MODULE -1

Introduction: Meaning of Research, Objectives of Engineering Research, and Motivation in Engineering, Research, Types of Engineering Research, Finding and Solving a worthwhile Problem. Ethics in Engineering Research, Ethics in Engineering Research Practice, Types of Research Misconduct, Ethical Issues Related to Authorship.

Textbook: Engineering Research Methodology by Dipankar Deb

INTRODUCTION: MEANING OF RESEARCH

Definition:

Research refers to a careful, well-defined, objective based, and systematic method of search for knowledge.

--OR--

Research is defined as formulation of a theory that is driven by inquisitiveness for that which is unknown and useful on a particular aspect so as to make an original contribution to expand the existing knowledge base.

--OR--

Research is a process of creating, or formulating knowledge that does not yet exist.

RESEARCH FLOW/RESEARCH CYCLE:

Step 1: Practical Problem:

- The research cycle starts with basically a analysing a practical problem
- Researcher should have clear idea about "*what the problem is* " and "*Why it is important?"*
- This is motivation for next step.

Step 2: Research Question:

- A research question is a question that a study or research project aims to answer.
- In turn defines a research project

Step 3: Research Project:

- It is an activity or set of activities that ultimately leads to result or answer.

Step 4: Result:

- In turn helps to solve the practical problem that one started with in the beginning of Research cycle as shown in Fig.1.1

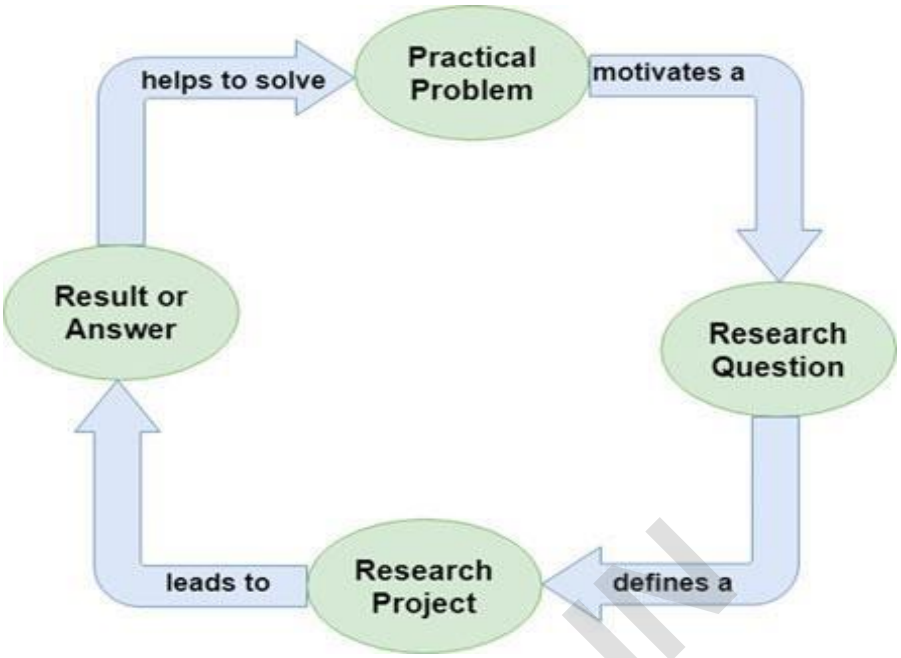

Fig.1.1: Research Flow (Cycle) Diagram

ENGINEERING RESEARCH TYPICALLY AIMS TO ACHIEVE SEVERAL MAIN OBJECTIVES:

- The objective of engineering research is to solve new and important problem, and since the conclusion at the end of one's research outcome has to be new, but when one starts, the conclusion is unknown.
- The main aim of the research is to apply scientific approaches to seek answer to open questions, and although each research study is particularly suited for certain approach.
- The objective of engineering research should be to develop new theoretical or applied knowledge and not necessarily limited to obtaining abilities to obtain the desired result.
- **Innovation and Advancement:** Creating new technologies, methods, or systems to improve existing processes or solve problems in various domains.
- **Problem-Solving:** Addressing real-world challenges by applying scientific principles, theories, and experimentation to devise practical solutions.
- **Optimization:** Enhancing efficiency, functionality, and performance of systems or processes through research-driven improvements.
- **Knowledge Expansion:** Contributing to the body of scientific knowledge by conducting experiments, gathering data, and publishing findings that add to the understanding of specific engineering fields.
- **Interdisciplinary Collaboration:** Fostering collaborations between different branches of engineering, as well as with other scientific disciplines, to tackle complex problems that require diverse expertise.
- **Sustainability and Ethical Considerations:** Developing technologies and solutions that not only solve problems but also consider environmental impact, ethical implications, and long-term sustainability.
- **Commercial Viability:** Some engineering research objectives include developing innovations that can be practically implemented and have commercial viability in industries, fostering economic growth.
- **Education and Training:** Contributing to educational materials, curriculum development, and training resources to prepare the next generation of engineers and researchers.
    - By pursuing these objectives, engineering research aims to push the boundaries of what is possible, improve quality of life, and drive societal and technological progress.

Engineering Research Is Fuelled By Various Motivations, Driving Scientists And Engineers To Explore, Innovate, And Solve Problems:

- **Solving Real-World Problems:** Many engineers are motivated by the desire to address pressing societal, environmental, or industrial challenges. They seek solutions to problems like climate change, energy efficiency, healthcare, infrastructure development, and more.
- **Innovation and Curiosity:** Curiosity is a powerful driver in engineering research. Engineers often seek to understand how things work and push the boundaries of what's possible. The pursuit of new technologies, methods, and discoveries drives them forward.
- **Improving Quality of Life:** Enhancing the quality of life for individuals and communities is a strong motivation. Engineering research aims to create products, systems, and solutions that make life easier, safer, and more enjoyable for people around the world.
- **Career Development and Recognition:** Advancement in the engineering field often relies on research contributions. Engineers may be motivated by personal and professional growth, striving for recognition and advancement in their careers.
- **Collaboration and Networking:** Many researchers are driven by the opportunity to collaborate with peers, experts from different fields, and industry partners. Collaborations often lead to new ideas, perspectives, and breakthroughs.
- **Financial Incentives and Industry Demand:** In some cases, the demand for innovative solutions in specific industries can be a strong motivator. Engineering research that leads to commercially viable products or services can have significant financial incentives.
- **Global Impact and Sustainability:** With increasing awareness of global challenges like climate change and sustainability, engineers are motivated to develop eco-friendly technologies and sustainable solutions that positively impact the planet.
- **Academic Pursuits and Intellectual Fulfilment:** For many researchers, the pursuit of knowledge itself is a strong motivator. They find fulfilment in contributing to the academic body of work and advancing the understanding of their field.
- **Regulatory or Policy Drivers:** Changes in regulations or policies can motivate engineering research. For instance, mandates for cleaner energy might drive research into renewable technologies.
- **Humanitarian and Social Causes:** Some engineers are motivated by the desire to contribute to humanitarian efforts, such as providing clean water, developing low-cost medical devices, or improving living conditions in underprivileged communities.

These motivations often intersect and overlap, guiding researchers to explore, innovate, and contribute to the diverse and ever-evolving field of engineering.

MOTIVATIONS IN ENGINEERING RESEARCH:

- **Intrinsic Motivations:** Interest, challenge, learning, meaning, purpose, are linked to strong creative performance.
- **Extrinsic Motivations:** They include money, fame, awards, praise, and status. These are very strong motivators, but may block creativity.
  Ex: Research outcome may enable obtaining a patent which is a good way to become rich and famous.
  Influences from others: Like competition, collaboration, commitment, and encouragement are also motivating factors in research.
  Ex: My friends are all doing research and so should i, or, a person that i dislike is doing well and i want to do better.
- **Personal motivation:** Solving unsolved problems, Intellectual joy, service to community, and respectability are all driving factors.
- **Other factors:** This would be a mix of extrinsic and intrinsic aspects
  a. Wanting to do better than what has been achieved in the world.
  b. Improve the state of the art in technology.
  c. Contribute to the improvement of society.
  d. Fulfilment of the historical legacy in the immediate sociocultural context.
  e. Several other factors like government directives, funding opportunities in certain areas, and terms of employment, can motivate people to get involved in engineering research.

TYPES OF ENGINEERING RESEARCH:

- **Basic Research:** This type of research aims to expand the fundamental understanding of scientific principles and phenomena. It often involves theoretical investigations and experimentation to explore underlying concepts without immediate practical applications.
- **Applied Research:** Applied research focuses on solving specific problems or developing practical solutions. It takes the knowledge gained from basic research and applies it to address real-world issues, often leading to the development of new technologies or processes.
- **Interdisciplinary Research:** Many engineering problems require expertise from multiple disciplines. Interdisciplinary research involves collaboration across different branches of engineering or with other scientific fields to tackle complex challenges that require diverse perspectives.
- **Design-Oriented Research:** This type of research focuses on improving the design process itself. It involves studying methodologies, tools, and frameworks to enhance the efficiency, effectiveness, and creativity of the design process in engineering.
- **Developmental Research:** Developmental research involves refining and enhancing existing technologies, products, or systems. It aims to optimize performance, functionality, and usability based on iterative improvements and feedback.
- **Experimental and Empirical Research:** This type of research relies on experiments, data collection, and empirical analysis to validate hypotheses, test theories, or evaluate the performance of engineering systems or innovations.

- **Computational and Modelling Research:** Computational research involves the use of computer simulations, modelling, and numerical analysis to understand complex phenomena, predict behaviours, and optimize designs without physical prototyping.
- **Innovative and Breakthrough Research:** Some engineering research focuses on groundbreaking innovations that disrupt existing technologies or create entirely new paradigms in various fields, often leading to significant advancements.
- **Industry-Driven Research:** Research conducted in collaboration with industries aims to address specific challenges faced by businesses. It often involves developing solutions that have direct applications in commercial settings.
- **Sustainability and Environmental Research:** With a focus on environmental impact and sustainability, this research aims to develop eco-friendly technologies, reduce carbon footprints, and improve resource efficiency in engineering processes and products.

These types of engineering research are not mutually exclusive and often overlap, with research projects incorporating elements from multiple categories to address multifaceted challenges in engineering and technology.

Comparison table between different Engineering research

Descriptive	Analytical
It includes Surveys and fact findings enquiries of different kinds	The researcher has to use facts or information already available, and analyze these to make a critical evaluation of material
Describes more about what has happened or what is happening.	It explains more about WHY and HOW
No control over variables	It concerns itself with cause-effect relationships among variables.
Ex: Researcher want to understand the smartphone usage patterns among teenagers in a particular city. They decide to conduct a survey to gather information.	**Ex**: Researcher want to understand if there is a relationship between smartphone usage and academic performance among teenagers in the same city. Analytical research goes beyond describing smartphone usage patterns. It provides insights into potential causes and effects.

Applied	Fundamental (Pure/Basic)
Applied research seeks to solve an immediate problem facing the organization,	Fundamental research is concerned with generalizations and formulation of a theory
Primary objective of applied research is to determine a solution for compelling problems in actual practice.	Basic research is aimed at seeking information which could have a broad base of applications in the medium to long term.

Ex: Research to identify social or economic trends, or those that find out whether certain communications will be read and understood.	Ex: Research concerning to natural phenomena or relating to pure mathematics.

Qualitative	Quantitative
Exploring ideas or formulating hypothesis/theories	Testing hypothesis/ theories
Analysis is through Summarizing, categorizing, Interpreting.	Analysis is by Mathematical and statistical analysis
It is expressed in words	It is expressed in graphs and numbers
It needs only few respondents	It requires many respondents
It is more exploratory	It is more conclusive research

HOW TO IDENTIFY AND ADDRESS SUCH ENGINEERING RESEARCH PROBLEMS:

1. Understanding the Context:

a) **Industry/Field Awareness**: Stay informed about current trends, challenges, and emerging needs within your field or industry.

b) **Market Research:** Conduct thorough market or societal research to identify gaps, unmet needs, or inefficiencies that require solutions.

2. Engaging with Stakeholders:

a) **Talk to Experts:** Engage with professionals, stakeholders, and experts to understand their pain points and needs.

b) **User-Centric Approach:** Focus on understanding end-users' experiences, problems, and desires to create meaningful solutions.

3. Problem Framing:

a) **Define the Problem:** Clearly articulate and define the problem statement to ensure a precise understanding of what needs to be solved.

b) **Prioritization:** Assess the urgency, impact, and feasibility of solving the identified problems.

4. Creative Ideation:

a) **Brainstorming Sessions:** Encourage brainstorming sessions to generate a variety of potential solutions.

b) **Innovation Workshops:** Organize workshops focused on creative problem-solving techniques to explore diverse ideas.

5. Research and Analysis:

a) **Literature Review:** Conduct thorough literature reviews to understand existing solutions and gaps in knowledge.

b) **Data Collection:** Gather data through experiments, surveys, or field studies to gain insights into the problem domain.

6. Prototyping and Testing:

a) **Prototyping:** Develop prototypes or models to test potential solutions and gather feedback.

b) **Iterative Testing:** Implement an iterative testing approach to refine solutions based on user feedback and performance evaluations.

7. Collaboration and Feedback:

a) **Cross-Disciplinary Collaboration:** Engage with experts from various disciplines to bring diverse perspectives to problem-solving.

b) **Continuous Feedback:** Seek feedback from stakeholders, users, and peers throughout the problem-solving process.

8. Impact Assessment:

a) **Evaluate Solutions:** Assess the effectiveness, efficiency, and potential impact of proposed solutions.

b) **Scalability and Sustainability:** Consider the scalability and long-term sustainability of the solutions.

9. Implementation and Monitoring:

a) **Implementation Strategy:** Develop a plan for implementing the chosen solution effectively.

b) **Monitoring and Adaptation:** Continuously monitor the implemented solution and be prepared to adapt based on real-world feedback and changing circumstances.

By following these steps, engineers and researchers can identify worthwhile problems, devise innovative solutions, and make a meaningful impact in their respective fields.

Engineering Research Process

i)**Formulating the research problem**: There are two types of research problems, viz.,those which relate to states of nature and those which relate to relationships between variables. At the very outset the researcher must single out the problem he wants to study,i.e., he must decide the general area of interest or aspect of a subject-matter that he would like to inquire into.

ii) **Extensive literature survey**: Once the problem is formulated, a brief summary of it should be written down. It is compulsory for a research worker writing a thesis for a Ph.D. degree to write a synopsis of the topic and submit it to the necessary Committee or the Research Board for approval. At this juncture the researcher should undertake extensive literature survey connected with the problem.

iii) **Preparing the research design:** The research problem having been formulated in clear cut terms, the researcher will be required to prepare a research design, i.e., he will have to state the conceptual structure within which research would be conducted. The preparation of such a design facilitates research to be as efficient as possible yielding maximal information. In other words, the function of research design is to provide for the collection of relevant evidence with minimal expenditure of effort, time and money.

iv) **Determining sample design:** The researcher must decide the way of selecting a sample or what is popularly known as the sample design. In other words, a sample design is a definite plan determined before any data are actually collected for obtaining a sample from a given population. Sampling can be done choosing a particular unit, random unit selection, systematic pattern, homogenous group (stratified sampling), quota, cluster or area, multi stages and sequential.

v) **Collecting the data:** In dealing with any real life problem it is often found that data at hand are inadequate, and hence, it becomes necessary to collect data that are appropriate.

There are several ways of collecting the appropriate data which differ considerably in context of money costs, time and other resources at the disposal of the researcher. Primary data can be collected either through experiment or through survey. If the researcher conducts an experiment, he observes some quantitative measurements, or the data, with the help of which he examines the truth contained in his hypothesis. But in the case of a survey, data can be collected by any one or more of the following ways by observation, through personal interview, through telephonic interview, by mailing the questionnaire etc.

vi) **Analysis of data:** After the data have been collected, the researcher turns to the task of analyzing them. The analysis of data requires a number of closely related operations such as establishment of categories, the application of these categories to raw data through coding, tabulation and then drawing statistical inferences. The unwieldy data should necessarily be condensed into a few manageable groups and tables for further analysis. Thus, researcher should classify the raw data into some purposeful and usable categories.

vii) **Preparation of the report or the thesis:** Finally, the researcher has to prepare the report of what has been done by him. Writing of report must be done with great care keeping in view the following:

 The layout of the report should be as follows: (i) the preliminary pages; (ii) the main text, and (iii) the end matter.

 In its preliminary pages the report should carry title and date followed by acknowledgements and foreword. Then there should be a table of contents followed by a list of tables and list of graphs and charts, if any, given in the report.

 The main text of the report should have the following parts:

(a) Introduction: It should contain a clear statement of the objective of the research and an explanation of the methodology adopted in accomplishing the research. The scope of the study along with various limitations should as well be stated in this part.

(b) Summary of findings: After introduction there would appear a statement of findings and recommendations in non-technical language. If the findings are extensive, they should be summarized.

(c) Main report: The main body of the report should be presented in logical sequence and broken-down into readily identifiable sections.

(d) Conclusion: Towards the end of the main text, researcher should again put down the results of his research clearly and precisely. In fact, it is the final summing up.

 At the end of the report, appendices should be enlisted in respect of all technical data. Bibliography, i.e., list of books, journals, reports, etc., consulted, should also be given in the end. Index should also be given specially in a published research report.

ETHICS IN ENGINEERING RESEARCH

Definition: Ethics refers to a set of rules distinguishing acceptable and unacceptable conduct, distinguishing right from wrong, or wise aphorisms like the sayings of Chanakya
It is crucial as it guides responsible conduct, ensuring integrity, safety, and accountability in the pursuit of knowledge and innovation. By prioritizing ethical principles in engineering research, researchers can build trust, foster innovation, and contribute responsibly to the advancement of science and technology for the benefit of society.

ETHICS IN ENGINEERING RESEARCH PRACTICE

Ethics in engineering research practices involves the application of ethical principles throughout the research process. Here are some specific practices that uphold ethical standards:

1. Informed Consent:
Obtain voluntary and informed consent from participants involved in experiments or studies. Ensure they understand the purpose, risks, and benefits of their participation.

2. Confidentiality and Privacy:
Safeguard the confidentiality of participants' information and ensure their privacy is protected. Handle data securely and only share information with authorized individuals.

3. Responsible Data Handling:
Collect, store, and analyze data responsibly, ensuring accuracy, integrity, and security. Handle sensitive or personal information with care and in accordance with relevant regulations.

4. Avoiding Plagiarism:
Attribute sources properly and avoid plagiarism by citing references accurately. Give credit to prior work and contributors appropriately.

5. Research Integrity:
Conduct research with honesty and integrity, avoiding fabrication, falsification, or manipulation of data. Maintain transparency in reporting methodologies and results.

6. Safety and Risk Mitigation:
Prioritize the safety of researchers, participants, and the environment during experiments or testing. Adhere to safety protocols and minimize risks associated with the research.

7. Ethical Review and Compliance:
Seek ethical review and approval from relevant institutional review boards or ethics committees before commencing research involving human subjects or sensitive data.

8. Conflict of Interest Disclosure:
Disclose any conflicts of interest that could influence research outcomes, publication, or decision-making. Maintain objectivity and transparency in dealing with potential conflicts.

9. Respect for Intellectual Property:
Respect intellectual property rights, including patents, copyrights, and trademarks. Adhere to legal and ethical standards when using others' work or protecting your own.

10. Social and Environmental Impact Consideration:
Consider the broader societal and environmental impacts of research outcomes. Strive to develop technologies and solutions that benefit society while minimizing negative consequences.

11. Continuous Ethical Reflection and Education:
Engage in ongoing ethical reflection and education within the research community. Stay updated on ethical guidelines, best practices, and emerging ethical challenges.

Upholding ethical practices in engineering research is essential not only for the credibility and integrity of the research but also for ensuring the well-being and rights of all involved stakeholders. Regular ethical evaluations and adherence to established ethical codes contribute to responsible and impactful research outcomes.

TYPES OF RESEARCH MISCONDUCT:

1. Fabrication:
Creating or inventing data or results that do not exist and have not been obtained through research or experimentation.

2. Falsification:
Manipulating research materials, processes, or data to change or omit results, methods, or other significant aspects of research to deceive others.

3. Plagiarism:
Presenting someone else's work, ideas, or words as one's own without proper acknowledgment or citation. This can include copying text, ideas, or concepts without permission or attribution.

4. Misrepresentation of Authorship:
Falsely attributing authorship or denying credit to individuals who have made substantial contributions to the research, leading to unfair distribution of credit.

5. Duplicate Publication:
Publishing the same research or data in multiple publications without proper acknowledgment or disclosure. This violates the principle of originality in research.

6. Undisclosed Conflicts of Interest: Failure to disclose financial or personal conflicts of interest that could influence research outcomes, funding sources, or publications, leading to biased results.

7. Failure to Comply with Ethical Standards:
Violating ethical guidelines, regulations, or institutional policies regarding research involving human subjects, animals, or sensitive data.

8. Research Mismanagement:
Inadequate supervision of research activities, failure to maintain accurate records, or improper handling of research data or materials.

9. Retaliation against Whistleblowers:
Taking punitive actions or retaliation against individuals who report or raise concerns about research misconduct, hindering the reporting of unethical behaviour.

10. Failure to Report Research Misconduct:
Neglecting to report known or suspected research misconduct or failing to cooperate with investigations into alleged misconduct.

ETHICAL ISSUES RELATED TO AUTHORSHIPS?

Authorship in research publications is central to academic integrity, and ethical issues can arise in various aspects of authorship, including:

1. Authorship Criteria:
Determining who qualifies as an author and the order of authorship can lead to ethical dilemmas. Clear criteria should be established based on substantial contributions to the research, avoiding honorary authorship or excluding deserving contributors.

2. Guest or Gift Authorship:
Granting authorship to individuals who haven't substantially contributed to the research, often due to seniority, affiliation, or professional courtesy, undermines the integrity of authorship.

3. Ghost Authorship:
Concealing the actual contributors of a study by not including individuals who made significant contributions. This unethical practice often occurs in industry-sponsored research or collaborations.

4. Changes in Authorship:
Altering authorship after the completion of the research, especially without the consent or acknowledgment of all parties involved, can lead to disputes and ethical concerns.

5.Disputes and Resolutions: Conflicts or disagreements among authors regarding contributions, order of authorship, or other issues can arise. Resolving these disputes ethically and transparently is crucial to maintaining trust and fairness.

6.Equal Contribution Statements:

Sometimes, authors contribute equally to a study. Ensuring fairness in acknowledging and highlighting these contributions can be challenging, leading to ethical considerations in equal contribution statements.

7.Corresponding Author Responsibilities:

The corresponding author is responsible for overseeing the publication process and communication with journals. Ethical issues may arise if there's a lack of transparency or accountability in these roles.

8. Authorship in Multi-Center Studies or Collaborations:

In collaborative research involving multiple institutions or researchers, determining authorship can be complex. Ethical issues can emerge regarding credit allocation and representation of contributors.

9. Honorary Titles or Position-Based Authorship:

Granting authorship based solely on titles, positions, or affiliations rather than substantial contributions to the research can compromise the integrity of authorship.

10. Ethical Responsibilities of Authors:

Authors have ethical responsibilities to ensure accuracy, validity, and integrity in their work. Failing to uphold these responsibilities can lead to ethical issues in authorship.

Maintaining transparency, fairness, and adherence to established guidelines regarding authorship is crucial to upholding ethical standards in research publications. + communication, mutual agreement on authorship criteria, and proper acknowledgment of contributions help prevent ethical.

Research Process

- Research process is a series of steps or action taken to conduct a research.
- The research process consists of a series of systematic procedures that a researcher must go through in order to generate knowledge.
- The research process starts with **identifying a research problem** and **conducting a literature review** to understand the context. The researcher sets research questions, objectives, and

hypotheses based on the research problem.

- **Formulation of research problem**
  First step of research process is selecting the research topic, area of study
- **Literature review**
  Reviewing the already published material on the topic under research, sources of literature are books, journals, research paper, scholarly articles etc,
  Literature review provide foundational knowledge of topics under research
- **Research design**
  It include strategies & methodologies used for research.
  Research design as a plan for a study, providing the overall framework for collecting data.
- **Data collection**
  Data is the integral part of research, without data you cannot conclude results.
  Many techniques are used for data collection e.g.questionaries, experiments, surveys, interviews etc.
- **Data analysis**
  Different statistical & mathematical tools are applied on data.
- **Conclusion**
  Conclusion means outcome of the research.

The three broad categories of developing and accessing knowledge in research are:

1. **Exploratory or Formulative research studies:** These studies aim to gain familiarity with a phenomenon or to achieve new insights into it. The purpose is to explore and understand a topic or issue that has not been extensively studied before.

2**. Descriptive research studies:** This category is focused on portraying accurately the characteristics of a particular individual, situation, or group. The goal is to provide a detailed and comprehensive description of the subject under study.

3**. Explanatory or Causal research studies:** These studies seek to identify the causes and effects of a particular phenomenon. The purpose is to establish causal relationships and understand the underlying mechanisms that drive certain outcomes. These categories help researchers to structure their approach to knowledge development and access by providing a framework for the type of research they are conducting.

IMPORTANT QUESTIONS:

1. Define Research. Explain Research flow with a neat diagram.
2. State different objectives of Engineering Research
3. Explain different motivations of Engineering Research
4. Classify different types of Engineering Research
5. Differentiate between Descriptive and Analytical research with examples
6. Differentiate between Fundamental and Applied research with examples
7. Compare Qualitative and Quantitative research with examples
8. Discuss how to identify and address Engineering research problems
9. Define Ethics in Engineering research. Give key aspects of ethics in engineering research
10. Write a short note on ethical issues related to Authorship
11. Summarize different types of Engineering Misconduct.