

Lecture 1,2

Units, Dimensions and Standards

Objectives

After completing this chapter, you should be able to:

- Understand the meaning of unit.
- Know the difference between the fundamental and derived unit.
- Know the SI units for various physical quantities.
- List the advantages and disadvantages of S.I units.

1.1 Introduction

There are several types of quantities in the field of engineering which need to be measured or expressed in day-to-day work. This includes physical, chemical, mechanical quantities etc. In order to record or to compare magnitude of quantities some magnitude of each kind must be taken as basis or unit. To measure or to define any quantity we need a well-defined unit. There are fundamental and supplementary fundamental units. These units are used to define all quantities. Many systems like SI (International System of Units), CGS (Centimetre-gram-second System), MKS (Metre-kilogram-second) etc. are developed to define the physical quantity.

1.2 Unit

The standard measurement of any physical quantity is known as Unit. The number of times the unit occurs in any given amount of the same quantity is the number of measure. For example 100

metres, we know that the metre is the unit of length and that the number of units of length is one hundred. The physical quantity, length, is therefore defined by the unit metre.

1.3 Fundamental and Derived Units

The units which are independent and are not related to each other are known as *Fundamental Unit*. These units do not vary with time, temperature and pressure etc. There are seven fundamental units, as given below:

Fundamental Units: length, mass, time, electric current, temperature, luminous intensity and quantity of matter.

The units which are derived from fundamental units or which can be expressed in terms of the fundamental units are called *Derived Unit*. Every derived unit originates from some physical law defining that unit. This unit is recognized by its dimensions, which can be defined as the complete algebraic formula for the derived unit. Like area, volume, velocity etc. For example, the area of rectangle is proportional to its length (l) and breadth (b) or $A = l \times b$. If the metre has been chosen as the unit of length, then the unit of area is m^2 . The derived unit for area (A) is then the square metre (m^2).

For convenience, some derived units have been given new names. For example, the derived unit of force in the S.I. system is called the Newton (N), instead of the dimensionally correct name $kg \cdot m/s^2$.

1.4 International System of Units

The International System of Units (abbreviated S.I. from the French *Système international d'unités*) is the modern form of the metric system and is generally a system of units of measurement devised around seven base units and the convenience of the number ten. It is the world's most widely used system of measurement, both in everyday commerce and in science.

Table 1.1 Definitions of Standard Units

<i>Physical Quantity</i>	<i>Standard Unit</i>	<i>Definition</i>
Length	metre	The length of path travelled by light in an interval of 1/299 792 458 seconds
Mass	kilogram	The mass of a platinum–iridium cylinder kept in the International Bureau of Weights and Measures, Sèvres, Paris
Time	second	9.192631770×10^9 cycles of radiation from vaporized caesium-133 (an accuracy of 1 in 10^{12} or 1 second in 36000 years)
Temperature	kelvin	The temperature difference between absolute zero and the triple point of water is defined as 273.16 kelvin
Current	ampere	One ampere is the current flowing through two infinitely long parallel conductors of negligible cross-section placed 1 metre apart in a vacuum and producing a force of 2×10^{-7} Newtons per metre length of conductor
Luminous intensity	candela	One candela is the luminous intensity in a given direction from a source emitting monochromatic radiation at a frequency of 540 terahertz ($\times 10^{12}$ Hz) and with a radiant density in that direction of 1.4641 mW/steradian. (1 steradian is the solid angle which, having its vertex at the centre of a sphere, cuts off an area of the sphere surface equal to that of a square with sides of length equal to the sphere radius)
Matter	mole	The number of atoms in a 0.012 kg mass of carbon-12

The system has been nearly globally adopted. Three countries which have not adapted are Burma (Myanmar), Liberia, and the United States.

The International System (or S.I. system) of Units consists of a set of units together with a set of prefixes. The units of S.I. can be divided into two subsets. There are seven base units: Every base unit represents different kinds of physical quantities. From these seven base units, several other units are derived. In addition to the S.I. units, there are some units accepted for use with SI which includes some commonly used units such as the litre. Table 1.1 shows the standard units and definition.

The S.I. system is divided into three classes: Fundamental Unit shown in Table 1.2, Supplementary Unit shown in Table 1.3 and Derived Unit shown in Table 1.4.

Table 1.2 S.I. Fundamental Units

<i>Quantity</i>	<i>Standard Unit</i>	<i>Symbol</i>
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Temperature	Kelvin	K
Luminous intensity	candela	cd
Matter	mole	mol

There are two supplementary units which are added to the S.I. system of units.

Radian for the plane angles: The plane angles subtended by an arc of a circle equal in length to the radius of the circle. It is denoted as rad.

The solid angle subtended at the centre of a sphere by the surface whose area is equal to the square of the radius of the sphere. It is denoted as sr.

Supplementary units are neither base units nor derived from base units. It is given in Table 1.3 below:

Table 1.3 Supplementary Fundamental Units

<i>Quantity</i>	<i>Standard unit</i>	<i>Symbol</i>
Plane angle	radian	rad
Solid angle	steradian	sr

The number of quantities in science is without limit, and it is not possible to provide a complete list of derived units. However, Table 1.4 shows some examples of derived unit:

Table 1.4 S.I. Derived Units

<i>Quantity</i>	<i>Standard Unit</i>	<i>Unit Standard</i>
Area square	metre	m ²
Volume cubic	metre	m ³
Velocity	metre per second	m/s
Acceleration	metre per second squared	m/s ²
Angular velocity	radian per second	rad/s
Angular acceleration	radian per second squared	rad/s ²
Density	kilogram per cubic metre	kg/m ³

Specific volume	cubic metre per kilogram	m ³ /kg
Mass flow rate	kilogram per second	kg/s
Volume flow rate	cubic metre per second	m ³ /s
Force	Newton	N
Pressure	Newton per square metre	N/m ²
Torque	Newton metre	Nm
Momentum	kilogram metre per second	kgm/s
Moment of inertia	kilogram metre squared	kgm ²
Kinematic viscosity	square metre per second	m ² /s
Dynamic viscosity	Newton second per square metre	Ns/m ²
Work, energy, heat	joule	J
Specific energy	joule per cubic metre	J/m ³
Power	watt	W
Thermal conductivity	watt per metre Kelvin	W/mK
Electric charge	coulomb	C
Voltage, e.m.f., pot. diff.	volt	V
Electric field strength	volt per metre	V/m
Electric resistance	ohm	Ω
Electric capacitance	farad	F
Electric inductance	Henry	H
Electric conductance	siemen	S
Resistivity	ohm metre	Ωm
Permittivity	farad per metre	F/m
Permeability	Henry per metre	H/m
Current density	ampere per square metre	A/m ²
Magnetic flux	Weber	Wb
Magnetic flux density	tesla	T
Magnetic field strength	ampere per metre	A/m
Frequency	hertz	Hz
Luminous flux	lumen	lm
Luminance	candela per square metre	cd/m ²
Illumination	lux	lx
Molar volume	cubic metre per mole	m ³ /mol
Molarity	mole per kilogram	mol/kg
Molar energy	joule per mole	J/mol

1.5 Advantages of S.I. Units

Although there are several advantages of S.I. units yet the following are important from the subject point of view:

1. S.I. unit measurement is a coherent system of units, *i.e.*, a system based on a certain set of fundamental units, from which all derived units are obtained by multiplication or division without introducing numerical factors.

2. S.I. unit measurement is a rational system of units, as it assigns only one unit to a particular quantity. For example, joule is the unit assign to all types of energies. This is not so in other system of units. For example, in MKS system of units, mechanical energy is in joules, heat energy is in calories and electrical energy is in Kilowatt hour.
3. S.I. unit measurement system is an absolute system of units. There are no gravitational systems of units in this system. Thus the use of factor ‘g’ is eliminated.
4. S.I. unit measurement system is a metric system, *i.e.*, the multiples and the submultiples of units are expressed as the exponents of 10.
5. In the current electricity, the absolute unit of electrical quantities like ampere (A) for electric current, volt (V) for potential difference, ohm (Ω) for resistance, Henry (H) for inductance, farad (f) for capacitance and so on, happens to be the practical units of these quantities.

The S.I. system of units applies to all branches of science, but the MKS system of units is confined to mechanics only.

1.6 Disadvantages of S.I. Units

Following are some of the disadvantages of S.I units:

1. The non S.I. “time units” minute and hour will still continue to be used until the clocks and watches are all changed to kilo seconds and mega second etc.
2. The base unit kilogram (kg) includes a prefix, which creates an ambiguity in the use of multipliers with gram.

1.7 Prefixes and Suffixes

It is often convenient to use units which are a multiple or fraction of the basic unit. The metric system, formally known as the International System of Units, defines a number of prefixes to denote powers of ten. The current official set is tabulated here: Prefixes used by the International System of Units (S.I.)

Prefixes used by the International System of Units (S.I.) are shown in Table 1.5.

Table 1.5

<i>Prefix</i>	<i>Factor</i>	<i>Symbol</i>
Exa	10^{18}	E
Peta	10^{15}	P
Tera	10^{12}	T
Giga	10^9	G
Mega	10^6	M
kilo	10^3	k
Hector	10^2	h
Deca	10	da
Deci	10^{-1}	d
Centi	10^{-2}	c
Milli	10^{-3}	m
Micro	10^{-6}	μ
Nano	10^{-9}	n
Pico	10^{-12}	p
Femto	10^{-15}	f
Atto	10^{-18}	a

