DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

GEE6201 – RESEARCH METHODOLOGY AND IPR

Module I - RESEARCH PROBLEM FORMULATION AND RESEARCH DESIGN

Research - objectives - types, Research process, Solving engineering problems - Identification of research topic - Formulation of research problem, literature survey and review. Research design - meaning and need - basic concepts - Different research designs, Experimental design - principle, Design of experimental setup, Mathematical modeling - Simulation, validation and experimentation.

1.1 RESEARCH - Definition

According to a typical English Dictionary, the meaning of 'research' is "a careful investigation or inquiry specifically through search for new facts in any branch of knowledge."

One can also define research "as a scientific and systematic search for pertinent information on a specific topic."

It is a voyage of discovery propelled by the instinct of inquisitiveness of human mind. It is an academic activity and as such the term should be used in technical sense. According to Clifford Woody, research comprises defining and redefining problems, formulating suitable solutions or hypothesis; collecting, organizing and evaluating data; making deduction and reaching conclusions; and at last carefully testing the conclusions to decide whether they satisfy the hypothesis formulated.

Research is an original contribution to the existing stock of knowledge making for its advancement. We try to establish the truth with the help of study, observation, comparison and experiment. In short, the search for knowledge through objective and systematic method of finding solution to a problem is research.

1.2 OBJECTIVES AND MOTIVATION

The primary objective of researches is to find answers to questions through the application of scientific procedures. The truth is hidden and has not been found out so far. Every research has its own specific purpose, but one can broadly group the research objectives as,

- To gain familiarity with the phenomenon or to get new insights into it. These studies are termed as exploratory or formative research studies.
- To determine accurately the characteristics of a particular individual, system, situation or a group. These studies are known as descriptive research studies.
- To decide the frequency with which a phenomenon occur or with which it is associated with something else. These studies are known as diagnostic research studies.
- To establish the causal relationship between variables by forming suitable hypothesis. They are termed as hypothesis testing research studies.

There are several motives for somebody undertaking a research work. The possible ones include,

- Desire to get a research degree along with its consequential benefits.
- Desire to face challenges in solving the unsolved problems.
- To get intellectual joy of doing some creative work.
- To do service to the society and get respectability.
- Direction by the employer, Govt. etc.

TECHNOLOGICAL INNOVATION

Engineering is concerned with problems whose solution is needed and / or desired by the society. The capacity to innovate, manage information, and nourish knowledge as a resource will dominate the economic domain as natural resources, capital and labour ones did. This places high premium on development of technology and delivery systems.

The advancement of technology has three phases.

Invention : The creative act whereby an idea is conceived

Innovation: The process by which an invention or idea is translated into successful practice and is utilized by the economy.

Diffusion : The successive and widespread initiation of successful innovation.

Science based innovation has made significant contributions to the development of industries like aircraft, computers, plastics and television in developed countries like USA. Traditionally, engineers play a major role in technological innovation. A strong basic research is needed to maintain the storehouse of new knowledge and ideas. Innovation in response to a need of the society has greater probability of success than innovation in response to technological research opportunity. The scope for doing applied research is high, which involves innovative solution to the problem of the society.

1.3 TYPES OF RESEARCH

The basic types of research from view point are as follows:

Based on Application:

- Pure research (Theoretical Reach, Fundamental Research)
- Applied Research

Based on Objectives:

- Exploratory research
- Descriptive Research
- Correlation Research
- Explanatory Research

Based on Application:

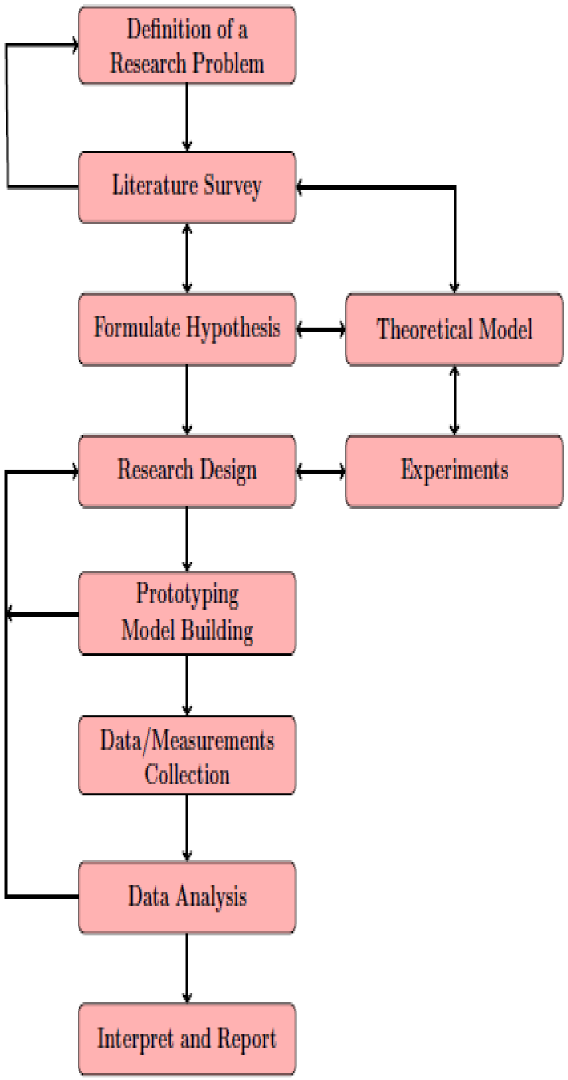
- Quantitative research
- Qualitative Research

i) Descriptive Vs Analytical

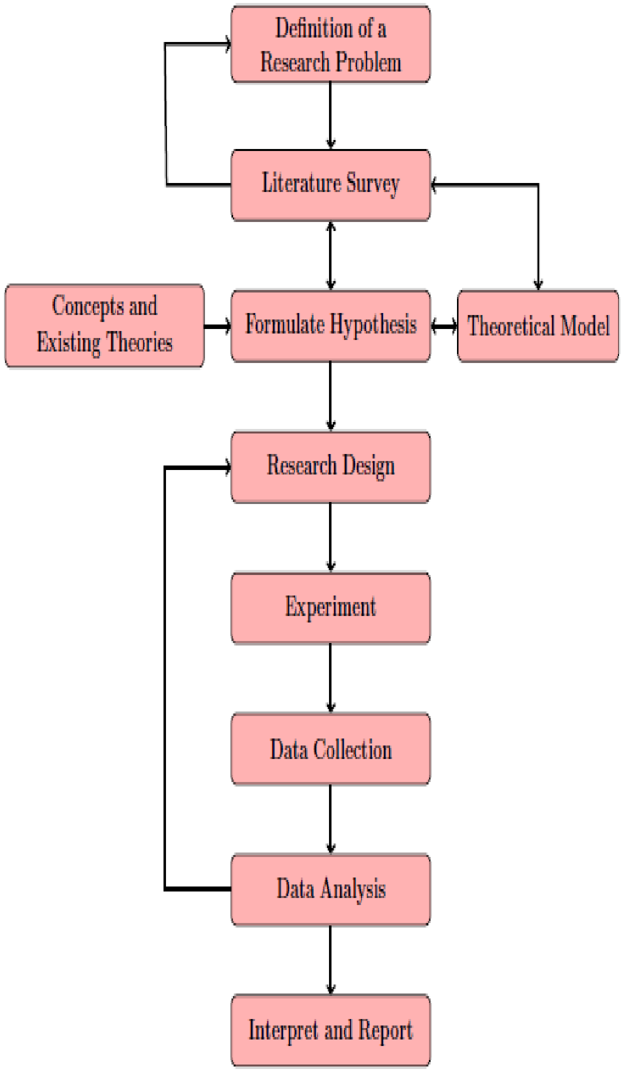
The major purpose of descriptive research is description of the state of affairs as it exists at present. This method includes surveys and fact finding enquiries of different kinds. The main characteristic of this method is that the researcher has no control over the variables, he can report only what is happening or what has happened (eg: frequency of arrival of vehicles for repairs in a workshop). In the analytical, researcher has to use facts or information already available from secondary sources and analyze them to make critical evaluation of the material.

ii) Applied Vs Fundamental

Applied research is also known as 'action research'. It aims at finding a solution for an immediate problem facing the society or on Industrial / business organization. On the other hand, the fundamental research is concerned with generalization and with the formulation of a theory. Research concerning some natural phenomenon or relating to pure mathematics are examples of fundamental research. The central aim of applied research is to discover a solution to some vital/critical practical problems, whereas basic research is directed towards finding information that has a broad base of applications and thus, adds to the already existing organized body of scientific knowledge.



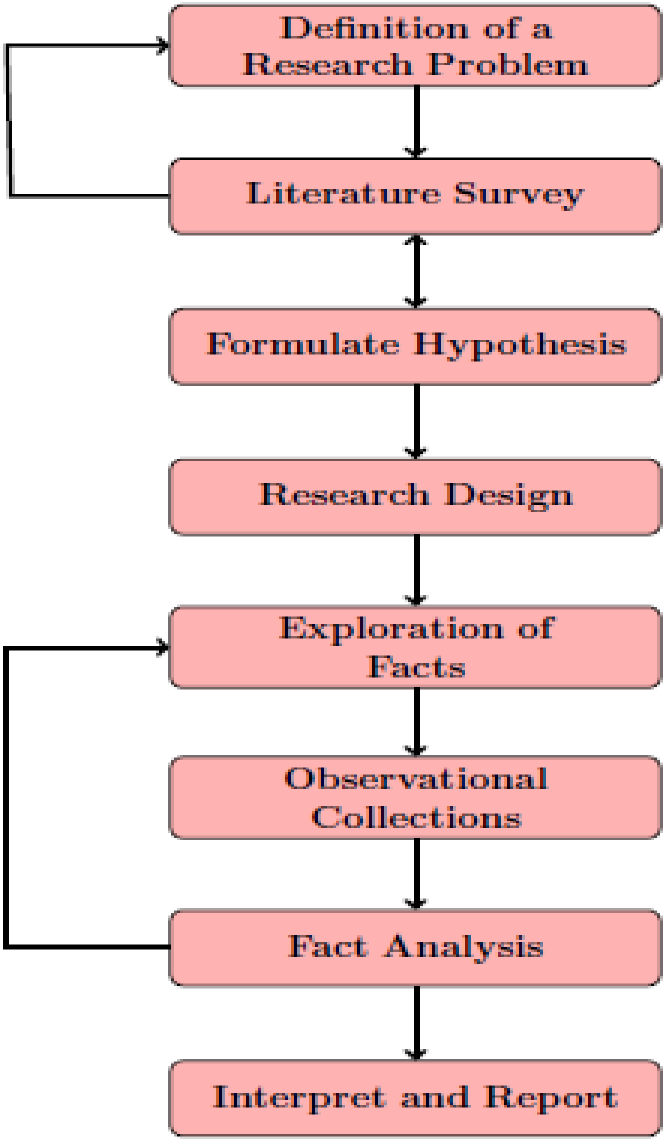
Applied Research-Structure



Fundamental Research-Structure

iii) Quantitative Vs Qualitative

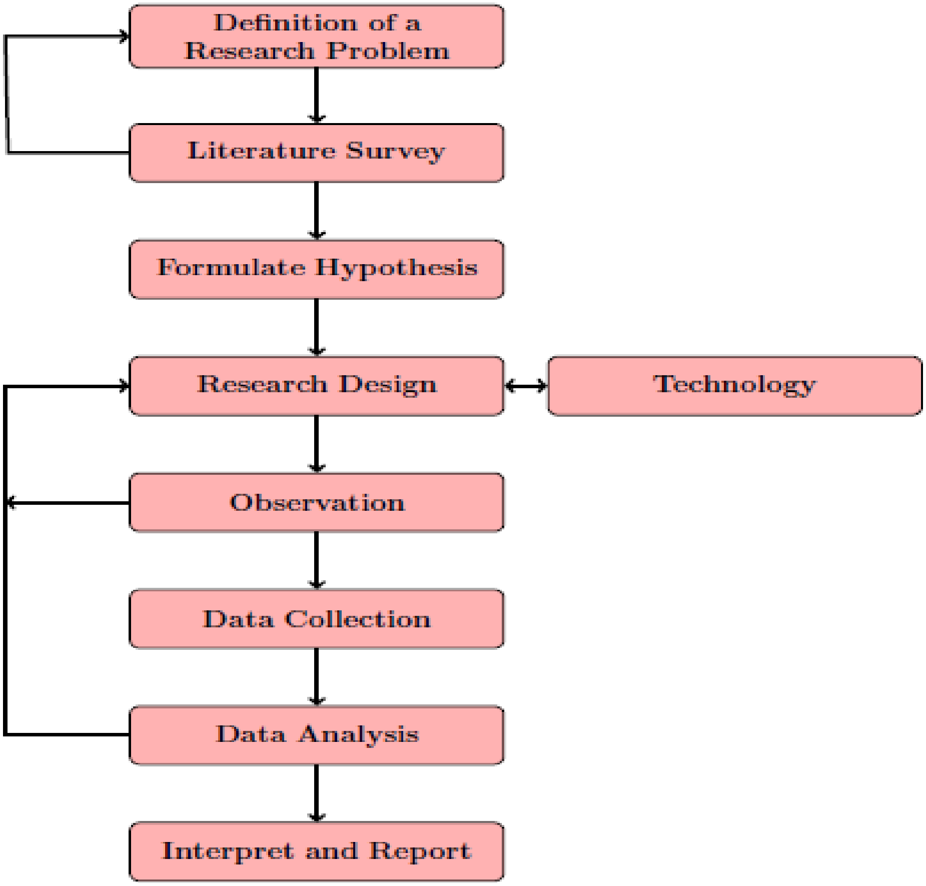
Quantitative research is based on the measurement of quantity or amount. This is applicable to phenomena that can be expressed in terms of quantity, amount, size or weight etc. Qualitative research on the other hand is concerned about the qualitative phenomena, that is, something relating to or involving quality. For example, research designed to find out how, people feel or what they think about a particular subject or institution is qualitative research.



Qualitative Research-Structure

iv) Conceptual Vs Empirical

A concept is an abstract idea, a visionary expression of a proposed or planned action that leads to achievement of an objective. Therefore, a conceptual research is related to some abstract idea or theory. It is generally used by thinkers to develop new concepts or reinterpret existing ones. On the other hand, empirical research relies on experience or observation alone, often without due regard for system and theory. It is data based research ending up with conclusions, which are capable of being verified by observation or experiment.



Conceptual (Observational) Research-Structure

Many engineering oriented research work are of empirical type involving physical experiments or simulation. In such a research, the researcher tries to establish a working hypothesis (probable) and then try to get enough facts (data) to prove or disprove the hypothesis. Then sets up experimental design to manipulate the material concerned so as to bring forth the desired information. In this type of research, the experimenter has control over the variables under study and he can deliberately manipulate any one of them to study its effects. Evidence gathered through experiments or empirical studies is considered to be the most powerful support for a given hypothesis.

v) Other types of research

Other types of researchers are there, which are variations of one or more of the above stated approaches they include,

✓ **One time or longitudinal**: One time is confined to a single period whereas the longitudinal is carried over several time periods.

- ✓ **Field setting or laboratory or simulation**: This is based on the environment in which the research work is carried out.
- ✓ **Conclusion oriented** and decision oriented: In conclusion oriented, a researcher is free to pick up a problem, redesign the enquiry as he proceeds and is prepared to conceptualize as he wishes. Decision oriented research is always to meet the needs of decision maker and the researcher is not free to embark upon research according to his own inclination. Operations research is an example of decision oriented research.

From the above description of the types of research, it is obvious that there are two basic approaches to research viz: Quantitative approach and Qualitative approach.

As already stated the quantitative approach involves generation of data in quantitative form (ordinal numbers), which are subjected to rigorous quantitative analysis in a formal and rigid fashion. This approach can be further sub-divided into (i) Inferential (ii) experimental (iii) simulation approaches. In the inferential approach, the characteristics of the population are inferred from the database. The variables are manipulated by the researcher in the experimental approach to observe the effect of a variable on others. Greater control is over the experiment. The simulation approach involves building a numerical model and manipulating the model with the help of a computer. This permits observation of the dynamic behavior of the system or sub-system under controlled conditions.

Qualitative approach to research is concerned with subjective assessment of attitudes, opinions and behavior. This approach generally generates results in non-qualitative form or in a form, which are not subjected to rigorous quantitative analysis.

Research Vs Scientific method

These two are closely related. The research can be termed as "inquiry into the nature of reasons and the consequences of any particular set of circumstances, whether these circumstances are experimentally controlled or recorded just as they occur. The researcher is interested in more than one particular results; he is interested in the repeatability of the results and in their extension to more complicated general situations."

The term 'scientific method' covers the philosophy common to all research methods and techniques, although they may very considerably from one science to another. The scientific method is one and the same in the branches of a particular science. This method encourages a rigorous, impersonal made of procedure dictated by the demands of logic and objective procedure.

HOW RESEARCH METHODOLOGY DIFFERS FROM RESEARCH METHODS?

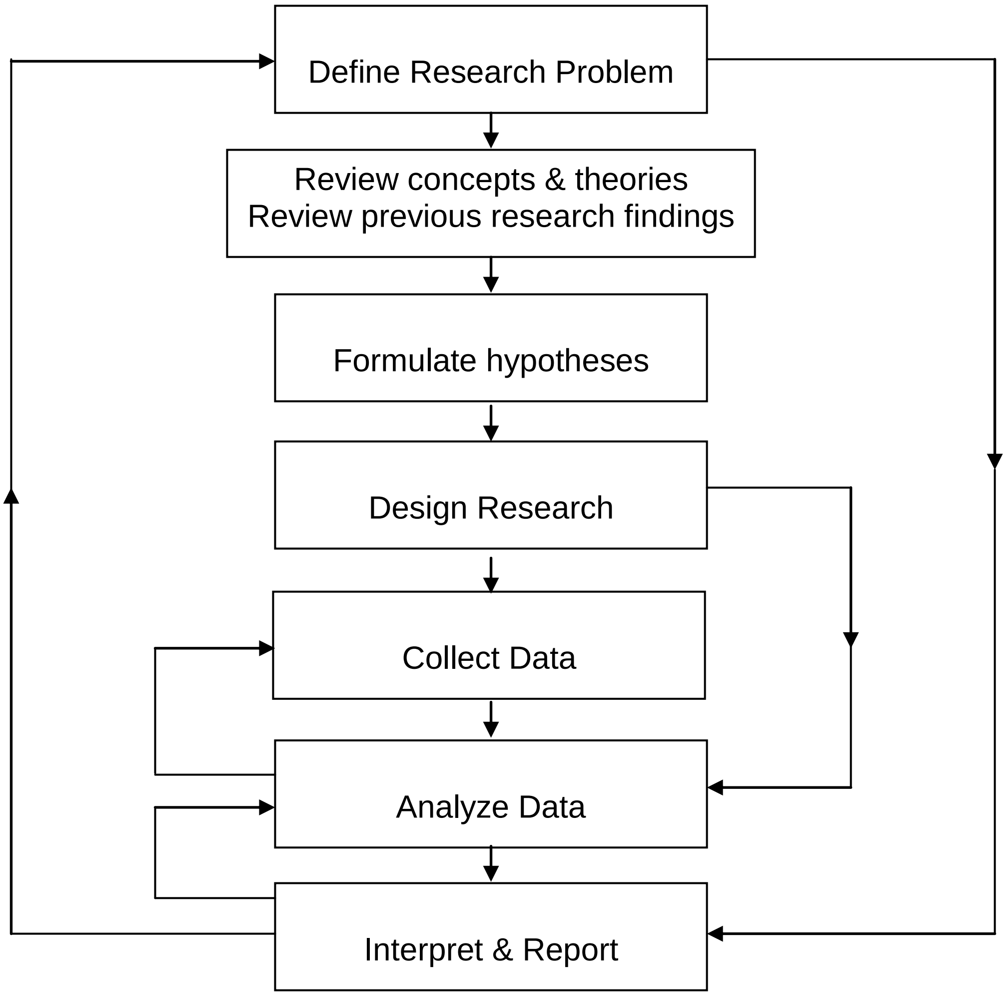
The Research methods refer to the methods the researcher use in performing research operations, For instance, in applied research, the objective is to arrive at a solution for a given problem, the available data and the unknown aspects of the problem have to be related to each other to make a solution possible. For this, the research methods employed can be grouped into i) methods used to collect data ii) statistical techniques used for establishing relationships between data and unknowns, and iii) methods used to evaluate the accuracy of the results.

The scope of Research methodology is wider than that of Research methods. Here, we not only talk of research methods, but also consider the logic behind the methods we use in the context of our research study and also explain why we are using a particular method or technique and why we are not using others. This is necessary to ensure that research results are capable of being evaluated either by the researcher himself or by others.

The researcher need to know which method or technique is relevant and which are not, and what would they mean and indicate and why. The researcher also needs to understand the assumptions underlying various techniques and they need to know the criteria by which they can decide that certain techniques and procedures will be applicable to certain problems and others will not. All this mean, the researcher has to design his methodology for his problems as the same may differ from problem to problem.

1.4 RESEARCH PROCESS

The Research process consists of series of actions or steps necessary to effectively carryout research and the desired sequencing of steps. The figure illustrates the research process. It may be seen that the research process consists of several closely related activities, which overlap considerably rather than strictly following a prescribed sequence. Many a times, the first step determines the nature of the last step to be undertaken. It is better that subsequent procedures are taken into account in the early stages, to avoid serious difficulties later. The various steps involved in the research process are not mutually exclusive, nor are they separate and distinct. They do not necessarily follow each other in any specific order and the researcher has to constantly anticipate at each step the requirements of subsequent steps.



The following sequence concerning various steps provides a useful procedural guideline regarding research process.

i) Formulating the research problem
ii) Extensive literature survey
iii) Developing the hypothesis
iv) Preparing the research design
v) Determining sample design
vi) Collection of data

vii) Project execution
viii) Data analysis
ix) Testing the hypothesis
x) Interpretation and generalization
xi) Report preparation

Formulating the research problem

At the outset the researcher must decide the general area of interest or aspect of subject matter that he would like to inquire into. The formulation of a general topic into a specific research problem constitutes the first step in a scientific enquiry. Essentially two steps are involved in formulating the research problem, viz; understanding the problem thoroughly, and rephrasing the same into meaningful terms from an analytical point of view.

Literature survey

Literature survey connected with the problem is very essential for a Ph.D. research work. One of the major reason is that the researcher should get himself acquainted with the selected problem both conceptually, ie. concepts and theories and empirically by reviewing studies made which are similar to the one proposed. This gives confidence in defining the problem and also to identify and narrow the topic of his research.

Development of working hypothesis

A working hypothesis is a tentative assumption made in order to draw out and test its logical or empirical consequences. In most of the research work, it plays an important role. The role of hypothesis is to guide the researchers by delimiting the area of research work.

Research Design

The function of research design is to plan for the collection of relevant data / evidence with minimum expenditure of effort, time and money. But, this depends mainly on the research purpose. Research purposes may be grouped into i) Exploration, ii) Description, iii) Diagnosis, and iv) Experimentation.

Sample Design

The field of inquiry cannot constitute the entire 'universe' or population as it involves great deal of time, money and energy and many a times impossible.

Hence, quite often we select a few items from the universe ie. sample for our study purpose. The way a researcher decides selecting a sample is popularly known as 'sample design'. There are several ways of selecting sample such as random sampling, systematic, stratified, sequential, multistage, cluster etc.

Data Collection

Primary data required for the research study can be collected either through experiment or through survey. It the researcher conducts an experiment, he observes some quantitative measurements or the data, with the help of which he examines the truth contained in the hypothesis. The secondary data are gathered from published reports, handbooks and literature.

Project execution

This is an important step in the research process. The execution of the entire project should have planned properly. If the execution proceed on correct lines, the data collected would be adequate and dependable. Many a times, it will be useful if a pilot experiment or preliminary survey conducted before proceeding to actual production run.

Data analysis

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. If the data is voluminous, use of computers and statistical packages can be resorted to.

Testing of hypothesis

In this step, the hypothesis formed already is tested using various statistical tests such as Chi-square, T-test, F-test etc. The hypothesis testing will result in either accepting the hypothesis or rejecting it.

Interpretation and generalization

If the researcher had no hypothesis to start with, he might explain his findings on the basis of some theory. It is known as interpretation. Quite often the process of interpretation may lead to new questions, which in turn may lead to further researches. If a hypothesis is tested and upheld several times, it may be possible for the researchers to arrive at generalization that is to build a theory. The real value of research lies in its ability to arrive at certain generalization

Reporting or thesis writing

Reporting or thesis writing is the culmination of the research work done. Generally it is a complete, stand-alone document aimed at persons having good background of knowledge especially in the case of a Ph.D. thesis. Enough time should be devoted for writing thesis and it should be in proper format. Manuals are available to guide the researcher. It is always better that a researcher should go through some of the well written thesis to grasp the nuances.

1.5 SOLVING ENGINEERING PROBLEMS - PROBLEM SOLVING IN ENGINEERING

While the research approach presented in the previous section provides a general framework, there are two fundamental approaches to solving engineering problems that arise in the discovery of knowledge and its application to society's needs.

i) Theoretical (Physical / Mathematical) modeling

ii) Experimental measurement.

In engineering, this is true regardless of the discipline such as mechanical, electrical etc. or the engineering function such as design, development, research, manufacturing etc. While some problems are adequately treated by using only theory or only experiment, most require a judiciously chosen mix of these techniques. Even though each specific application has its own peculiarities, there are some important general characteristics of the theoretical and experimental methods which will be helpful in deciding the proper blend when a choice is necessary. This will help us in organizing our thinking about the whole process.

COMPARISON BETWEEN THEORETICAL AND EXPERIMENTAL PROCESS

i) All physical principles and their mathematical expressions (mathematical models) are approximations of the real world behavior. Though by making the model more complex, the quality of approximations can be improved, perfection is not always possible. The practical engineering always labors under constraints-of time, money, facility etc. But, however depending upon the overall project objective, a researcher can choose an experimental method, which is simpler and less accurate and may be judged as and quote for the purpose.

Thus, this comparison centre's on the fact that theories are always approximations involving simplifying assumptions; whereas experiments when properly designed and executed or run on the actual system reveal true behavior. This comparison favors experiment over theory.

ii) The second comparison is based on the generality of results. The main reason we prefer theoretical approaches (when their accuracy is adequate) is that theoretical results are usually applicable to a whole class of problems whereas experimental results are peculiar to the specific apparatus on which the measurements were made. The ability to solve entire classes of problems with a single analysis gives theoretical methods an efficiency which is their major advantage. A significant price paid for the generality of theory is the universal need for simplifying assumptions.

But, however when models are made more closer to real world, leads to mathematical formulations of deeper complexity and mathematical intractability. Today, of course, this problem has been greatly alleviated by the development of computerized numerical methods (eg: FEA), these methods sacrifice generality; they do not provide formula solutions, i.e. they give only numerical answers for individual specific cases, analogues to physical experiment.

Just as pursuit of accuracy in mathematical modeling leads to undesired complexity, the experimental approaches also generally become more intricate when we require higher accuracy in the measured result. Thus, this comparison shows no obvious or uniform advantage for each approach.

iii) The third comparison can be based on facilities needed to undertake theoretical or experimental studies. Theoretical studies may be initiated with less commitment of financial resources, while experimentation requires investment in equipment, laboratory space etc. This apparent advantage partially disappears when we realize that most current theoretical studies require good computing facility supported by suitable software's. Thus, neither approach has clear superiority.

iv) The next comparison is based on the time required to achieve results. Any technical endeavor has an appropriate time scale associated with its success. Deciding the time frame is difficult at the beginning of the project. Theory seems to offer advantages, since one can start immediately, whereas experimentation requires the building of experimental set up, debugging, pilot run, calibration before the first data available. But, however, if the chosen theoretical approach turns out fruitle, we may have to reformulate, which again requires more time.

It should be clear that sometimes, a theoretical approach is quickest and at other times experimentation gives the most rapid solution. In general, simple problems are more likely to yield quickly to theory, whereas puzzling phenomena may require a strong component of experiment.

1.6 IDENTIFICATION OF RESEARCH TOPIC

Selecting the problem

In the research process, the first and foremost step happens to be that of selecting and properly defining a research problem. A researcher must find the problem and formulate it so that it becomes susceptible to research. The research problem undertaken for study should be carefully selected. The task is difficult, though it may not appear to be so. The guide may be of some help to the researcher in this. Nevertheless, every researcher must find out his own salvation, as research problems cannot be borrowed. A problem must spring from the researcher's mind. For instance while prescribing glasses for eyes, the optician alone cannot decide, we have to cooperate with him to prescribe the right type of glass. Thus, a research guide can be at the most only help a researcher choose a subject.

The following pointes may be taken into account a researcher while selecting a research problem or a subject for his research.

- Subject which is overdone should not be normally chosen, as it will be difficult to throw any new light in such a case.
- Controversial subject should not become the choice of an average researcher
- Avoid too narrow or too vague problem

- Choose a familiar and feasible subject so that the related research material or sources of research are within one's reach. An expert or supervisor already engaged in similar research work or journal publications will be of use in this.
- Importance of the subject, the background of the researcher, costs and time factor involved are a few other aspects which should be considered.
- Selection of a problem must be preceded by a preliminary study if needed.

What constitutes research?

In a research work leading to the award of Ph.D degree, the researcher always looks for some original contribution. The originality under normal circumstances may be confined to,

- New interpretation or application of known facts.
- Bringing new evidences to support a known fact
- Empirical work of one's choice and not a repetition of what someone has already done.
- Using a known technique in an untested area
- Furthering knowledge by continuing the work suggested by another scholar at the end of his research work.
- Propounding a new concept or a formulae in the chosen discipline or subject
- Evolving a new methodology to solve an existing problem.

A suggested approach to identify research problem

It appears there is no universal approach to identify the research problem especially as how to start defining the research topic and zooming in on specific research problem. The following are general guidelines, which may be followed by research students of M.S. and Ph.D. programmes.

i) First choose a direction or area of interest based on the background knowledge of the researcher obtained through courses undertaken, readings, conferences attended and discussions with professors etc. There could be a list of topics of interest to the researcher, but it could be limited to not more than three.

ii) Compile a set of 'key words' to start searching for higher quality readings for each of the previously selected topics. May be one can refer to library on-line or search on the web. But, one should check the publication details for quality.

iii) Out of the search hits, select 15 - 20 papers that are most related to what the researcher had in mind and are of highest quality. One read not need all these papers. Check the title, abstract, names of authors, their affiliations and most importantly the conference or journal. Try to refine the set of key words and perform multiple searches to most related quality work. To check for quality one can use references and citations. Usually the most cited work by high quality papers is also of high quality. The list of references of a specific paper will provide a good direction to follow.

iv) For the selected 15 - 20 papers, read only the abstract, introduction and conclusion in detail. If necessary skim the rest of the paper to get general idea. Identify the emphasis of each paper.

- Which problem it addresses
- What solution it proposes
- How the solution differs from previous solutions, and
- What are the major contributions and conclusions

After going through these 15 – 20 papers and understanding select a list of 4 – 6 papers that are of highest quality and addresses the researcher's interest and challenges in the field most appropriately.

v) Read these 4 – 6 papers from beginning to end and identify (1) major approaches (2) methods of analysis (a) metrics (b) evaluation tools (c) analysis and interpretation of resulting measured data, and (3) conclusions. At the same time try to keep a list of what you think that the authors may have missed in the paper / study, gaps or limitations that could be improved upon and any ideas on how to accomplish these improvements. One can ask these questions.

- Did all / some papers use similar approaches?
- Have they used the same evaluation criteria or method of analysis?

- If not, than what are the strengths / weaknesses of each method?

Also, keep a list of ideas that you want to explore, further, or background material you want to brush upon. This will create another list of readings for you in later stages.

vi) Write a two page proposal defining as clearly as possible the following items.

- Motivation
- Research challenges
- Overview of existing work
- Limitations of existing work
- Potential directions and ideas for improvement
- Expected results and impact on the field.

The two page report can be reviewed by knowledgeable friends and with the research supervisor. Based on their comments the proposal may be rewritten. If some major items missed, then go back to the 15 – 20 list and select another 3 – 5 good papers, read in detail and rewrite parts of your proposal.

Other sources to look for research problems:

Many industries and government organizations indicate the research areas of interest to them. By going through website of the Government organizations, the thrust areas or specific topics of interest can be identified. Similarly, company's annual reports do provide information about their R & D activities, from which some useful hints can be picked up and explored.

One can find many excellent research topics by considering specific products or processes already in existence and looking into ways of better understanding their behaviour and improve their performance. When properly defined this is not 'routine testing' inappropriate for academic research study but rather the essence of most experimental study in engineering. Many industrial undertakings may be willing to contribute by way of sample products and company engineers willing to share their expertise.

In many standard books on the broad area of research interest, the authors would have indicated the current status and what further exploration needs to be made. It is better to go through the latest edition of such books to identify possible specific area, which can be explored.

It is a normal practice in the Ph.D theses, the researcher indicate scope for further research and the limitations of his study due to certain constraints. By going through these theses, one can identify many research problems for investigation.

Discussion with experts, who have been working in the proposed area for several years and attending of seminars, conferences and workshops related to the areas of interest to the researcher will provide ample opportunities to choose a topic of research.

1.7 FORMULATION OF RESEARCH PROBLEM

The selection of a topic for research obviously includes a certain level of definition of the problem selected. It is most important to develop a thoughtful and detailed problem description early. Quite often one hears “A problem well defined is a problem half solved”. The problem to be investigated must be defined unambiguously for that will help to discriminate relevant data from the irrelevant ones and what sort approach we have to adopt. It helps to answer questions like,

- What data are to be collected?
- What characteristics of data are relevant and need to be studied.
- What relations one to be explored?
- What techniques, experiments etc are to be used?

In an academic environment, choice of problem topics can be wider since no economic pay off is needed. But, however, the major constraints are time frame available facilities and preparation for studies. The faculty, who is a guide to the scholar, is likely to exert influence on the choice of topic.

Defining a problem involves the task of laying down boundaries within which a researcher shall study the problem with a predetermined objective in view. Though, this is a little difficult task, it has to be tackled intelligently to avoid the perplexity encountered in the research operation. The usual approach of researcher posing a question himself and set up techniques and procedures for throwing light on the question concerned for defining the research problem may not produce definite results. Defining a research problem properly and clearly is a crucial part of research study and must in no case be accomplished hurriedly.

The research problem should be defined in a systematic manner giving weight age to all related points. A suggested technique for the purpose involves the following steps generally one after the other.

i) State the problem in a general way
ii) Understand the nature of the problem
iii) Survey the available literature
iv) Develop ideas through discussions
v) Rephrase the research problem into a working proposition

General statement of the problem

Keeping in view either some practical concern or some scientific or intellectual interest or taking the clue from other published sources, state the problem in a general way broadly. The researcher should thoroughly immerse first in the subject matter, which concern with the aspect of the problem he wants to pose. Sometimes, the guide gives a broad hint, and it is then up to the researcher to narrow it down and phrase it in operational terms. There may some ambiguities in the problem stated, which must be resolved by cool thinking Also, the feasibility of a particular solution has to be considered and the some should be kept in view while stating the problem. If necessary a pilot survey or cursory simulation could be attempted.

Understanding the problem

The next step in defining the problem is to understand its origin and nature clearly. The best way of understanding the problem thoroughly is by going through bench mark or base papers, connected books and other literatures. The researcher can discuss with other researchers who worked in similar problems or with a persons who have a good knowledge of the problem concerned. The researcher should also keep in view the environment and facilities within which the problem is to be studied.

Surveying the available literature

Study of available literature concerning the problem broadly considered will be very useful for identifying the type of difficulties that may be encountered in the proposed approach as also the possible analytical shortcomings. At times such studies may also suggest useful and even new lines of approach to the problem being considered.

Develop ideas through discussions

Discussion concerning a problem often produce useful information, As already stated, the researcher should discuss his problem with his colleagues or others who have enough experience in the same area or working on similar problems. Such discussions should not be confined only to formulation of specific problem at hand, but should also be concerned with the general approach to the given problem, techniques and tools that might be used, possible solutions etc.,

Rephrasing the problem

The researcher must rephrase the research problem into a working proposition. Once, one goes through the steps stated above, rephrasing the problem into analytical or operational terms is not a difficult task. By rephrasing, the researcher puts the problem in specific terms as possible so that it may become operationally viable and may lead to suggested solutions of research problem, which may or may not lead to the real solutions. These propositions should be amenable to testing within a reasonable time and should be consistent with most of the known facts.

Apart from the above, the following points should also be taken into account while defining a research problem.

- Technical terms, words which have special meanings used in the statement of the problem be defined.
- Basic assumptions relating to the research problem should be clearly stated.
- The criteria for the selection of the problem should be stated.
- The source of data, such as survey or experiment etc. and the time period should also be considered in defining the problem
- Scope and limitations of the problem should be mentioned explicitly.

1.8 LITERATURE SURVEY AND REVIEW

Literature survey:

Once we have agreed upon a clear problem definition, the logical next step will be survey of background literature. This is essential whether the proposed problem deals only with theoretical or with experimental aspects or both. The survey should be extensive which means that all available literature concerning the problem at hand must necessarily be surveyed and examined before the definition of the problem made. The researcher must be well conversant with relevant theories in the field, reports and records and all other relevant literature. The researcher must spent sufficient time in reviewing of literature of research already undertaken on related problems.

The literature review is mainly to find out what material and other data are available for operational purposes. If somebody has done experimental study or simulation, he might have mentions the problem and difficulties faced in his study, which may be useful for the current study. Knowing what data are available often serves to narrow the problem itself as well as the technique that might be using. This would also help a researcher to know if there are certain gaps in the theories, or whether the existing theories applicable to the problem under study are inconsistent with each other, or whether the findings of the different studies do not follow a pattern consistent with the theoretical expectations and so on. All this will enable a researcher to take new strides in the field of furtherance of knowledge i.e., he can move up starting from the existing premise. Studies on related problems are useful for indicating the difficulties that he may encounter in the present study as also the possible analytical shortcomings. At times such studies may also suggest useful and even new lines of approach to the present problem.

Sources of information

The sources of information can be classified as indicated below.

a) Public sources

i. Govt. Departments (Defence, Energy, Set etc) ii) State and local Government (Highway, PCB, etc.) iii) Libraries iv) Universities v) Internet

b) Private sources

i. Non profit organizations and services (professional societies, trade associations, membership organizations)
ii. Profit oriented organizations (manufacturers, vendors catalogs, samples, test data etc., consultants)
iii. Individuals (Direct conversation or correspondence, personal friends, faculty)

Depending upon the nature of the problem undertaken for research study, the researcher has to seek the needed information form different sources. But, however major sources of information nowadays is library and internet. When we look for information in the library, there are hierarchy of information sources as given below.

- Technical dictionaries
- Encyclopedias
- Handbooks
- Bibiliographies
- Indexing and abstract services
- Technical and professional journals
- Translations
- Technical reports
- Books
- Patents
- Catalogs and manufacturer's brochures.

When we deal with a project in a new technical area, there may be a need to have a broad overview of the subject. Technical dictionaries and Handbooks provide useful technical data. Many handbooks also provide ample technical description of theory and its application, so they are good refreshers of material once studied in greater detail.

Some libraries and research institutes provide indexing and abstracting services. These provide current information on periodical literature and they also provide a way to retrieve published literature. An 'indexing service' cites the article by title, author, and bibliographic data. An 'abstracting service' also provides a summary of the content of the article. Some of the indexes and abstracts include,

Ceramic abstracts,
Chemical abstracts,
Corrosion abstracts,
Fuels and energy abstracts,
Highway research abstracts,
Applied science and Technology Index,
Engineering Index

Another useful source of much detailed information is 'Dissertation abstract', which gives abstract of most doctoral dissertations compiled in the United States and Canada. A copy of the dissertation can be ordered at a nominal cost. In India, the UGC started putting abstract of research thesis in their website. Now, they are making it mandatory all Universities to send them a soft copy of the thesis to UGC.

Conducting a search of the published literature is like putting together a complex puzzle. One has to select a starting place, but some starts are better than others. A good strategy is to start with the most recent subject indexes and abstracts and try to find a current review article or general purpose technical paper. The references cited in it will be helpful in searching back along the 'ancestor references', to find the search that led to the current state of knowledge. However, this search path will miss any references that were over looked or ignored by the original researchers.

The next step should therefore involve citation sending to find the descendent references using "Science Citation Index". Once you have a reference of interest, you can use citation index to find all other references published in a given year that cited the key reference. These two search strategies will uncover as many references as possible about the topic.

The next step is to identify the key documents. One way to do this is to identify the references which has the greatest number citations, or those that other experts in the field cite as particularly important. One should keep in mind that take 6 to 12 months for a reference to be included in a index or abstract service, so current research will not be picked up using this strategy. Current awareness can be achieved by searching current context on regular basis using key words, subject headings, journal titles and authors already identified from literature search.

Information through Internet

The fastest growing communication medium is the Internet. The internet is a computer network inter-connecting numerous computers or local computer networks linked by common technical protocols. The most recent and most rapidly growing component of the internet is the world wide webs (www), an enormous, far-flung collection of colourful on screen documents that are linked to each other by high lighted words called 'hypertext'. The popularity of www comes from the fact that it makes distributing and accessing digital information simple and inexpensive. Since a large collection of documents are involved, using the web requires a 'search engine'. Nowadays a number of user friendly highly graphical search tools – often called 'web browsers' are extensively used. The most commonly used include Netscape communicator, Microsoft Internet explorer.

Locations on the internet are identified by Universal Resource Locators (URL). For example, a URL that gives a brief history of the Internet is http:// www.isoc.org internet – history. The prefix http://www indicates we are typing to access a HTTP server on the World Wide Web at a computer with the domain name "isoc.org". The document is stored in that computer in a file called 'internet – history'.

To search the World Wide Web, we need a search engine. Each search engine works differently in combing through the web. Some scan the information in the title or header of the document, while others look at the bold headings on the page. In addition the way information is sorted, indexed and categorized differs between search engines. Therefore all search engines will not produce the some result for a specific enquiry, The most commonly used general purpose search engines include,

Alta Vista	http:// www.altavista.digital.com
Hot Bot	http://www.hotbot.com
Yohoo	http://www.yahoo.com

It is important to understand how search engines obtain and maintain their databases and also the search methods. Another important aspect is the degree to which a search engine covers all the materials out of the web. A recent study estimated that even the best search engine covered about one third of the web pages. Therefore, the best strategy for maximizing information retrieval from internet is to pick two or three search engines.

The researcher should also have knowledge of many URLs devoted to engineering topics and the need of the user. Some examples of URLs are,

NASA Technical Information service http://tech reports.lors.nasa.gov / egi-bin / NTRs

This covers all NASA centres and provides abstracts only. Reports must be ordered.

National Technical Information service http://ntis.gov

Large numbers of reports are available on file

The purposes of a literature search are several. A main purpose is ofcourse, to find whether the study you are about to undertake has already been done. We do not want to waste time and energy repeating someone work, unless we question their results for some reasons. Because of the vastness of open literatures and the inaccessibility of many proprietary files, we can never be sure that we have uncovered all works that has been done. Therefore, a sincere effort in doing a thorough literature survey is essential.

1.9 Literature Review

It will be every useful while preparing the thesis if a proper review of literature gathered is made by the researcher. The review should encompass genesis of the problem in the researcher's mind, the extent of knowledge already available and a fairly extensive list of significant papers or other works in the area along with summary of the relevant findings. This can be done easily if the researcher keeps a proper record of these. A suggested form of literature survey / review is given below

Sl.No.	Author (s)	Paper title	Publication details	points	Conclusion& Future work
1	Hung-Yu Chin	Secure Access Control schemes for RFID system with anonymity	Mobile Data Management, 2006.MDM2006.7th International Conference10-12 May 2006 pp 90-96	- Forward Vs Backward channel - Hash based access control - Randomized access control	- NewHash scheme preposed
2	Lee Shajit etal.,	QoS improvement in networking	IEEE transactions on networking and its applications, Vol.12, Issue 3, pp 12 -27, 2016	-Effective utilization of various layers -Methods of channel modeling	-Adaptation of different layers with respect to specific function
3.					

Preparations of a review paper will help to infuse confidence in the mind of the researcher about the problem he proposes to explore. If necessary, he can publish such a review paper in journals or present in conferences.

Format for the References

References to be with author name, title of publication, name of the journal, volume, issue, pp., year of publication as given below;

[1] M.Shahin Uddin , J.Cha , J. Kim and Y. Min Jang, “Mitigation Technique for Receiver Performance Variation of Multi-Color Channels in Visible Light Communication, IEEE Sensors Journal, Vol. 11, pp.31-44, 2011.

[2] K. Cui, G. Chen, Z. Xu, and R. D. Roberts, “Line-of-sight visible light communication system design and demonstration,” Proc. of 7th IEEE, IET International Symposium on Communication Systems, Networks & Digital Signal Processing: 2nd Colloquium on Optical Wireless Communications, Newcastle, UK., 2010

[3] I.E Lee, M.L Sim, F.W Kung “Performance Enhancement of Outdoor Visible-Light Communication System Using Selective Combining Receiver”, “IET Optoelectronics”. Vol. 3, pp.30-39, 2009

1.10 RESEARCH DESIGN

RESEARCH DESIGN: WHAT IT IS?

A research design is the arrangement of conditions for collection and analysis of data in a manner that aims to combine relevance to the research purpose with economy in procedure. It constitutes the blue print for the collection, measurement and analysis of data. The overall research design can be split into the following parts.

i) Evolving a suitable method for selecting items to be observed for the study - **sampling design**
ii) Identifying the conditions under which the observations are to be made - **observational design**

iii) Methods dealing with as how many items are to be observed and how to gather information / data and how to analysis them – **statistical design**

iv) Procedures specified (i) to (iii) can be carried out by using which techniques - **Operational design**.

1.11 WHY WE NEED RESEARCH DESIGN?

Research design is needed because, it facilitates the smooth sailing of the various research operations, thereby making research as efficient as possible yielding maximum information with minimum expenditure of effort, time and money. It also stands for advanced planning of methods to be adopted for collecting the relevant data and techniques to be used in their analysis, keeping in view the objective of the research In fact preparation of the research design should be done with great care, as any error in it may upset the entire project. Not only, this improves the reliability of the results arrived at, but also constitute a firm foundation of the entire edifice of the research work.

A good design is often characterized by adjectives like flexible, appropriate, efficient, and economical and so on. It is related to the purpose or objective of the research problem and also with the nature of the problem studied. A design, which is quite suitable in one case, may be inadequate in the context of some other problem. In fact, a single design cannot serve the purpose of all types of problems.

In an exploratory research study, where the major emphasis is on discovery of ideas and insights, the research design must be flexible enough to permit consideration of many different aspects of a phenomenon. But in a study dealing with accurate description of a situation or an association between variables, accuracy becomes a major consideration. Studies involving the testing of hypothesis of causal relationship between variables require a design which will permit inferences about causality, ensuring minimum bias and maximum reliability.

We may not be able to put a particular study in a particular group in practice, as a given study may have in it elements of two or more of the functions of different studies. Only on the basis of primary function, a study can be categorized as exploratory or descriptive or hypothesis testing and accordingly the choice of a research design may be made in the case of a particular study.

1.12 BASIC CONCEPTS

We use various terminology and concepts in Research design. Some of the important terminology with short explanation for each of them is given to ensure better understanding of the subjects

Variable: A concept which can take on different quantitative values is called a variable. For example weight, stress, strain are variables. Qualitative phenomena (or attributes) are also quantified on the basis of the presence or absence of the concerned attribute. Certain variable take continues values and they are called " continuous variables " and variables which takes only fixed, integer values are called as " discrete variables ". If one variable depends upon or is a consequence of another variable, it is termed as "dependent variable"; and the variable that is antecedent to the dependent variable is called as "independent variable".

Extraneous Variable: Independent variables that are not related to the purpose of study, but may affect the dependent variable are termed as 'extraneous variables'. Any effect noticed on the dependent variable as a consequence of extraneous variable is technically called as "experimental error".

Control: One important characteristic of a good research design is to minimize the influence or effect of extraneous variable(s). The technical term "control" is used when we design the study minimizing the effect of extraneous variables.

Confounded relationship: When the dependent variable is not free from the influence of extraneous variables, the relationship between dependent and independent variable is said to be confounded by an extraneous variable.

Research hypothesis: The research hypothesis is a prediction statement that relates an independent variable to the dependent variable.

Experimental and non-experimental hypothesis testing: When the purpose of research is to test a research hypothesis, it's termed as hypothesis - testing research. Research in which the independent variable is manipulated is termed as "experimental hypothesis testing research". On the other hand, a research in which an independent variable is not manipulated is called "non-experimental hypothesis testing research".

Experimental and Control groups: In an experimental hypothesis testing research, when a group or sample is exposed to usual conditions, it is termed as control groups, but when the group is exposed to some novel or special conditions, it is termed as experimental group. It is possible that certain studies involve only experimental groups or involve both experimental and control groups.

Treatments: The different conditions under which experimental and control groups usually exposed are referred as "treatments".

Experiment: The process of examining the truth of a statistical hypothesis, relating to some research problem is known as experiment. The experiments can be of two types viz, absolute experiment and comparative experiment.

Experimental units: The predetermined plots or the blocks, where different treatments are used are known as experimental units. Such experimental units must be selected (defined) very carefully.

1.13 DIFFERENT RESEARCH DESIGNS

The research designs can be categorized as i) Designs involving exploratory research studies, ii) Descriptive and diagnostic type research design studies, and iii) Research studies involving hypothesis – testing.

Design involving exploratory research

This type of study is also termed as formulative research studies. The major emphasis of such studies is the discovery of concepts (ideas) and better insights. Since, this is of exploratory nature; study design should be flexible enough to provide opportunity for considering different aspects of the problem under study. In this, the research problem is initially defined broadly, and may get transformed into one with more precise meaning. This may require changes in the research procedure for gathering data, hence inbuilt flexibility in research design is needed.

In studies relating to engineering, the experimental work may be tentative and somewhat unfocused nature initially or in the early stages of familiarization with a physical phenomenon. Hence, one wants to keep an open mind, in the hope of observing some unusual or potentially useful behaviors, which might become the subject matter later for more focused investigation. In routine work we usually look for reasons to throw out data points that don't repeat themselves (outliers); in exploratory work the "wild" point may be the basis of an important new product or process, and hence we should not be too quick to dismiss it.

For exploratory research work, the following three methods of research designs are contemplated i) survey of concerned literature, ii) experience survey, and iii) analysis of " insight – stimulating " examples.

Survey of concerned literature

The survey of literature concerning the issue is the most simple and fruitful method of formulating the research problem or developing the necessary premise. The premise or hypothesis stated by earlier researchers may be reviewed and their usefulness be evaluated as a basis for further research. Thus, the researcher should review and build upon the work already done by others, but in cases where no premise has been formulated, the task of the researcher will be to review the available material for deriving the premise from it.

Apart from the biographical survey of studies made in one's area of interest, the researcher should cross breed concepts and theories developed in different research areas to the area in which the researcher is currently working. For Example many of the concepts in biology have been successfully adopted in engineering designs, optimization etc.

Experience survey

This implies survey of people or experts who have practical experience with the problem to be studied. The object of the survey is to obtain insight into the relationships between variables and new ideas relating to the research problem. This survey may enable the researcher to define the problem more concisely and help in the formulation of research hypothesis.

Analysis of insight – stimulating examples

This is particularly suitable in issues where there is little experience to serve as guide. In this approach an intensive study of selected instances of phenomenon in which the researcher is interested will be useful.

Thus, in an exploratory research study, which leads to insights or premises, whatever method of research design outlined above is adopted, the only thing essential is that it must continue to remain flexible, so that many different facets of the problem are considered as and then they arise and come to the notice of the researcher.

Descriptive and diagnostic research studies

Descriptive research studies are those studies, which are concerned with describing the characteristics of a particular material, process, individual or a group. In diagnostic research studies, we are concerned with the frequency with which something occurs or its association with something else. Studies concerning whether certain variables are associated are examples of diagnostic research studies. Investigation which leads to characterization of materials in chemistry, polymer etc. comes under descriptive study. Most of the social research comes under this group.

From the point of view of research design, the descriptive as well as diagnostic studies share common requirements. The researcher in both the cases should define clearly what he wants to measure and must decide suitable methods for measuring it along with clear cut definition of ‘population’, he wants to study. The research design must make enough provision for protection against bias and must maximize reliability, with due concern for the economic completion of the research study.

In both the cases, the design must be rigid and inflexible and should focus attention on the following.

- Formulating the objective of the study (to indicate what is the study about and why it is being made)
- Designing the methods of data collection (what techniques to gather data will be adopted)
- What should be the sample size?
- Manner of collecting data (periodicity etc.)
- How to process the data collected?
- Reporting of findings.

All data collection equipments should be properly calibrated and pretested to minimize bias. The data collected should be examined for completeness, consistency, comprehensiveness and reliability. Since, sample design is involved; it should be tackled in such a fashion that samples yield accurate data / information with a minimum amount of research effort. Usually one or more forms of probability sampling like random sampling may be used. The appropriate statistical operations, along with appropriate tests of significant should be carried out for drawing conclusions.

The difference between research design in respect of the above two types of research studies can be summarized as given below:

Design	Exploratory	Descriptive / diagnostic
Overall aspects	Flexible design to consider different aspects of the problem	Rigid design to protect against bias and should maximize reliability
Sampling	Non-probability sampling design	Probability sampling design
Statistical aspect	No pre-planned design for analysis	Pre-planned design for analysis
Observation	Unstructured instruments for data collection	Structured and well thought out instrument of data collection
Operational	No fixed decisions about the operational procedures	Prior decision about operational procedures

Hypothesis – testing research studies

Hypothesis – testing research studies, generally known as experimental studies, are these where the researcher test the hypothesis of causal relationship between variables. Such studies require procedures that will not only reduce bias and increase reliability, but should permit drawing inferences about causality. Usually experiments meet this requirement, when we talk of research design in such studies; we often mean the 'design of experiments'.

1.14 EXPERIMENTAL DESIGNS

The study of experimental design has its origin in Agricultural research and Professor R.A. Fisher's name is associated with experimental designs. Prof. Fisher found that by dividing agricultural fields into different blocks and then by conducting experiments in each of these blocks, the information gathered and inferences drawn happens to be more reliable. Today the experimental designs are being used in researches relating to phenomena of several disciplines.

Basic principles

Professor **Fisher** has enumerated the following three principles of experimental designs.

i) The principle of replication
ii) The principle of randomization
iii) The principle of local control

The principle of Replication implies that the experiment should be repeated more than once. The experiment (treatment) is applied to many experimental units instead of one. By doing so, the statistical accuracy of the experiment is increased. Conceptually replication does not present any difficulty, but computationally it does. For example if an experiment requiring two way analysis of variance is replicated, it will then require three way analysis of variance since replication itself may be a source of variation in the data. Nevertheless, replication is introduced in order to increase the precision of a study ie, to increase the accuracy with which the main effects and interactions can be estimated.

The principle of randomization provides protection, when we conduct an experiment against the effects of extraneous factors. This principle indicates that we should design the experiment in such a way that the variations caused by extraneous factors can all be combined under the general heading ‘chance’. In an experimental program involving a large number of tests, it is important to randomize the order in which the specimens are selected for testing. By this, any one of the many specimens involved in the experiment have an equal chance of being selected for the test. The bias due to uncontrolled second order factors is reduced.

The principle of local control is another important principle of experimental design. In this, the extraneous factor, the known source of variability, is made to vary deliberately over a wide a range as necessary and this needs to be done in such a way that the variability it causes can be measured and can be eliminated from experimental error. This means that we should plan the experiment in a manner that we can perform a two way analysis of variance, in which the total variability is divided into three components attributed to treatments, the extraneous factor and experimental error. Here, the experiment is divided into homogeneous blocks, each block subdivided into parts equal to the number of treatments and treatments are randomly assigned to these parts of a block. In general blocks are the levels at which we held an extraneous factor fixed, so that we can measure its contribution to the total variability of the data by way of two-way ANOVA. Thus, through the principle of local control, we can eliminate the variability due to extraneous factor(s) from experimental error.

Important Experimental Designs

The most important benefit from statistically designed experiments is that more information per experiment will be obtained than with unplanned experiments. Second benefit is that statistical design results in an organized approach to the collection and analysis of information. Another advantage is the credibility that is given to the conclusions of an experimental programme when the variability and sources of experimental error are identified. Finally an important benefit of proper design of experiment is the ability to discover interaction between experimental variables. A major impetus to the experimental design has been given by the strong emphasis being shown in the design for quality (DFQ).

The experimental designs can be broadly divided into two categories, viz, i) Informal experimental designs and ii) Formal experimental designs. Informal experimental designs are those designs that normally use less sophisticated form of analysis based on difference in magnitudes. Formal designs or statistically designed experiments offer relatively better control and use precise statistical procedures for analysis.

i) Informal experimental designs

a) Before – and – after without control design
b) After only with control design
c) Before – and – after with control design.

ii) Formal experimental designs

a) Blocking designs
  - Completely randomized block (CRD)

- Randomized block design (RBD)
- Latin square Design (LSD)
- Graeco – Latin square design

b) Factorial designs
- Fractional factorial
- Full factorial
- Use of orthogonal arrays

c) Response surface designs.

Informal experimental designs will be covered in this unit, while formed experimental designs will be covered in the next unit after introducing some statistical concepts.

Before – and - after without control design

In this design a single test group is selected and the dependent variable is measured before the introduction of the treatment. The treatment ‘is then introduced and the dependent variable is measured again after the treatment has been introduced. The effect of the treatment is equal to the difference between after exposure to treatment and prior to treatment. The main difficulty of such a design is that with the passage of time considerable extraneous variations may be there in the treatment effect.

After-only with control design

In this design two groups (test group and control group) are selected and treatment is given to the test group only. The impact of the treatment is assessed by subtracting the value of the dependent variable in the control group from its value in the test group. The basic assumption is that the two groups are identical with respect to the behavior of interest. If this assumption is not true, there is the possibility of extraneous variation entering into the treatment effect. This design is superior to the previous one.

Before-and-after with control design

In this design two groups are selected and the dependent variable is measured in both the groups for an identical period of time-period before the treatment. The treatment is introduced in the test group only, and the dependent variable is measured in both the groups for an identical period of time. The treatment effect is determined by finding the difference in the change in the dependent variable in the control group from the change in the dependent variable in the test group.

	Time period – I		**Time period II**
Test group	Level of dependant variable before treatment (x)	treatment $\longrightarrow$	Level of dependant variable after treatment (y)
Control group	Level of dependant variable without treatment (a)		Level of dependant variable without treatment (b)

$\therefore$ Treatment effect = [(y – x) – (b – a)]

This design is superior to both the previous cases for the simple reason that it avoids extraneous variation resulting from both the passage of time and from non-comparability of test and control groups.

1.15 DESIGN OF EXPERIMENTAL SETUPS

Many research studies may involve development of experimental setup to meet the specific needs of the researcher. Using the experimental set up the researcher finds out the effect of independent variable(s) on the dependent variable or response variable. Of course, the experimental set up may vary depending upon the objective of the experiment. Arranging an experiment shares many common features with product design. Design of an experimental set up or developing a new product is a one-of-a-kind rather than a mass produced, since it is built for a specific purpose.

For developing an experimental set up, we can follow the approaches recommended for a new product design. The flow - chart for product design process is given in the figure. The whole process is divided into three major phases viz: conceptual, substantive and detail design.

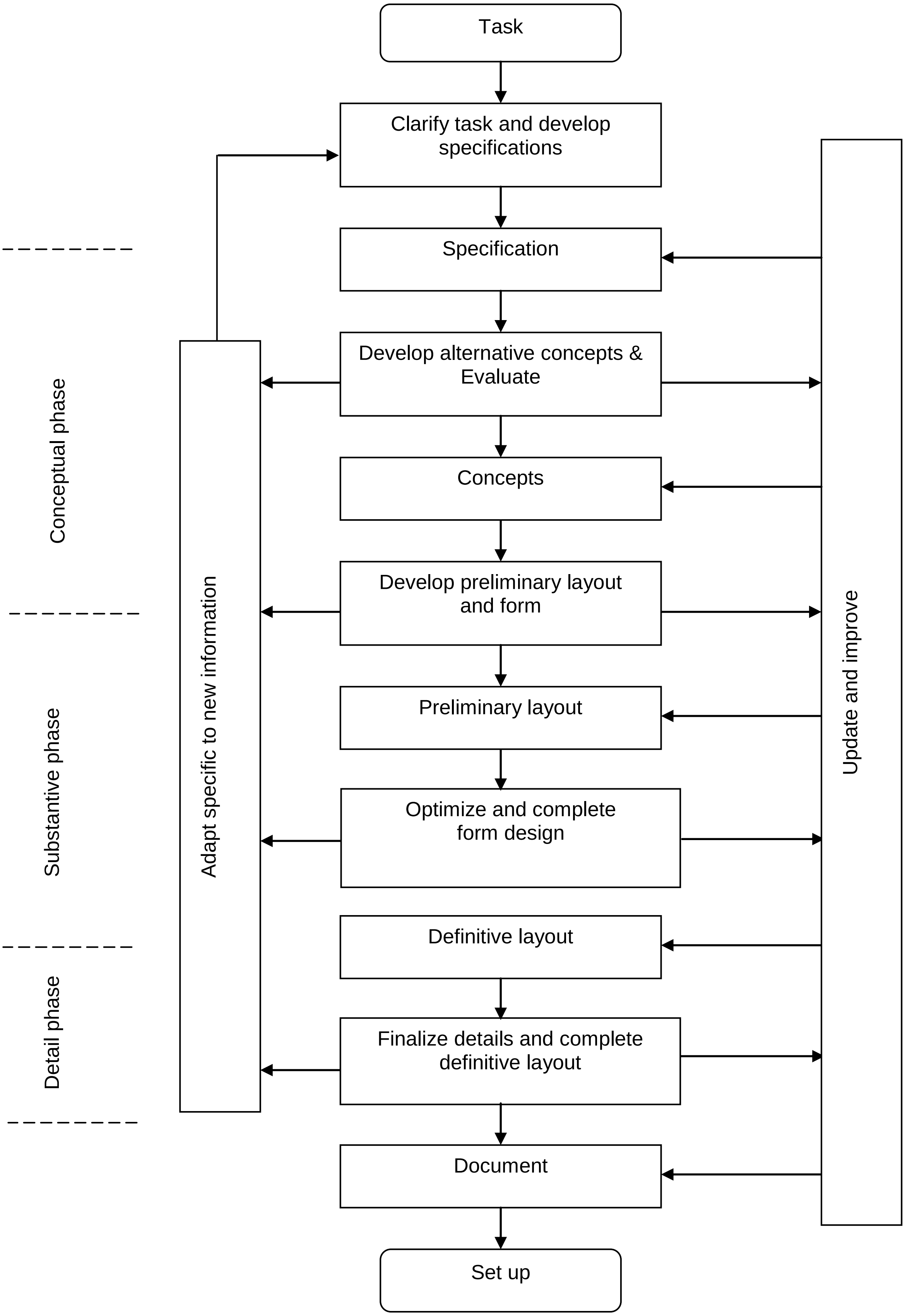


Figure: Design of Experimental Setup

During the conceptual phase, we think of all the different ways we could accomplish the basic task. Evaluate each approach and select those which are feasible ones and move to the next phase. In the substantive phase, we need to embody our concept in an actual physical device which can be analyzed for function and cost.

Each of the approach must be carefully analyzed, improved and adopted to our specific needs and then evaluated critically against performance and cost specifications. When we reach this stage, we would have learned about the problems, so that we may return to the conceptual stage and add some new concepts to our initial list.

After completing the substantive design phase one of the alternative designs stands out as clearly superior and we may reject others. If several alternative concepts have survived to this stage, an intelligent choice among them can be made. For experimental set up more weightage be given to technical functioning. It is generally better to start with a complete list of considerations to ensure that nothing important to specific set up has been overlooked.

During conceptual phase one should avoid thinking about physical hardware and should concentrate on functional requirements. The steps that may help moving from the specification to one or more concepts include:

- abstract to identify the essential functions
- establish function structures (overall and sub functions)
- search for solution principles to fulfill sub functions
- combine solution principles to fulfill overall function
- selection of suitable combinations
- firm up concept variants

The approaches that may help to search for solution principles to fulfill sub functions are: (i) literature search (ii) known technical systems (iii) analogies (iv) previous experimental studies (v) design catalogs (vi) discussion with colleagues and experts etc.

Use of standards and codes

There are many standard practices produced and disseminated by various engineering societies and committees. These documents are a vast store house of accumulated engineering practices, which have been critically sifted and evaluated by knowledgeable experts. Annual book of standards of American Society for Testing Materials (ASTM) is a source. It deals with several subject areas such as iron and steel, non ferrous metals, petroleum products, plastics, rubber, water and environment, instrumentation, chemicals etc. There are many international standard books which the researcher can explore.

The significance and use of standards describe its practical importance and the various ways it might be applied. Standards cover instrument accuracy test apparatus and environment. They also specify number of sample specimens, detailed discussion are included on statistic tools which are useful to the researcher in sampling.

Use of readymade apparatus

An important aspect is the need for the researcher to be familiar with the existing devices, which might provide all or part of the requirements for an experimental set up needed by the researcher. This familiarity can lead to purchase of such parts or can serve as a source of idea for a part that will enable us to make ourselves. We can also combine and adopt features from existing devices in an optimum fashion for our specific needs.

The useful sources of information include standardized testing procedures, vendors of testing equipments, buyer’s guides etc.

1.16 MATHEMATICAL MODELLING

Models

A model is an idealization of the part of real world that aids in the analysis of a problem. In engineering we come across several conceptual models like free body diagram, electric circuit diagram, crystal lactic etc.

A model may be either descriptive or predictive. A descriptive model enables us to understand the real-world system or phenomenon (eg: sectional model of an aircraft gas turbine). A predictive model on the other hand is used primarily in engineering design because, it helps us to both understand and predict the performance of the system.

Models can also be classified as follows: (i) Dynamic or static (ii) Deterministic or probabilistic and (iii) Iconic-analog-symbolic.

Static or Dynamic: A static model is one whose properties do not change with time; a model in which time-varying effects are considered is dynamic.

Deterministic or Probabilistic: A deterministic model describes the behavior of a system in which the outcome of an event occurs with certainty. In many real-world situations, the outcome of an event is not known with certainty and these must be treated with probabilistic models.

Iconic model: It is a model that looks like the real thing (eg: model of an aircraft for wind tunnel test or enlarged model of a polymer molecule). These models are used to describe the static characteristics of a system. The experimental model is a functioning model, which embody the ideas of the design concept. It is as nearly like the proposed design as possible, but it may be incomplete in appearance. This model is subjected to extensive testing and modification. A prototype model is a full scale working model of the design, which is technically and usually complete.

Analog models: They behave like real systems. They are used to compare something that is unfamiliar with something that is very familiar. Unlike iconic model, analog model may look nothing like a real system.

Symbolic models: They are abstraction of the important quantifiable components of a physical system. A mathematical equation expressing the dependence of the system output parameter on the input parameter is a common symbolic model. A symbol is a shorthand label for a class of objects, a specific object, a state of nature, or simply a number. Symbols are useful because, they are convenient, add to simplicity of explanation, and increase the generality of the situation. A symbolic model probably is the most important class of models, because it provides the greatest generality in attacking a problem.

Symbolic models are further distinguished between models that are “theoretical models”, which are based on established and universally accepted laws of nature, and empirical models, which are the best approximation of mathematical representations based on existing experimental data.

MATHEMATICAL MODELS

A mathematical model, as already stated, uses mathematical language to describe a system. Mathematical models are not only used in natural sciences and engineering disciplines but also in social sciences. Physicists, engineers, computer scientist and economists use mathematical models extensively. The process of developing a mathematical model is termed as “mathematical modeling”.

Mathematical models can take many forms, including but not limited to dynamical system statistical models, differential equations, or game theory models.

For example, a frequently used model in engineering is Linear-multiple regression equation.

$$y = a_0 + a_1x_1 + a_2x_2 + \ldots\ldots.\ a_mx_m$$

In case y represents the yield strength of hot rolled ferritic- pearlitic steel based on chemical composition volume, fraction of pearlite and the grain size, than the model is

$$y = 13.29 + 5.30\ Mn + 10.21\ Si + 0.22\ (\%\ of\ pearlite) + 0.47\sqrt{d}\ .$$

The term‘d’ is the mean linear ferrite intercept grain size inches. The correlation co-efficient is 0.89 and 95% confidence limit for prediction of yield strength is $\pm$3800 psi.

Another example is a model which shows the steady – state relationship between the temperature and heat flow in a material is given by Fourier’s Law of Heat conduction.

$$\frac{Q_h}{A} = -k_1\frac{dT}{dx}$$

The heat transfer Q_h is related to the temperature gradient in the direction of heat flow $\frac{dT}{dx}$. The negative sign indicates that there is a temperature drop in the direction of flow.

Background to modeling

Often, when engineers analyze a system to be controlled or optimized, they use a mathematical model. In analysis, engineers can build a descriptive model of the system as a hypothesis of how the system could work or try to estimate how an unforeseeable event could affect the system. Similarly, in control of a system engineers can try out different control approaches using simulation.

A mathematical model usually describes a system by a set of variables and a set of equations that establish relationships between variables. The values of variables can be practically anything; real numbers, integer numbers, Boolean values or strings. The variables represent some properties of the system, for example measured system outputs often in the form of signals, timing data, counters and even occurrences (yes / no). The actual model is a set of functions that describe the relations between the different variables.

Building blocks

There are six basic groups of variables: decision variables, input variables, state variables, exogenous variables, random variables and output variables. Since there can be too many variables of each type, the variables are generally represented by vectors.

Decision variables are also known as independent variables. Exogenous variables are sometime known as parameters or constants. The variables are not independent of each other as the state variables are dependent on the decision, input, random and exogenous variables. Furthermore, the output variables are dependent on the state of system (represented by state variables).

Objectives and constraints of the system and its users can be represented as functions of the output variables or state variables. The objective function will depend on the perspective of the model's user. Although, there is no limit to the number of objective functions and constraints a model can have, using or optimizing the model becomes more computationally involved.

Model classifications:

The mathematical models can be classified in the following ways.

Linear Vs non-linear: Mathematical models are composed of variables, which are abstractions of quantities of interest in the described systems and operators that act on those variables, which can be algebraic operators, functions, differential operators, etc. If all the operators in a mathematical model present linearity, the resulting mathematical model is defined as linear. A model is considered to be non-linear otherwise. Examples of linear models are,

$L = ax + by$; Where ‘a’ and ‘b’ are constants and ‘x, y’ are variables

$L = a\frac{d^2x}{dt} + b.\frac{dx}{dt} + cx$; Where a, b, c are constants

The question of linearity and non-linearity dependent on context, and linear models may have non-linear expressions in them. For example a differential equation is said to be linear if it can be written with linear differential operators, but still it can have non-linear expressions in it. A common approach to non-linear problems is linearization, but this can be problematic if one is trying to study aspects such as irreversibility, which are strongly tied to non-linearity.

Deterministic Vs probabilistic: A deterministic model is one in which every set of variable states is uniquely decided by parameters in the model and by sets of previous states of these variables. Therefore deterministic models perform the same way for a given set of initial conditions. Conversely, in a probabilistic or stochastic model, randomness is present, and variable states are not described by unique values, but rather by probabilistic distributions.

Static Vs dynamic: A static model does not account for the element of time, while dynamic model does. Dynamic models typically represented with difference equations or differential equations.

Lumped Vs Distributed parameters: If the model is homogeneous (consistent state throughout the entire system), the parameters are distributed. If the model is heterogeneous; (varying state within the system), then the parameters are lumped. Distributed parameters are typically represented with partial differential equations.

A priori / subjective information: Mathematical modeling problems are often classified into ‘black box or white box’ models, according to how much a priori information is available of the system. A black-box model is a system of which there is no priori information available. A white-box model (glass box) is a system where all necessary information is available. Practically all systems are somewhere between the black-box and white-box models.

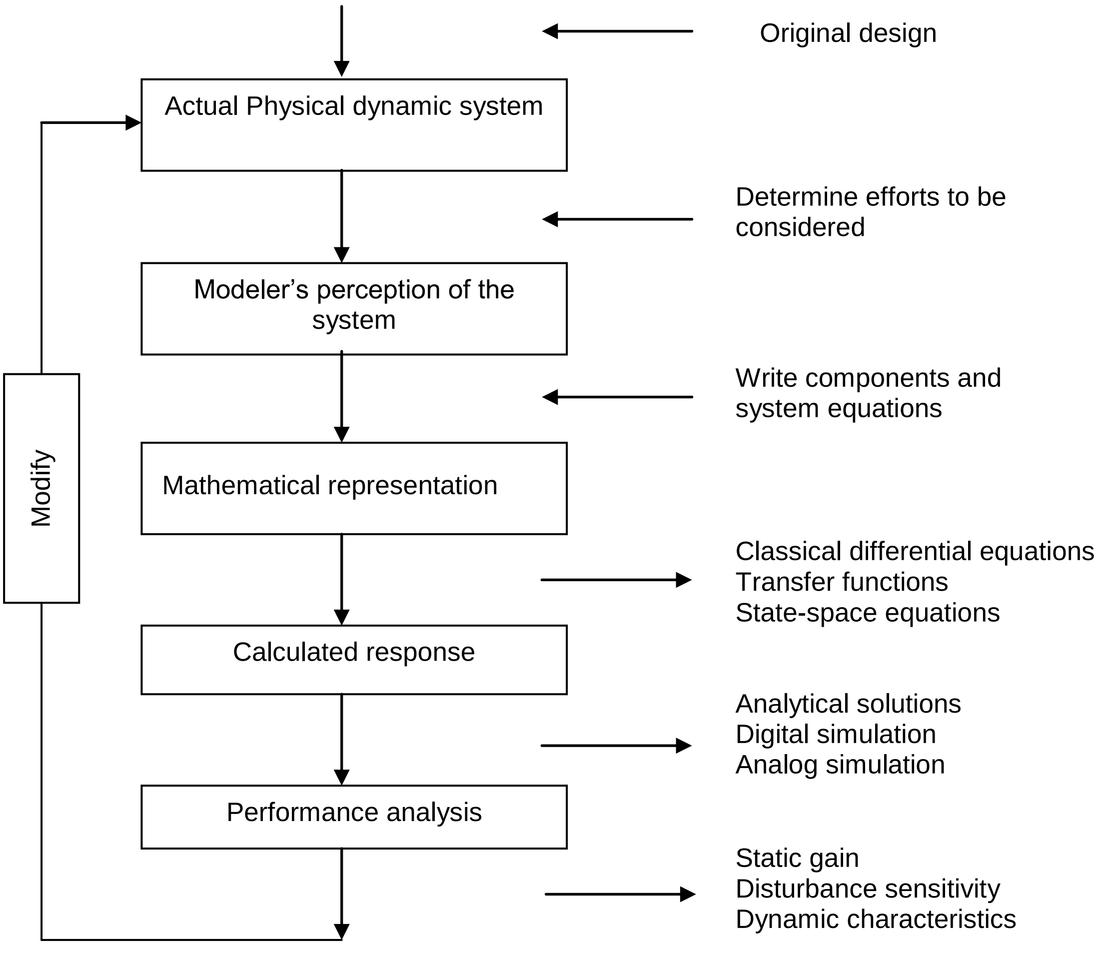
It is always preferable to use as much a priori information as possible to make the model more accurate. Therefore, white-box models usually considered easier, because if you have used the information correctly then the model will behave correctly.

In black-box models one tries to estimate both the functional form of relations between variables and the numerical parameters in those functions. An often used approach for black-box models are neural network which usually do not make assumptions about incoming data.

Sometimes it is useful to incorporate subjective information into a mathematical model. This can be done based on intuition, experience or expert opinion or based on convenience of mathematical form. Bayesian statistics provides a theoretical framework for incorporating such subjectivity into a rigorous analysis: One specifies a prior probability distribution (which can be subjective) and then update this distribution based on empirical data.

Steps in Modeling:

The figure illustrates the several stages involved in modeling of dynamic systems



The actual dynamic system of interest has all the dynamic characteristics that correspond to the exact linear or non-linear behavior of the system. The actual system of course possesses the true response we wish to determine.

Second step is the engineer's perception of the system and its dynamic characteristics. The modeler may neglect some non-linearities or higher order dynamic characteristics for simplicity; however, the actual system does not include all of these effects and characteristics. Hence, the engineer's perception might not truly represent the actual dynamic system.

The third step is the mathematical model of the system represented by the differential equations derived from the conservation and property laws of appropriate disciplines. If the actual system is linear, the development of a suitable mathematical model is quite straight forward. However, if the system is non-linear, the mathematical model may include some approximation to simplify analysis; therefore the equations may not represent exactly the engineer's perception of real system.

In the fourth step, the system response expressed by analytic solutions to differential equations is an exact solution of the equations. Some error might exist between the solution computed by numerical and the actual solution of differential equations.

The fifth step involves the analysis of performance of the dynamic system, as expressed by specific response measures. If after the performance has been evaluated, the system does not display the desired response, the system and its model should be modified or the components of the existing model adjusted to obtain the desired output.

Model Complexity

The model complexity involves a trade-off between simplicity and accuracy of the model. The essential idea is that among the models with roughly equal predictive power, the simplest one is the most desirable. The added complexity improves the fit of the model; it can make the model difficult to understand and work with and can also pose computational problems including numerical instability.

It is therefore usually appropriate to make some approximations to reduce the model to a sensible size. Engineers generally accept some approximations in order to get a more robust and simple model. For example Newton's classical mechanics is an approximated model of the real world. Still, Newton's model is quite sufficient for most ordinary life situations that are as long as particle's speed is well below the speed of light, and we study macro-particles only.

Model evaluation

A crucial part of modeling process is the evaluation whether or not a given mathematical model describes a system accurately. Answering this question involves several different types of evaluations.

Any model which is not pure white-box contains some parameters that can be used to fit the model to the system it describes. If the modeling is done by neural network, the optimization of parameters is called training. In more conventional modeling through explicitly given mathematical functions, parameters are determined by curve fitting.

An easier way of model evaluation is to check whether a model fits experimental measurements or other empirical data. In models with parameters, a common approach is to split the data in to two sets; one set for training and the other set for verification. The training data are used to estimate the model parameters. Any accurate model will closely match the verification data even though this set of data was not used to estimate the parameters. This practice is known as cross-validation in statistics.

Defining a metric to measure the deviation between observed and projected data is a useful tool of assessing a model fit.

It is difficult to test the validity of the general mathematical form of a model. Mathematical tools are available to test the fit of statistical models than models involving differential equations. Tools from non – parametric statistics can sometimes be used to evaluate how well data fits known distribution.

Assessing the scope of the model, that is determining what situations the model is applicable to, can be less straight forward. If the model was constructed based on a set of data, one must determine for what system or situations the data is a typical set of data from. The model should also describe well the properties of the system between data points, which is called 'interpolation'. If it is capable of describing events or data points outside the observed data, it is called 'extrapolation'. As the purpose of modeling is to increase our understanding of the situation / phenomena of real work, the validity of the model rests not only on its fit to empirical observations, but also on its ability to extrapolate situations or data beyond those originally described in the model.

1.17 SIMULATION, VALIDATION AND EXPERIMENTATION

Importance of Simulation

Simulation refers to the application of computational models to the study and prediction of physical events or the behavior of engineered systems. The development of computer simulation has drawn from a deep pool of scientific, mathematical, computational and emerging knowledge and methodologies. With the depth of its intellectual development and its wide range of applications, computer simulation has emerged as a powerful tool, one that promises to revolutionize the way engineering and science are conducted in the 21st century.

Computer simulation represents on extension of theoretical science in that it is based on mathematical models. Such models attempt to characterize the physical predictions or consequences of scientific theories. Simulation can be much more however. For example, it can be used to explore new theories and to design new experiments to test these theories. Simulation also provides a powerful alternative to the techniques of experimental science and observation when phenomena are not observable or when measurements are impracticable or too expensive.

Although the use of computer simulation in engineering science began over a half a century ago, only in the past decade or so have simulation theory and technology made a dramatic impact across the engineering fields. That remarkable change has come about mainly because of developments in the computational and computer science and the rapid advancement in computing equipment and systems.

Simulation – Based Engineering Science (SBES) is considered as a discipline that provides the scientific and mathematical basis for the simulation of engineered system. Such systems range from microelectronic devices to automobiles, aircraft, and even infrastructures of oil fields and cities. SBES fuse the knowledge and techniques of the traditional engineering fields – electrical, civil, mechanical, chemical, aerospace, biomedical, nuclear and material science – with the knowledge and techniques of fields like computer science, mathematics and the physical and social sciences. As a result, engineers are better able to predict and optimize systems affecting almost all aspects of our lives and work, including our environment, security and safety and the products we use.

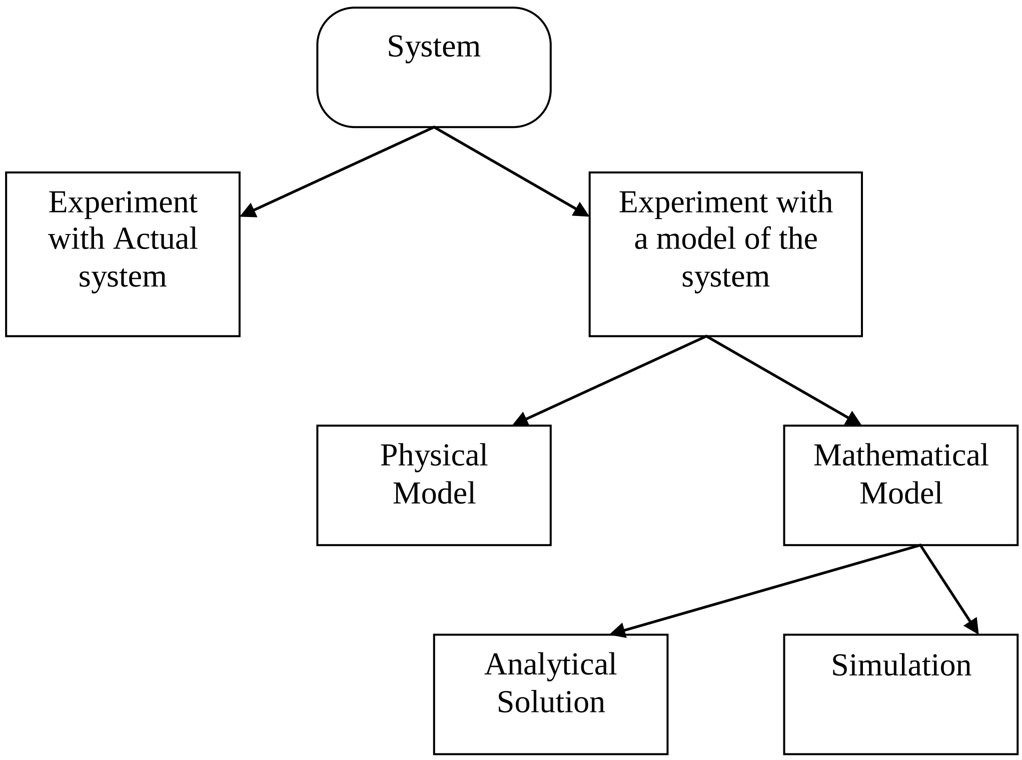
A panel appointed by USA Government in 2004, observed that SBES is an indispensable discipline to the nations continued leadership in Science and Engineering. They have further added that it is central to advances in biomedicine, manufacturing, security of the homeland, micro electronics, energy and environmental sciences, advanced materials and product development. This new discipline could significantly impact every aspect of human experience.

System simulation

System simulation comprises of a mathematical model of a real world situation called 'the system', in such a way that the model behaves like the actual system to events and inputs that takes place over time. It is the process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behavior of the system or evaluating various strategies for the operation of the system.

By collecting data on system's response under various conditions, it is possible to learn how the real system may perform, without having to attempt costly experiments with the actual system. The main value of simulation is that it can be conveniently manipulated until the desired results are obtained. Simulation can be performed on existing systems to identify options for problem solving or system improvements. It is also an excellent forward planning tool to evaluate and compare proposed systems before they are acquired and installed.

Figure given below maps out different ways, in which, a system might be studied; and the position of simulation.



Classification of simulation models

We have a mathematical model to be studied by means of simulation and then we must look for a particular tool to do this. It is useful for this purpose to classify simulation models along three different dimensions.

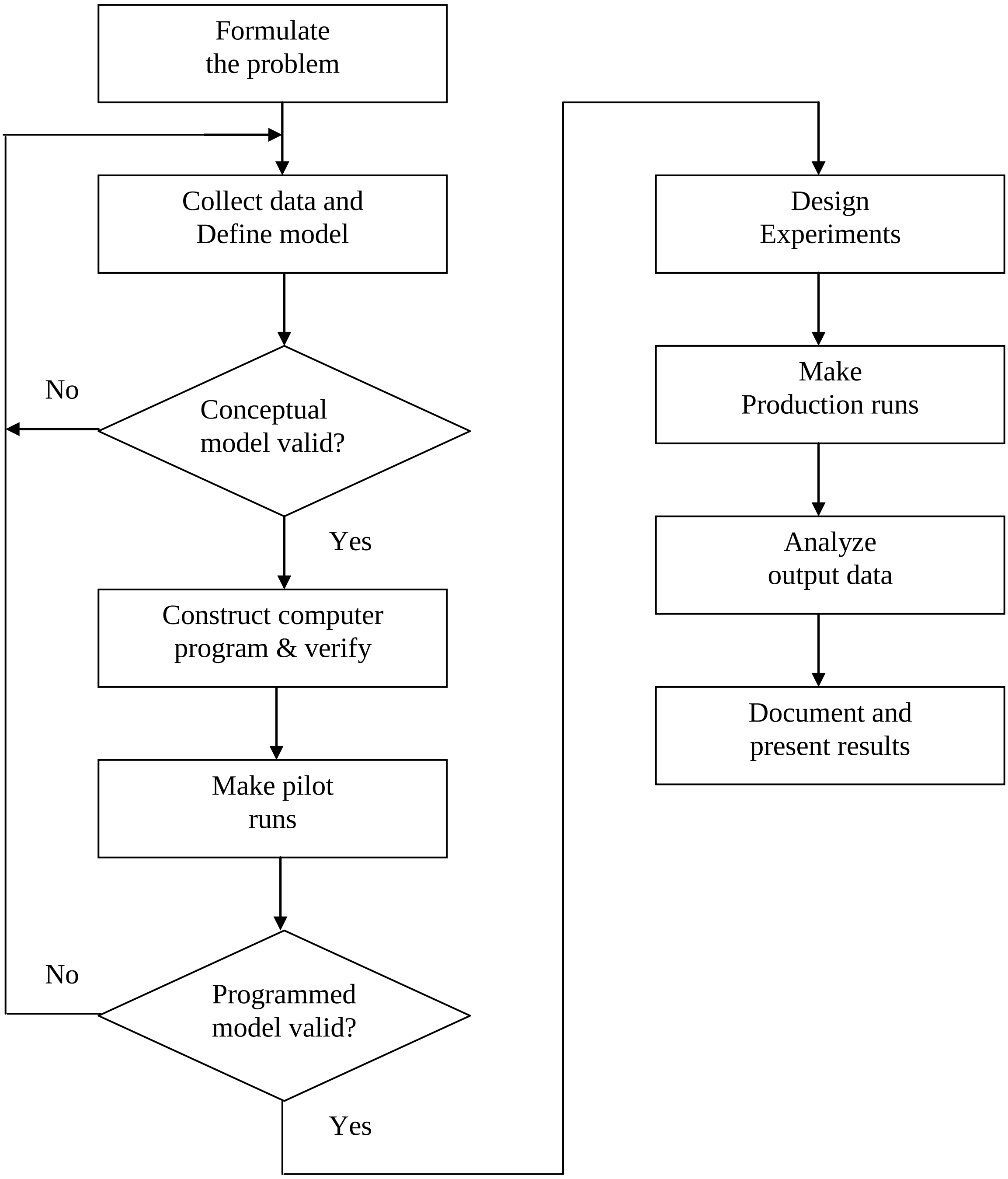
- **Static vs Dynamic simulation models:** A static simulation model is a representation of a system at a particular point in time. A dynamic simulation model on the other hand represents a system as it evolves over time such as a conveyor system in a factory.
- **Deterministic vs Stochastic:** If a simulation study does not contain any probabilistic (ie.random) components, it is called deterministic (e.g.: a system of differential equation describing a chemical reaction). If a system modeled has at least one random component (input), this gives rise to stochastic simulation.
- **Continuous vs Discrete simulation:** Discrete event simulation concerns the modeling of a system as it evolves over time by a representation in which the state variables change instantaneously at separate points in time. Continuous simulation concerns the modeling over time of a system by a representation in which the state variable changes continuously with respect to time.

Steps in a simulation study

There are various steps involved in a discrete event simulation study. The figure shows the steps that will compose a typical sound simulation study. It should be noted that a simulation study is not a simple sequential process. As one proceeds with the study, it may be necessary to go back to a previous step(s).

Eventhough the figure self is explanatory; some of the steps may need some explanation. For instance to check conceptual model validity, we have to perform a structured walk-though of the conceptual model using the assumptions to ensure that the model's assumptions are correct and complete. The model may be programmed in any programme language (eg: C or FORTRAN) or in simulation software (eg: Areyna, Automod, Extend, MATLAB, etc.). The use of simulation software not only reduces the programming time, but also the cost of the project.

Steps in Simulation Study



To check the validity of programmed model, if the is an existing system, compare model and system performance. The model results should be reviewed for correctness. Use sensitivity analysis to determine what model factors have significant impact on performance measures and thus, have to be modeled carefully. In Design of experiments, the length of each run, length of warm up period, numbers of independent simulation runs using different random number have to be taken into account.

Simulation software's

The simulation packages are classified as two major types viz. simulation languages and application oriented simulators. Simulation languages are general in nature and the model development is done by writing code by the user. Simulation languages in general provided a great deal of modeling flexibility, but are often difficult to use as it consumes time. On the other hand simulators are oriented towards a particular application and a model can be developed by using graphics, dialog boxes and pull down menus. Simulators are easier to learn, but may not be flexible enough for some problems. In recent years vendors of simulation languages are attempting to make their software easier to use by employing a graphical model building approach.

Similarly, the vendors of simulators make their software more flexible by allowing programming in certain model locations using an internal pseudo – language. Thus, a general purpose simulation package can be used for any applications, but might have special features for certain ones (eg. for manufacturing, communications). On the other hand application oriented simulation package is designed to be used for a certain class of applications. Examples of some application oriented simulation package, include; manufacturing – Automod, Extend, Pro Model, QUEST, Arena; communication Networks – COMNET, OPTNET; Process Engineering – Process Model, SIMPROCESS; Health care – Med Model;

Some major applications

Infrastructure:

- Simulation based studies can help detect and measure the presence of biological or chemical contaminants in the air, and given the weather data identify the likely release location and magnitude of the release. This will help to evolve an optimal response plan.
- Optimize the designs of buildings and other infrastructure elements. Such designs could be cite specific, interact well with natural and manmade surrounding and blend with other urban systems of which they are a part.
- Can predict the effects of effluents from existing and proposed facilities in urban and natural environments. This will increase the reliability and usefulness of environmental impact studies.

- Can be used to assist in the design and placement of air and water contaminant disposal and flood abetment.

Energy and environment

- The energy related industries rely on modern simulation methods to monitor the production of oil reservoirs, plan pollution remedial measures, and devise control strategies.

Material science

- Multiscale modeling and simulation are transforming the science and technology of new material development and improvement of existing materials. The new methods enable unprecedented ability to manipulate metallic, ceramic, semiconductor and polymeric materials.
- The principle of materials design is rooted in the correlation of molecular structure with physical properties. From these correlations, models can be formulated that predict micro structural evolutions. Such models allow the researcher to investigate the mechanisms underlying the critical behaviors of materials and to systematically arrive at improved designs.

Industry:

- Plays a significant role in the design of materials, manufacturing processes and products. Increasingly, simulation is replacing physical tests to ensure product reliability and quality.
- In automotive industry crash worthiness studies are made using simulation instead of using real vehicles and dummies.
- Simulation is used in perto chemical plants to develop steady-state process simulation models to perform detailed optimization. As a result chemical plants are more efficient both in energy and environmentally.
- Over the past two decades the integrated circuit industry has been a major player in simulation based engineering. Highly integrated easy – to – use software such as SPICE is used for circuit analysis. With the clock rates move into gigahertz range, circuit theory may not be of much use. Future generation transistors such as single electron transistors, low threshold transistors and quantum computing devices will be based on new physics that links quantum mechanics and electromagnetic.

REVIEW QUESTIONS

Module 1

Part A

1. Define the term research and its need.
2. Define the terms: Innovation, Invention, Diffusion and discovery with two examples for each.
3. Brief the parameters of good research.
4. Summarize the objective and motivation of good research.
5. Justify the statement with any two suitable examples as, “Research is different from doing a project”.
6. What is action Research? Give an example.
7. State the methods applied to solve the engineering problems.
8. How do you choose a research problem?
9. What are the factors to be considered, while identifying the research topic?
10. Brief the use of ‘IEEE xplore’ digital library interms of research
11. What is the role of search engines in research process?
12. Mention a quick method for literature survey.
13. What is a digital library? State its significance.
14. Give the format of literature review.
15. Match the following;

1	Scientific method is committed to	A	feasibility
2	Research is classified on the basis of	B	Primary data
3	Applied research	C	Secondary data
4	descriptive research	D	Research design
5	Invention	E	creative act
6	Innovation	F	surveys and fact finding
7	Literatures	G	Intent and methods
8	“Empirically verifiable observation” is	H	Process translated into successful practice
9	Experimentation	I	Objectivity
10	Procedures specified to carry the research	J	Action research
11	Research Problem	K	Fact

16. What is the meaning of research design?
17. State the need of research design?
18. Name the three major categories of research design.
19. Is research design and design of experimental set up are similar in its functionality?
20. Differentiate between concept and principle.

21. State the 3 principles of experimental design by Prof.Fisher.
22. State the terms ‘treatment’ and ‘experiment’ with example.
23. Classify models based on information source for development.
24. Classify models based on the basis of mathematical property.
25. What is an empirical model? When this to be applied.
26. Brief the difference between the static and dynamic behavior of a system?
27. Name any 2 software for simulation studies relating to your field of interest.
28. Fill up the blanks with best answers from given terminologies;

    Descriptive research design must be ….(i)…..and an exploratory research design must be ………(ii)………. The motivation research is a type of ………(iii)……. research. Research which follows case study method is called as……(iv)……. Empirically verifiable observation is referred as……(v)……. Experimentation with control groups is………(vi)……. The method by which a sample is chosen is a ………(vii)……. ……… Research related to abstract ideas is ……(viii)……

    (Diagnostic, Treatment, Conceptual Research, Inflexible, Design, Flexible, Fact, Qualitative)
29. Match the following;

1.	An essential Criterion of Scientific study is	A.	Observational design
2.	Path for the various research operations	B.	Operational design
3.	Basis of research classification	C.	Literature survey
4.	Method for selecting items	D.	Statistical design
5.	Identifying the conditions	E.	Primary function
6.	Data analysis is specified by	F.	Objectivity
7.	Procedures specified to carry the research	G.	Sampling design
8.	Digital library	H.	Research design

Part B

1. What are the different types of research? Explain any two in detail.
2. What are the factors to be considered, while identifying the research topic?
3. Justify the statement with any two suitable examples as, “Research is different from doing a project”.
4. Compare the two fundamental approaches of research frame work with example
5. Describe the various steps involved in research process and its organization with example.
6. Explain the various steps involved in research process with its flow chart to resolve the issues occurred in consumer product.

7. Describe research process through neat bock diagram for fundamental Research, Empirical research, Quantitative research and Qualitative research with suitable example.
8. Discuss the various steps involved in research problem formulation with its issues
9. With suitable example justify the statement, “While carrying research doubt is often better than overconfidence”.
10. Using an example, describe the steps involved in solving engineering problems.
11. Describe the role of literature survey in research problem identification?
12. Illustrate the steps involved in literature survey for research.
13. “For any research to be successful it must be well designed.” Justify this statement with suitable example.
14. “Research design in exploratory studies must be flexible but in descriptive studies, it must minimize bias and maximize reliability.” Discuss with suitable examples.
15. Illustrate the constructive type of research design and its implications to provide the solution for an “e learning system”.
16. Illustrate the importance of experimental design with its limitations.
17. Discuss the classifications of important experimental designs with its limitations through examples
18. Illustrate the principles of experimental design to resolve the network traffic issues and its significance through example.
19. Describe the principles of mathematical model and experimental model through suitable example.
20. Develop a mathematical modeling for an efficient traffic control system of dense high way road system
21. Discuss the steps involved in simulation study with its issues through examples.
22. Is Simulation and validations are the essential process of quality research? Explain with relevant examples.