1 Introduction to Engineering Design

1.1 INTRODUCTION

Modern industry requires Mechanical Engineers who are capable of designing machinery to perform specific tasks. In most cases the engineer receives an explanation or statement of the task which the machine is to perform, and from this he proceeds to design a machine which when built will perform the desired task. To do this the engineer must exercise creative ability, sound judgement and good technical knowledge. He must first actually invent or create a machine to perform this task, using his judgement to affect necessary compromises between conflicting requirements, and then by using analysis and calculations show as best as he can that the machine will perform satisfactorily. This is a challenging procedure, sometimes being very exciting, other times very frustrating, and always requiring a lot of hard work. However, when the design is completed it provides the design engineer with a feeling of real accomplishment, for he has created some thing which did not exist before.

The designing of mechanical machines often is a difficult task for the beginner. This is in part due to his not knowing exactly how to go about the job of designing a machine, as well as to his not being sure of just what things he must consider in the process of doing the design job. Furthermore, he is generally handicapped by his lack of knowledge about the various aspects of design. In this chapter, we shall discuss the basic principles of engineering design which are very useful for the design of mechanical machines.

1.2 DEFINITIONS

Engineering—It has been defined in many ways, as follows:

- The art of directing the great sources of power in nature for the use and convenience of man (Thomas Tredgold, 1828).
- The art of constructing (A.W. Wellington, 1887).
- The art of organising and directing men and controlling the forces and materials of nature for the benefit of the human race (Henry G. Stott, 1907).

- To utilize the natural energy to the best advantage, so that there may be least possible waste (Willard A. Smith, 1908).
- The conscious application of science to the problems of economic production (H.P. Gillete, 1910).
- The art of science of utilizing, directing or instructing others in the utilization of the principles, forces, properties and substances of nature in the production, manufacture, construction, operation and use of things, etc. or of means, methods, machines, devices and structure, etc. (Alfred W. Kiddle, 1920).
- The practice of safe and economic application of the scientific laws governing the forces and materials of nature by means of organization, design and construction, for the general benefit of mankind (S.E. Lindsay, 1920).
- An activity other than purely manual and physical work which brings about the utilisation of the materials and the laws of nature for the good of humanity (R.E. Hellmund, 1929).
- The science and art of efficient dealing with materials and forces to achieve economic design, assuring most advantageous combination of accuracy, safety, durability, speed, simplicity, efficiency (J.A.L. Waddell et al, 1933).
- The professional and systematic application of science to the efficient utilization of natural resources to produce wealth (T.J. Hoover and J.C.L. Fish, 1941).
- The profession in which a knowledge of the mathematical and physical sciences gained by study, experience and practice is applied with judgement to develop ways to utilize, economically, the materials and forces of nature for the progressive well being of mankind (The Engineers Council for Professional Development).

Designing. To design is to innovate and to create. The process of designing is to suggest or outline ways to put together man-made things, or to suggest modifications in man-made things to satisfy optimally (under the given constraints) some specified human needs.

Engineering Design. It has been defined in many ways as follows:

Iterative decision making process to conceive and implement optimum systems to solve societies problems and needs (E.P. Mikol).

A goal directed problem solving activity (Archer, 1965).

Finding the right physical components of a physical structure (Alexander, 1963).

Simulating what we want to make (or do), before we make (or do) it as many times as may be necessary to feel confident in the final result (Booker, 1964).

Decision making in the face of uncertainty, with high penalties for error (Asimow, 1962).

The conditioning factor for those parts of the product which come into contact with people (Farr, 1966).

Relating product with situation to give satisfaction (Gregory, 1966).

The performing of a very complicated act of faith (Jones, 1966).

A creative activity which involves bringing into being something new and useful that has not existed previously (Reswick, 1965).

The optimum solution to the sum of the true needs of a particular set of circumstances (Matchett, 1968).

To initiate change in man-made things. (Jones, J.C., 1970).

Engineering design being practical in nature, must be concerned with physical reliability, or economic and financial feasibility. The difference between Design and Engineering Design is the level of sophistication required in the manipulation and application of technological factors and the extent to which a well developed understanding of the underlying physical phenomena is necessary. When the technology involved is complex then the design is termed as Engineering Design and if the routine technology can be used to accomplish the goal, it is termed Design.

Mechanical Design. If the end product of the Engineering Design can be termed as mechanical, then this may be termed as Mechanical Design. According to Fielden (1963), the Mechanical Engineering Design may be defined as the use of scientific principles, technical information and imagination in the Design of a mechanical structure, machine or system to perform prescribed functions with the maximum economy and efficiency.

Machine Design. It may be defined as a process of achieving a plan for the construction of a machine.

Machine. It may be defined as a combination of kinematic links having unique relationships of motion so as to result in useful work being done in a controlled manner.

Rational Design. It is purely mathematical design based upon principles of mechanics of materials and machines.

Empirical Design. It is based upon existing standard practice and past experience.

Industrial Design. Here we consider aesthetics, ergonomics and production aspects of design.

Optimum Design. A design which is best for the given objective function under the specified constraints.

System Design. A system is an orderly combination or arrangement of parts into a whole. The system design may be defined as an iterative decision making process to conceive and implement optimum systems to solve societies problems and needs considering it as a part of the whole universe.

Computer Aided Design. In many design calculations, computers relieve designers of the routine work. So when the help of a computer is taken to solve a design problems the design is said to be computer aided design.

1.3 THE MORPHOLOGY OF DESIGN

The most general design problem can be stated as: devise or design subject to certain constraints a product system or process to accomplish the given task or fulfill the given need optimally. The simplest sequence for problem solving activities is:

(*a*) analysis, (*b*) synthesis, and (*c*) evaluation. The three phases of design in chronological sequence are:

(*a*) divergence phase, (*b*) transformation phase, and (*c*) convergence phase. These phases are shown in Fig. 1.1.

The term divergence refers to the act of extending the boundary of a design situation. This is usually the exploration phase where the designer is to get as much understanding of the problem as possible. The typical divergence methods are: (*a*) literature survey, (*b*) questionnaire, (*c*) strategy switching, (*d*) brain storming, (*e*) synectics, etc. The analysis of need consists of exploring the design situation, establishing the specifications of the system desired, deciding on the standards against which the performance of the design can be measured the stating the constraints within which one has to work. The optimality criterion has also to be fixed.

The transformation phase is the creative phase wherein the designer makes use of all his experience, innovative capabilities, insights and genius to conceive of a number of plausible alternate solutions to the problems.

The final stage is the convergence phase which starts with narrowing down of the field of plausible solutions to the most promising one on the basis of physical realizability, anticipated utility and financial feasibility. The next step is the preliminary design in which the proposed design concepts are synthesised to achieve a prespecified level of performance. The next step is the evaluation of preliminary design based upon reliability, wear and consequent deterioration in quality and performance. In the detailed design, the detailed dimensions, tolerances, finishes, etc., are specified. Finally the design is implemented, a prototype prepared and tested.

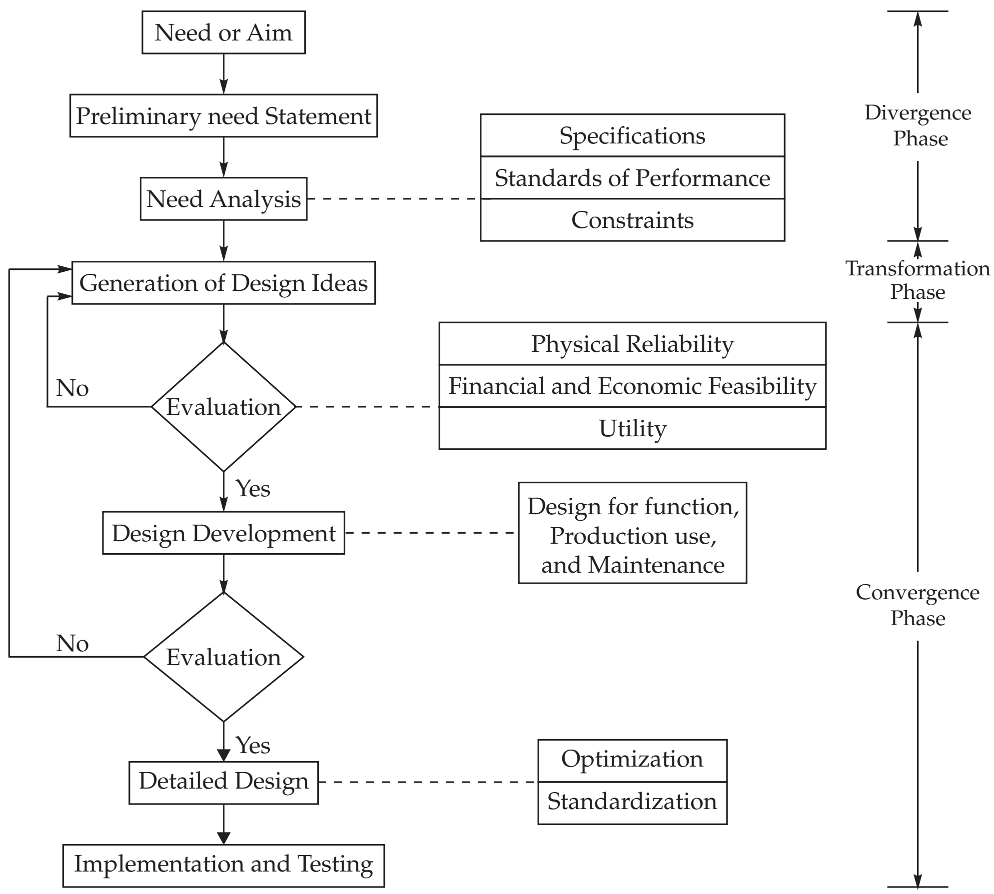

Fig. 1.1 Morphology of Design.

1.4 THE DESIGN PROCESS

The design process is an iterative cycle like a feedback loop, where a preliminary design is made based on the available information, and is improved upon as more and more information is generated. The design process is shown in Fig. 1.2. The three elements of the design process are: (*a*) general principles, (*b*) design discipline, and (*c*) feedback apparatus. The feedback loop is operative only as long as the design is considered inadequate.

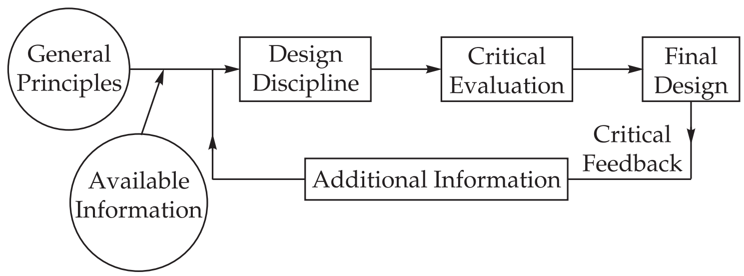

Fig. 1.2 Iterative Cycle.

The point at which a designer stops gathering information and prefers taking a decision under uncertainty is a decision itself. Comparing the advantages and disadvantages in choosing one alternative over another is called trade-offs. The detailed design process is shown in Fig. 1.3.

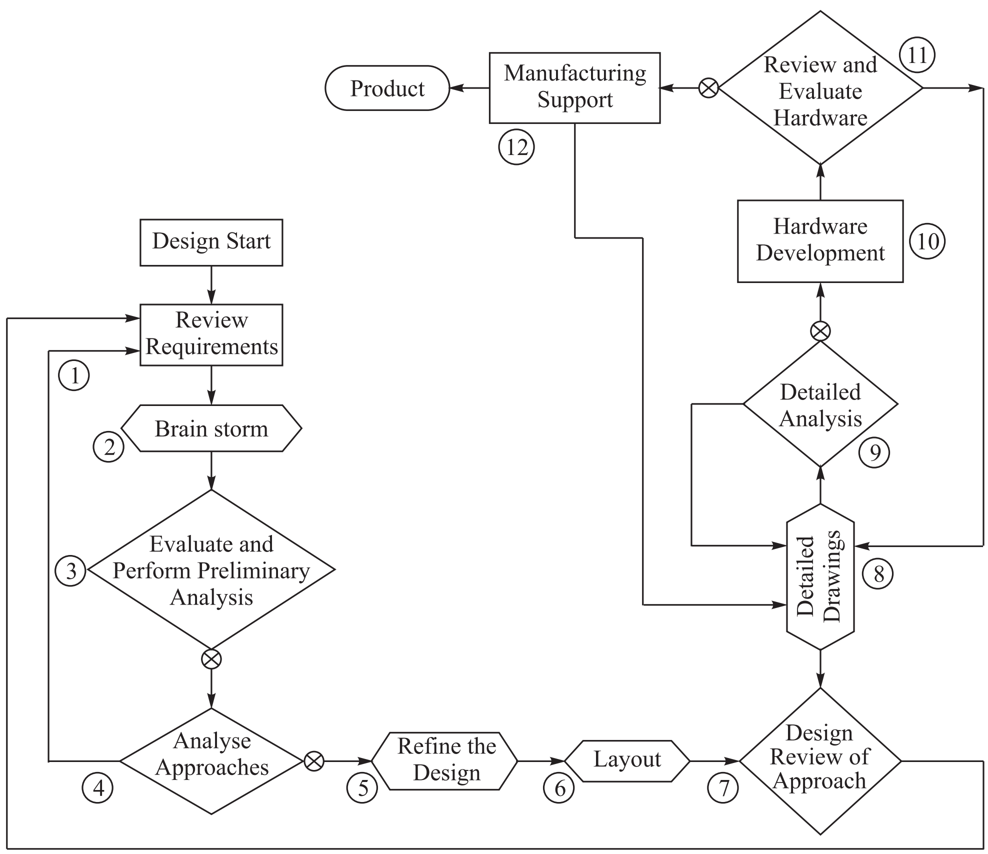

Fig. 1.3 The Design Process.

1.5 SKILLS OF ENGINEERING DESIGN

The main skills of engineering design are:

(*a*) **Inventiveness.** The ability to think of or discover valuable, useful ideas or concepts for things or processes to accomplish given objectives.

(*b*) **Engineering Analysis.** The ability to analyse a given component, system, or process using engineering or scientific principles in order to arrive quickly at meaningful answers.

(*c*) Engineering science

(*d*) Inter disciplinary ability

(*e*) Mathematical skills

(*f*) Decision making

(*g*) Manufacturing processes

(*h*) Communication skill.

1.6 CREATIVITY

The secret of inventiveness is to saturate the mind with all the information pertinent to the problem and then let it incubate. The creative process is a three step process in which after soaking the mind with all the information pertinent to the situation and trying the various consciously possible combinations, a period of incubation is allowed and then throw up the solution by the unconscious to the conscious which is then verified and further developed. Factors of inventiveness are:

(*i*) Practice being perceptive. Believe in seeing.

(*ii*) Plan problem-solving activity with the inventive process in mind.

(*iii*) Be aware of set or fixity of mind.

(*iv*) Learn how to brain storm.

(*v*) Use inversion.

(*vi*) Use analogy.

(*vii*) Use empathy.

(*viii*) Use fantasy.

(*ix*) Try a systematic search for a new combination.

Inversion-calls for conscious breaking of the set, the old way of looking at the problem, for the purpose of looking at it in some new or inverted fashion, *e.g.,* upside down, inside out, reversed etc., are some of the inversion methods.

Analogy-calls for searching the solution for similar problems which exist in other areas whose solution might give hints.

Empathy-means personal identification and feeling for another. This means roughly putting oneself "in the other man's shoes". The term can also be applied to the act of identifying personally with a thing, part, or process being devised. It requires willingness to do some play acting.

Fantasy-means to make-believe-wishing it were so. It involves dreaming of some fanciful solutions which use unreal or supernatural processes, if necessary.

1.7 DESIGN METHODS

There are two design methods for problem solving, namely, the black-box methods and the glass-box methods. In the black-box methods, the actual process of creativity remains a mystery whereas in the glass-box methods the mechanism of transformation is completely understood. The aids for these methods are:

1. Black-Box Methods
   (*a*) Morphological analysis
   (*b*) Analysis of interconnected decision areas (AIDA).
   (*c*) Brain storming.
2. Glass-Box Method
   (*a*) Synectics.

Morphological Analysis recognizes that the solution to a design problem consists of certain essential constituent parts and a good design is one which selects the proper matching combination of components. The following procedure may be followed for morphological analysis:

1. Recognize the essential parameters acceptable for design.
2. Determine the number of possible ways for achieving each of the parameters.
3. Set up a matrix in the left hand column of which are listed all the parameters and in the rows against each of these parameters are listed the possible methods of achieving them.
4. Study all combinations of sub-solutions for feasibility and select the best on the basis of some valid criterion.

The precondition for morphological analysis is that the structure should be stable.

Analysis of Interconnected Decision Areas (AIDA)

This method may be described as a procedure to identify and evaluate all compatible combinations of sub-solutions generated by morphological analysis. If we view each of the design parameters as a decision area where the designer has to choose amongst the available options, these decision areas are somewhat interconnected. Ideally, if these were selected to be mutually independent, all combinations of the sub-solutions will be compatible. The procedure consists in drawing a compatibility matrix in which the compatibility or otherwise of each pair of design options is indicated.

Brain storming. This is a method of generating ideas.

The following rules should be observed during a brain storming session:

First Rule. Criticism and judgement, whether favourable or unfavourable are not allowed.

Second Rule. Generate a lot of ideas.

Third Rule. Think wild.

The following scheme is quite useful for conducting brain storming sessions for engineering design problems:

- Select a group of persons (around 5) to generate ideas.
- State the problem as simply as possible.
- Give about ten minutes to each person to write down on a piece of paper as many solution ideas as possible.
- Allow each person to read one idea in turn and ask the remaining persons to suggest any additional ideas to improve or modify the idea being suggested.
- Do not allow to criticise or discourage whether an idea is practical or not. Only shortcomings and improvements may be entertained.
- Encourage humour to release the members and to build up mutual trust.
- At the end, find a logical classification of all the ideas generated.

- Evaluate the design concepts generated and select one which you feel to be the best for further development.

This is a very useful method for generating ideas when the problem can be stated simply. However the method is rather ineffective for more technical and complex problems.

Synectics. It is a method for collective problem solving which attempts to apply much more control on the idea generation process. This method may be applied as follows:

- Select about six persons drawn from diverse areas having only one person who has direct experience with the problem, and one person having expertise in the area of biology.
- Choose a leader of the group who himself shall not contribute any ideas, but shall ensure that group functions properly.
- Attempt a group discussion of readily available solution, if any.
- Make use of analogies to understand the nature of the problem.

1.8 MACHINE DESIGN PROCEDURE

It is difficult to lay down any set rules of procedure for the design of machines. The situations encountered are too varied to allow this. However, it is possible to point out a general procedure which will, in the majority of cases, prove to be helpful to the beginning designer. This general procedure can be stated briefly as follows:

1. Before starting work on the design of any machine, get thoroughly familiar with what the machine is intended to accomplish and what special requirements or limitations must be considered.
2. Make free hand sketches of various ways the machine might be constructed and make any preliminary calculations which might be required to substantiate your ideas or to establish approximate sizes.
3. Make a layout drawing of the feasible construction of the machine bringing out the details of the construction.
4. Analyze the layout of forces, stresses, etc., and make whatever calculations are necessary to be certain that the parts will perform satisfactorily.
5. Revise the layout drawing as necessary for the finished design.

1.9 THINGS TO BE CONSIDERED

While working on the procedure the designer must be careful to consider every important factor which should rightfully influence his design. In general, the most important things to be considered can be listed as follows:

1. Proper functioning of the finished machine
2. Cost
3. Lubrication
4. Strength and rigidity of parts
5. Ease of manufacture and assembly
6. Wear of parts
7. Ease of service and replacement of parts
8. Proportion of parts.

We shall consider these factors in detail in the various chapters to follow.

1.10 DESIGN BY EVALUATIONS

Design by evaluations involves to find the best design by way of comparative merits of each with respect to cost, strength, function, and market appeal. The general areas of design by evaluations are:

1. Functional analysis
2. Human engineering
3. Market and product analysis
4. Specification analysis
5. Strength analysis
6. Economic analysis, and
7. Model analysis.

Engineering graphics and descriptive geometry are valuable tools for analysis. A product must be analysed to determine its acceptance by the market before it is released for production. Much of the engineering is denoted to the analysis of the strength of designs to support dead loads, withstand shocks, and to endure repetitive usages of a variety of motions ranging from slow to fast. Cost analysis must be performed to determine the production cost of the item and the margin of profit that can be realized from it. Models are effective aids in analysing a design in final stages of its development.

1.11 AESTHETIC CONSIDERATIONS IN DESIGN

The products are manufactured for a specific purpose and function to meet the requirements of the customers. The contact between the product and the user arises due to the dire necessity of this functional requirement. However, when there is a choice available to the customer of a product having the same qualities of efficiency, durability and cost, the customer is naturally attracted towards the most appealing product. The external appearance is an important feature, which gives grace and luster to the product and dominates the market. This is called aesthetic sense in design. Aesthetic considerations are very important for consumer durables like automobiles, household appliances and audio-visual equipment.

The aesthetic considerations in design have given rise to a separate discipline, known as industrial design. The job of an industrial designer is to create new forms and shapes which are aesthetically pleasing to the mind.

There are five basic forms: step, stream, taper, shear and sculpture. The step form is similar to the shape of a 'skyscraper' or multistorey building. This involves shapes with a vertical rather than a horizontal accent. The stream or streamline form is seen in automobiles and aeroplane structure to reduce the air drag resistance. The taper form consists of tapered blocks interlocked with tapered plinths or cylinders. The shear form has a square outlook, which is ideally suitable for free-standing engineering products. The sculpture form consists of ellipsoids, paraboloids and hyperboloids. The sculpture and stream form are suitable for automobile, while step and shear forms for stationary products.

There is a relationship between functional requirement and appearance of a product. In many cases, functional requirements result in shapes which are aesthetically pleasing. The evolution of streamlined shapes of boeing and racing cars is the result of studies in aerodynamics for reducing air drag. The chromium plating of many household appliances is for the purpose of corrosion resistance rather than appearance.

Selection of proper colour is an important consideration in product aesthetics. The meaning of various colours is as given in Table 1.1.

TABLE 1.1 Aesthetic Meaning of Colours

Colour	*Aesthetic meaning*
Red	Danger–Hazard–Hot
Orange	Possible danger
Yellow	Caution
Green	Safety
Blue	Caution–Cold
Grey	Dull

Other factors affecting aesthetic consideration are:

1. Rigidity and resilience.
2. Tolerance.
3. Surface finish.
4. Motion of individual components.
5. Materials.
6. Manufacturing methods.
7. Vibration and noise.

1.12 ERGONOMIC CONSIDERATIONS IN DESIGN

The word '*ergonomics*' is derived from two Greek words: ergon = work and nomos = natural laws. Thus Ergonomics means the natural laws of work. It is the relationship between man and machine and the application of anatomical, physiological principles to solve the problems arising from man-machine relationship. It is also called human engineering.

Anatomy **:** Study of body dimensions and relations for work design.

Physiology **:** Study of man and his working environment.

Psychology **:** Study of adaptive behaviour and skills of people.

Ergonomica includes the following factors for study from design considerations:

1. Anatomical factors in design.
2. Control of physical work environment.
3. Design of man-machine system.
4. Design of controls and displays.
5. Accidents, fatigue and safety.
6. Work place design.

The fundamental concept in human engineering is the system. A system is composed of humans, machines and other things that interact to accomplish some goal which these same components could not produce independently. The man-machine system is a closed loop system as shown in Fig. 1.4.

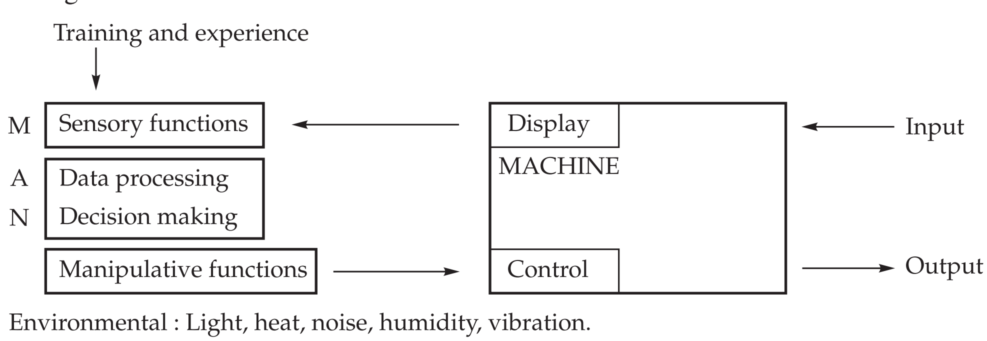

Fig. 1.4 Man-machine system.

The man will receive certain information from the machine either from dials, displays, etc., designed for that purpose or by observation of machine itself. He will process this information and make decisions on what action to take and manipulate controls or attend machine in some other ways so as to affect its behaviour in the required manner. The efficiency with which the man functions depends on environmental factors, on his own characteristics such as age, motivation, training and experience as well as efficiency with which the machine provides the information feedback and accepts control measures.

1.13 GUIDELINES FOR WRITING MACHINE DESIGN ASSIGNMENTS

A course on "*Design of Machine Elements*" (Machine Design) is offered to under-graduate students in Mechanical Engineering and many other branches of engineering, when they have acquired sufficient knowledge in various subjects of this specialization. Teaching of this course to the students is very important as this course is of much use to them in their practical life later on. While designing the various components of a particular machine member, the students and sometimes the teachers as well are at a loss as to how to write the given assignment in a fairly good manner, depicting the whole information needed of a good design practice.

In the following paragraphs some brief guidelines for writing machine design assignment have been given. It is expected that these guidelines would be quite helpful while writing the machine design assignments.

1. *Paper.* Always use a white sheet of A4 bond size only. Write only on one side of the sheet, *i.e.,* the right hand side of the bound note book.
2. *Enunciation of the Problem.* The problem should be enunciated on a separate page and nothing should be written on that page. If the problem is small, it can be written at the top of the first page and the calculations started immediately after that. A clear line of demarcation should be marked between the problem and the rest of the report.
3. *Columns.* Four columns should be used as shown below :

Part Name (1)	*Design calculations (2)*	*References (3)*	*Results (4)*

4. *Sketch.* A sketch of the each component designed should be given as far as possible. The sketch should invariably be drawn in pencil on the page facing the design calculations pertaining to the sketch. The sketch should be complete in all respects, having the dimensions, alphabetical notations and heading. Sometimes the component to be designed will look too simple to require a sketch, but it is always found more useful to give a sketch as it will add to the many information being given in the calculations.
5. *Explanations.* Add explanations in the design calculations of all features about the sketch, tables and figures etc.
6. *Part Name Headings.* Use both main headings and sub-headings for the component parts being designed.
7. *Design Calculations Procedure.* Follow step-by-step procedure. The designer should state the method of approach for the design. Standard notations and same symbols should be used throughout the report.

8. *Assumptions.* There are many simplifying assumptions to be made by the designer in many cases where detailed analysis is not possible. All such simplifying assumptions should be mentioned clearly and a discussion be given about the extent of their validity in actual case.
9. *Preliminary Decisions.* All preliminary decisions regarding materials, manufacturing process and factor of safety etc., should be made before actually making the design calculations. The material selected should be specified as per Indian Standards. The reasons for selecting a particular material and not any other similar material may be added in the report. The method of heat treatment to be given to the material should be specified. While selecting a particular manufacturing process, its economic aspects should be taken into account. A brief discussion about the manufacturing process and the order of the manufacturing process would be sufficient.

   Sometimes the factor safety is specified by a design code. But mostly a designer has to choose a suitable value for the factor of safety. The choice of the factor of safety is based on many considerations, *e.g.,* type of loading, material behaviour temperature considerations, type of applications and service conditions etc. The reasons for selecting a very high or very low values of the factor of safety should be given.
10. *Design Calculations.* All calculations should be done by an electronic calculator, which is now easily available at a reasonable price. All calculations involve mathematical computations to come to the required dimensions of parts. Calculations can be done more comfortably, if the following instructions are followed:
    (*a*) A sub-heading for each step should be used as the calculations will usually be composed of more than one step.
    (*b*) The equations to be used should be stated clearly giving the explanations of the notations and the units.
    (*c*) All the quantities should be used in the same units. Use preferably SI units.
    (*d*) Mathematical simplifications of the equations to solve for the unknown quantities should be done carefully.
    (*e*) The calculations should be checked for accuracy and it should be assured that the results obtained are reasonable and adequate.
    (*f*) All results should be obtained to the same decimal place of accuracy.
11. *Final Decisions.* The numerical results obtained for each component designed must be interpreted according to the standard sizes of parts and materials available. Each component or part standardized in this manner must be entered in the fourth column of the sheet. The compatibility of various dimensions obtained should be checked from assembly point of view.
12. *Result.* All results and adopted values of dimensions should be mentioned in the fourth column. All dimensions required for making an assembly drawing should be put in rectangular brackets in the second column itself.
13. *References.* A list of books, journals, research reports and pamphlets consulted should be given at the end of the report as per standard format, indicating the name of the author(*s*), title of the book or heading of the article, name of the journal or publisher's name, volume number and issue number or edition number, year and place of publication and page or pages or table number or figure number. In the third column, the serial number of reference cited at the end of the report alongwith the page number, figure number or table number should

only be given to save space and time. In the case of an empirical formula, the name of the investigator if any, should also be given. References from Indian Standards may be given by stating the Standard Number alongwith the year, clause number, table number or figure number.

14. *Drawings.* The assembly drawing should be prepared on a bond size drawing sheet. All the instructions for machine drawing as per IS : 696-1972 should be followed while making the drawing. Drawing should invariably be made with a pencil. The drawing should be exactly in conformity with the dimensions obtained. On the drawing sheet, the part list, materials, unit of dimensions, machining symbols, tolerances and a brief description of the manufacturing method must be given. Small drawings should be made on A4 size drawing sheet and bigger drawings on half of full size drawing sheet, as may be thought convenient. These drawings should be attached at the end of the assignment.

1.14 THE INTERNATIONAL SYSTEM OF UNITS (SI)

The SI system consists of seven base units, two supplementary units and a number of derived units. Base units are defined as follows:

1. *Length.* The metre (m) is the length equal to 1650763.73 wavelengths in vacuum of the radiations corresponding to the transition between the levels $^2p_{10}$ and $^5d_5$ of the krypton-86 atom.
2. *Mass.* The kilogram (kg) is the unit of mass; it is equal to the mass of the international prototype of the kilogram.
3. *Time.* The second (s) is the duration of 9192631770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom.
4. *Electric Current.* The ampere (A) is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed one metre apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newtons for each metre of length.
5. *Thermodynamic Temperature.* The Kelvin (K) is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.
6. *Luminous Intensity.* The candela is the luminous intensity, in the perpendicular direction, of a surface of 1/600000 square metre of a black body at the temperature of freezing platinum under a pressure of 101325 newtons per square metre.
7. *Amount of Substance.* The mole (mol) is the amount of substance of a system that contains as many elementary entities as the number of atoms in 0.012 kilogram of carbon 12.

Supplementary units are as follows:

1. *Plane Angle.* The radian is the unit of measure of a plane angle with its vertex as the centre of a circle and subtended by an arc equal in length to the radius.
2. *Solid Angle.* The steradian is the unit of measure of a solid angle with its vertex at the centre of a sphere and enclosing an area of the spherical surface equal to that of a square with sides equal in length to the radius.

Derived units are as follows:

1. *Force.* The Newton (N) is that force which, when applied to a body having a mass of one kilogram, gives it an acceleration of one metre per second squared.

2. *Energy.* The Joule (J) is the work done when the point of application of a force of one Newton is displaced a distance of one metre in the direction of the force.
3. *Power.* The Watt (W) is the power which gives rise to the production of energy at the rate of one joule per second.
4. *Electric Potential Difference.* The Volt (V) (unit of electric potential difference and electromotive force) is the difference of electric potential between two points of a conductor carrying a constant current of one ampere, when the power dissipated between these points is equal to one watt.
5. *Pressure or stress.* The Pascal (Pa) is a pressure of one Newton per square metre (1 Pa = 1 N/m^2).
6. *Frequency.* The Hertz (Hz) is the frequency in cycles per second.

Other derived units are: electric inductance, electric resistance, quantity of electricity, electric capacitance, magnetic flux, luminous flux, electric conductance, illuminance and magnetic flux density.

EXERCISES

1.1 Write an essay on "What is Engineering"?

1.2 Describe brain storming. What are its rules?

1.3 Brain storm the problem of window cleaning, air pollution control, removal of illiteracy in India, World's food problem.

1.4 A student has been dropped from the university on certain grounds. Discuss in retropect your decision to attend to your classes or not. List the alternatives and factors relevant to this decision. Did you make a good decision? What can you learn from your experience?

1.5 At a clinic for large animals a number of operations must be performed on horses, cows and bulls. Getting one of these animals to lie on an operating table is a real challenge. Specify the general features of a device or system that you recommend for placing these animals on their sides on the operating table.

1.6 Describe briefly how the design of a new machine should be done systematically.

1.7 What is meant by problem formulation? How the alternate solutions depend on the problem formulation?

1.8 A cloth washing machine is to be designed. How would you analyse and formulate the problem setting design criteria and limitations?

1.9 (*a*) What do you understand by Engineering Design? What are the different phases of Engineering Design?

(*b*) In the available pressure stove, there is no device to know the level of kerosene oil and the pressure of the oil. Sometimes this leads to considerable inconveniences or proves hazardous. It is desired to remove these short comings in the pressure stove. How would you formulate and analyse the problem? Give your possible solution together with implications.

1.10 In an examination hall where large number of candidates appear in the examination, great difficulties are encountered in distributing the examination materials due to shortage of supervisory staff. It is proposed to distribute the examination materials so that each candidate gets his requirements fulfilled. Find the solution to this problem giving clearly the problem formulation, criteria and restrictions.

1.11 The library in a college is situated at the fourth floor. Some of the readers do not go to the library as they get fatigued to climb to the fourth floor. Make a problem study and give possible solutions.

1.12 (*a*) What is meant by criterion and restriction as applied to an engineering problem?

(*b*) A table method of electric hot plate is to be designed. How would you formulate and analyse the problem? Make reasonable assumptions wherever necessary. Present your answer with neat sketches.

1.13 (*a*) What is design? Give explanatory notes on the various types of design.

(*b*) A hunter wants a device for night shooting of lions that he is safe from the beast and is also sure of his success. Give the problem study and formulation together with the restrictions.

1.14 In the kitchens of the hostels, large quantities of food is cooked in large vessels on hearth placed at a height of 0.6 m from the floor. The cooks have difficulty in shifting these vessels with cooked food from the hearth to the racks for serving. Find the solutions to this problem giving clearly the problem formulation, criteria and restrictions.

1.15 (*a*) Make the problem study of a power driven vehicle for carrying human beings by road.

(*b*) A firm that manufactures rechargeable batteries is seeking new applications of its product. Suggest as many possibilities as you can.

1.16 Give the appropriate need statement and carry out the need analysis giving important specifications : standards of performance and constraints for the following system devices. Indicate where further research or inquiry is needed to set specifications:

(*a*) a city water supply

(*b*) a cheap family vehicle

(*c*) a television set for rural education programmes

(*d*) a national highway system

(*e*) a cart for villagers.

1.17 Make a systematic search of fresh design ideas using morphological analysis for the following:

(*a*) A wall-clock

(*b*) A liquid-link writing instrument

(*c*) An automatic chapati-making machine

(*d*) A clothes-washing machine

(*e*) A kerosene stove.

1.18 The armed forces often face situations when an armoured column has to cross a river across which either there is no bridge or the bridge has been destroyed by enemy action. Carry out a systematic search for design ideas for constructing an emergency bridge across the river so that the armoured column may pass.

1.19 Carry out a brain storming session for the following problems:

(*a*) to make the Indian people accept the concept of planned families.

(*b*) low cost housing for the urban middle-class.

(*c*) hand drying in a hostel having 200 students.