own and implement change to close the gap.

- The essence of benchmarking is the process of borrowing ideas and adapting them to gain competitive advantage.
- It is a tool for continuous improvement.

Reasons to benchmark:

- To achieve business and competitive objectives.
- To develop organization strengths and reduce weaknesses.
- To inspire mangers to compete
- It allows goals to be set objectively based on external information
- Benchmarking is time and cost efficient because the process involves imitation and adaptation rather than pure invention.
- It provides a working model of an improved process which reduces some of the planning, testing and prototyping efforts.

Benchmarking Process: Six steps:

- Decide what to benchmark
- Understand current performance
- Plan
- Study others
- Learn from the data
- Use the findings

Step 1: Decide what to benchmark

- Most organizations have a strategy that defines how the firm wants to position itself and compete in the market place.
- This strategy is usually expressed in terms of mission and vision statement.
- Supporting these statements is a set of critical activities which the organization must do successfully to realize its vision.
- They are often referred as "critical success factors"

Broad and shallow:

- What is done?
- Broad and shallow studies are useful in developing strategies, setting goals and reorganizing functions to be more effective.

Narrow and Deep:

- How it is done?
- It is useful in changing how people perform their jobs**.**

Step 2: Understanding Current Performance

- To compare outside practices, it is necessary to thoroughly understand and document the current process.
- Attention must be paid to inputs and outputs.
- The benchmarking team should be comprised of those who won or work in the process to unsure suggested changes are actually implemented.
- When documenting the process it is important to quantify it.
- Units of measure must be determined.
- These are the key metrics that will be compared during the benchmarking investigation.
- Common examples are unit costs, hourly rates, asset measures and quality measures.

Step 3: **Planning**

- Once internal processes are understood and documented it is possible to make decisions about how to conduct the study.
- Benchmark planning is a learning process.
- The first is to use the information that are available in the public domain to focus the inquiry and to find appropriate benchmark partners.
- 3 types of benchmarking
- Internal
- Competitive
- Process
- **Internal**-internal comparisons have several advantages, data are easy to obtain because problems of confidentiality does not exist.
- **Competitive**-product competitors are an obvious choice to benchmark. An organizations survival depends on its performance relative to the competition.
- **Process-**process benchmarking is sometimes known as functional or generic benchmarking.

Step 4: **Studying others**

- Benchmarking studies look for two types of information: descriptions of how best in class processes are practiced and the measurable results of these practices.
- In seeking this information bench markers can use internal sources, data in the public domain, original research or most likely a combination of sources.
- When most people of benchmarking they generally think of conducting original research through site visits and interviews.
- This is not always necessary and some organizations find industrial tourism a waste of time.
- Three techniques for conducting original research are questionnaires, site visits and focus groups.

Step 5: **Learning from the data**

- Is there a gap between the organizations performance and the performance of the best in class
- Organizations?
- What is the gap? How much is it?
- Why is there a gap? What does the best in class do differently that is better?
- If the best in class practices were adopted what would be the resulting improvement?
- Benchmarking studies can reveal three different outcomes
- External processes may be significantly better than internal processes (a negative gap)
- Process performance may be approximately equal(parity)
- The internal process may be better than that found in external organizations(positive gap)
- Negative gap calls for a major improvement effort
- Parity requires further investigation to determine if improvement opportunities exist.
- Positive gap should result in recognition for the internal process.
- When best in class processes have been described and quantified, additional analysis is necessary to determine the root causes of the gaps.

Step 6: Use the findings

- When a benchmark study reveals a negative gap in performance, the objective is to change the process to close the gap.
- Benchmarking is a waste of time if change does not occur as a result.

FAILURE MODE AND EFFECT ANALYSIS (FMEA)

- FMEA is an analytical technique that combines the technology and experience of people in identifying foreseeable failure modes of a product or process and planning for its elimination.

- FMEA is a “before the event” action requiring a team effort to easily and inexpensively alleviate changes in design and production.

Types:

- Design FMEA
- Process FMEA

Reliability:

- Reliability is one of the most important characteristics of any product, no matter what its application.
- It is also an important aspect when dealing with customer satisfaction, whether the customer is internal or external.
- Customers want a product that will have a relatively long service life, with long times between failures.
- Reliability may be defined as the probability of the product to perform as expected for a certain period of time, under the given operating conditions and at a given set of product performance characteristics.

Types of failures:

i. Debug ii. Chance iii. Wear out

Debug- includes a high failure rate at the initial stages because of inappropriate use or flaws in the design for manufacturing.

Chance-is the failure of the product due to accidents, poor maintenance or limitations on the design.

Wear out-covers failure after the product or process has performed as expected for at-least the time given by the manufacturer as the product or process life. A successful design or product should ideally fail only in this last method.

Intent of FMEA:

- When acquiring new machines, creating a new product or even modifying an existing product, it is always necessary to determine the product or process.
- One of the most powerful methods available for measuring the reliability of the process or product is FMEA.
- FMEA can be implemented both in design and process areas as it basically involves the identification of the potential failure modes and the effect of those on both the internal and external customers.

- FMEA attempts to detect the potential product related failure modes.
- The technique is used to anticipate the causes of failure and prevent them from happening.
- In order to make FMEA as successful, it is extremely important to treat the FMEA as a living document, continually changing as new problems are found and being updated to ensure that the most critical problems are identified and addressed quickly.
- One purpose of FMEA is to compare the design characteristics relative to the planned manufacturing or assembly methods to make certain that the product meets the customer requirements.
- Corrective action should begin as soon as failure mode is identified.
- Consumers today are far more particular than they have been in the past, demanding products of the highest quality for the lowest possible cost.
- FMEA also allows the engineer to keep a record of all thoughts and actions taken to ensure a safe and reliable product.

FMEA Team:

- The FMEA methodology is a team effort where the possible engineer involves assembly, manufacturing, materials, quality, service, supplier and the customer.
- The team leader has certain responsibilities, which include determining the meeting time and place, communicating with the rest of the team, coordinating with the rest of the team, coordinating corrective action assignment and follow-up, keeping files and records of FMEA forms, leading the team through completion of the forms, keeping the process moving and finally drawing everyone in to participation.
- There also should be a recorder who records the results on the form and distributes to participants in a timely manner.

Stages of FMEA:

There are four stages of FMEA

Specifying Possibilities

- Functions
- Possible Failure Modes
- Root Causes
- Effects
- Detection/Prevention

Quantifying Risk:

- Probability of Cause
- Severity of Effect
- Effectiveness of Control to Prevent cause
- Risk Priority Number

Correcting High Risk causes

- Prioritizing Work
- Detailing Action
- Assigning Action Responsibility
- Check Points on completion

Re-evaluation of Risk:

- Recalculation of Risk Priority Number

FMEA DOCUMENTATION

- The Design FMEA document
- The top section in the form is used mainly for document tracking and organization.

1. FMEA Number: On the top left corner of the document is the FMEA number, which is only needed for tracking

2. Item: The item space is used only to clarify which exact component or process is being analyzed.

3. Design Responsibility: The team in charge of the design or process should be included. The name and company of the person or group responsible for preparing the document should be included.

4. Prepared By: The name, telephone number and address should be included.

5. Model number/Year: Both the name and identification number of the system, sub-system or component should be included to avoid confusion between similar components.

6. Key Date: The date the initial FMEA is due should be placed.

7. FMEA date: The date the original FMEA was compiled and the latest revision date should be placed in the FMEA date space.

8. Core Team: The names of the responsible individuals and departments that have authority to perform tasks should be listed.

9. Item/Function: The name and number of the item being analyzed is recorded here. This information should be as precise as possible to avoid confusion involving similar items. Next the function of the item is to be entered here.

10. Potential failure Mode: It may be the method in which the item being analyzed may fail to meet the design criteria.

11. Potential Effects of Failure: It is the effect of failure as perceived by the customer. The effects of failure must be described in terms of what the customer will notice or experience in the product.

12. Severity: Severity is the assessment of the seriousness of the effect of the potential failure mode to the next component, subsystem, system or customer if it occurs.

13. Classification: This column is used to classify any special product characteristics for components, subsystems or systems that may require additional process controls.

14. Potential Causes/ Mechanisms of Failure: The failure modes may have more than one cause or mechanism of failure, each of these must be examined and listed separately. Then each of these causes must be reviewed with equal weight.

15. Occurrence: Occurrence is the chance that one of the specific cause/mechanism will occur.

16. Current Design Controls: It consist of prevention measures, design validation and design verification.

17. Detection: It is a relative measure of the assessment of the ability of the design control to detect either a potential cause/mechanism before the component, subsystem or system is completed for production

18. Risk Priority Number (RPN): RPN= (S) * (O) * (D)

19. Recommended Actions: After every concern has been examined and given a risk priority number, the team should begin to examine the corrective actions that may be employed, beginning with the greatest RPN and moving to descending RPN number

20. Responsibility and Target Completion dates: Here the individual or group responsible for the recommended actions and the target completion date should be entered.

21. Actions Taken: After an action has been implemented, a brief description of the actual action and its effective date should be entered.

UNIT - IV TQM TOOLS AND TECHNIQUES

TQM Tools:

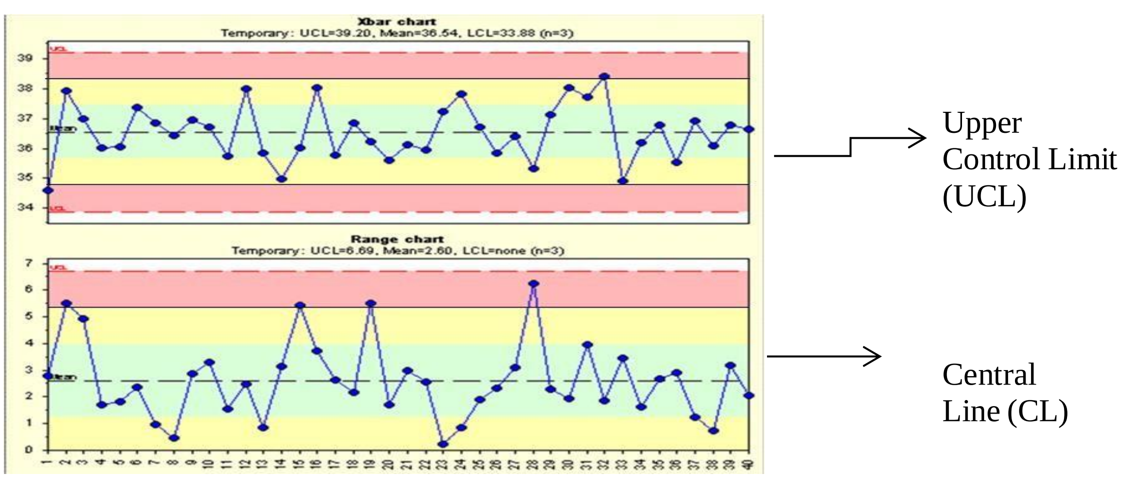
The seven tools are:

- Cause-and-effect diagram (also known as the "fishbone" or Ishikawa diagram)
- Check sheet.
- Control chart.
- Histogram.
- Pareto chart.
- Scatter diagram.
- Stratification (alternately, flow chart or run chart)

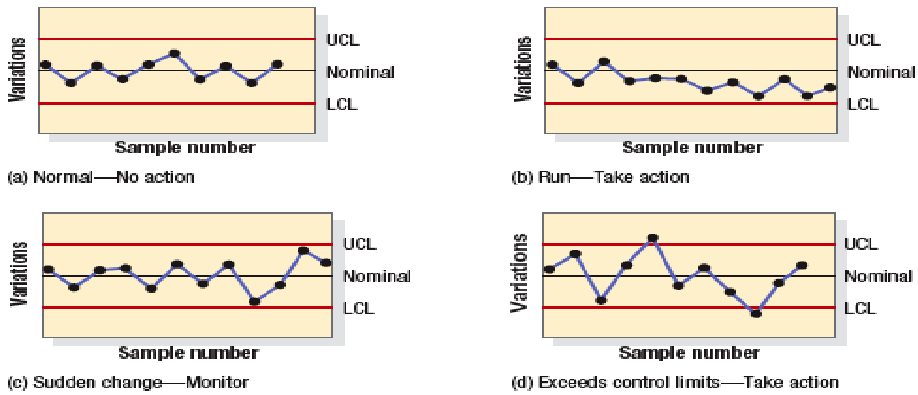
CONTROL CHARTS

- Developed by Walter shewhart in 1920.
- A Control Chart is a graph that displays data taken over time and variations of this data
- Control charts are particularly useful for monitoring quality and giving early warnings that a process may be going "Out of Control" and on its way to producing defective parts.
- Objective is to restrict the variation of the process to variation due to chance causes, by detecting and eliminating the assignable causes.
- The basis is that the laboratory runs control samples together with the routine samples.
- The control values are plotted in a control chart.

Control Chart Example



Lower Control Limit (LCL)



When to Use a Control Chart?

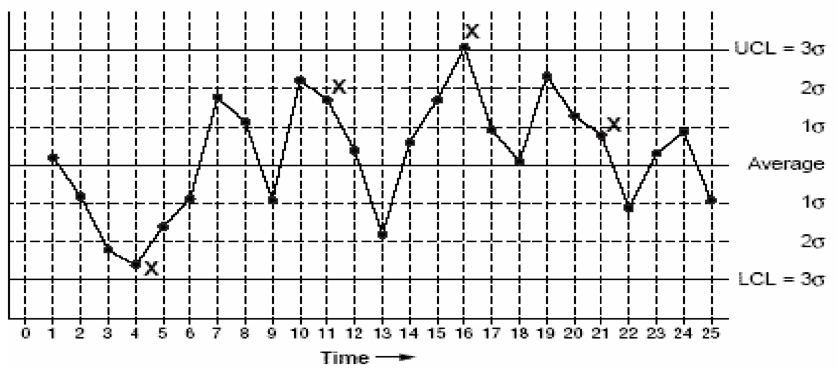
- When controlling ongoing processes by finding and correcting problems as they occur.
- When predicting the expected range of outcomes from a process.
- When determining whether a process is stable (in statistical control).
- When analyzing patterns of process variation from special causes (non-routine events) or common causes (built into the process).
- When determining whether your quality improvement project should aim to prevent specific problems or to make fundamental changes to the process.

Control Chart Basic Procedure

1. Choose the appropriate control chart for your data.
2. Determine the appropriate time period for collecting and plotting data.
3. Collect data, construct your chart and analyze the data.
4. Look for "out-of-control signals" on the control chart. When one is identified, mark it on the chart and investigate the cause. Document how you investigated, what you learned, the cause and how it was corrected.

Out-of-control signals

- A single point outside the control limits. In Figure 1, point sixteen is above the UCL (upper control limit).
- Two out of three successive points are on the same side of the centerline and farther than 2 σ from it. In Figure, point 4 sends that signal.
- Four out of five successive points are on the same side of the centerline and farther than 1 σ from it. In Figure, point 11 sends that signal.
- A run of eight in a row are on the same side of the centerline. Or 10 out of 11, 12 out of 14 or 16 out of 20. In Figure, point 21 is eighth in a row above the centerline.
- Obvious consistent or persistent patterns that suggest something unusual about your data and your process.



Control Chart: Out-of-Control Signals

5. Continue to plot data as they are generated. As each new data point is plotted, check for new out-of-control signals.
6. When you start a new control chart, the process may be out of control. If so, the control limits calculated from the first 20 points are conditional limits. When you have at least 20 sequential points from a period when the process is operating in control, recalculate control limits.

Control Charts for Variables and Attributes

1. Variable Control Charts

1. Deal with items that can be measured.

Example

1) Weight

2) Height

3) Speed

4) Volume

Types:

• X chart: deals with a average value in a process

• R chart: takes into count the range of the values

• MA chart: take into count the moving average of a process

2. Attribute Control Chart

Control charts that factor in the quality attributes of a process to determine if the process is performing in or out of control.

Types:

• P chart

• C Chart

• U Chart

P Chart: a chart of the percent defective in each sample set.

C chart: a chart of the number of defects per unit in each sample set.

U chart: a chart of the average number of defects in each sample set.

Reasons for using Control Charts:

• Improve productivity

• Make defects visible

• Determine what process adjustments need to be made

• Determine if process is "in" or "out of control

PROCESS CAPABILITY

In process improvement efforts, the process capability index or process capability ratio is a statistical measure of process capability: the ability of a process to produce output within specification limits. The concept of process capability only holds meaning for processes that are in a state of statistical control

Importance:

- The output of a process can be product characteristic or process output parameter.

- Process capability indices provide a common metric to evaluate and predict the performance of processes.
- Process capability compares the output of an in-control process to the specification limits by using capability indices.

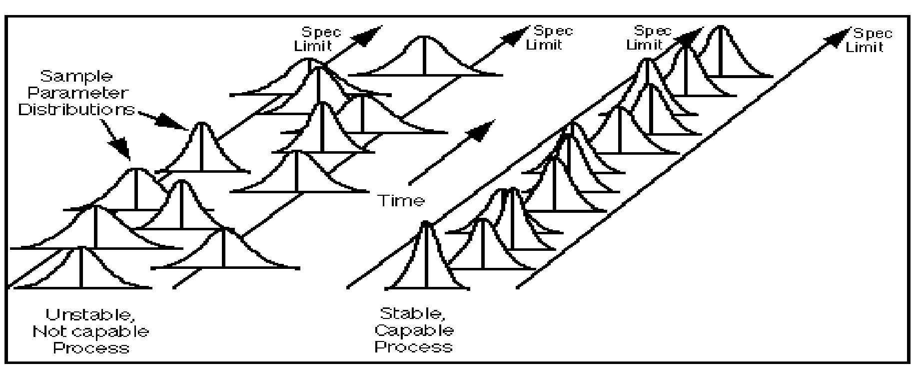
Being in control of a manufacturing process using statistical process control (SPC) is not enough. An "in-control" process can produce bad or out-of-spec product. Manufacturing processes must meet or be able to achieve product specifications. Further, product specifications must be based on customers' requirements.

Process capability is the repeatability and consistency of a manufacturing process relative to the customer requirements in terms of specification limits of a product parameter. This measure is used to objectively measure the degree to which your process is or is not meeting the requirements.

Capability indices have been developed to graphically portray that measure. Capability indices let you place the distribution of your process in relation to the product specification limits. Capability indices should be used to determine whether the process, given its natural variation, is capable of meeting established specifications. It is also a measure of the manufacturability of the product with the given processes.

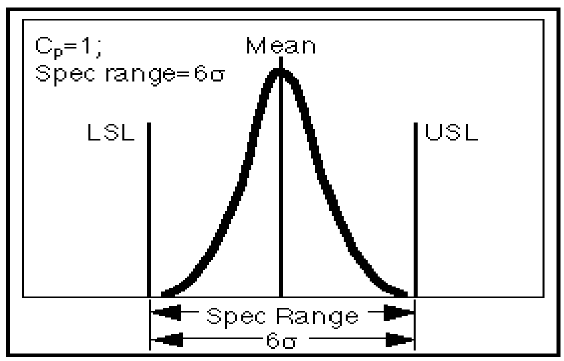
Capability indices can be used to compare the product/process matches and identify the poorest match (lowest capability). The poorest matches then can be targeted on a priority basis for improvement.

If we sample a group of items periodically from a production run and measure the desired specification parameter, we will get subgroup sample distributions that can be compared to that parameter's specification limits. Two examples of this are represented below.



The diagram on the left shows a series of sample distributions that fall inside of and outside of the specification limit. This is an example of an unstable, not capable process. The right side of the diagram shows all of the distributions falling within the specification limits. This is an example of a capable process.

Process capability can be expressed with an index. Assuming that the mean of the process is centered on the target value, the process capability index Cp can be used. Cp is a simple process capability index that relates the allowable spread of the spec limits (spec range or the difference between the upper spec limit, USL, and the lower specification limit, LSL) to the measure of the actual, or natural, variation of the process, represented by 6 sigma, where sigma is the estimated process standard deviation.



If the process is in statistical control, via “normal” SPC charts, and the process mean is centered on the target, then Cp can be calculated as follows:

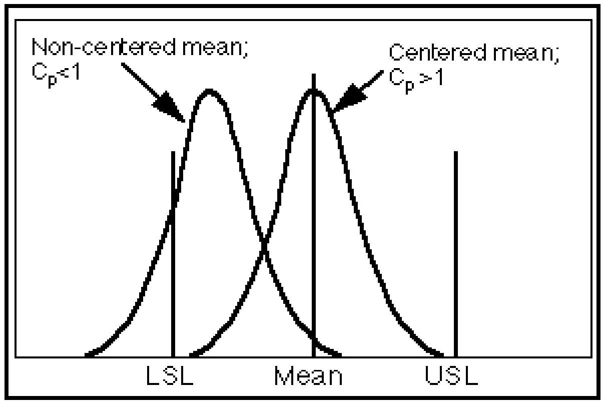
Cp = (USL – LSL) / 6 sigma

Cp<1 means the process variation exceeds specification, and a significant number of defects are being made.

Cp=1 means that the process is just meeting specifications. A minimum of .3% defects will be made and more if the process is not centered.

Cp>1 means that the process variation is less than the specification, however, defects might be made if the process is not centered on the target value.

While Cp relates the spread of the process relative to the specification width, it does not address how well the process average, ***X,*** is centered to the target value. Cp is often referred to as process “potential”.



Cpk measures not only the process variation with respect to allowable specifications, it also considers the location of the process average.

Cpk is taken as the smaller of either Cpl or Cpu where

Cpl = (X -LSL) / 3 sigma where X is the process mean

Cpu = (USL – X) / 3 sigma where X is the process mean

Many companies are establishing specific process capability targets. They may typically start with 1.33 for supplier qualification and have an expected goal of 2.0. If the process is near normal and in statistical control, Cpk can be used to estimate the expected percent of defective material.

Process Capability Studies are designed to see what the process is "capable" of doing under controlled conditions. The studies look at how capable the process is given ideal conditions over a short period of time (such as one hour to twenty-four hours.) The individual who is mainly responsible for the process capability study is a Process Engineer. The Process Engineer must keep in mind the following two considerations when conducting the study.

- Eliminate or minimize special causes of variation, for example using the same operator, same batch of material, same machine and so on.
- Collect a minimum of 50 consecutive pieces in at least 10 subgroups of 5.

The benefits of conducting a Process Capability Study allows you to determine the "short" term stability and capability of a process.

Process Performance Studies are performed to identify how well a process, that is in statistical control, performs long term (for example, one week or longer). Two types of variations within the process are statistically measured: variation within subgroups and variations between subgroups. Variables should include different operators, material, tool changes, adjustments and so on. For the Process Performance Study to be successful the Process Engineer must ensure the following:

- Data is obtained over an extended period of time (a minimum of 5 days of data) under normal conditions
- A minimum of 100 pieces in 20 subgroups of 5 is gathered

The benefit of a Process Performance Study allows you to determine the "long" term stability and capability of a process.

CONCEPTS OF SIX SIGMA

Six Sigma is a highly disciplined process that helps us focus on developing and delivering near-perfect products and services.

Features of Six Sigma

- Six Sigma's aim is to eliminate waste and inefficiency, thereby increasing customer satisfaction by delivering what the customer is expecting.
- Six Sigma follows a structured methodology, and has defined roles for the participants.
- Six Sigma is a data driven methodology, and requires accurate data collection for the processes being analyzed.
- Six Sigma is about putting results on Financial Statements.
- Six Sigma is a business-driven, multi-dimensional structured approach for −
  - Improving Processes
  - Lowering Defects
  - Reducing process variability
  - Reducing costs
  - Increasing customer satisfaction
  - Increased profits

The word *Sigma* is a statistical term that measures how far a given process deviates from perfection. The central idea behind Six Sigma: If you can measure how many "defects" you have in a process, you can systematically figure out how to eliminate them and get as close to "zero defects" as possible and specifically it means a failure rate of 3.4 parts per million or 99.9997% perfect.

Key Concepts of Six Sigma

At its core, Six Sigma revolves around a few key concepts.

- **Critical to Quality** − Attributes most important to the customer.
- **Defect** − Failing to deliver what the customer wants.
- **Process Capability** − What your process can deliver.
- **Variation** − What the customer sees and feels.
- **Stable Operations** − Ensuring consistent, predictable processes to improve what the customer sees and feels.
- **Design for Six Sigma** − Designing to meet customer needs and process capability.

Our Customers Feel the Variance, Not the Mean. So Six Sigma focuses first on reducing process variation and then on improving the process capability.

Myths about Six Sigma

There are several myths and misunderstandings surrounding Six Sigma. Some of them few are given below −

- Six Sigma is only concerned with reducing defects.
- Six Sigma is a process for production or engineering.
- Six Sigma cannot be applied to engineering activities.
- Six Sigma uses difficult-to-understand statistics.
- Six Sigma is just training.

Benefits of Six Sigma

Six Sigma offers six major benefits that attract companies −

- Generates sustained success
- Sets a performance goal for everyone
- Enhances value to customers
- Accelerates the rate of improvement
- Promotes learning and cross-pollination
- Executes strategic change

Origin of Six Sigma

- Six Sigma originated at Motorola in the early 1980s, in response to achieving 10X reduction in product-failure levels in 5 years.
- Engineer Bill Smith invented Six Sigma, but died of a heart attack in the Motorola cafeteria in 1993, never knowing the scope of the craze and controversy he had touched off.

- Six Sigma is based on various quality management theories (e.g. Deming's 14 point for management, Juran's 10 steps on achieving quality).

There are three key elements of Six Sigma Process Improvement −

- Customers
- Processes
- Employees

The Customers

Customers define quality. They expect performance, reliability, competitive prices, on-time delivery, service, clear and correct transaction processing and more. This means it is important to provide what the customers need to gain customer delight.

The Processes

Defining processes as well as defining their metrics and measures is the central aspect of Six Sigma.

In a business, the quality should be looked from the customer's perspective and so we must look at a defined process from the outside-in.

By understanding the transaction lifecycle from the customer's needs and processes, we can discover what they are seeing and feeling. This gives a chance to identify weak areas with in a process and then we can improve them.

The Employees

A company must involve all its employees in the Six Sigma program. Company must provide opportunities and incentives for employees to focus their talents and ability to satisfy customers.

SIX SIGMA ORGANIZATIONS:

Under a Six Sigma program, the members of an organization are assigned specific roles to play, each with a title. This highly structured format is necessary in order to implement Six Sigma throughout the organization.

There are seven specific responsibilities or "role areas" in a Six Sigma program, which are as follows.

Leadership

A leadership team or council defines the goals and objectives in the Six Sigma process. Just as a corporate leader sets a tone and course to achieve an objective, the Six Sigma council sets the goals to be met by the team. Here is the list of leadership Council Responsibilities −

- Defines the purpose of the Six Sigma program
- Explains how the result is going to benefit the customer

- Sets a schedule for work and interim deadlines
- Develops a mean for review and oversight
- Support team members and defend established positions

Sponsor

Six Sigma sponsors are high-level individuals who understand Six Sigma and are committed to its success. The individual in the sponsor role acts as a problem solver for the ongoing Six Sigma project. Six Sigma is generally led by a full-time, high-level champion, such as an Executive Vice President.

Sponsors are the owners of processes and systems, who help initiate and coordinate Six Sigma improvement activities in their areas of responsibilities.

Implementation Leader

The person responsible for supervising the Six Sigma team effort, who supports the leadership council by ensuring that the work of the team is completed in the desired manner, is the implementation Leader. Ensuring success of the implementation plan and solving problems as they arise, training as needed, and assisting sponsors in motivating the team are some of the key responsibilities of an implementation leader.

Coach

Coach is a Six Sigma expert or consultant who sets a schedule, defines result of a project, and who mediates conflict, or deals with resistance to the program.

Duties include working as a go-between for sponsor and leadership, scheduling the work of the team, identifying and defining the desired results of the project, mediating disagreements, conflicts, and resistance to the program and identifying success as it occurs.

Team Leader

It is an individual responsible for overseeing the work of the team and for acting as a go-between with the sponsor and the team members.

Responsibilities include communication with the sponsor in defining project goals and rationale, picking and assisting team members and other resources, keeping the project on schedule, and keeping track of steps in the process as they are completed.

Team Member

An employee who works on a Six Sigma project, given specific duties within a project, and has deadlines to meet in reaching specific project goals.

Team members execute specific Six Sigma assignments and work with other members of the team within a defined project schedule, to reach specifically identified goals.

Process Owner

The individual who takes on responsibility for a process after a Six Sigma team has completed its work.

QFD-QUALITY FUNCTION DEPLOYMENT

Introduction:

- Quality Function Deployment (QFD) is a planning tool used to fulfill customer expectations.
- It is a disciplined approach to product design, engineering and production and provides in-depth evaluation of a product.
- QFD focuses on customer expectations or requirements often referred to as the voice of the customer.
- It is employed to translate customer expectations in terms of specific requirements, in two directions and actions, in terms of engineering or technical characteristics that can be deployed through

  - Product planning
  - Part development
  - Process Planning
  - Production Planning
  - Service Industries

QFD Team:

- When an organization decides to implement QFD, the project manager and team members need to be able to commit a significant amount of time to it, especially in the early stages.
- Teams compose of members from marketing, design, quality, finance and production.
- One of the most important tools in the QFD process is communication.
- Team meetings are very important in the QFD process.
- The team leader needs to ensure that the meetings run in the most efficient manner and that the members are kept informed.
- The meeting format should have some way of measuring how well the QFD process is working at each meeting and should be flexible depending on certain situations.

Voice of the Customer:

- Words used by the customer to describe their expectations are often referred to as the voice of the customer.
- Customer satisfaction like quality is defined as meeting or exceeding customer expectations.
- QFD begins with marketing to determine what exactly the customer desires from a product.
- During the collection of information, the QFD team must continually ask and answer

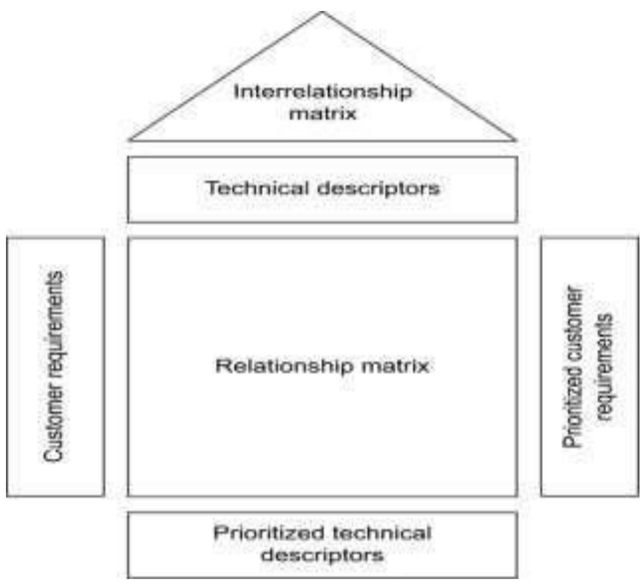
numerous questions such as

a) What does the customer really want?
b) What are the customers' expectations?
c) Are the customers' expectations used to drive the design process?
d) What can the design team to do achieve customer satisfaction?

House of Quality:

The primary planning tool used in QFD is the house of quality. The house of quality translates the voice of the customer in to design requirements that meet specific target values and matches those against how an organization will meet those requirements.

Many managers and engineers consider the house of quality to be primary chart in quality planning.



Building a House of Quality:

Step1: List Customer Requirements (WHATs)

QFD starts with a list of goals and objectives.

- ➢ This list is often referred as the WHATs that a customer needs or expects in a particular product.
- ➢ This list of primary customer requirements is usually vague and very general in nature.

- Further a most detailed list of secondary customer requirements is needed to support the primary customer requirements.

Step 2: List Technical Descriptors (HOWs)

- The goal of the house of quality is to design or change the design of a product in a way that meets or exceeds the customer expectations.
- Here the customer needs and expectations are expressed in terms of customer requirements; it is the duty of the QFD team to convert these requirements in to engineering characteristics or technical descriptors.
- Implementation of the customer requirements is difficult until they are translated in to counterpart characteristics.
- Counterpart characteristics are an expression of the voice of the customer in technical language.
- The list of technical descriptors is divided in two primary, secondary and tertiary technical descriptors.
- Determine their respective relationships.
- One way to reduce the confusion associated with determining the relationships between customer requirements and technical descriptors is to use an L-Shaped matrix.
- The L-Shaped matrix makes interpreting the complex relations very easy and does not require a significant amount of experience.

Step 3: Relationship Matrix

- The inside of the house of quality is called as the relationship matrix and it is usually filled by the QFD team.
- It is common to use symbols to represent the relationship between the customer requirements and descriptors.

Example:

A solid circle represents a strong relationship

A single circle represents a medium relationship

A triangle represents a weak relationship.

●

○

△

An empty column indicates that a particular technical descriptor does not affect any of the customer requirements and after careful scrutiny may be removed from the house of quality.

Step 4: Develop an interrelationship Matrix between HOWs

The roof of the house of the quality called the correlation matrix is used to identify any interrelationships between each of the technical descriptors.

Symbols:

- A solid circle represents a strong positive relationship
- A circle represents a positive relationship
- An X represents a negative relationship
- An asterisk represents a strong negative relationship.

Step 5: Competitive Assessments

- The competitive assessments are a pair of weighted tables that depict item for item how competitive products are compared with current organization products.
- The competitive assessment tables are separated in to two categories customer assessment and technical assessment.
- The numbers 1 through 5 are listed in the competitive evaluation column to indicate a rating of 1 for worst and 5 for best.
- The customer competitive assessment is a good way to determine is the customer requirements has been met and identifies areas to concentrate in on the next design.

Technical Competitive Assessment:

- Customer requirements and technical descriptors that are strongly related should also exhibit a strong relationship in their competitive assessments.
- If an organization technical assessment shows its products to be superior to the competition, then the customer assessment should show a superior assessment.
- If the customer disagrees, then a mistake in engineering judgment has occurred and should be corrected.

Step 6: Develop Prioritized customer requirements

- Importance to customer
- Target value
- Scale-up factor
- Sales point
- An absolute weight

Step 7: Develop Prioritized technical descriptors

- Degree of technical difficulty
- Target value
- Absolute weights
- Relative weights

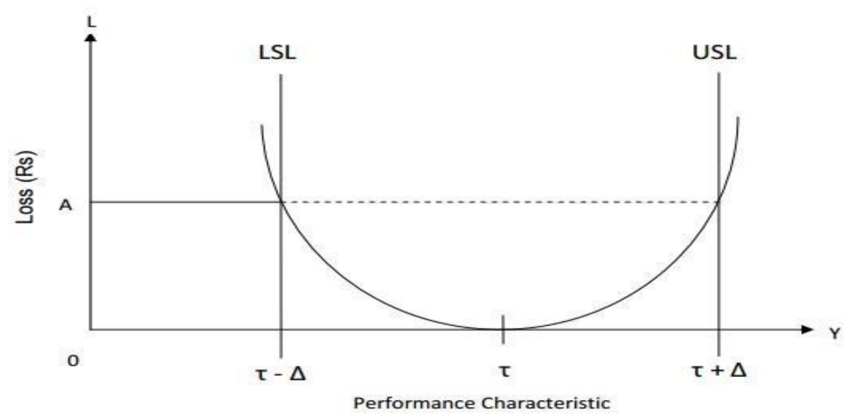
TAGUCHI'S QUALITY LOSS FUNCTION

- Taguchi's Quality Loss Function concept combines cost, target and variation in one metric with specifications being of secondary importance.
- Taguchi has defined quality as the loss imparted to society from the time a product is shipped. Societal losses include failure to meet customer requirements, failure to meet ideal performance and harmful side effects.
- There are three common quality loss functions

1. Nominal - the - best.
2. Smaller - the - better.
3. Larger - the – better

NOMINAL – THE – BEST:

Although Taguchi developed so many loss functions, many situations are approximated by the quadratic function which is called the **Nominal – the – best** type.



Quadratic Loss Function

The quadratic function is shown in figure. In this situation, the loss occurs as soon as the performance characteristic, y, departs from the target τ.

At τ, the loss is Rs. 0.

At LSL (or) USL, the loss is Rs. A.

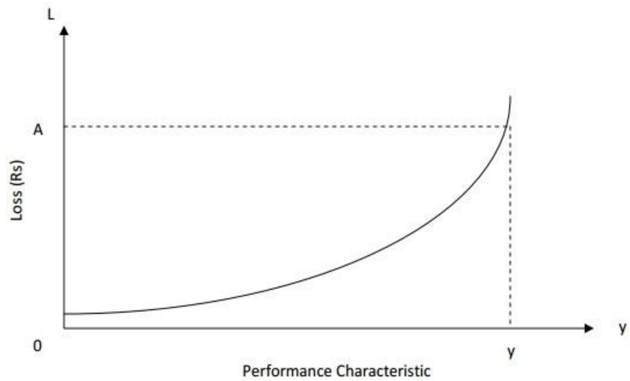
The quadratic loss function is described by the equation L = k (y - τ) 2. Where,

L = cost incurred as quality deviates from the target.

y = Performance characteristic, τ = target, k = Quality loss coefficient.

The loss coefficient is determined by setting Δ = (y – τ), the deviation from the target. When Δ is the USL (or) LSL, the loss to the customer of repairing (or) discarding the product is Rs. A.

Thus, K = A / (y – τ)2 = A / Δ2 .



SMALLER – THE – BETTER:

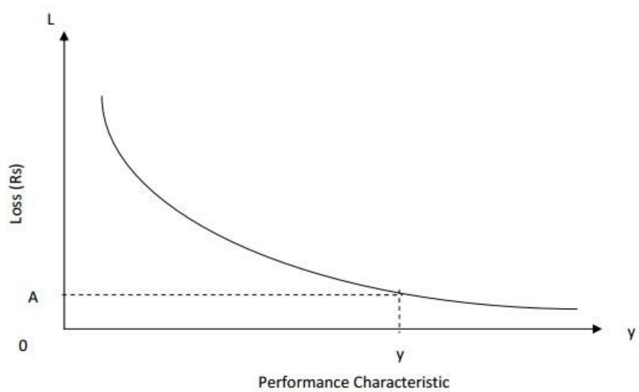
The following figure shows the smaller – the – better concepts.

The target value for **smaller – the – better** is 0. There are no negative values for the performance characteristic.

The radiation leakage from a microwave appliance, the response time for a computer, pollution from an automobile, out of round for a hole etc. are the performance characteristics for this concept.

LARGER – THE – BETTER:

The following figure shows the concept of the Larger – the – better.



In the Larger – the – better concept, the target value is ∞ (infinity), which gives a **zero loss**. There are no negative values and the worst case is at y = 0. Actually, larger – the – better is the reciprocal of smaller – the – better. The performance characteristics in Larger – the – better are bond strength of adhesives, welding strength etc.

TOTAL PRODUCTIVE MAINTENANCE

Definition:

TPM (Total Productive Maintenance) is a maintenance philosophy designed to integrate equipment maintenance into the manufacturing process. The goal of any TPM program is to eliminate losses tied to equipment maintenance or, in other words, keep equipment producing only good product, as fast as possible with no unplanned downtime.

Meaning:

Total- All-encompassing by maintenance and production individuals working together.

Productive-Production of goods and services that meet or exceed customers' expectations

Maintenance- Keeping equipment and plant in as good as or better than the original condition at all times.

Steps:

- Management learns the new philosophy
- Management promotes the new philosophy
- Training is funded and developed for everyone in the organization
- Areas of needed improvement are identified
- Performance goals are formulated
- An implementation plan is developed
- Autonomous work groups are established.

1. Learning the new philosophy:

- TPM is merely trying to tap in to an unused resource, the brain power and problem solving ability of all the organizations employees.
- Thus it is necessary to allow people to make decisions.
- Many organizations have had the flavor-of-the-mouth approach to changing management techniques.
- This approach has led to credibility problems with employees.
- Management is changed and the new manger does not build on past accomplishments but

develops a new system that will presumably solve all of the organizations problems.

- Lack of ownership seems to cause low cause morale and dissatisfaction with management.
- Ownership should be based on what is good for the customer and for the employees that serve the customer.

2. Promoting the new philosophy:

Senior management must spend more time in promoting the system.

- They must sell the idea and let the employees know that they are totally committed to its success.
- If the belief in the new philosophy and commitment are not there, then positive results will not happen.
- Too often lip service is given to a "new idea".
- This can be solved by a belief that the new system will solve some immediate problems and lead to an immediate return on investment.
- A long term commitment to the new philosophy is required.
- One of the best ways to implement the new philosophy is just to start doing it.
- In other words start giving the maintenance and production personnel more autonomy.
- Once the employees realize that management is serious about taking the organization in a new, more positive direction, employees will usually respond.

3. Training:

- Teach the new philosophy to mangers at all levels.
- Begin with senior management and work down to first line supervisors.
- Don't teach the **HOW** also teach the **WHY**
- Senior management must spend time learning about and understanding the ramifications of this philosophy to their organization.
- Some managers are needed to be replaced because they don't accept change and also identify managers who readily respond to new philosophy.
- First line supervisors need to learn their role in what most likely will be a new environment.
- There needs to be some instruction in the areas of jobs that maintenance people do and jobs that production people do.
- A great benefit of TPM is the cross-pollination of ideas between maintenance technicians and production operators.

3. Improvement Needs:

- There are usually some machines that seem to be on the verge of breaking down or require an excessive amount of maintenance.

- Employees who work with the equipment on a daily basis are better able to identify those conditions than anyone else in the organization.
- A good first step is to let the operators and maintenance technicians tell management which machines and systems need the most attention.
- An implementation team of operators and technicians to coordinate this process is essential.

Six Losses:

Downtime Losses:

Planned

- ➢ Start ups
- ➢ Shift Changes
- ➢ Coffee and lunch breaks

Unplanned

- ❖ Equipment breakdown
- ❖ Change over’s
- ❖ Lack of material

- ✓ Idling and minor stoppages
- ✓ Slowdowns and poor quality losses
- ✓ Process nonconformities
- ✓ Scrap

5. Goal:

- Goal should be set after the improvement needs are identified.
- The first goal is to establish the time frame for fixing the prioritized problem.
- Technicians and operators will probably want it done faster than management because it causes them more problems on a daily basis.
- Identifying needs and setting goals begins the process of getting the organization to work as a team.

6. Developing Plans:

- ✓ First, develop and implement an overall plan of action for training all employees.
- ✓ Plans for developing the autonomous work groups should take place during the training phase.
- ✓ Plan to use, team of maintenance technicians and operators to work on particularly troublesome problems.

- ✓ Priorities can be set and management can make a commitment with resources to correct some of the basic problems.

7. Autonomous Work Groups:

- Autonomous work groups are established based on the natural flow of activity.
- First make the operator responsible for the equipment and the level of maintenance that he is capable of performing.
- Next, identify the maintenance personnel who work in certain areas or have certain skill levels.
- Operators and maintenance personnel are brought together resulting in an autonomous work group.
- These groups must have the authority to make decisions about keeping the equipment in first class running order.

<u>Performance Measure</u>

- The organisations can adopt any of the performance measures depending on its requirements.
- However, for successful implementation, the selected measure should try to satisfy the ten requirements/criteria.

REQUIREMENTS (or CRITERIA) OF THE PERFORMANCE MEASURE

The organisations can adopt any of the performance measures depending on its requirements. However, for successful implementation, the selected measure should try to satisfy the ten requirements/criteria.

PERFORMANCE INDICATORS (WHAT ARE THE ITEMS TO BE MEASURES?)

The performance measures of an organisation includes the performance measures if its each functional elements such as customers, production, suppliers, research and development , human resources, marketing/sales and administration.

PERFORMANCE INDICATORS

1. Customers
    - Number of customer's complaints
    - Number of warranty claims
    - Number of suggestions per employee
    - Number of suggestions implemented
    - % returns by customers
    - Customer satisfaction index
    - Time to resolve complaints

    - Mean time to repair

2. Production
    - Productivity= Output/Input= Result/Costs
    - Labour productivity= Result/Labour costs
    - Capital productivity= Result/Capital costs
    - Material productivity= Result/Material costs
    - Effectiveness= Actual result/Expected result
    - Efficiency= Expected costs/Actual costs
    - Revenue growth
    - %rejects; % scrap
    - Failure rate= (no. of failures/total no. of products tested) X 100%
    - Quality grade = {(production quantity – no. of defects) / production quantity} X 100%
    - Throughput time = Processing time + inspection time + movement time + waiting time
    - Manufacturing cycle effectiveness= Processing time/throughput time
    - Number of breakdowns
    - Availability = MTBF/MTTR
    - Where MTBF= Mean time b/w failures, and MTTR= Mean time to repair.
    - Actual processing time Vs waiting times
    - Lead time for product development

3. Suppliers
    - Service rating
    - On-time delivery
    - Quality performance
    - SPC charts
    - Billing accuracy
    - Average lead time
    - Just-in-time delivery target

4. Research and Development
    - New product time to market
    - Time needed to launch a new product

- Design change orders
- Cost estimating errors
- %of sales from new products

5. Human resources
    - %personnel turnover
    - %absence due to illness
    - Employee satisfaction index
    - No. of training hours per employee
    - No. of active teams
    - Number of suggestions / grievances
    - % Safety incidents
    - % environmental incidents.
6. Marketing/ Sales
    - Sales growth
    - Market growth
    - %delivery completed
    - Sales expense to revenue
    - New customers
    - Sales income to number of sales people
    - Order accuracy
7. Administration
    - Revenue growth
    - Revenue per employee
    - Expense to revenue
    - Cost of poor quality
    - % of payroll distribution on time
    - Office equipment up-time

UNIT - V QUALITY SYSTEMS

ISO 9001 REQUIREMENTS

1. **Scope**
2. **Normative References**
3. **Definitions**
4. **Quality Management Systems**
    - ➢ Documentation
    - ➢ Quality Manual
    - ➢ Control of documents
    - ➢ Control of records
5. **Management Responsibility**
    - ✓ Management Commitment
    - ✓ Customer Focus
    - ✓ Quality policy
    - ✓ Planning
    - ✓ Responsibility, authority and communication
    - ✓ Management review
6. **Resource Management**
    - Human resources
    - Infrastructure
    - Work Environment
7. **Product or service realization**
    - ▪ Planning of product realization
    - ▪ Customer related processes
    - ▪ Design and development
8. **Measurement, Analysis and improvement**
    - □ Monitoring and measuring
    - □ Analysis of data

ISO 9001

IMPLEMENTATION

Top Management Commitment:

- ✓ The chief executive officer (CEO) must be willing to commit the resources necessary to achieve the certification.
- ✓ Without the CEO's support the process may continuously run in to unnecessary road blocks or even be doomed to failure.

Appoint the Management Representative:

- ✓ The next step is to appoint the management representative.
- ✓ This person is responsible for coordinating the implementation and maintenance of quality system and he is the contact person for all parties involved in the process both internal and external.
- ✓ The representative can be a member of the top management group who is able to ensure that the quality system is effectively implemented, documented and maintained.

Awareness:

- ✓ An awareness program is required because the process is going to affect every member of the organization as well require their input, it stands to reason that everyone should understand the quality system.
- ✓ The employees should know how it will affect their day-to-day operations and the potential benefits.
- ✓ This information can be relayed through short, one hour awareness training sessions.

Appoint an implementation team:

- ✓ After every one has been informed of the organizations intentions to develop the quality system, an implementation team should be assembled.
- ✓ This team should be drawn from all levels and areas of the organization so that it is representative.
- ✓ It is important to keep the project visible for all employees.

Training:

- ✓ The implementation team, supervisor and internal audit team should be trained.
- ✓ This activity can be accomplished by sending team leaders for training and make them to train the rest of the members by one or two day seminar.

Time Schedule:

- ✓ A time schedule has to be framed for the implementation and registration of the system.
- ✓ This time frame will vary depending on the size and type of organization and the extent of its existing quality system.
- ✓ Most organizations can complete this entire process in less than 1.5 years.

Select Element Owners:

- ✓ The implementation team should select owners for each of the system elements.
- ✓ Many of these owners will be the members of the implementation team.
- ✓ Owners may be assigned more than one element.
- ✓ The more people involved, the more effective the system.

Review the present system:

- ✓ The present system has to be reviewed.
- ✓ Copies of all the quality manuals, procedures, work instructions and forms which are used presently are obtained.
- ✓ These documents are sorted in to system elements to determine what is available and what is needed to complete the system.
- ✓ This is called as gap analysis.

Write the document:

- ✓ Prepare written quality policy and procedure manuals, they can be combined in to one document.
- ✓ Write appropriate work instructions to maintain the quality of specific function.
- ✓ This process should involve every employee, because the best person to work with instruction is the one who performs the job on a regular basis.

Install the new system:

- ✓ Integrate the policies, procedures and work instructions in to the day today workings of the organization and document what is being done.
- ✓ Be sure all people are trained.

Internal Audit:

- ✓ Conduct an internal audit of the quality system.
- ✓ This step is necessary to ensure that the system is working effectively.
- ✓ Minor corrections to the system are made as they occur.
- ✓ A cross section of the trained people should be used for the audit team.

Management Review:

- ✓ A management review is conducted.
- ✓ The management review is used to determine the effectiveness in achieving the stated quality goals.

Pre assessment:

- o This step is optional.
- o If a good job has been done on the previous steps pre assessment is not necessary.

Registration:

- o It has three parts
  - ▪ Choosing a registrar
  - ▪ Submitting an application
  - ▪ Conducting the registrar's system audit.
- ✓ A registrars audit usually lasts one to three days and will consist of an opening meeting , the process the auditors will follow, the audit itself and closing meeting to discuss the findings of the audit.

DOCUMENTATION OF QUALITY SYSTEM

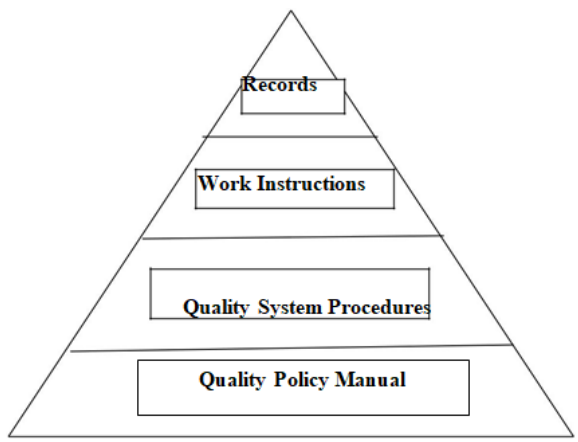
- ✓ Proper documentation is the pre-requisite for implementing quality system.
- ✓ The documentation serves as a reference for the management, the staff and other agencies whose involvement is essential for implementation of the quality system.
- ✓ Advantages of having a documented quality system:
  - ➢ Serves as a reference
  - ➢ Brings about clarity of objectives and targets

- ➢ Provides standardization in work procedures
- ➢ Brings about consistency in operations
- ➢ Develops confidence amongst employees
- ➢ Generates customers confidence
- ➢ Provides a basis for continuous improvement

Documents to be prepared:

- ➢ Quality Policy Manual
- ➢ Quality System Procedures
- ➢ Work Instructions
- ➢ Records/formats/forms.

The documentation Pyramid:



1. **Quality Policy Manual:**
   - ✓ Quality policy manual is the first level of documentation. This is the document that defines 'what will be done 'and 'why'.
   - ✓ It should be short and simple definition of the organizations quality intentions.
   - ✓ The remainder of the policy manual addresses what will be done to comply with the standard being used.
   - ✓ The policy manual communicates the quality policy and objectives of an organization.
   - ✓ This manual is a living document. Because it reflects the current system being followed in the organization.
2. **Quality System Procedures:**
   - ❖ The second level of documentation is the quality procedures. These procedures describe the methods that will be used to implement and perform the stated policies**.**

- ❖ These procedures define who should perform specific tasks, when the task should be done and where the documentation will be made.
- ❖ These documents collectively define the organizations operations from receiving an enquiry to delivering a completed product or service.
- ❖ These procedures are confidential documents of the organization and therefore need not to be revealed to others.

3. **Work Instructions:**
    - ➢ The third level of documentation is generally company specific. It gives details of how individual work processes (e.g.: welding, casting) are carried out with in a company.
    - ➢ Work instructions should also specify how the work should be done, who should undertake the work and what records are to be maintained.
    - ➢ The work instructions may be in the form of a detailed drawing, recipe, routing sheet, specific job function, photograph, video or simply a sample for comparison of conformity.
    - ➢ The work instructions should be written by the employee who performs the task.
4. **Records:**
    - These provide evidence of activity having been performed in compliance with quality system procedure.
    - Records may be forms that are filled out, a stamp of approval on a product or a signature and date on some type of document.

QUALITY AUDITING

Quality auditing should be carried out in order to verify whether a quality system is effective and suitable.

Definition:

A quality system audit is defined as "a systematic and independent examination to determine whether quality activities and related results comply with planned arrangements, whether these arrangements are implemented effectively and whether these are suitable to achieve objectives"

Objectives of Quality Audits:

- ➢ To determine the conformity or non-conformity of the quality system elements with regard to specified requirements.
- ➢ To determine the effectiveness of the implemented quality system in meeting specified quality objectives.
- ➢ To meet regulatory requirements, if applicable.

- To permit the listing of the audited organizations quality system in a register for third party certification.
- To evaluate an organization, own quality system against a quality system standard.

Types of Audits:

- ✓ **First party audit (or internal audit):**
  - This refers to an internal audit where the auditee is its own client, i.e. audit is done by an organization, working on itself.
- ✓ **Second party audit:**
  - This refers to audit by one organization on another organization (auditee). This type of audit is normally done on a supplier by a customer.
- ✓ **Third party audit:**
  - This refers to audit by an independent organization on a supplier, for accreditation assessment purposes.

Stages of an Audit:

There are four stages

1. Audit Planning
2. Audit Performance
3. Audit reporting
4. Audit follow-up

Stage 1: Audit Planning (It has 4 key elements)

i. **Audit schedules**: It is a matrix of the timings, which details when each audit element is to be checked throughout the year.
ii. **Audit personnel**: It refers to the appointment of an auditor.
iii. **Notification to the auditee**: This is the formal and timely request by audit to auditee for making available all quality system documents relevant to the audit.
iv. **Preparation of checklist:** This lists all specific questions to be asked during audit.

Stage 2: Audit Performance

i. **Opening/entry meetings:** Opening meeting is organized to initially brief the auditee about the scope of audit.
ii. **Audit process:** Audit is done according to the schedule and should cover entire scope, as planned. Regular liaison meetings should be held.

iii. **Audit deficiencies:** During auditing, clear and precise discrepancy reports are raised. All discrepancies should be based on sound and objective evidence.

Stage 3: Audit Reporting

i. Audit reporting deals with the recording of any non conformity and summarizing the audit findings.

ii. The audit report may contain:

- ✓ Identification of the reference documents against which audit is conducted (ie quality system standard), company's quality manual.
- ✓ Observation of non-conformities
- ✓ Corrective action requests

Stage 4: Audit Follow-up

i. The auditor is only responsible for identifying the non-conformity. But the auditee is responsible for determining and initiating corrective action needed to correct a non conformity.

ii. Corrective action and subsequent follow up should be completed within a time period.

These 4 stages complete the ISO 9000 quality system audit

ISO 14001

What is ISO 14001?

- It is an Environmental Management System (EMS) that uses a continual improvement approach in achieving and demonstrating sound environmental performance.
- The goal is for organizations to control the impacts that their activities, products and services have on the environment.
- ISO 14000 is the standard, and ISO 14001 is the document containing the requirements.

Overview of the Requirements of the ISO 14001 Standard

- The organization must develop an effective system that meets the requirements of the Standard.
- Document, implement and maintain the system.
- The EMS documents need to be controlled.

Follow a Plan-Do-Check-Act approach.

– Plan - Establish the objectives and processes needed to deliver the results.

– Do - Implement the needed processes of the EMS.

– Check - Check the processes against the policy, objectives, targets, regulations, and report on the results. (Auditing)

– Act - Take actions that will continually improve the EMS.

Requirements (Plan): Management

- Top Management must be committed to and involved in the design and implementation of the EMS.
- They will write the Environmental Policy and be responsible for making sure it is communicated and implemented.
- Many specific responsibilities are assigned to Top Management to ensure their input and participation.
- After implementation Management will conduct management review to ensure continued effectiveness of the system.
- Requirements (Plan): Resources
- The EMS must clarify what resources, human and physical are required to create safe products and operations.
- During development of the system you will determine how to ensure competent personnel, identify training that is required, and identify the infrastructure and work environment required
- Requirements (Plan): Form EMS
- Your organization will need to plan all of the processes that go into making your product to ensure safe conditions.
- You will need to state of scope of the EMS and clearly identify the products and define the locations or sites that are part of the EMS.

Requirements (Do): Environmental Review

- An initial environmental review will be needed.
- An assessment of environmental aspects and their Impacts will have to be performed.
- Regulatory, legal and other requirements will need to be identified.
- Environmental programs with targets and objectives will need to be established, implemented and evaluated on an ongoing basis.
- Emergency preparedness procedures will be required to address potential accidents and emergencies.

- Measuring and monitoring of product and process characteristics that can have an impact on the environment will be required.
  - Measuring and monitoring equipment will need to be controlled and calibrated.
  - A process will be needed for the Environmental Safety Team to evaluate compliance to legal and other requirements.

Requirements (Check): Control Nonconformities

- Establish and document a system for controlling nonconformities.
  – When specified product and process limits are exceeded potentially unsafe conditions must be identified, assessed, controlled and dispositioned appropriately.
  – Identify corrections and corrective actions to mitigate environmental impacts and to eliminate the nonconformity and its cause.
- Establish the internal audit process.
  - Train auditors, and plan internal audits to establish an audit program that will determine if the EMS is effective and up to date.
- Control the records associated with the EMS.
- Conduct regular management reviews to ensure effectiveness of the EMS.

Requirements (Act): Improve your EMS

- Continually improve the EMS through the use of:
  – Management reviews
  – Internal audits
  – Corrective actions
  – Analysis of data / results
  – Update the EMS

<u>ISO 14001 IMPLEMENTATION STEPS</u>

Implementation: Conduct the Environmental Gap Analysis

You must determine your position with regards to the environment:

– Are there GAPS that need to be bridged?
– What are they and where are they located?
– How can they be improved?
– Who will be taking corrective / preventive actions?

Your environmental position needs to be analyzed so that the GAPS can be bridged / closed.

Conduct the Environmental Gap Analysis

Conduct a Gap Analysis – Complete a series of assessments in the following order:

- Perform Initial Environmental Review
- Perform Environmental Assessment – Aspects/Impacts
- Identify Legal and Other Requirements
- Identify Environmental programs with objectives and targets

Based on the results of the assessments, implement Improvement actions.

- Implementation: Form a Team
- Appoint a Management Representative
  - This individual will be the ISO project manager.
- Assign a Environmental Safety Team
  - This team will be active in the design and development of the EMS and participate in the ongoing operation of the system.
- Assign a Management Team
  - This team will be providing the direction and guidance for the development and implementation of the EMS.
- The Management Team will act as a steering team for the project, assigning responsibilities, providing resources and coordinating the project.
  - The Management Team can assign task teams to work on specific processes that must be designed and documented for the EMS.
- Each task team will evaluate the current process that they are assigned to and the requirements of the standard.
  - A new or modified process will be developed, documented and submitted to the Management Team for review and approval.
- After the task teams have designed and documented a new or modified process, it must be implemented.
- Train all employees that are involved in the process
- When the required processes have been implemented, start your internal audit program and management review meetings.
- Use information / results from internal audits and management review to make improvements to the EMS.
- Run your system long enough to generate records for the Registrar to audit.
- Make sure all employees are trained on ISO 14001

- Have a Registrar conduct your Registration Audit?

TQM IMPLEMENTATION IN MANUFACTURING AND SERVICE SECTORS.

Manufacturing and Service Sectors:

- Manufacturing organizations are those that produce physical.
- Service organizations produce non-physical outputs, such as medical, educational, or transportation services provided for customers.
- Services also include the sale of merchandise. Although merchandise is a physical good, the service company does not manufacture it but merely sells it as a service to the customer. Retail stores such as SM and Robinson's are service organizations.
- Services differ from manufactured products in two ways:
- First, the service customer is involved in the actual production process.
- Second, manufactured goods can be placed in inventory whereas service outputs, being intangible, cannot be stored.
- Despite the differences between manufacturing and service firms, they face similar operational problems
- Each kind of organization needs to be concerned with scheduling.
- Both manufacturing and service organizations must obtain materials and supplies.
- Both types of organizations should be concerned with quality and productivity in order to compete.
- The service provided is often something that the consumer cannot touch or feel.
- The service is often created and delivered on the spot, in many cases with significant involvement of the customers in the service process.
- Because of the visibility of the service process in many instances and the intangibility of many services, operations management and marketing are more interdependent than in manufacturing.

Implementation of TQM

- Phase One - Define Vision and Mission
- Phase Two - Document Processes
- Phase Three - Establish Measurements
- Phase Four - Control Processes Based on Measurements
- Phase Five - Implement Continuous Improvement

Phase I: Define Vision and Mission

- The first step is to develop vision and mission statements for the company or to revisit existing ones to ensure that they still fit the company and where it is going.
- These statements help solidify the goals and objectives and provide a common focus point.
- One key advantage of a common focus point is that it gives direction to all personnel and helps them determine how to prioritize their activities.
- The first step is to develop vision and mission statements for the company or to revisit existing ones to ensure that they still fit the company and where it is going.
- These statements help solidify the goals and objectives and provide a common focus point.
- One key advantage of a common focus point is that it gives direction to all personnel and helps them determine how to prioritize their activities.
- With input from all employees, these two statements are used as guides for the rest of the quality journey.
- It is important to tie quality into the overall company vision so that each department or area of the company realizes that quality is important to the company.
- When a company collaboratively decides to express its vision, beliefs, goals, values and mission in words, it will give direction to everyone in the company.
- The way that the vision and mission are communicated is important.
- This requires full commitment from senior management and may result in several changes depending on where the company presently is and how well it presently represents its vision.
- Quality must be recognized not as a separate entity but as an integral part of a person's overall job.
- This communication process can take time and much effort but does become easier as people see that the company truly uses these statements in their decision process and refers to them for guidance on a regular basis.
- Once the direction is defined, then it will impact such things as strategic planning, objectives and goals
- Strategic planning includes reviewing the vision and mission of the company and then determining what has to be done in order to achieve the goals of these statements.
- The company determines how it will know when the statements have been achieved.
- From the measures, each department can set goals, objectives and measures that will help the company achieve its strategic objectives.

Phase-II: Document Process

- Now that the company knows what it is and where it wants to go, the next step in the quality journey is to determine how it presently does its business.
- It must know how it presently does things and be able to measure its ability to be consistent in meeting customer requirements.
- Customers remember a company's name under two conditions: When the company provides extremely poor products or service, or when the company provides surprisingly good products or service.
- In order to provide surprisingly good products or service (output), companies must look at what is involved in delivering that output. It is the business processes that deliver the output.
- Companies must focus on the process in order to keep customers coming back and staying loyal to the product or service.
- Companies must start focusing on the processes that control the customer interfaces, rather than the organizational structure.
- Companies that focus on delivering surprisingly good output and building their reputations will be more successful than companies that just focus on the bottom line as the bottom line will not bring customers back.
- The only way to determine how to consistently deliver this type of output is by focusing on processes within your company/business.
- Every product/service (output) is the result of a process.
- A process can be defined as any activity or group of activities that takes an input, adds value to it, and provides an output to an internal or external customer.
- The key elements of a process are: inputs, activities, outputs, customers, resources (materials, pesos and person/processing time), and cycle time (how long does it take). SIPOC
- 6 Ms: man, machines, materials, methods, measurement, Mother Nature (environment)
- A company must first document the current state
- Define what the company does, who does it, and how and why it is done
- Procedures that are critical to the process need to be documented.
- Organizational Focus
    - Employees are the problem.
    - Employees

    - Doing my job
    - Understanding my job
    - Measuring individuals
    - Change the person
- Process Focus
    - The process is the problem.
    - People
    - Help to get things done
    - Knowing how my job fits into the total process
    - Measuring the process
    - Change the process

Phase Three - Establish Measurements

- A company must first document the current state
    - Define what the company does, who does it, and how and why it is done
- Procedures that are critical to the process need to be documented.
- The next step in the quality journey is to set standards and measures for each process, product, and service.
- The focus must be on improving the customer's perception of the company, its products and services.
- To do this the company must measure customer satisfaction.
- Companies need to determine precisely where they stand in their customer's eyes by engaging in ongoing information-gathering activities to measure customer satisfaction.
- Listening to customer complaints, identifying and measuring critical processes that are responsible for generating poor service or products, and implementing corrective action are integral in developing a quality management philosophy.
- The focus should be on indicators of performance and customer service standards that measure the quality of service to the customers. Standards must be realistic.
- Standards are not set in stone, they must be adjusted to reflect changes in customer requirements, processes, technology, or competitive offerings.
- *What Gets Measured, Gets Managed and Never Assume You Know What The Customer Wants*

- Companies need to: know on an ongoing basis what their customers are thinking, analyze their own structures and processes to ensure that they do not hinder or interfere with customer satisfaction, and, implement measures to monitor the effectiveness of all critical processes that impact customer satisfaction

Phase Four - Control Processes Based on Measurements

- Use the measurement results to fine tune processes and align them with the desired outcomes and standards.
- Processes, standards and measures need to be controlled and aligned to ensure that the company is serving its customers and supporting the people who are serving the customers or producing the products or services.
- Measurement allows management to "Manage by Fact" rather than managing by intuition or judgment by providing data about the operating environment and performance.
- There are two primary uses of "Management by Fact". They are
    - Manage service quality - Manage the processes and the deliverables to make sure they meet customer requirements/specifications.
    - Manage process improvement - Identify opportunities for process improvement, and then implement them.
- The obstacles of "Management by Fact" include:
    - Unreliable, invalid measures
    - Reliance on “gut feel”, intuition, or past experience
- If the measures are not reliable and are not valid, they are not believable and not be used.
- Measuring individuals instead of groups/teams or projects
    - When measurements are thought to be individual performance indicators, the tendency is to manipulate those measures to make personal performance look better.
- Process improvement will have an effect on systems.
- Systems are basically the vertical and horizontal organization of a company such as human resources, shipping/receiving or distribution, customer complaints or customer relations, purchasing, and accounting.
- As processes are controlled, improved and aligned, other parts of the company (such as systems, organizational structures, and personnel competencies) will be affected and may need to change and to ensure that the company vision goals and objectives are met.

- Teams will need training in statistics and the various tools as needed to ensure that they are kept up-to-date with new methods.
- Plan-Do-Check-Act (PDCA)
    - The PDCA cycle ensures that changes are introduced in a controlled manner
    - You PLAN what has to happen. You DO the change in a controlled manner (small scale), CHECK the result. If the result is good, you ACT to implement and standardize the change. If it is not, you go back to PLAN to refine it.
    - The cycle can apply to process problem solving or to company strategic planning.

Phase Five - Implement Continuous Improvement

- The company continues doing what it has been doing; that is mapping its processes, establishing standards and measures and then controlling the processes based on the measurement data
- The company starts expanding what are has been doing to all aspects of its business.
- The company needs to continue its focus on customer requirements and improving value to customers and improvement of the overall company performance and capabilities.
- But the company must also start learning from others and assessing its progress
- Using benchmarking or comparing the company to World Class quality standards (e.g., the Malcolm Baldrige National Quality Award, the JCIA Standards, etc.) are ways to assess the improvement progress.

UNIT I **INTRODUCTION** **9** Introduction - Need for quality - Evolution of quality - Definitions of quality - Dimensions of product and service quality - Basic concepts of TQM - TQM Framework - Contributions of Deming, Juran and Crosby - Barriers to TQM - Customer focus - Customer orientation, Customer satisfaction, Customer complaints, Customer retention.		
	PART – A	**BL**
1	**Define Total Quality Management (TQM).** 1. The art of managing the total organization to achieve excellence in all spheres of activity. (Bester field). 2. The integration of all functions and processes within an organization in order to achieve the continuous improvement of the quality of goods and services. (Omachonu). TQM is the management approach of an organization, centered on quality, based on the participation of all its members and aiming at long-term success through customer satisfaction, and benefits to all members of the organization and to society. Total -Made up of the whole Quality -Degree of excellence a product or service provides Management -Act, art, or manner of handling, controlling, directing, etc. TQM is an enhancement to the traditional way of doing business. It is the art of managing the whole to achieve excellence. It is defined both a philosophy and a set of guiding principles that represent the foundation of a continuously improving organization. It is the application of quantitative methods and human resources to improve all the processes within an organization and exceed customer needs now and in the future. It integrates fundamental management techniques, existing improvement efforts, and	**BL1**

	technical tools under a disciplined approach.	
2	**What are the elements of TQM? (Jan/Feb 2022)** There are eight key elements of TQM such as: Ethics, Integrity, Trust, Training, Teamwork, Leadership, Recognition, Communication.	**BL1**
3	**Mention the basic features of TQM.** 1. Management commitment, 2. Focus on customer (both external and internal), 3. Employee involvement, empowerment, 4. Continuous improvement, 5. Treating suppliers as partners and 6. Establish performance measures for processes.	**BL2**
4	**What are the benefits of TQM?** Improved quality, higher productivity, employee participation, teamwork, working relationships, customer satisfaction, employee satisfaction, communication, profitability, market share, and stock price performance	**BL1**
5	**Define quality. (Nov/Dec 2022)** Quality = Performance/Expectations 1. Predictable degree of uniformity and dependability at low cost and suited to the market -Deming 2. Fitness for use – Juran 3. Conformance to requirements – Crosby	**BL1**
6	**What are the various quality statements?** Quality statements include the vision statement, mission statement, and quality policy statement.	**BL2**
7	**What is a vision statement?** A short declaration of what an organization aspires to be in the future. It is an ideal state that an organization continually strives to achieve. It is timeless, inspirational, and becomes deeply shared within the organization	**BL1**

8	**What is a mission statement?** The mission statement answers the following questions: who we are, who are our customers, what we do, and how we do it. The mission provides the guide map, milestones for achieving the vision.	**BL1**
9	**What is Deming cycle?** P-D-S-A (Plan-Do-Study-Act) cycle of continuous improvement.	**BL1**
10	**What are the major dimensions of product quality? (Nov/Dec 2017)** Performance, features, usability, conformance to standards/specifications, reliability, durability, maintainability, etc	**BL3**
11	**What are the three levels of quality in the Kano model of customer satisfaction?** 1. Basic quality, 2. Performance quality and 3. Excitement quality. The products corresponding to these three quality levels were termed as 'Dissatisfies', 'Satisfiers' and 'Delighters/Exciters' respectively in the Kano model.	**BL3**
12	**What is importance of customer retention?** It costs a company six times more to sell a product to a new customer than it does to sell to an existing one. Loyal customers generate more revenue, and are also cheaper to maintain. Customer loyalty facilitates cross-selling/up-selling of a company's other products/services, and also acts as an effective barrier to the entry of competition.	**BL2**
13	**Distinguish between internal customer and external customer.**	**BL4**

External customer	Internal customer
An external customer exists outside the organization and can be defined in many ways – user, buyer, influencer. He generally falls into one of	Every function within the organization (engineering, production, order processing, etc.) has an internal customer. Every person in a process is considered a customer of the preceding

<table>
<tr><td></td><td><table><tr><td>three categories: current, prospective, or lost customer.</td><td>operation. For example, Manufacturing is a customer for Purchasing, and Dispatching is a customer for Packaging.</td></tr></table></td><td></td></tr>
<tr><td>14</td><td>What do you mean by service quality?
Service quality is nothing but, Service duration, timeliness, completeness, consistency, convenience, accuracy, courtesy, etc</td><td>BL1</td></tr>
<tr><td>15</td><td>What is meant by cost of quality?
Quality costs are defined as costs associated with non-achievement of product/service quality. In simple terms, quality cost is the cost of poor products/services. All costs associated with poor quality and its correction are integrated into one system to enhance the quality management function.</td><td>BL1</td></tr>
<tr><td>16</td><td>What are the four categories of quality costs? (Nov/Dec2016)
1. Prevention costs, 2. Appraisal costs, 3. Internal failure costs and 4. External failure costs.</td><td>BL2</td></tr>
<tr><td>17</td><td>What are internal failure costs?
These are costs required to identify, repair, replace, or dispose off defective products/services prior to delivery to the customer.</td><td>BL1</td></tr>
<tr><td>18</td><td>Mention the names of some major contributors to the quality movement. (OR)
List the quality gurus in TQM.
1. Edwards Deming, 2. Joseph M. Juran, 3. Philip Crosby, 4. Feigenbaum, 5. Ishikawa, 6. Taguchi, 7. Shingo and 8. Walter Shewhart.</td><td>BL2</td></tr>
<tr><td>19</td><td>Mention the four pillars of TQM?
Customer satisfaction, continuous improvement, Quality leadership and systems approach</td><td>BL2</td></tr>
<tr><td>20</td><td>What is the importance of customer focus for an organization?
Customers are the most important asset of an organization. An organization’s</td><td>BL1</td></tr>
</table>

	success depends on how many customers it has, how much they buy, how often they buy, and how long they are retained (loyalty).	
21	**What is Deming's "System of Profound Knowledge"?** Deming summarized his philosophy in what he called "A System of Profound Knowledge". It comprised of 4 parts: 1. Appreciation for a system, 2. Some knowledge of the theory of variation, 3. Theory of knowledge, and 4. Psychology. Deming recognized the synergy among these diverse subjects and developed them into a theory of management.	
22	**What are some major obstacles to TQM implementation? (Nov/Dec 2022)** Lack of management commitment, Inability to change organizational culture, Improper planning, Lack of continuous training and education, Paying inadequate attention to internal and external customers, Inadequate use of empowerment and teamwork, Lack of employee involvement, Emphasis on short-term results, etc.	**BL1**
23	**What is customer satisfaction?** Customer satisfaction is a measure of the degree to which a product or service meets the customer's expectations.	**BL1**
24	**How can quality be quantified? (April/May 2016)** Quality can be expressed as P/E, where P denotes performance and E denotes expectation.	**BL3**
25	**What do you mean by service quality? (April/May 2016; Nov/Dec 2017)** Quality of service offered is judged based on the following dimensions: Reliability, Responsiveness, Assurance, Empathy, Tangibles etc	**BL2**
26	**What are the different ways to create customer oriented culture in an industry? (Nov/Dec 2016)** 1. Base their values on customer feedback 2. Involve their employees in the development of values	**BL6**

	3. Link these values to their brand 4. Encourage their employees to align their behaviors to the values. 5. Reward their employees for living the brand.	
27	**What are the four absolutes of quality defined by Crosby? (April/May 2017)** 1. Quality is defined as conformance to requirements, not goodness 2. The system for achieving quality is prevention, not appraisal 3. The performance standard is zero defects, not that's close enough and 4. The measure of quality is the price of non-conformance, not indexes.	**BL3**
28	**Define quality policy statements. (April/May 2017; Nov/Dec 2017)** Quality policy statement is a document developed by management to express the directive of the top management with respect to quality.	**BL2**
29	**What are the tangible benefits and intangible benefits of TQM? (Jan/Feb 2022)** The common tangible benefits would be cash flow, cash income, and cost reduction. In essence, it is the net profit gain for a running business. The intangible benefits would include raising customer satisfaction rate, improved employee motivation, growing market share, and better reputation for a company’s brand. In the IT industry, the intangible benefits are important, especially for many startup companies.	**BL4**
30	**Why is quality required in products and services today? MAY/JUNE 2014** Quality in business, engineering and manufacturing has a pragmatic interpretation as the non-inferiority or superiority of something; it is also defined as fitness for purpose. Quality is a perceptual, conditional, and somewhat subjective attribute and may be understood differently bydifferent people. There are five aspects of quality in a business context: • Producing – providing something.	**BL3**

	• Checking – confirming that something has been done correctly. • Quality Control – controlling a process to ensure that the outcomes arepredictable. • Quality Management – directing an organization so that it optimizes itsperformance through analysis and improvement. • Quality Assurance – obtaining confidence that a product or service will besatisfactory. (Normally performed by a purchaser.	
31	**List the characteristics of TQM.** • TQM is a customer oriented • TQM required a long term commitment for continuous improvement of all processes. • TQM is teamwork. • TQM requires the leadership of top management and continuous involvement • TQM is a strategy for continuous improving performance at all levels and in all areas ofresponsibility.	**BL1**
32	**What are the general duties of a quality council?** • Develop, with input from all personnel, the core values, vision statement,mission statement, and quality policy statement. • Develop the strategic long-term plan with goals and the annual qualityimprovement program with objectives. • Create the total education and training plan. • Determine and continually monitor the cost of poor quality. • Determine the performance measures for the organization, approve those for thefunctional areas, and monitor them.	**BL1**

33	**List the tools used for feedback.** Comment cards, Customer questionnaire (online, phone and mail surveys), Focus groups, Toll-free telephone lines, Customer visits, Report cards, Post transaction surveys, Employee feedback, and Social media.	**BL1**
34	**Define Customer complaint, Customer Retention and Customer care.** A **customer complaint** may be defined as an expression of dissatisfaction with a product/ service, either orally or in writing, from an internal or external customer. **Customer retention** is the process of retaining the existing customers. It is obvious that customer retention is more powerful and effective than customer satisfaction. **Customer care** can be defined as every activity which occurs within the organization thatensures that a customer is not only satisfied but also retained.	**BL2**
	PART – B	
1	**Discuss in detail about the dimensions of quality in the context of service/product./ Compare the dimensions of product quality and service quality with an example. (Nov/Dec 2016, Jan/Feb 2022, Nov/Dec 2022)**	**BL6**
2	**Explain the Juran's view of TQM. / Discuss Juran's principle of quality improvement. (April/May 2013) / Explain in detail about Juran Trilogy. (April/May 2014; April/May 2016)**	**BL2**
3	**Explain the basic concepts and evolution of TQM (Jan/Feb 2022).**	**BL2**
4	**Explain Deming's principles for quality achievement. / Explain Deming's fourteen principles of quality management. How do you feel that these will be useful in today's context in service industry? (April/May 2014; Nov/Dec 2016; Nov/Dec 2017,Jan/Feb 2022)**	**BL2**
5	**Elaborate the fourteen steps involved in Crosby's total quality approach.**	**BL2**

	(April/May 2017)	
6	**Explain the TQM framework.**	**BL2**
7	**State and explain the barriers to TQM implementation in an organization. / What are the barriers while implementing TQM? Also explain evolution of quality. (May/June 2016)**	**BL3**
8	**What do you understand by the term quality statements? Elaborate them with examples. (April/May 2017)**	**BL2**
9	**Illustrate the various steps in the customer satisfaction process. (Nov/Dec 2016)**	**BL3**
10	**Explain the issues related to customer complaints. MAY/JUNE 2015 (or) Explain thecommon customer feedback collection tools?**	**BL2**
11	**Discuss the implementation of TQM with a case study in a manufacturing sector. (June/July 2021).**	**BL6**
12	**Explain the following in detail: (i) Customer orientation (ii) Customer satisfaction (iii) Customer retention. (Nov/Dec 2022)**	**BL2**
PART – C		
12	**Explain the role of senior management in TQM implementation. (Nov/Dec 2016)**	**BL3**
13	**Explain the contributions of Crossby to TQM.**	**BL2**
14	**(i) Describe the various dimensions of quality with respect to the following: quality in products and quality in services.** **(ii) Explain the common customer feedback collection tools. (April/May 2017)**	**BL2**
15	**Why to measure quality costs? Classify the various types of quality costs and give examples. (Nov/Dec 2017) (Nov/Dec 2022)**	**BL5**

UNIT II TQM PRINCIPLES 9

Leadership - Quality Statements, Strategic quality planning, Quality Councils - Employee involvement - Motivation, Empowerment, Team and Teamwork, Recognition and Reward, Performance appraisal - Continuous process improvement - PDCA cycle, 5S, Kaizen - Supplier partnership - Partnering, Supplier selection, Supplier Rating.

PART – A		
1	**List out any four benefits of employee involvement? (April/May 2016)** Conformance, acceptance, contribution, commitment, cooperation, concentration, accountability, ownership.	**BL1**
2	**What is the Juran Trilogy (Quality Trilogy)?** The Juran Trilogy (Quality Trilogy) consists of three inter-related processes – quality planning, quality control, and quality improvement – for managing quality.	**BL1**
3	**What are the roles assigned to people in quality circles?** The QC organization has a four-tier structure consisting of Members, Leaders, Facilitators, and Steering Committee **.**	**BL3**
4	**Mention the major contribution of Feigenbaum to quality.** He was the originator of the concept of Total Quality Control (TQC). His concept of Total Quality Control was used as the foundation by the Japanese for their practice called 'Company-Wide Quality Control' [CWQC], which began in the 1960s and later evolved into TQM.	**BL1**
5	**What are quality circles (QC)? (Nov/Dec 2017)** QC is a small team of people (around 8 to 10) coming from the same work area/department who voluntarily meet on a regular basis (about an hour every week) to identify, investigate, analyze and solve work-related problems. QC can be viewed from three angles: 1. as a form of participative management, 2. as a HRD technique and 3. as a problem-solving technique.	**BL2**
6	**What are Crosby's four absolutes of quality management?** 1. Quality means conformance to requirements, not elegance. 2. Quality is achieved by prevention, not appraisal. 3. The performance standard is zero defects, not acceptable quality levels. Quality is free. 4. Quality is measured by the price of non-conformance, not indexes	**BL2**

7	**What are the steps in implementing quality circle projects?** 1. Select the problem, 2. Study the problem, 3. Plan the improvement, 4. Carry out the improvement 5. Check the results, 6. Form conclusions, 7. Present to management, 8. Obtain approval and 9. Implement on regular basis.	**BL2**
8	**Mention some tools used by quality circles for solving problems.** Data collection, Brainstorming, Check sheets, Pareto Analysis, Cause & Effect diagrams, Control charts, Presentation techniques, etc. are used by quality circles in solving problems.	**BL1**
9	**Mention some major objectives of quality circle projects.** 1. Improve quality and productivity, 2. Cost reduction, 3. Effective utilization of resources, 4. Avoid unnecessary errors, defects and 5. Solve work-related problems that interfere with production.	**BL3**
10	**What is 5 s? / What are the Japanese 5S principles?** The 5S's stand for five Japanese words: Seiri, Seiton, Seiso, Seiketsu and Shitsuke. In English, they mean Sort, Arrange, Clean up, Systematize, and Discipline respectively.	**BL2**
11	**What does Seiri mean?** Separate out all unnecessary things and remove them, retaining only necessary things.	**BL2**
12	**What does Seiton mean?** Seiton means orderliness. It means setting everything in proper order so that they can be easily accessed for use and quickly put away in their proper locations after use.	**BL1**
13	**What does Seiso mean?** Keep machinery and work environment clean.	**BL1**

14	**What does Seiketsu mean?** Develop routine practices for orderly, systematic working.	**BL1**
15	**What does Shitsuke mean?** Impart systematic training and coaching to ensure discipline in 5S implementation	**BL1**
16	**Explain Kaizen. (April/May 2017)** Kaizen, which is a Japanese word that means gradual and orderly continuous improvement, is a philosophy that covers all business activities and everyone in an organization. In the kaizen philosophy, improvement in all areas of business – cost, meeting delivery schedules, employee safety and skill development, supplier relations, new product development, and productivity – serve to improve the quality of the firm. Thus, any activity directed toward improvement falls under the kaizen umbrella.	**BL1**
17	**Explain supplier rating.** A supplier rating system (often called a scorecard system) is usually based on quality, delivery, and service; however, some customers have added other categories, such as lead time, product support, technology, etc.	**BL1**
18	**Define empowerment.** Empowerment requires a sincere belief and trust in people. It involves employees directly in decision-making processes, giving them the security and confidence to make decisions, and providing them with the necessary tools and training.	**BL1**
19	**Distinguish between reward and recognition. (Nov/Dec 2022)** Creating incentives for suppliers is one way to ensure that they remain committed to a quality improvement strategy. Incentives may be in the form of a preferred supplier category with its rewards. Recognition may be in the form of publication of outstanding contributions in the customer's newsletter, a letter of commendation, or a plaque.	**BL4**

20	**Why should suppliers be treated as partners?** Costs due to inferior materials/components from suppliers increase costs in the later stages of production. Suppliers themselves are part of the whole system and hence should be treated as long-term partners.	**BL3**
21	**Mention some benefits of implementing 5S principles.** 5S increases productivity, eliminates waste, reduces inventory, creates a pleasant workplace, improves safety, and increases the overall efficiency and effectiveness of people and machines	**BL3**
22	**What are the functions of quality circles? (April/May 2016)** QC is a small team of people coming from the same work area/department who voluntarily meet on a regular basis to identify, investigate, analyze and solve work related problems. They improve quality and productivity, concentrate on cost reduction, plan effective utilization of resources, avoid unnecessary errors, defects etc.	**BL1**
23	**How employee involvement can be improved in an organization? (Nov/Dec 2016)** 1. Use the right employee involvement survey, 2. Focus on involvement at the local and organizational levels, 3. Select the right managers, 4. Coach managers and hold them accountable for their employees' involvement and 5. Define involvement goals in realistic, everyday terms.	**BL2**
24	**What are internal failure costs?** These are costs required to identify, repair, replace, or dispose off defective products/services prior to delivery to the customer.	**BL2**
25.	**Write the requirements of reliable supplier rating. (Nov/Dec 2016)** Supplier rating system requires 3 key factors: 1. An internal structure to implement and sustain the rating program, 2. A regular and formal review process and 3. A standard measurement system for all suppliers.	**BL3**
26.	**List any four benefits of employee involvement. (April/May 2016)**	**BL3**

	Conformance, Acceptance, Contribution, Commitment, Cooperation, Accountability and ownership.	
27.	**Why team and teamwork are required in TQM? (April/May 2017)** Teams are formed when individuals with a common preference, liking, and attitude come and work together for a common goal. Teams play a very important role in organizations. Team work is essential in corporate for better output and a better bonding among employees.	**BL4**
28.	**Define Leadership. (Jan/Feb 2022).** Leadership is the ability of an individual or a group of individuals to influence and guide followers or other members of an organization. Leadership involves making sound and sometimes difficult decisions, creating and articulating a clear vision, establishing achievable goals and providing followers with the knowledge and tools necessary to achieve those goals.	**BL1**
29.	**What are the benefits and drawbacks of sourcing a component or accessories? (Jan/Feb 2022)** There are many advantages to understanding the importance of sourcing a component 1. **Cheap Manpower** 2. **Scalability** 3. **Accessibility** Drawbacks 1. **Quality Loss** 2. **Intellectual Loss** 3. **Job loss**	**BL4**
30	**Define the characteristics of a leader. (NOV/DEC 2011,MAY/JUNE 2013)** 1. The customers first, 2. Value people, 3. Build supplier partnership, 4. Empower people, 5. Demonstrate involvement/ Commitment, 6. Strive for	**BL1**

	excellence 7. Explain and deploy policy, 8. Improve communication, 9. Promote teamwork, 11. Benchmark continuously, 12. Encourage collaboration.	
31	**List the various styles of effective leaders.** 1. Directing Style of leadership 2. Consulative style of leadership 3. Participative style of leadership 4. Delegating style of leadership	**BL1**
32	**Define Motivation.** Motivation means a process of stimulating people to accomplish desired goals. Motivation is the process of attempting to influence others to do your will through thepossibility of reward. Motivation is the process of inducing people inner drives and action towards certain goalsand committing their energies to achieve these goals.	**BL1**
33	**State Maslow's Hierarchy of Needs.** Physiological needs Safety Social Esteem Self-actualization	**BL1**
34	**State Frederick Herzberg's Two-factor theory?** Herzberg found that people were motivated by recognition, responsibility, achievement and the work itself.	**BL1**
35	**Define team.** A team can be defined as a group of people working together to achieve commonobjectives or goals.	**BL1**
30 6	**What is performance appraisal**? Performance appraisal is a systematic and objective assessment or evaluationof performance and contribution of an individual.	**BL1**
37	**What are the benefits of performance appraisal?** It provides useful feedback to the employee, supervisor and personnel specialists and allows them to take corrective measures to improve	**BL2**

	performance further. • It helps in determining the pay adjustments, increments and bonuses as it rates themerit of the employee • It provides basis for employee promotion, transfer or demotion. • It helps the employee to plan their career.	
38	**What are the types of quality problems?** Compliance problems, Unstructured problems, Efficiency problems, Process Design problems, Product- design problems	**BL2**
40	**What are the steps in the PDSA cycle?** The basic Plan-Do-Study-Act is an effective improvement technique. • Plan carefully what is to be done • Carry out the plan • Study the results Act on the results by identifying what worked as planned and what didn't.	**BL2**
41	**What are the benefits of PDSA cycle?** Daily routine management- for the individual and /or the team, Problem solving process, Project management, Continuous development, Vendor development, Human resources development, New product development Process trials.	**BL2**
42	**What are the phases of a Continuous Process Improvement Cycle?** Identify the opportunity, Analyze the process, Develop the optimal solutions, Implement, Study the results, Standardize the solution, Plan for the future.	**BL1**
43	**Define supplier partnering. NOV/DEC 2014** Partnering is defined as a continuing relationship between a buying firm and supplying firm, involving a commitment over an extended time period, an exchange of information,and acknowledgement of the risks and rewards of the relationship.	**BL1**
44	**List the responsibilities of the Quality council coordinator.**	**BL1**

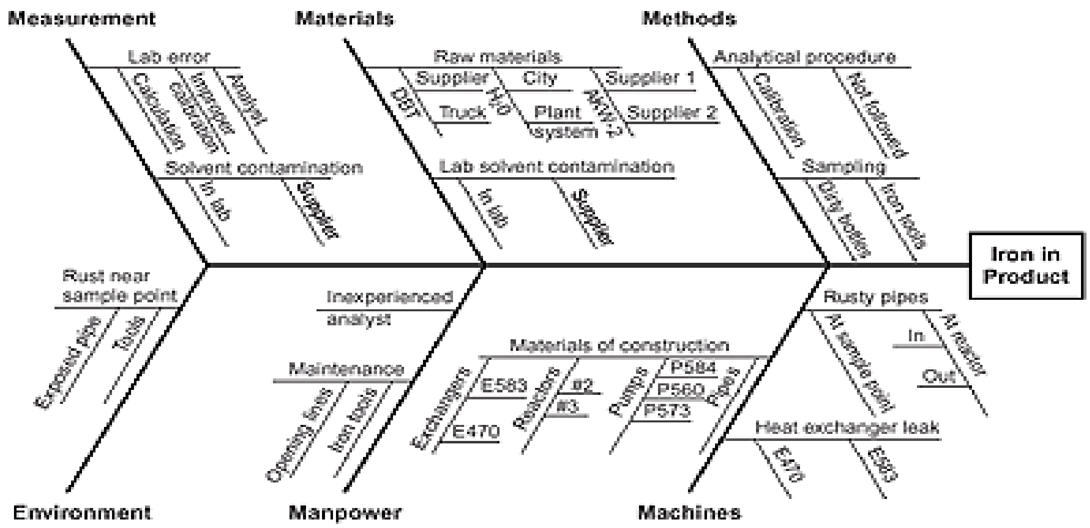
	• To develop two way trust • To propose team requirements to the council • To share council expectations with the team • To empower the team • To brief the council on team progress.	
45	**Why strategic quality planning is important? (Nov/Dec 2022)** In order to integrate quality with the strategic planning process, a systematic and sequential procedure has to be adopted. It focuses on the following; Customer needs-customer position-gap analysis (current and future state mapping)-closing the gaps (process improvements)-alignment with the vision, mission, and core values of an organization- Implementation strategy	**BL2**
PART – B		
1	**Write a note on quality planning and strategic quality planning. (April/May 2014; Nov/Dec 2016**)	**BL2**
2	**Explain the different types of teams. (Nov/Dec 2011)**	**BL2**
3	**Explain all the elements in 5'S principle and also the implantation procedure of 5'S in a manufacturing company. / Elaborate the Japanese 5s as applicable to services. (Nov/Dec 2011; Nov/Dec 2017)**	**BL3**
4	**Give detailed notes about quality circle. / Explain about structure of quality circle and quality circle tools.**	**BL3**
5	**Write about the system of recognition and reward followed in an organization. (Nov/Dec 2011)**	**BL2**
6	**What are the steps involved in continuous improvement process. (Nov/Dec 2011)**	**BL2**
7	**List the five levels in Maslow's hierarchy of needs and describe in detail each level.**	**BL3**
8	**What are the characteristics of empowered employee? And also discuss the benefits of empowered environment. / Explain the concept of employee**	**BL3**

	empowerment and general principles & characteristics of it. (Nov/Dec 2022)	
9	**Explain in detail the concept of employee involvement.**	**BL2**
10	**Write short note on: (i) supplier partnership, (ii) partnering, (iii) supplier selection and (iv) supplier rating. (Nov/Dec 2016)**	**BL1**
11	**Differentiate quality control and quality testing department of an organization. (Jan/Feb 2022)**	**BL4**
12	**Explain the concepts of Leadership? (MAY/JUNE 2014.)**	**BL2**
13	**Explain McGregors theory X and theory Y? (May 2017).**	**BL2**
14	**Explain Juran's Trilogy in detail. June/ July 2021.**	**BL2**
PART – C		
15	**Discuss how quality council is structured in (i) university academic department and (ii) manufacturing facility. (April/May 2016) (Nov/Dec 2022)**	**BL6**
16	**(i) Explain the phases of PDSA cycle and its illustration. (April/May 2016) / Give a detailed note on PDCA cycle. (Nov/Dec 2016) (Nov/Dec 2022)** **(ii) What is 5S and why does the organization adopt this technique? (April/May 2016)**	**BL2**
17	**Portray the characteristics of empowered employees. (Nov/Dec 2016)**	**BL3**
18	**Enumerate the duties of quality council. / Discuss the role and contributions of quality council. (April/May 2017; Nov/Dec 2017, Jan/Feb 2022)**	**BL3**
19	**List out the possible kaizen activities can be applied in your house. Explain each case separately. (for example: corridor, kitchen, water tank, drawing room, fortigo, vehicle parking shed, rest room etc). Jan/Feb 2022**	**BL2**

UNIT III TQM TOOLS AND TECHNIQUES I 9

The seven traditional tools of quality - New management tools - Six sigma: Concepts, Methodology, applications to manufacturing, service sector including IT - Bench marking -

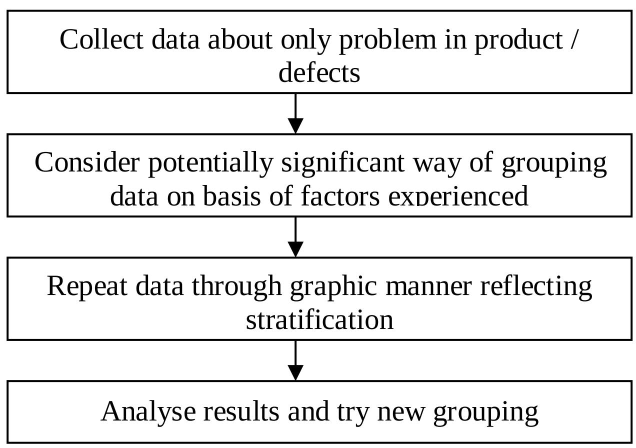
Reason to bench mark, Bench marking process - FMEA - Stages, Types.		
PART – A		
1	**List the seven tools of quality.** 1. Check sheets, 2. Histograms, 3. Cause and effect diagrams, 4. Pareto diagrams, 5. Stratification analysis, 6. Scatter diagrams and 7. Control charts.	**BL1**
2	**What is check sheet?** A check sheet or tally sheet is a form for systematic data gathering and registering to get a clear view of the facts.	**BL1**
3	**When do you use the check sheet?** A check sheet is used to indicate the frequency of a certain occurrence.	**BL2**
4	**What are the types of check sheets commonly used? (April/May 2016)** 1. Process distribution check sheet, 2. Defective item check sheet, 3. Defect location check sheet and 4. Defect factor check sheet.	**BL2**
5	**Write the different concepts of six sigma. (April/May 2017; Nov/Dec 2017)** Six sigma is similar to Zero Defects (ZD), is a philosophical benchmark or standard of excellence proposed by Philip Crosby. Six sigma strives for perfection. It allows for only 3.4 defects per million opportunities (or 99.99966 percent accuracy).	**BL1**
6	**What is histogram? When do you use histogram?** A histogram is a bar chart / diagram showing a distribution of variable quantities or characteristics. It is graphical display of the frequency distribution of numerical data. A histogram is used to show clearly where the most frequently occurring values are located and the data is distributed. It enables the analyst to quickly visualize the features of a complete set of data.	**BL1**
7	**What is meant by bench marking? (Nov/Dec 2016, Jan/Feb 2022)** A measurement of the quality of an organization's policies, products, programs, strategies, etc., and their comparison with standard measurements, or similar	**BL1**

<table>
<tr><td></td><td>measurements of its peers.</td><td></td></tr>
<tr><td>8</td><td>How to use cause and effect diagram. (Nov/Dec 2016)
The cause and effect diagram or Fishbone diagram is a graphical-tabular chart to list and analyze the potential causes of a given problem.
It can be used (i) When identifying possible causes for a problem and (ii) When a team tends to fall into ruts.

</td><td>BL2</td></tr>
<tr><td>9</td><td>Under what situations, one can use cause and effect diagram?
The cause and effect diagram has unlimited application in research manufacturing, marketing, office operations, services, etc.</td><td>BL3</td></tr>
<tr><td>10</td><td>What are the uses of CE diagram?
The cause and effect diagrams are used: 1. to analyse cause and effect relationships, 2. to facilitate the search for solutions of related problems, 3. to standardize existing and proposed operations and
4. to educate and train personnel in decision-making and corrective action activities.</td><td>BL2</td></tr>
<tr><td>11</td><td>What are the various types of histogram?
1. Bell-shaped, 2. Double-peaked, 3. Plateau, 4. Comb, 5. Skewed, 6. Truncated, 7. Isolated peak and 8. Edged peak.</td><td>BL2</td></tr>
<tr><td>12</td><td>What is pareto diagram? State the pareto principle. (Jan/Feb 2022)</td><td>BL1</td></tr>
</table>

	(Nov/Dec 2022) A pareto diagram is a diagnostic tool commonly used for separating the vital few causes that account for a dominant share of quality loss. Pareto principle states that a few of the defects accounts for most of the effects.	
13	**What are the purposes of pareto principle?** Pareto analysis can be used in a wide range of situations, where one need to priorities problems based on its relative importance.	**BL2**
14	**What is stratification?** Pareto analysis can be used in a wide range of situations, where one need to priorities problems based on its relative importance.	**BL1**
15	**What is scatter diagram?** The scatter diagram is a simple graphical device to depict the relationship between two variables.	**BL1**
16	**When do you use the scatter diagram?** The purpose of the scatter diagram is to display what happens to one variable when another variable is changed.	**BL2**
17	**Define statistics applications of statistical techniques.** Statistics is defined as the science that deals with the collection, tabulation, analysis, interpretation and presentation of quantitative data.	**BL3**
18	**What are major functions of statistical analysis? Write down the applications of statistical techniques.** The major functions of statistical analysis are: 1. reducing the complexity of the situation, 2. making comparisons and drawing conclusions, 3. estimating and predicating, and Decision-making. Statistical techniques are applicable in all situations where quantification is possible. The statistical analysis has become indispensable to practically every field that exists.	**BL3**
19	**What are the types of graphs used in representing frequency**	**BL2**

	distribution? Histogram, Frequency polygon and frequency curve, and Cumulative frequency or the 'Ogive'.	
20	**How do obtain frequency curve?** A frequency curve is obtained by drawing a smooth freehand curve through the points of the frequency polygon. The cumulative frequency curve (also called an Ogive) obtained by plotting upper class limits (or lower class limits) against the 'less than' (or 'more than') cumulative frequencies is known as 'less than' Ogive (or 'more than' Ogive).	**BL2**
21	**What do you mean by measure of central tendency? What are the three measures of central tendency?** A measure of central tendency of a distribution is a numerical value that describes the central position of the data. Three measures of central tendency are 1. Mean, 2. Median and 3. Mode.	**BL2**
22	**What are the three measures of dispersion?** Measures of dispersion tell us how the individual observations are spread on either side of the center. 1. Range, 2. Mean deviation and 3. Standard deviation.	**BL2**
23	**What is meant by attribute? What is the use of control charts for attributes?** 1. An attribute refers to those quality characteristics that confirm to specifications or do not conform to specifications. 2. Control charts for attributes monitor the number of defects or fraction defects or fraction defect rate present in the sample. 3. p chart: The chart for fraction rejected as non-conforming to specification 4. np chart: The control chart for number of non-conforming items. 5. c chart: The control chart for number of defects. 6. u chart: The control chart for number of defects per unit.	**BL1**

24	**Define fraction defective (p).** It is defined as the ratio of the number of defective articles found in any inspection to the total number of articles actually inspected. Mathematically, **P = np/n** Where, P= Fraction defective, np = Number of defectives, and n = Number of items inspected in the sub-group	**BL1**
25	**Write the specific use of np chart. (Nov/Dec 2016)** Np-charts are used to determine if the process is stable and predictable, as well as to monitor the effects of process improvement theories.	**BL2**
26	**Write down the difference between a defect and defective.** An item is said to be defective if it fails to conform to the specifications in any of the characteristics. Each characteristics that does not meet the specifications is called defect. For example, if a casting contains undesirable hard sports, below holes, etc., the casting is defective and the hard spots, below holes, etc., are the defects.	**BL4**
27	**Differentiate between producer’s risk and consumer’s risk.** Producer’s risk: It is the probability of rejecting a good lot which otherwise would have been accepted. Consumer’s risk: It is the probability of accepting a defective lot which otherwise would have been rejected.	**BL4**
28	**What are the five phases in six sigma process?** The five phases in six sigma process are: 1. Define, 2. Measure, 3. Analyze, 4. Improve and 5. Control	**BL2**
29	**Brief the scope of six sigma principle.** The six sigma concept is originated from manufacturing field. Now it is applied to non-manufacturing processes also. Today one can apply six sigma to many fields such as services, medical and insurance procedures, call centres, etc.	**BL2**
30	**What are the types of check sheets commonly used?** 1. Process distribution check sheet, 2. Defective item check sheet, 3. Defect location check sheet and	**BL2**

	4. Defect factor check sheet.	
31	**State the primary objectives of six sigma. (April/May 2017) (Nov/Dec 2022)** The primary objective of six sigma is to reduce the process variability σ (standard deviation) from the target (mean μ).	**BL3**
32	**Mention the use of Stratification chart in TQM. (April/May 2017)** Stratification chart is a used for data analysis. When data from variety of sources have been lumped together this chart separates the data so that patterns can be seen. Stratification is a method of analysis of data by grouping it in different ways. It is a simple, very effective QC tool for improving the quality. 	**BL2**
33	**Define flow chart.** • A flow chart, also known as process flow chart, flow diagram and process deployment flow, is a diagrammatic view of the various steps in sequential order that form an overall process in an organization. • Flow charts are used in the quality management for depicting the steps of a process inan easily understandable form, by using standard symbols.	**BL1**
34	**Define control chart.** A control chart is a graph that displays data taken over time and the variations of this data. A control chart illustrates the dynamic performance of the process. This is based on a series of random samples taken at regular	**BL1**

	intervals.	
35	**What are the new seven management tools? June/July 2021.** i. Affinity Diagram ii. Interrelationship Digraph (or) Relationship diagram iii. Tree Diagram iv. Matrix Diagram v. Prioritization Matrices (or) Matrix data analysis vi. Process Decision Program Chart (or) decision tree vii. Activity Network diagram (or) Arrow diagram	**BL1**
36	**Define Affinity diagram.** An affinity diagram is a tool to collect a large amount of verbal expressions andorganize then in according to natural relationship between individual items. This diagram is also referred to as a KJ diagram after its inventor Jiro Kawakita. This is a special kind of brainstorming tool.	**BL1**
37	**Define relationship diagram.** Relationship diagram is a tool for finding causes to a problem. The basic logic behind the tool is the same as those of the cause and effect diagram. This diagram not only clarifies the relationship between cause and effect but also between the various causes. It is a graphical representation of all factors in a complicated problem, system or situation.	**BL1**
38	**Define tree diagram.** A tree diagram systematically breaks down a topic into its components elements and shows the logical and sequential links between these elements. The tree diagram systematically outlines the complete spectrum of paths and tasks that must be carried out to achieve a goal.	**BL1**
39	**Define Matrix diagram.**	**BL1**

	A matrix diagram is a tool that is used to systematically organize information that must be compared on a variety of characteristics in order to make a comparison, selection or choice. It is a tool which the relations between two sets of factors in the form of a table ora matrix. Matrix diagram, sometimes referred as a "quality table", is the starting point in building a"house of quality".	
40	**Define decision tree.** A Process Decision Programme Chart (PDPC), also known as decision tree, is aplanning tool to outline every conceivable and likely occurrence in any planning. The PDPC forces proactive thinking on what can go wrong with one's plan and whatwould one do to overcome the effect of such adverse occurrences.	**BL1**
41	**Define Arrow diagram.** An arrow diagram is a graphic description of the sequential steps that must be completed before a project can be completed. The PERT (Program Evaluation and Review Technique) and CPM (Critical Path Method) charts are the best known arrow diagram. It is a planning tool that determines the critical path of a process or a project.	**BL1**
42	**List the benefits and pitfalls of benchmarking.** **Benefits:** Creating a culture that values continuous improvement to achieve excellence. Sharing the best practices between benchmarking partners Prioritizing the areas that need improvement. Enhancing creativity by devaluing the not-invented-here syndrome. Increasing sensitivity to changes in the external environment.	**BL1**

	Pitfalls: - This is based on learning from others, rather than developing new and improvedapproaches. - Benchmarking should not be a substitute for innovation. - It must be a mere improvement tool.	
43	**What is FMEA? NOV/DEC 2013** Failure and Effect Analysis, also known as Risk analysis, is a preventive measure to systematically display the causes, effects and possible actions regarding observed failures. The objective of FMEA is to anticipate failures and prevent them from occurring. FMEAprioritises failures and attempts to eliminate their causes.	**BL1**
44	**List some of the benefits of FMEA.** - Improve Product/ Process reliability and quality. - Increase customer satisfaction - Early identification and elimination of potential product/process failure modes. - Prioritize Product/Process deficiencies. - Capture engineering/organization knowledge - Document and track the actions taken to reduce risk. - Provide focus for improved testing and development. - Minimize late changes and associated cost. - Act as catalyst for teamwork and idea exchange between functions.	**BL1**
45	**What are the reasons for the benchmarking? MAY/JUNE 2013,MAY/JUNE2014** - It aims at a goal setting process to facilitate comparison with the best. - It aims at motivating and stimulating company employees towards the goal ofcontinuous quality improvement.	**BL2**

	- It aims at external orientation of the company. - It aims at identifying a technological breakthrough. - It aims at searching for industry best practices.	
PART – B		
1	**What is six sigma concept? How can it be effective in a service organization? (Nov/Dec 2016)**	**BL2**
2	**Define histogram. Mention its types. Illustrate with an example. / Discuss about types of histograms and their interpretations.**	**BL3**
3	**Explain the cause and effect diagram (or) fishbone diagram.**	**BL2**
4	**Define pareto diagram. Explain how to construct it? Also explain the stratification analysis. What is it?**	**BL2**
5	**Define the scatter diagram. Mention its types. What is it?**	**BL2**
6	**Explain briefly about check sheet (or) data collection sheet with an example.**	**BL2**
7	**Explain the New Seven Management Tools? MAY/JUNE 2013, NOV/DEC2013,MAY/JUNE 2014, NOV/DEC 2014,MAY/JUNE 2016 , NOV/DEC 2016,June/July 2021.**	**BL2**
8	**What is bench marking? Explain its Types (Jan/Feb 2022).**	**BL2**
9	**Why bench marking is required in an organization? Write down the general procedure for bench marking process. (Jan/Feb 2022)**	**BL3**
10	**Explain the failure mode and effect analysis (FMEA). / Explain in detail the concept of FMEA. (Nov/Dec 2016; Nov/Dec 2017, Jan/Feb 2022) (Nov/Dec 2022)**	**BL3**
11	**Compare six sigma and TQM concepts.**	**BL4**
12	**Explain the seven traditional tools of quality in detail. (Nov/Dec 2022)**	**BL2**
PART – C		
12	**What benefits have been achieved by the organization that has been successfully completed their benchmarking programs? Name any four best**	**BL4**

	practiced companies. (Nov/Dec 2016)	
13	**List out the different situations where FMEA is to be carried out. Give detailed FMEA procedure. (April/May 2017, Jan/Feb 2022)**	**BL5**
14	**Perform an FMEA to anticipate various problem faced and method to eliminate the problem of getting up from bed in the morning and going to school. (April/May 2016)**	**BL6**
UNIT IV TQM TOOLS AND TECHNIQUES II Quality Circles - Cost of Quality - Quality Function Deployment (QFD) - Taguchi quality loss function - TPM - Concepts, improvement needs - Performance measures.		**9**
	PART – A	
1.	**List the objectives of TPM programme.** The overall goals of TPM are: Maintaining and improving equipment capacity. Maintaining equipment for life. Using support from all areas of operation. Encouraging inputs from all employees. Using teams for continuous improvement.	**BL2**
2.	**What is product life characteristics curve?** The failure rate curve, called the product life characteristics curve, shows the failure rates (failures per unit time) against time. It is also called as bathtub curve because of its shape.	**BL1**
3.	**What are the three stages shown on a product life characteristics curve?** The curve consists of three distinct stages: Early failure ('infant mortality' or 'debug'), useful life ('normal failure' or 'chance') and wear out ('old age') failure. The curve shows that the failure rates are higher at the early and end stages of a product's life and relatively low in between the two extremes.	**BL2**
4.	**What is the usefulness of the product life characteristics curve?** Knowing the product life characteristics curve for a particular product helps engineers predict failure behavior and take suitable decisions.	**BL2**
5.	**What is the essential feature of Total Productive Maintenance (TPM)?** TPM is keeping plant and equipment at their highest productive level through	**BL1**

	cooperation of all areas of the enterprise. TPM brings maintenance into focus as a necessary and vital part of the business. It is not regarded as a non-profit activity. Down time for maintenance is scheduled as an integral part of the manufacturing process.	
6.	**What are the various approaches to improving reliability of a product?** Standardization, redundancy, over-design, de-rating, design simplification, understanding the physics of failure, burn-in, and Failure Mode and Effect Analysis (FMEA).	**BL1**
7.	**What are the different ways of classifying maintenance activities?** Maintenance activities can be classified in various ways: 1. Planned (or preventive) maintenance vs. Unplanned (or breakdown) maintenance 2. Preventive maintenance can be sub-classified into periodic maintenance and predictive maintenance 3. Running maintenance vs. Shutdown maintenance 4. Time-based maintenance vs. Condition-based maintenance	**BL2**
8.	**What is some performance measures used to assess the success of TPM?** Mean Time Between Failures (MTBF), Mean Time To Repair (MTTR), Availability (A), Reliability (R), Maintainability (M), Rate efficiency (RE), Speed efficiency (SE), Performance efficiency (PE), Quality rate (Q), and Overall Equipment Efficiency (OEE).	**BL1**
9.	**What are the three categories of losses identified in TPM? (Nov/Dec 2022)** 1. Losses that impede equipment efficiency, 2. Losses that impede human work efficiency and 3. Losses that impede effective use of production resources.	**BL2**
10.	**What are the eight pillars of TPM?** The eight pillars of TPM are: 1. 5S, 2. Jishu Hozen (Autonomous Maintenance), 3. Kobetsu Kaizen (KK), 4. Planned Maintenance (PM), 5.	**BL2**

	Quality Maintenance (QM), 6. Training, 7. Office TPM and 8. Safety, Health and Environment.	
11.	**What is office TPM?** Office TPM is aimed at improving quality, productivity and efficiency in the administrative functions and identifying and eliminating losses.	**BL1**
12.	**Distinguish between Kaizen and business process reengineering.** Kaizen involves incremental improvements, whereas Business Process Reengineering involves breakthrough improvements. Both are essential for successful implementation of TQM.	**BL4**
13.	**What is quality loss?** This loss includes costs to operate, failure to function, maintenance and repair costs, customer dissatisfaction injuries caused by poor design and similar costs.	**BL1**
14.	**What is QFD?** Quality function development may be defined as a system for translating consumer requirements into appropriate requirements at every stage, from research through product design and development, to manufacture, distribution, installation and marketing, sales and service.	**BL1**
15.	**What is control chart? List the types of control charts. (Nov/Dec 2017)** A control chart is a graph that displays data taken over time and the variation of this data. Control charts for variables – for measurable data such as time, length, temperature, weight, pressure, etc. Control charts for characteristics- for quantifiable data such as number of defects, typing errors in a report, etc.	**BL1**
16.	**When do you use control chart?** The purpose of control chart is to identify when the process has gone out of statistical control, thus signaling the need for some corrective action to be taken.	**BL2**

17.	**What is an external failure cost? June/July 2021.** External failure costs arise from the rejection of the products/ services by the customers due to poor quality. The external failure costs are tests that occur when non conforming product or service reaches the customer. These costs are associated with the adjustments of malfunctions after delivery of the product, such as: repair costs, travel and lodging expenses, replacement costs, stock spare parts, lost goodwill of customer, guarantee and warranty costs and dispatchment costs.	**BL1**
18.	**What are the performance measures of TQM?** Customer orientation, value based operations, performance compatibility, teamwork, development and monitoring.	**BL1**
19.	**What is meant by process capability? (April/May 2016)** Process capability may be defined as the "minimum spread of a specific measurement variation which will include 99.7% of the measurements from the given process". Process capability=6σ. Since 99.7% area in the normal curve is between -3σ and +3σ.	**BL1**
20.	**What are the benefits of TPM? (or) List out the benefits of total productive maintenance. (April/May 2016; April/May 2017)** Increased equipment productivity, Improvement equipment reliability, Reduced equipment downtime, Increased plant capacity, Extended machine time, Lower maintenance and production costs, Approaching zero equipment-caused defects, Improved team work between operators and maintenance people, Enhanced job satisfaction, Improved return on investment, Improved safety.	**BL3**

21.	**Define process capability index. (Nov/Dec 2016)** The process capability index or process capability ratio is a statistical measure of process capability; the ability of a process to produce output within specification limits. The concept of process capability only holds meaning for processes that are in a state of statistical control. Process capability indices measure how much "natural variation" a process experiences relative to its specification limits and allows different processes to be compared with respect to how well an organization controls them.	**BL1**
22.	**Write down the various stages of FMEA. (April/May 2016; Nov/Dec 2017))** The FMEA methodology has four stages. They are: Stage1: Specifying possibilities, Stage2: Quantifying risk, Stage3: Correcting high risk causes and Stage4: Re-evaluation of risks.	**BL1**
23.	**What is house for Quality?** - The primary planning tool used in QFD is the House of Quality (HOQ). - The House of Quality converts the voice of the customer into product designcharacteristics. - QFD uses a series of matrix diagrams, also called, “quality tables” that resemblesconnected houses.	**BL1**
24.	**What are the objectives of performance measures?** - Establish Baseline measures and reveal trends - Determine which processes need to be improved - Indicate process gains and losses. - Compare goals with actual performance - Provide information for individual and team evaluation	**BL2**

	Provide information to make informed decision Determine the overall performance of the organization.	
25.	**What is a QFD? NOV/DEC 2018** Quality Function Deployment is a planning tool used to fulfill customer expectations. It is a disciplined approach to product design, engineering, and production and provides in- depth evaluation of a product. QFD may be defined as a system for translating customer requirements into appropriate requirements at every stage, from research through product design and development, to manufacture, distribution, installation and marketing, sales and service.	**BL1**
26.	**How will you Construct a house of quality? (or) QFD Methodology.** a) List customer requirements b) List technical descriptors c) Develop a relationship matrix between WHATs and HOWs d) Develop an interrelationship matrix between HOWs e) Competitive assessments f) Develop prioritized customer requirements g) Develop prioritized technical descriptors	**BL3**
27.	**List the users of QFD**. Currently many U.S. and Japan companies are using QFD. In the automobile industry, Ford, Chrysler, and General Motors are users of QFD. In the electronics field, Digital Equipment Corporation and Texas instruments havebeen QFD pioneers. Numerous other companies use QFD including : Procter & Gamble, Deere & company, The Kendall Company, Polaroid, Rockwell International, Hughes Aircraft, and Hewlett- Packard.	**BL1**

28.	**Define Taguchi method.** Taguchi methods are statistical methods developed largely by Genichi Taguchi toimprove the quality of manufactured goods.	**BL1**
29.	**Define Taguchi Loss function. NOV/DEC 2012, MAY/JUNE 2015** Taguchi defines quality as" the loss imparted by the product to society from the time theproduct is shipped. The essence of the loss function concept is that whenever a product deviates from itstarget performance, it generates a loss to society.	**BL1**
30.	**Write the formula for Taguchi's QLF.** **Taguchi's QLF:** $L(x)= k(x-N)^2$ $k= C/d^2$ Where L(x) = Loss functionk= Constant of proportionality x= Quality characteristics of selected product N= Nominal value of the chosen productC= Loss associated with the specification limit d = Deviation of the specification from the target value	**BL3**
31.	**Define maintenance.** Maintenance is defined as the management, control, execution and quality assurance of activities which ensure the achievement of optimum availability and performance of a plant in order to meet business objectives.	**BL1**
32.	**List the types of maintenance.** • Corrective or breakdown maintenance • Scheduled or routine maintenance	**BL2**

	- Preventive maintenance - Predictive maintenance	
33.	**Write down the formula of OEE (Overall Equipment Effectiveness) NOV/DEC 2011** Overall Equipment Effectiveness (OEE)= Availability * { Performance efficiency}*{Rate of Quality Products}	**BL2**
34.	**What are the objectives of quality circles? or what are the functions of quality circles? MAY/JUNE 2013, NOV/DEC 2013** **Objectives:** - To promote job involvement - To create problem solving capability. - To improve communication - To promote leadership qualities. - To promote personal development - To develop a greater awareness for cleanliness. - To develop a greater awareness for safety - To reduce errors. - To enhance quality. - To inspire more effective team work. - To build an attitude of problem prevention.	**BL3**
35	**What is quality circle? (Nov/Dec 2022)** A quality circle is a group of company employees who regularly meet to determine how to resolve problems. It aims to improve how part of the company operates, such as the production process. Members are employees who do similar or the same work. They meet periodically to identify, examine, analyze, and solve problems in the company or workplace. A quality circle is typically autonomous and small. In most cases, a senior worker or supervisor heads it.	**BL1**

PART – B		
1	**Explain control chart (or) Shewhart chart. / Explain with an example of any three control charts. (April/May 2016; Nov/Dec 2016)**	**BL2**
2	**Compare the variable charts and attribute charts.**	**BL4**
3	**Briefly outline the six sigma DMAIC process.**	**BL3**
4	**Briefly explain the steps involved in QFD. (Nov/Dec 2010; April/May 2016)**	**BL3**
5	**Explain each section of the basic structures of house of quality. (Apr/May 2010) / Explain in detail about the structure of house of quality. (April/May 2014; Nov/Dec 2016)**	**BL2**
6	**Discuss objectives of quality function deployment. (Nov/Dec 2022)**	**BL2**
7	**Highlight the benefits of QFD. (Apr /May 2010; Nov/Dec 2016) (Nov/Dec 2022)**	**BL4**
8	**Explain about Taguchi's quadratic quality loss function. How it differs from traditional approach of quality loss cost? (April/May 2013, Nov/Dec 2022)**	**BL2**
9	**(i) The Taguchi loss function for a certain component is given by L(X) = 7500 $(X\text{-}N)^2$, where X = the actual value of a critical dimension and N is its Nominal value. Company Management has decided that the maximum loss that can be accepted is Rs. 400. If the nominal dimension is 35.00 mm, find the tolerance limits.** **(ii) Explain the concept of signal to noise ratio. (Nov/Dec 2017)**	**BL5**
10	**Explain Total Productive Maintenance (TPM) with case study / What is Total Productive Maintenance (TPM)? / Discuss the concepts of TPM. (Nov/Dec 2017)**	**BL6**
PART – C		
11	**Devise a QFD methodology for design and development of cups used in vending machine for dispersing hot and cold beverages. (April/May 2016, Jan/Feb 2022)**	**BL6**

12	**Write down the objectives of implementing total productive maintenance. Discuss about the core elements of TPM program. Compare TQM and TPM. (April/May 2017; Nov/Dec 2017, Jan/Feb 2022, Nov/Dec 2022)** **(or) Explain in detail about the 8 pillars of TPM.**	**BL3**
13	**(i) List out the benefits of performance measure. (April/May 2017)** **(ii) Briefly explain the DMAIC procedure**	**BL2**
14	**Draw the quality function deployment QFD diagram for comparing an education institution in comparison with competing institution by referring various quality assessment parameters. (Jan/Feb 2022)**	**BL6**

UNIT V QUALITY MANAGEMENT SYSTEM 9

Introduction—Benefits of ISO Registration—ISO 9000 Series of Standards—Sector-Specific Standards—AS 9100, TS16949 and TL 9000-- ISO 9001 Requirements—Implementation—Documentation—Internal Audits—Registration--**ENVIRONMENTAL MANAGEMENT SYSTEM:** Introduction—ISO 14000 Series Standards—Concepts of ISO 14001—Requirements of ISO 14001—Benefits of EMS.

PART – A		
1	**What is the concept of Environment Management System (EMS)?** **What is meant by environmental policy? (Jan/Feb 2022)** 1. An EMS meeting the requirements of ISO 14001:2004 is a management tool enabling an organization of any size or type to: 2. Identify and control the environmental impact of its activities, products or services, and to 3. Improve its environmental performance continually, and to 4. Implement a systematic approach to setting environmental objectives and targets,to achieving these and to demonstrating that they have been achieved	**BL2**
2	**What are ISO 9000 quality standards?** ISO 9000 are a set of quality standards aimed at promoting the growth of international trade by facilitating harmonious interactions between suppliers and customers located in diverse locations globally. It is a quality management system [QMS] to ensure quality of products and services.	**BL1**
3	**Write about documentation pyramid.**	**BL1**

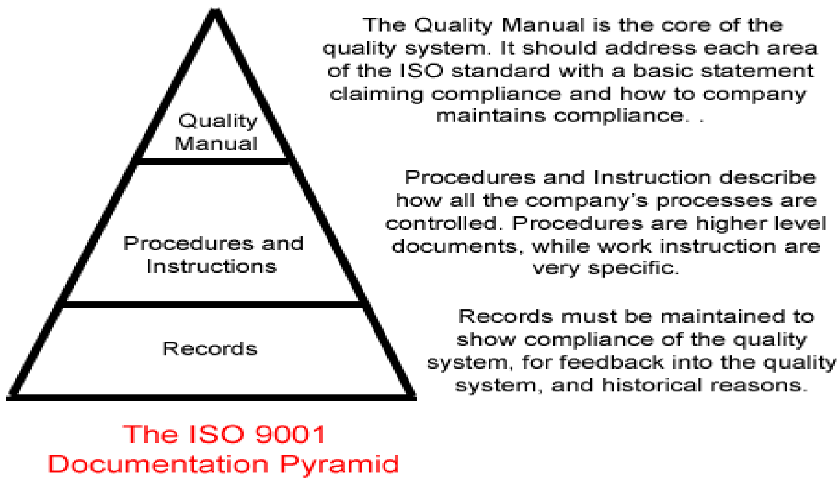
	Tier 1 - Quality manual The top tier is the quality manual, which contains: • Statements about management's commitment to quality • Quality Policies • Information about responsibilities for quality related processes • It should also contain a list of tier-2 quality documents and how to locate them. • The manual also may contain high-level information about key areas of the quality system like documentation and design control. **Tier 2 - Procedures and instructions** Tier-2 of the ISO 9001:2008 Documentation pyramid is the bulk of the quality procedures, standard operating procedures (SOPs), work instructions and explains detailed responsibilities for process control. **Tier 3 - Quality records** Tier-3 consists of quality records. Most of the quality records are generated based on tier-2 procedures. Quality records include customer specifications, order processing paperwork or records, incoming inspection records, and product test results	
4	**Define quality management systems.** Quality management systems are the organizational structures, responsibilities, processes, procedures, and resources used for implementing quality.	**BL1**
5	**What are the quality function needs served by the computer?** 1. Data collection, 2. Data analysis and reporting, 3. Statistical analysis, 4. Process control, 5. Test and inspection and 6. System design	**BL2**
6	**What are the different types of documents found in ISO 9000?** 1. Quality Policy Manual (What? Why?), 2. Quality System Procedures (Who? When? Where?), 3. Work Instructions (How?) and 4. Records, formats and forms (Evidence).	**BL3**

7	**What are the eight quality principles underlying ISO 9000:2000?** 1. Customer focus, 2. Leadership, 3. Involvement of people, 4. Process approach, 5. System approach to management, 6. Continuous improvement, 7. Decisions based on facts and 8. Mutually beneficial supplier relationships.	**BL2**
8	**Define quality system audit. (Nov/Dec 2017)** Quality system audits is a systematic, independent examination to determine whether quality activities and results comply with planned arrangements, whether these arrangements are implemented effectively, and whether these are suitable to achieve objectives.	**BL1**
9	**What are the different types of audit?** First party audit (internal), Second party audit (by customer), and Third party audit (by independent agency). Another classification: System audit, Process audit, Product audit, Adequacy audit, and Compliance audit	**BL2**
10	**What are the different stages in conducting quality audit?** 1. Audit planning – schedules, personnel, notifications, checklist. 2. Performance – opening meetings, audit process, noting of non-conformities. 3. Reporting – Observations, suggestions for corrective action 4. Follow-up – implementation of corrective action.	**BL2**
11	**Give any five elements of ISO 9000.** 1. Management responsibility, 2. Quality system, 3. Contract review, 4. Design control, 5. Document control, 6. Purchasing, 7. Purchaser supplied product, 8. Product identification and traceability, 9. Process control and 10.Inspection & testing.	**BL2**
12	**Give the objectives of internal audit.** 1. Determine the actual performance conforms to the documented quality systems. 2. Initiate corrective action activities in response to deficiencies. 3. Follow up on noncompliance items of previous audits.	**BL3**

	4. Provide continued improvement in the system through feedback to management.	
13	**What are the uses of ISO standards?** 1. Fewer on-site audit by customers, 2. Increased market share, 3. Improved quality, both internally and externally, 4. Improve product and service quality levels from suppliers, 5. Greater awareness of quality by employees, 6. A documented formal systems and 7. Reduced operating costs.	**BL3**
14	**Explain the management's responsibility for ISO.** Top management shall provide evidence of its commitment to the development and implementation of the quality management system and continually improving its effectiveness by 1. Communicating to the organization the importance of meeting customer as well as statutory and regulatory 2. Requirements, establishing the quality policy, 3. Ensuring that quality objectives are established, 4. Conducting management reviews, and 5. Ensuring the availability of resources.	**BL2**
15	**What is the need for ISO standards? (Nov/Dec 2017)** ISO 9000 is needed to unify the quality terms and definitions used by industrialized nations and use terms to demonstrate a supplier's capability of controlling its processes.	**BL2**
16	**What is third party audit?** The third party certification audit is carried out much in the same way as first party and second party quality system assessments and audits. However, the big difference is that an independent accredited auditing body carries out the assessment and audit, as opposed to carrying it out by the organization themselves. Also note that the organization going for third party audits are responsible for the payment of the third party audit process.	**BL1**

17	**What are the documentation requirements of quality management systems?** The quality management system documentation shall include: 1. Documented statements of a quality policy and quality objectives, 2. A quality manual, 3. Documented procedures and records required by this International Standard and 4. Documents, including records, determined by the organization to be necessary to ensure the effective planning, operation and control of its processes.	**BL4**
18	**What are the requirements of ISO 14001?** 1. General requirements, 2. Environmental policy, 3. Planning. 4. Implementation and operation and 5. Checking and corrective action and 6.Management review.	**BL4**
19	**What are the benefits of ISO 14001?** 1. Facilitate trade and remove trade barriers, 2. Improve environmental performance of planet earth and 3. Build consensus that there is a need for environment management and a common terminology for EMS.	**BL3**
20	**What are the general requirements of quality management system?** The organization shall establish, document, implement and maintain a quality management system and continually improve its effectiveness in accordance with the requirements of this International Standard. The organization shall (a) determine the processes needed for the quality management system and their application throughout the organization, (b) determine the sequence and interaction of these processes, (c) determine criteria and methods needed to ensure that both the operation and control of these processes are effective, (d) ensure the availability of resources and information necessary to support the operation and monitoring of these processes,	**BL4**

	(e) monitor, measure (where applicable), and analyses these processes and (f) implement actions necessary to achieve planned results and continual improvement of these processes.	
21	**What is quality manual?** The organization shall establish and maintain a quality manual that includes: 1. scope of the quality management system, including details of and justification for any exclusions, 2. The documented procedures established for the quality management system, or reference to them and 3. A description of the interaction between the processes of the quality management system.	**BL1**
22	**What are the benefits of ISO 14001?** 1. Facilitates trade and remove trade barriers, 2. Improves environmental performance of planet earth and 3. Builds consensus that there is a need for environment management and a common terminology for EMS.	**BL4**
23	**Name any two generic ISO standards. Why it is called generic standards? (Nov/Dec 2016)** ISO 9001 and ISO 14001 are generic standards. Generic means that the same standards can be applied: 1. To any organization, large or small, whatever its product or service, 2. In any sector of activity, and 3. Whether it is a business enterprise, a public administration, or a government department.	**BL2**
24	**Draw the documentation pyramid. (Nov/Dec 2011)**	**BL4**

		
25	**List down the main elements of ISO 14000. (April/May 2016)** 1. Environmental policy, 2. Environmental aspects, 3. Legal and other requirements, 4. Objectives and targets Environmental management program Structure and responsibility, 5. Training awareness and competence, 6. Communication, 7. EMS documentation, 8. Document control, 9. Operational control Emergency preparedness and response, 10. Monitoring and measurement and 11. Non-conformances and corrective and preventive.	**BL2**
26	**Write down the benefits of ISO 9000 certification. (April/May 2016)** Increased marketability, Reduced operational expenses, Better management control, Increased customer satisfaction, Improved internal communication, Improved customer service, Reduction of product-liability risks and Attractiveness to investors.	**BL4**
27	**What are the core elements of QMS? (Nov/Dec 2016) (Nov/Dec 2022)** 1. Quality Policy with quality objectives and KPIs 2. Quality Manual detailing management responsibilities, organizational chart, description of the company and what it does 3. Procedures – overview of specific parts of Nemesis Now operations – e.g. warehousing, sales etc. Should also include procedure for Non-conformities, corrective actions and preventive actions, and control of documents and	**BL2**

	records 4. Work instructions – detailed description of specific operations, such as completing a quote, invoicing, sales appointment etc. 5. Internal audit – periodic review of the Quality Management System and how it is being implemented, including a review of non-conformities 6. Management review – a review by senior management of the internal audit results and other quality data, including whether the KPIs have been achieved and any tends in data	
28	**What are the important requirements of QS9000? (April/May 2017)** 1. Quality systems assessment guide, 2. Advanced product quality planning and control plan reference manual, 3. Production part approval process manual, 4. Measurement system analysis reference manual and 5. Fundamental statistical process control reference manual.	**BL4**
29	**Mention the different types of quality audits. (April/May 2017)** Quality auditing is done by both internal and external bodies. Based on the type of auditor, it is classified as: 1. First party audit, 2. Second party audit and 3. Third party audit It is also classified based on the area of coverage as: 1. System audit, 2. Process audit and 3. Product audit.	**BL2**
30	**Give the ISO 9000 Series of Standards?** ISO 9000, "Quality Management and Quality Assurance Standards Guidelines for Selection and Use". ISO 9001, "Quality Systems - Model for Quality Assurance in Design, Development, Production, Installation & Servicing". ISO 9002, "Quality Systems - "Model for Quality Assurance in Production, Installation & Servicing". ISO 9003, "Quality Systems - "Model for Quality Assurance in Final Inspection and Test". ISO 9004-1, "Quality Management and Quality System Elements -	**BL2**

	Guidelines”.	
31	**What is the objective of QS 9000?** To develop fundamental quality systems based on continuous improvement, direct prevention, reduction of variation and waste elimination in the automobiles supply chain.	**BL2**
32	**Differentiate between ISO 9000 and QS 9000.(Nov/Dec 2012)** **ISO 9000** has become an international reference for quality management requirements are being achieved in the delivered product. **QS 9000** is set of quality system requirements to help automotive suppliers to ensurethat they are meeting/exceeding customer requirement.	**BL4**
33	**Compare QS 9000 with TS 16949 quality system** • Both are related to automotive quality system standards, now QS 9000 is beingreplaced by ISO /TS 16949 standards. • QS 9000 is basically product approach whereas TS 16949 is a processapproach. • The other difference between QS 9000 and ISO/TS 16949 relate to the aspectsof customer satisfaction and employee motivation • TS 16949 is much less focus on documentation and more focus on how thesystem is performing in achieving customer satisfaction	**BL4**
34	**What does it mean to be AS9100 certified?** AS9100 Certification Definition. AS9100 is a company level certification based on a standard published by the Society of Automotive Engineers (SAE) titled "Quality Systems-Aerospace Model for Quality Assurance in Design, Development, Production, Installation and Servicing".	**BL1**
35	**Define TL 9000.** TL 9000 is a quality management practice designed by the QuEST Forum in 1998. It was created to focus on supply chain directives throughout	**BL1**

	the international telecommunications industry, including the USA.	
36	**What are the organizations are present to maintain and inspection of EMS.(Jan/Feb 2022)** **Organization standard** (i) Environmental Management system, (ii) Environmental Auditing (EA) and (iii) Environmental Performance Evaluation (EPE) **Product standard** (i) Environmental Aspects in product Standards(EAPS), (ii) Environmental Labels and Declaration(ELD),and (iii) Life Cycle Assessment(LCA)	**BL1**
37	**What are the benefits of ISO registration? (Nov/Dec2022)** Meet customer requirements as committed 1. Improve firm and product quality 2. Increased customer satisfaction 3. More clients and more revenue 4. Become a multinational company with global acceptance to do business 5. Consumers can have confidence that the products are reliable and of good quality 6. International Standards (ISOs) ensure safety and quality, showing consumers that businesses they buy from are operating in a safe way, producing reliable goods without unduly harming the environment. 7. One of the main benefits of ISO standards is that it prepares organizations in advance to deal with risks and turn them into opportunities	**BL4**
PART – B		
1	**Explain documentation in quality standard.**	**BL2**
2	**Explain the requirements of ISO system to documentation. (April/May 2016)**	**BL4**
3	**Explain quality audits in detail. (Nov/Dec 2011)**	**BL2**
4	**List and explain the elements of ISO 9000 quality system. (April/May 2013; April/May 2014) (Nov/Dec 2022)**	**BL3**

5	**Discuss about implementation of ISO 9001. (Nov/Dec 2016)**	**BL5**
6	**Discuss the benefits of ISO 9000 certification. (April/May 2013)**	**BL5**
7	**Explain various divisions of ISO 14000 Standards. (Nov/Dec 2016).**	**BL2**
8	**Explain the major elements of environmental management system. (April/May 2014) (Nov/Dec 2022)**	**BL2**
9	**Explain the benefits of EMS. (Nov/Dec 2011)**	**BL2**
10	**Explain ISO 14000 standards and list the benefits. / What are the requirements, objectives and benefits of ISO 14000 system? (April/May 2016; Nov/Dec 2017, Jan/Feb 2022)**	**BL4**
11	**Discuss the implementation of AS 9100.**	**BL5**
12	**Discuss the implementation of TQM with a case study from the manufacturing industry. (Nov/Dec 2011) (Apr/May 2019, Jan/Feb 2022)**	**BL6**
PART – C		
11	**Discuss the need for standardization procedures for quality assurance. (April/May 2016)**	**BL5**
12	**Enumerate the various aspects of ISO 14000 environmental management system. Brief the various principles of ISO 14000 series. (April/May 2017)**	**BL5**
13	**Illustrate the detailed procedure for quality auditing. Brief the attributes of a good auditor. (April/May 2017)**	**BL5**
14	**Explain how each element of TQM contributes to products and services of superior quality. (Nov/Dec 2017)**	**BL2**