MODULE:3
ENGINEERING AS SOCIAL EXPERIMENTATION

Engineering as Experimentation – Engineers as responsible Experimenters- Codes of Ethics- Plagiarism- A balanced outlook on law - Challenges case study- Bhopal Gas tragedy

Although the launching of **maiden voyage of Titanic in 1912** was regarded as the most wonderful engineering achievement, the most pathetic and tragic accident of **Titanic** claiming the lives of 1500 people on board, could reflect the technical flaws and lack of far-sighted safety measures. Technological advancements are to be thoroughly scrutinised and potentially assessed in terms of certain massive failures in technical design systems that have resulted in some horrifying historical incidents like Bhopal gas tragedy in India and Chernobyl nuclear plant at Ukraine (then USSR).

It is a justifiable statement that engineering system involves **typical experimental applications,** with a unique combination of ethical moral values. Positive features of engineering technology in terms of its huge contributions and beneficial applications for human society, clearly **outweigh** its negative features in terms of wrongful and harmful applications. The experimental procedures of engineering technology produce a direct influence on **"social and cultural systems of human society".**

Engineering itself is based on the improvement of current life, whether in terms of technology or efficiency or availability with less financial efforts. The process of engineering lets you go through a series of different experiments when it comes to practical use. Though it is not like an experiment in laboratory under controlled conditions, which is done while learning, an engineer should be ready to do the same on a social scale involving human subjects.

Experimentation is the main aspect of designing process. An engineer who is ought to design the parts of a car, will be able to understand the result only when it is tested practically. Preliminary simulations are conducted from time to time to know how the new concept of engineering acts in its first rough design. Materials and processes are tried out, usually employing formal experimental techniques. Such tests serve as a basis, which help in developing the final product.

ENGINEERING AS EXPERIMENTATION

Before manufacturing a product or providing a project, we make several assumptions and trials, design and redesign and test several times till the product is observed to be functioning satisfactorily. We try different materials and experiments. From the test data obtained we make detailed design and retests. **The design processing** which constitutes the vital component of engineering technology is the dynamic outcome of several experimental procedures called **experimentation.** These experimental techniques involve various sequential stages of testing that lead to the formation of specific products. The designed production are further evaluated by subjecting them to final phase of testing processes for their viable standards.

Thus, design as well as engineering is an interactive process as illustrated in Fig.given below.

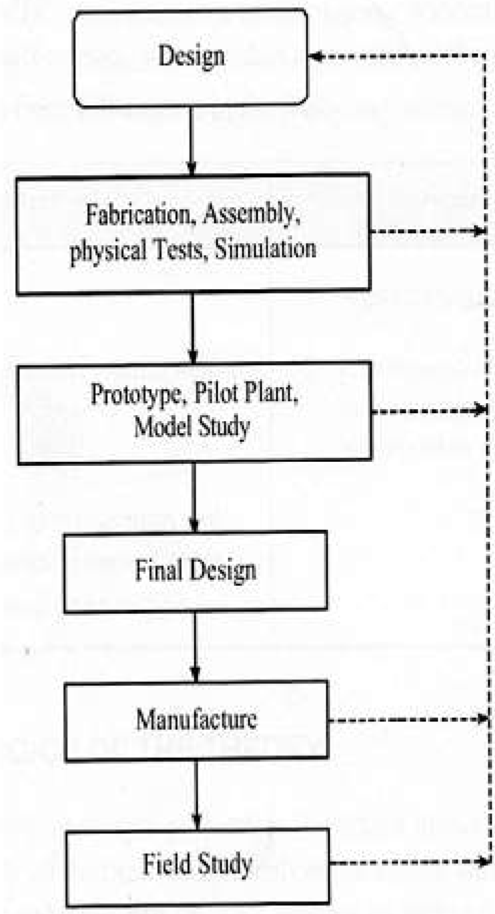

Fig.1Design as an interactive process

Compare & Contrast engineering experiments with standard experiments.(8)

ENGINEERING PROJECTS VS. STANDARD EXPERIMENTS

Similarities to Standard Experiments

There are so many aspects, which are of virtual for combining every type of engineering works to make it suitable 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 uncertainties 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 uncertainties 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, environmentalimpactanditsvaluethatdependsupontheutilitytothesociety should also be monitored. It also extends to the stage of client use.

Comparisons with standard Experiments

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 specialexperimentaltreatment.Thegroup„B"donotreceivethesamethoughthey 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.

Explain informed consent? (7)

2. Informed Consent

Engineeringiscloselyrelatedtothemedicaltestingofnewdrugsandtechniqueson human beings as it also concerned with human beings.

When new medicines have been tested, it should be informed to the persons whoundergothetest.Theyhavemoralandlegalrightstoknowaboutthefactwhich 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 m e d i c i n e , 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.

List the essential conditions for a valid informed consent.(7)

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 b y 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. Meanwhile, the unexpected outcomes put us search for new knowledge.

Evaluate how an engineer can be a responsible experimenter. (7)

ENGINEERS AS RESPONSIBLE EXPERIMENTERS)

Engineers as Experimenters

An overall analysis has to be made about the **bounden responsibilities** of professional engineers to society. Engineers, who are considered to be the **'technical contributors',** owe their responsibilities and commitments to managements and the public society. Engineers are credited with the responsible duties to make the clients and public to be conscious about the problems and risks that are involved in the projects undertaken by them. In the process of developing a product, an engineer generally learns through experimentation. To simply put, a trial and error method is the mostly used one to obtain results, but that goes with some calculations. Hence, we can say that, primarily any experiment is carried out with partial ignorance. Even the outcomes of the experiments may not be as expected. An engineer should always be ready for the unexpected output. The improvement of current prototype will lead to some change which may or may not be fruitful.

Why engineers are called responsible experimenters? (7)

If at all, engineers could be regarded as 'responsible persons', it is better to highlight their characteristic features in the following:

1. Engineers have the moral obligation to provide protection to the continued safety of human subjects thereby respecting their sentiments and right of consent.

2. They have total awareness of the experimental nature of the projects and are capable to foreseeing any future side effects and risks. They have their own capabilities of rectifying defects through their far-sighted planning strategies.
3. They are personally motivated to have a dedicated involvement in all aspects of a project.
4. They have the flexible tendency to become accountable for all the outcome of result of a project.
5. Exhibiting their technical competence and other characteristics of professionalism.

The above-mentioned features exhibit professional competence of engineers and firmly emphasize the **'specific style** of engineering procession.

Define Conscientiousness. (3)

CONSCIENTIOUSNESS

The term conscientiousness strictly means **awareness which warrants an individual to examine and approach the social problems in an open-minded and fair manner.** It is admissible in true sense that working atmosphere of engineers sometimes restricts their moral implications and commitments.

Conscientious moral commitment means:

(*a*) Being sensitive to full range of moral values and responsibilities relevant to the prevailing situation and

(*b*) the willingness to develop the skill and put efforts needed to reach the best balance possible among those considerations. In short, engineers must possess open eyes, open ears, and an open mind (i.e., moral vision, moral listening, and moral reasoning).This makes the engineers as social experimenters, respect foremost the safety and health of the affected, while they seek to enrich their knowledge, rush for the profit, follow the rules, or care for only the beneficiary. The human rights of the participant should be protected through voluntary and informed consent.

As already pointed out, most of engineers who are the **'salaried employees'** are subjected to varieties of professional and non-professional pressures within their bureaucrat systems. Social commitments, compulsion for livelihood and family commitments are the crucial factors which would prevail upon the employees to become obliged to their employers. Avoidance of certain negative qualities such as **misinterpretation of scientific or engineering data, violation of patent**

rights and breaching of trustworthiness would lead to the fulfilment of moral aspirations by engineers.

Define Informed Consent. (3)

INFORMED CONSENT

As a responsible engineer, one should be informed of the facts so as to be conscious. Theengineeredproductsofthecompanyshouldbeinsuchawaythattheycannever be used to perform any illegal or unsocial activities, which causesdestruction.Itistobeobservedthatifacompanyproducessomeproductsthatareoutoffashion or the items which promote wastage of energy and do not fetch in benefits, such things are to be well explained to the employer and alternative solutions should also be suggested by the engineers.

Define Moral Autonomy. (3)

MORAL AUTONOMY

Any person can be morally autonomous only when one is being genuine in one's commitment towards moral values. Moral beliefs and attitudes must be integrated into an individual's personality which leads to a committed action. The responsibility to answer an unexpected result influences an engineer to involve himself personally into the work. This leads to moral autonomy wherein, he also gains the trust of the employer, through his commitment. Such responsible actions lead to great outcomes.

Explain the importance of accountability in professional life? (7)

ACCOUNTABILITY

Accountability can be understood as the moral responsibility that we have towards our actions. It means a tendency to be willing to openly accept the moral examinations towards one's actions and being responsive to the assessment of others. The gap between casual responsibility and moral accountability is common in any profession, along with engineering.

Let us now consider the following instances to understand accountability −

- When a group of persons are involved in the completion of a project, then the accountability refers to the group minimizing the chances of acceptance of moral responsibility towards a specificaction, where each person makes only a small contribution to something much larger.

- The accountability is diffused within the organization and one has to accept it. Both credit and failure need to be considered for accountability where the workisdiffusedandtheareasofpersonalaccountabilityaredelimitedwithin the organization.
- At times, when the engineers are pressurized to move to another project while the current is still underway, then the accountability is limited only for meeting schedules.
- There is always amoral involvement beyond the laid down institutional role, where the engineers cannot separate themselves from personal responsibilities of their work.

Define Code of Ethics. (3)

Explain the role of code of ethics in the service life of a professional? (7)

Examine its merits & demerits. (7)

CODES OF ETHICS

The engineers who are represented as professionals, and who belong to a professional society need to have some moral responsibilities. A code of conduct is important for engineers to remain committed to their world. The engineering societies such as **AAES, ABET, NSPE, IEEE** and **AICTE** have framed these codes of ethics which are helpful to engineers to strengthen the moral issues on their work. The codes of ethics play at least eight important roles such as the following:

The 'codes of ethics' exhibit, rights, duties, and obligations of the members of a profession and a professional society. The codes exhibit the following essential roles:

1. *Inspiration and guidance*: The codes express the collective commitment of the profession to ethical conduct and public good and thus inspire the individuals. They identify primary responsibilities and provide statements and guidelines on interpretations for the professionals and the professional societies.

2. *Support to engineers*: The codes give positive support to professionals for taking stands on moral issues. Further they serve as potential legal support to discharge professional obligations.

3. *Deterrence (discourage to act immorally)* and discipline (regulate to act morally):The codes serve as the basis for investigating unethical actions. The professional societies sometimes revoke membership or suspend/expel the members, when proved to have acted unethical. This sanction along with loss of respect from the colleagues and the society are bound to act as deterrent.

4. *Education and mutual understanding*: Codes are used to prompt discussion and reflection on moral issues. They develop a shared understanding by the professionals, public, and the government on the moral responsibilities of the engineers. The Board of Review of the professional societies *encourages moral discussion for educational purposes*.

5. *Create good public image:* The codes present positive image of the committed profession to the public, help the engineers to serve the public effectively. They promote more of self- regulation and lessen the government regulations. This is bound to raise the reputation of the profession and the organization, in establishing the trust of the public.

6. *Protect the status quo*:They create minimum level of ethical conduct and promotes agreement within the profession. Primary obligation namely the safety, health, and welfare of the public, declared by the codes serves and protects the public.

7. *Promotes business interests*: The codes offer inspiration to the entrepreneurs, establish shared standards, healthy competition, and maximize profit to investors, employees, and consumers.

The engineering societies have developed two types of codes of ethics with different approaches. They are IEEE **code and** NSPE **code.** Both these codes differ in unique respects. While, IEEE code **(Institute of Electrical and Electronics Engineers)** deals with simple and generalized features in a crisp manner. Whereas, **NSPE Code** provides much more detailed aspects. The NSPE code which is a longer version than IEEE code, covers more useful applications with a wide range of explanations for the use of engineers.

Apart from this, societies such as **American society of civil Engineers** (ASCE) **and American society of Mechanical Engineers** (ASME) have also contributed their shares in emphasizing the concepts of code of ethics. Similarly, several multinational companies in USA such as **Bechtel, Hughes Aircrafts, McDonnell Douglas and Texas Instruments** have also formulated their own codes of ethics for their employees and technically graded engineers.

Advantages of Codes of Ethics

Let us now see the following advantages of codes of ethics. The codes

- Set out the ideals and responsibilities of the profession.

- Exert a **de facto** regulatory effect protecting both clients and professionals.
- Improve the profile of the profession.
- Motivate and inspire practitioners, by attempting to define their priority.
- Provide guidance on acceptable conduct.
- Raise awareness and consciousness of issues.
- Improve quality and consistency.

Limitations: The codes are not remedy for all evils. They have many limitations, namely:

1. General and vague wordings: Many statements are general in nature and hence unable to solve all problems.

2. Not applicable to all situations: Codes are not sacred, and need not be accepted without criticism. Tolerance for criticisms of the codes themselves should be allowed.

3. Often have internal conflicts: Many times, the priorities are clearly spelt out, e.g., codes forbid public remarks critical of colleagues (engineers), but they actually discovered a major bribery, which might have caused a huge loss to the exchequer.

4. They cannot be treated as final moral authority for professional conduct: Codes have flaws by commission and omission. There are still some grey areas undefined by codes. They cannot be equated to laws. After all, even laws have loopholes and they invoke creativity in the legal practitioners.

5. Limited members: Only a few enroll as members in professional society and non-members cannot be compelled.

6. *Even as members of the professional society, many are unaware of the codes.*

7. Different societies have different codes: The codes cannot be uniform or same! Unifying the codes may not necessarily solve the problems prevailing various professions, but attempts are still made towards these unified codes.

8. Codes are said to be coercive: They are sometimes claimed to be threatening and forceful.

PLAGIARISM

Define Plagiarism. (3)

Plagiarism is defined in multiple ways in higher education institutions and universities. For example:

- Stanford sees plagiarism as the "use, without giving reasonable and appropriate credit to or acknowledging the author or source, of another person's original work, whether such work is made up of code, formulas, ideas, language, research, strategies, writing or other form."
- Yale views plagiarism as the "use of another's work, words, or ideas without attribution" which includes "using a source's language without quoting, using information from a source without attribution, and paraphrasing a source in a form that stays too close to the original."
- Princeton perceives plagiarism as the "deliberate" use of "someone else's language, ideas, or other original (not common-knowledge) material without acknowledging its source."
- Oxford characterizes plagiarism as the use of "a writer's ideas or phraseology without giving due credit."
- Brown defines plagiarism to be "appropriating another person's ideas or words (spoken or written) without attributing those word or ideas to their true source".

Avoid Plagiarism

North western's "Principles Regarding Academic Integrity" defines plagiarism as "submitting material that in part or whole is not entirely one's own work without attributing those same portions to their correct source." Plagiarism can occur in many forms besides writing: art, music, computer code, mathematics, and scientific work can also be plagiarized. This document pays special attention to plagiarism in writing, but it is important to understand that unauthorized collaboration in a math or science assignment is also plagiarism.

In all academic work, and especially when writing papers, we are building upon the insights and words of others. A conscientious writer always distinguishes clearlybetweenwhathasbeenlearnedfromothersandwhatheorsheispersonally contributing to the reader's understanding. To avoid plagiarism, it is important to understand how to attribute words and ideas you use to their proper source.

Guidelines for Proper Attribution

Everyone in the university needs to pay attention to the issue of proper attribution. All of us--faculty and students together--draw from a vast pool of texts, ideas, and findings that humans have accumulated over thousands of years; we could not thinktoanyproductiveendwithoutit.Eventhesuddeninsightsthatappearatfirst glance to arrive out of nowhere come enmeshed in other people's thinking. What we call originality is actually the innovative combining, amending, or extending of material from that pool.

Hence each of us must learn how to declare intellectual debts. Proper attribution acknowledges those debts responsibly, usefully, and respectfully. An attribution is responsible when it comes at a location and in a fashion that leaves readers in no doubt about whom you are thanking for what. It is useful when it enables readers to find your source readily for themselves. You help them along the way, just as that same source helped you along yours. To make sure that our attributions are useful, we double-check them whenever we can. Quite literally, it is a habit that pays. Colleagues in every field appreciate the extra care. Nothing stalls a career faster than sloppy, unreliable work.

Finally, an attribution is respectful when it expresses our appreciation for something done well enough to warrant our borrowing it. We should take pride in the intellectual company we keep. It speaks well of us that we have chosen to use the work of intelligent, interesting people, and we can take genuine pleasure in joining our name with theirs.

Explain the term balanced outlook on law. (3)

A BALANCED OUTLOOK ON LAW

The 'balanced outlook on law' in engineering practice stresses the necessity of laws and regulations and also their limitations in directing and controlling the engineering practice. Laws are necessary because, people are not fully responsible by themselves and because of the competitive nature of the free enterprise, which does not encourage moral initiatives. Laws are needed to provide a minimum level of compliance. The necessity of laws and regulations and the limitations they have in engineering practice can be understood with an overview of the laws in the Engineering profession. To live in harmony in the society, one should learn to maintain a balance between individual needs and collective needs of the society. The following codes are typical examples of how they were enforced in the past:

Explain the Babylon's Building code and The United States Steamboat Code. (14)

I. CODE FOR BUILDERS BY HAMMURABI

Hammurabi the king of Babylon in 1758 framed the following code for the builders:

"If a builder has built a house for a man and has not made his work sound and the house which he has built has fallen down and caused the death of the householder, that builder shall be put to death. If it causes the death of the householder's son, they shall put that builder's son to death. If it causes the death of the householder's slave, he shall give slave for 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 sound condition at his own cost "This code was expected to put in self-regulation seriously in those years.

II. STEAM BOAT CODE IN USA

Whenever there is crisis we claim that there ought to be law to control this. Whenever there is a fire accident in a factory or fire cracker's store house or boat capsize we make this claim, and soon forget. Laws are meant to be interpreted for minimal compliance. On the other hand, laws when amended or updated continuously would be counterproductive. Laws will always lag behind the technological development. The regulatory or inspection agencies such as Environmental authority of India can play a major role by framing rules and enforcing compliance. In the early 19th century, a law was passed in USA to provide for inspection of the safety of boilers and engines in ships. It was amended many times and now the standards formulated by the American Society of Mechanical Engineers are followed.

A few independent organisations such as **Food and Drug Administration** (FDA), **Federal Aviation Agency** (FAA) and **the Environmental Protection Agency** (EPA) came into existence in USA for monitoring an over-all control on varieties of industries. Industries seriously complained about the severe restrictions imposed by regulatory agencies. One should be aware of the fact that the valid reasons for the enforcement of these strict and stringent laws were due to the lacunae in the regulative laws.

PROPER ROLE OF LAW IN ENGINEERING

Good laws when enforced effectively produce benefits. They establish minimal standards of professional conduct and provide a motivation to people. Further they serve as moral support and defense for the people who are willing to act ethically.

Thus, it is concluded that:

1. The rules which govern engineering practice should be construed as of responsible Experimentation rather than rules of a game. This makes the engineer responsible for the safe conduct of the experiment.
2. Precise rules and sanctions are suitable in case of ethical misconduct that involves the violation of established engineering procedures, which are aimed at the safety and the welfare of the public.
3. In situations where the experimentation is large and time consuming, the rules must not try to cover all possible outcomes, and they should not compel the engineers to follow rigid courses of action.
4. The regulation should be broad, but make engineers accountable for their decisions, and
5. Through their professional societies, the engineers can facilitate framing the rules, amend wherever necessary, and enforce them, but without giving-in for conflicts of interest.

THE CHALLENGER CASE STUDY

List a few factual issues, conceptual issues, and moral/normative issues in the space shuttle challenger issue.(14)

The world has known about much number of accidents. Among them, the explosion of the space shuttle **Challenger** is one of the most familiar ones. Back then, 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. A few questions are listed below −

- What is the exact role of the engineer when safety issues are concerned?
- Who should have the ultimate authority for decision making to order for a launch?
- Whether the ordering of a launch is engineering or a managerial decision?

Challenger space shuttle mainly consisted of an orbiter, two solid propellant boosters and a single liquid-propeller booster, which was actually designed to be a reusable one. All the boosters were ignited and the orbiter took a lift-off from the earth. But the cold temperature caused trouble to the O-rings which were eroded. 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, whose function is to prevent the combustion gases of the solid propellant from escaping. The O-rings were eroded by hot gases, as these were made up of synthetic rubber. 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 restrained from completely burning out then the design of the joint would be acceptable.

In the post flight experiment in 1985, the Thiokol engineers noticed black soot and grease on the outside of the boosters due to the leakage 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.Butunfortunatelythisnewdesignwasnotreadybythattimeofflightin1986.

DELAY IN LAUNCH

The political conditions under which NASA operated is the main cause for unavoidable delay in the decision to be taken for the shuttle performance. The launching date had already been postponed for the availability of the then Vice President George Bush, the space NASA supporter. Later, the launch further got delayedduetoaprobleminmicroswitchinthehatch-lockingmechanism.Thecold weather problem and long discussions went on among the engineers. The number of tele-conferences further delayed the previous testing in 1985itself.

The O-rings required temperature bearings of 53°F whereas the challenger had temperature bearings of only 29°F, which was far below the environment temperature at which NASA had the previous trail. This might not be matter of concern, as the revised final decision made with the available data then, was that there was 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.

UNEXPECTED CHANGE

But unexpectedly the overnight temperature at the time of launch was 8°F colder than ever experienced. It was estimated that the temperature of the right hand boosterwouldbeonlyat28°F.Thecameranoticedapuffofsmokecomingoutfrom 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.

Thoughimmediatelyfurthersealingwasmadebytheby-productsofcombustionin 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 stressescausedbythewind.Againthejointswereopenedandthehotgasesescaped 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 the **Rogers Commission** which constituted of 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.

After the hearings of the commission, Thiokol engineers and NASA investigated possible causes of the explosion, which led to a lot of arguments among the other officials that this investigating team is trying to look for other causes, which are not at all plausible. However, the debacle highlights how lack of responsibility and morality, improper functions, and lax performance of duties of the engineers resulted in the failure of the launch.

Some of the factual issues, conceptual issues and moral/normative issues in the space shuttle challenger incident are highlighted hereunder for further study.

MORAL/NORMATIVE ISSUES

1. The crew had no escape mechanism. Douglas, the engineer, designed an abort module to allow the separation of the orbiter, triggered by a field-joint leak. But such a 'safe exit' was rejected as too expensive, and because of an accompanying reduction in payload.
2. The crew were not informed of the problems existing in the field joints. The principle of informed consent was not followed.
3. Engineers gave warning signals on safety. But the management group prevailed over and ignored the warning.

CONCEPTUAL ISSUES

1. NASA counted that the probability of failure of the craft was one in one lakh launches. But it was expected that only the 100000th launch will fail.
2. There were 700 criticality-1 items, which included the field joints. A failure in any one of them would have caused the tragedy. No back-up or stand-bye had been provided for thesecriticality-1 components.

FACTUAL/DESCRIPTIVE ISSUES

1. Field joints gave way in earlier flights. But the authorities felt the risk is not high.
2. NASA has disregarded warnings about the bad weather, at the time of launch, because they wanted to complete the project, prove their supremacy, get the funding from Government continued and get an applaud from the President of USA.
3. The inability of the Rockwell Engineers (manufacturer) to prove that the lift-off was unsafe. This was interpreted by the NASA, as an approval by Rockwell to launch.

BHOPAL GAS TRAGEDY

List a few factual issues, conceptual issues, and moral/normative issues in the Bhopal Gas Tragedy.(14)

Bhopal's Gas tragedy is the world's worst industrial disaster that occurred in 1984, due to the gas leakage from a pesticide production plant, The **Union Carbide India Limited (UCIL)** located in **Bhopal**, Madhya Pradesh. It was believed that's lack management and deferred maintenance together created a situation where routine pipe maintenance caused a backflow of water into the MIC tank, triggering the disaster.

It is a catastrophe that has no parallel in industrial history. In the early morning hours of December 3, 1984 a rolling wind carried a poisonous grey cloud past the walk of the 'Union Carbide Plant 'at Bhopal, India. Union Carbide's pesticide- manufacturing plant in Bhopal, leaked 42 tons of the deadly gas **Methyl Isocyanate (MIC)** into a sleeping, impoverished community - killing 3000, injuring 200,000 people.

WHAT LED TO THE DISASTER?

In the early hours of December 3rd, 1984, a rolling wind carried a poisonous gray cloud from the Union Carbide Plant in Bhopal, Madhya Pradesh of India. The poisonous gas released was 40tons of **MethylIsoCyanate (MIC)**.This particular gas is very toxic that leaked and spread throughout the city. The residents of the city, woke up to the clouds of suffocating gas and struggled to breath. They started running desperately through the dark streets. The victims arrived at hospitals, breathless and blind. The people who survived had their lungs, brain, eyes, muscles affected severely. Their gastro intestinal system, neurological, reproductive and immune systems were also dangerously affected. By the morning, when the sun rose clearly, the roads were all filled with dead bodies of humans and animals, the trees turned black and the air filled with foul smell.

- 1. The plant was established in 1969 in which Union Carbide Corp. shares 51% and remaining by state authority. A chemical called Methyl Isocynate (MIC) was used as raw material to produce pesticide hence factory stored a large amount of MIC.

- 2. On the faithful night of 2nd December, 1984 a regular maintenance activity was under progress. During pipeline washing workers observed a leak and little attention was given with casual remedial actions. But leak continued and pressure in one of the MIC tanks increased beyond acceptance limit.

- 3. Due to water leak in tank lead by exothermic reaction, concrete tank cracked and relief valve of plant gave away large amount of MIC in the atmosphere.

4. Now the workers understood the scale of disaster and hence tried at their level best to activate safety system present in factory. But none of the safety system was in working condition. By that time workers felt that nothing can stop this disaster.

5. As on the three sides of the plant people used to live in slums and hence people living in this area were the worst sufferers. Due to delayed use of warning and alarming system, most of the people left unwarned. As an effect of MIC gas leakage people started suffering through suffocation, vomiting and other health problems. On the same night around 3000 people died and another 8000 people died within week and yet another 15000-20000 people died over a period of time. Still a half a million people directly or indirectly affected due to poisonous gas.

Investigations into the tragedy show that there were many shortcomings on all levels, which are listed as below

- 1. Union Carbide Factory did not have much information about safe storage of these highly toxic gases.
- 2. The Medical fraternity did not have the requisite about how to deal with contamination of this level.
- 3. The lack of co-ordination between factory and emergency services.
- 4. Lack of trained personnel in the factory along with impact of cost cutting on safety of plant, its employees and the people living around the plant.
- 5. Location of factory in dense populated area which is against many norms.
- 6. Negligence to similar events reported by workers such as leak of Phosgene on 25th December, 1981; another leak on 9th January 1982 from higher authority.

CASUAL FACTORS

- Three protective systems out of service.

- Plant was understaffed due to costs.
- Very high inventory of MIC, an extremely toxic material.
- The accident occurred in the early morning.
- Most of the people killed, lived in a shanty town located very close to the plant fence.

This gruesome tragedy has greatly exposed the serious lacunae and lapses in the safety measures taken by union carbide in the manufacturing of harmful and toxic insecticides or pesticides. The drastic failures in fixing the moral responsibilities for this tragedy have strongly focussed on the role of ethical values and applications to be framed by the multinational companies across the entire world, not only for the prevention of environmental degradation but also to protect human life.

THE FATAL EFFECTS

- As per government's announcement, a total of **3,787** deaths occurred immediately. Around **8,000** of the survivors died within two weeks and other **8,000 or more** died from acute diseases caused due to the gas later.
- A government affidavit in 2006 stated that the gas leak incident caused **5, 58,125**injuries, including **38,478** temporary partial injuries and approximately **3,900** severely and permanently disabling injuries. None can say if future generations will not be affected.
- Initial effects of exposure were −
- Coughing, Severe eye irritation, Feeling of suffocation, Burning sensation in the respiratory tract, Blepharospasm, Breathlessness, Stomach pains, Vomiting
- The staff at the nearby hospitals lacked the knowhow required to treat the casualties in such situations. To add to this, there is no antidote known for **MIC**. Hence, even after running to the hospitals, the survivors could not be cured and most of them had to face death eventually. Primary causes of deaths were – Choking, Reflexogenic Circulatory Collapse, Pulmonary Edema, Cerebral Edema, Tubular Necrosis, Fatty Degeneration of the Liver, Necrotizing Enteritis

- As an after effect of this disaster, the rate of stillbirths increased by 300% and the neonatal mortality rate by around 200%. This came to be known as the world's worst disaster in the industrial sector. Since the disaster, India has experienced rapid industrialization. While some positive changes in government policy and behavior of a few industries have taken place such as The Environment Protection Act was passed in 1986, creation the Ministry of Environment and Forests (MoEF) and strengthening India's commitment to the environment. It established the importance of integrating environmental strategies into all industrial development plans for the country.

QUESTIONS

Part-A
(3 –Mark Questions)

1. Engineering as experimentation: - Discuss.
2. What is sustained monitoring in engineering experimentation?
3. What is informed consent in social experimentation?
4. What are the essential conditions in valid consent?
5. Engineers as responsible Experimenters: - Discuss
6. Give a brief account of learning from the past mentioning two examples.
7. What do you mean by experimental control?
8. What are the characteristic features of Engineers as a responsible person?
9. Define the term "conscientiousness".
10. What is moral autonomy?
11. An Engineer requires moral justification and satisfaction- Discuss.
12. Write the salient features of accountability.
13. What are the functions of code of ethics?
14. Distinguish between code of ethics and code of conduct.
15. Explain how the codes of ethics inspire and guide the Engineers.
16. Use of ethical codes in an educational institution:-Discuss:
17. What are the Limitations of code of ethics?
18. Codes cannot serve as final authority: - Discuss.

19. What is ‘balanced outlook on law’ stress in engineering practice?
20. What is said to be a 'regulated society'?
21. What do you mean by industrial standards?
22. What are the objectives and functional roles of standards?
23. Problems with law in engineering: - Discuss.
24. Explain how good laws and ethical conduct act as a protector of ethical engineer.
25. Discuss: Challenger case study.
26. What was the technical failure in challenger case?
27. What is meant by ‘informed consent’ when bringing an engineering product to market?
28. List a few factual issues, conceptual issues, and moral/normative issues in the space shuttle challenger issue.

PART-B

ESSAY (14 Marks)

1. "Engineering as experimentation plays an important role in the design process". Discuss this statement.
2. Discuss briefly about the various aspects of engineers as responsible experimenters.
3. Briefly explain the moral autonomy of engineers.
4. Compare the engineering experiments with standard experiments.
5. Write a brief account on the internal infrastructure of space shuttle challenger, with a suitable diagram on the field joints.
6. Write a brief note on the various aspects of safety issues in the challenger case.
7. Briefly explain the negative and positive features of codes of ethics.
8. Explain role of various rules and their ethical implications in engineering profession, by citing ancient examples of codes.
9. What are the various limitations of codes and their implications on engineering profession?
10. Explain the following (a) Learning from the past (b) Informed consent
11. What is the proper role of law in Engineering?
12. What engineering aspects make it appropriate to view engineering projects as experiments?
13. What are the main elements included in informed consent? Enumerate the conditions that would define valid consent.

14. Discuss the problems with law in engineering practice.

15. What are the general features of morally responsible engineers?

16. Discuss Bhopal Gas Tragedy.

UNIVERSITY QUESTIONS

MODULE: 3

ENGINEERING AS SOCIAL EXPERIMENTATION

SHORT ANSWER (3 MARKS)

1. Indicate the advantages of using standards.

2. Point out the conditions required to define a valid consent.

3. Define plagiarism

4. Give three conditions essential for valid informed consent.

5. Explain the term balanced outlook on law.

6. What are the advantages of code of ethics?

7 .List out the limitations of code of ethics.

ESSAY

8. Describe the causes and fatal effects of Bhopal Gas tragedy. (7)

9. Illustrate the role of engineers as managers. (7)

10. Evaluate the importance of accountability in a professional's life. (6)

11. Explain the role of Codes of Ethics in the service life of a professional Engineer.

12. What are the different roles and functions of "codes of ethics". (14)

13. Explain the Bhopal Gas tragedy .Discuss the violation of moral, ethics, and professional codes of standards in it.

14. Explain the Babylon's Building code and The United States Steamboat Code. (14)

15. Explain about Bhopal Gas Tragedy and write its cause and fatal effect.

16. Explain the role of code of ethics in the service life of a professional Engineer. (7)

17. Explain the moral, conceptual, & factual issues that lead to challenger tragedy of 1986.(7)

18. Evaluate the importance of accountability in a professionals' life. (7)

19. Evaluate how an engineer can be a responsible experimenter. (7)

20. Summarize the following features of morally responsible engineers

    i) Moral Autonomy   ii) Accountability   (8)

UNIVERSITY QUESTIONS: MODULE 3