- Step 6: Design Modifi cations
- The geometric dimensions of the machine element are modifi ed from assembly and manufacturing considerations.
- For example, the transmission shaft illustrated in Fig. 1.4 is provided with steps and shoulders for proper mounting of gear and bearings.
- Revised calculations are carried out for operating capacity, margin of safety at critical cross-sections and resultant stresses taking into consideration the effect of stress concentration.
- When these values differ from desired values, the dimensions of the component are modifi ed.
- The process is continued till the desired values of operating capacity, factor of safety and stresses at critical cross-sections are obtained.

- Step 7: Working Drawing
- The last step in the design of machine elements is to prepare a working drawing of the machine element showing dimensions, tolerances, surface fi nish grades, geometric tolerances and special production requirements like heat treatment.
- The working drawing must be clear, concise and complete. It must have enough views and crosssections to show all details.
- The main view of the machine element should show it in a position, it is required to occupy in service.
- Every dimension must be given. There should not be scope for guesswork and a necessity for scaling the drawing. All dimensions that are important for proper assembly and interchangeability must be provided with tolerances.

- TRADITIONAL DESIGN METHODS
- There are two traditional methods of design— design by craft evolution and design by drawing. Bullock cart, rowing boat, plow and musical instruments are some of the products, which are produced by the craft-evolution process. The salient features of this age-old technique are as follows:
- (i) The craftsmen do not prepare dimensioned drawings of their products. They cannot offer adequate justifi cation for the designs they make.
- (ii) These products are developed by trial and error over many centuries. Any modifi cation in the product is costly, because the craftsman has to experiment with the product itself. Moreover, only one change at a time can be attempted and complete reorganization of the product is diffi cult.
- (iii) The essential information of the product such as materials, dimensions of parts, manufacturing methods and assembly techniques is transmitted from place to place and time to time by two ways. First, the product, which basically remains unchanged, is the main source of information. The exact memory of the sequence of operations required to make the product is second source of information. There is no symbolic medium to record the design information of the product.

- USE OF STANDARDS IN DESIGN
- Standardization is defi ned as obligatory norms, to which various characteristics of a product should conform. The characteristics include materials, dimensions and shape of the component, method of testing and method of marking, packing and storing of the product. The following standards are used in mechanical engineering design:
- (i) Standards for Materials, their Chemical Compositions, Mechanical Properties and Heat Treatment For example, Indian standard IS 210 specifi es seven grades of grey cast iron designated as FG 150, FG 200, FG 220, FG 260, FG 300, FG 350 and FG 400. The number indicates ultimate tensile strength in N/mm2. IS 1570 (Part 4) specifi es chemical composition of various grades of alloy steel. For example, alloy steel designated by 55Cr3 has 0.5–0.6% carbon, 0.10–0.35% silicon, 0.6–0.8% manganese and 0.6–0.8% chromium.
- (ii) Standards for Shapes and Dimensions of Commonly used Machine Elements The machine elements include bolts, screws and nuts, rivets, belts and chains, ball and roller bearings, wire ropes, keys and splines, etc. For example, IS 2494 (Part 1) specifi es dimensions and shape of the crosssection of endless V-belts for power transmission. The dimensions of the trapezoidal cross-section of the belt, viz. width, height and included angle are specifi ed in this standard. The dimensions of rotary shaft oil seal units are given in IS 5129 (Part 1). These dimensions include inner and outer diameters and width of oil seal units

- (iii) Standards for Fits, Tolerances and Surface Finish of Component For example, selection of the type of fi t for different applications is illustrated in IS 2709 on ‘Guide for selection of fi ts’. The tolerances or upper and lower limits for various sizes of holes and shafts are specifi ed in IS 919 on ‘Recommendations for limits and fi ts for engineering’. IS 10719 explains method for indicating surface texture on technical drawings. The method of showing geometrical tolerances is explained in IS 8000 on ‘Geometrical tolerancing on technical drawings’.
- (iv) Standards for Testing of Products These standards, sometimes called ‘codes’, give procedures to test the products such as pressure vessel, boiler, crane and wire rope, where safety of the operator is an important consideration. For example, IS 807 is a code of practice for design, manufacture, erection and testing of cranes and hoists. The method of testing of pressure vessels is explained in IS 2825 on ‘Code for unfi red pressure vessels’.
- (v) Standards for Engineering Drawing of Components For example, there is a special publication SP46 prepared by Bureau of Indian Standards on ‘Engineering Drawing Practice for Schools and Colleges’ which covers all standards related to engineering drawing. There are two words—standard and code— which are often used in standards. A standard is defi ned as a set of specifi cations for parts, materials or processes. The objective of a standard is to reduce the variety and limit the number of items to a reasonable level. On the other hand, a code is defi ned as a set of specifi cations for the analysis, design, manufacture, testing and erection of the product. The purpose of a code is to achieve a specifi ed level of safety.

- There are three types of standards used in design office. They are as follows:
- (i) Company standards They are used in a particular company or a group of sister concerns.
- (ii) National standards These are the IS (Bureau of Indian Standards), DIN (German), AISI or SAE (USA) or BS (UK) standards.
- (iii) International standards These are prepared by the International Standards Organization (ISO)

- SELECTION OF PREFERRED SIZES
- In engineering design, many a times, the designer has to specify the size of the product.
- The ‘size’ of the product is a general term, which includes different parameters like power transmitting capacity, load carrying capacity, speed, dimensions of the component such as height, length and width, and volume or weight of the product.
- These parameters are expressed numerically, e.g., 5 kW, 10 kN or 1000 rpm. Often, the product is manufactured in different sizes or models; for instance, a company may be manufacturing seven different models of electric motors ranging from 0.5 to 50 kW to cater to the need of different customers.
- Preferred numbers are used to specify the ‘sizes’ of the product in these cases. French balloonist and engineer Charles Renard fi rst introduced preferred numbers in the 19th century.
- The system is based on the use of geometric progression to develop a set of numbers.
- There are fi ve basic series2, denoted as R5, R10, R20, R40 and R80 series, which increase in steps of 58%, 26%, 12%, 6%, and 3%, respectively. Each series has its own series factor. The series factors are given in Table 1.1.

R5 Series	$\sqrt[5]{10} = 1.58$
R10 Series	$\sqrt[10]{10} = 1.26$
R20 Series	$\sqrt[20]{10} = 1.12$
R40 Series	$\sqrt[40]{10} = 1.06$
R80 Series	$\sqrt[80]{10} = 1.03$

- It is observed from Table 1.2 that small sizes differ from each other by small amounts, while large sizes by large amounts. In the initial stages, the product is manufactured in a limited quantity and use is made of the R5 series. As the scale of production is increased, a change over is made from R5 to R10 series, introducing new sizes of intermediate values of R10 series. Preferred numbers minimise unnecessary variation in sizes. They assist the designer in avoiding selection of sizes in an arbitrary manner. The complete range is covered by minimum number of sizes, which is advantageous to the producer and consumer. There are two terms, namely, 'basic series' and 'derived series', which are frequently used in relation to preferred numbers. R5, R10, R20, R40 and R80 are called basic series. Any series that is formed on the basis of these fi ve basic series is called derived series. In other words, derived series are derived from basic series. There are two methods of forming derived series, namely, reducing the numbers of a particular basic series or increasing the numbers.

R5	*R10*	*R20*	*R40*
1.00	1.00	1.00	1.00
			1.06
		1.12	1.12
			1.18
	1.25	1.25	1.25
			1.32
		1.40	1.40
			1.50

1.60	1.60	1.60	1.60
			1.70
		1.80	1.80
			1.90
	2.00	2.00	2.00
			2.12
		2.24	2.24
			2.36
2.50	2.50	2.50	2.50
			2.65
		2.80	2.80
			3.00
	3.15	3.15	3.15
			3.35
		3.55	3.55
			3.75
4.00	4.00	4.00	4.00
			4.25
		4.50	4.50
			4.75
	5.00	5.00	5.00
			5.30
		5.60	5.60
			6.00
6.30	6.30	6.30	6.30
			6.70
		7.10	7.10
			7.50
	8.00	8.00	8.00
			8.50
		9.00	9.00
			9.50
10.00	10.00	10.00	10.00