Lecture-4

Systems of Units and Standards

4.1 Introduction

The unit is the standard measure of each kind of physical quantities. In order to perform the measurement, the physical quantity must be defined both in kind and magnitude. The number of times that the unit occurs in any given amount of the same quantity is called "the number of measure".

A standard of measurement is the physical representation of the unit. The unit may be realized by reference to an arbitrary material standard or to natural phenomena including physical and atomic constants.

4.2 System of Units

In science and engineering, two kinds of units are used:

1. The Fundamental Units

An agreed set of standard units or (Systeme International d'Units), (SI Units) has been defined and strong efforts were being made to encourage the adoption of this system through the world.

The SI units and their symbols are given in table 4.1 shown below:

Table 4.1 The Fundamental SI Units

Class	No.	Quantity	Unit	Symbol
Primary Fundamental Units	1	Length	meter	m
	2	Mass	Kilogram	Kg
	3	Time	second	s
Auxiliary Fundamental Units	4	Electric current	Ampere	A
	5	Temperature	Kelvin	K
	6	Luminous intensity	candela	Cd
	7	Matter	mole	mol
Supplementary Fundamental Units	8	Plane angle	radian	rad
	9	Solid angle	steradian	Sr

2. The Derived Units

The derived units are those which can be expressed in terms of the fundamental units. Every derived unit is originated from some physical law defining that unit. The derived unit may take special name such as the names of famous scientists.

Some of the derived units are listed in table 4.2 shown below:

Table 4.2 The Derived SI Units

No.	Quantity	Unit	Symbol
1	Area	Square meter	m^2
2	Volume	Cubic meter	m^3
3	Velocity	Meter per second	m/s
4	Acceleration	Meter per square second	m/s^2
5	Angular velocity	Radian per second	rad/s
6	Angular acceleration	Radian per square second	rad/s^2
7	Density	Kilogram per cubic meter	Kg/m^3
8	Mass flow rate	Kilogram per second	Kg/s
9	Volume flow rate	Cubic meter per second	m^3/s

10	Force	Newton	N
11	Pressure	Newton per square meter	N/m^2
12	Torque	Newton-meter	N.m
13	Moment of inertia	Kilogram-square meter	$Kg.m^2$
14	Momentum	Kilogram- meter/second	Kg.m/s
15	Work, energy	Joule	J
16	Power	Watt	W
17	Voltage	Volt	V
18	Electric charge	Coulomb	C
19	Electric conductance	Siemens	S
20	Electric resistance	Ohm	Ω
21	Electric inductance	Henry	H
22	Electric capacitance	Farad	F
23	Resistivity	Ohm-meter	Ω.m
24	Permeability	Henry per meter	H/m
25	Permittivity	Farad per meter	F/m
26	Electric field strength	Volt per meter	V/m
27	Magnetic field strength	Ampere per meter	A/m
28	Magnetic flux	Weber	Wb
29	Magnetic flux density	Tesla	T
30	Current density	Ampere per square meter	A/m^2
31	Frequency	Hertz	Hz
32	Luminous flux	Lumen	lm
33	Luminance	candela per square meter	cd/m^2
34	Illumination	Lux	lx (lm/m^2)
35	Molarity	mole per kilogram	mol/Kg
36	Molar volume	Cubic meter per mole	m^3/mol
37	Molar energy	Joule per mole	J/mol
38	Kinematic viscosity	Square meter per second	m^2/s
39	Dynamic viscosity	Newton-second per square meter	$N.s/m^2$
40	Thermal conductivity	Watt per meter-Kelvin	W/m.K

Some of units are inconveniently large or small in practical circumstances. Hence, a standard multiplier and sub-multipliers of the base "10" are commonly used.

Table 4.3 shows these multiplier and sub-multipliers with their symbols and prefix.

Table 4.3 Multipliers and Sub-multipliers of SI Units

No.	Prefix	Power of 10	Symbol
1	Exa	10^{18}	E
2	Peta	10^{15}	P
3	Tera	10^{12}	T
4	Giga	10^{9}	G
5	Mega	10^{6}	M
6	Kilo	10^{3}	k
7	Hecta	10^{2}	h
8	Deca	10	da
9	Deci	10^{-1}	d
10	Centi	10^{-2}	c
11	Milli	10^{-3}	m
12	Micro	10^{-6}	µ
13	Nano	10^{-9}	n
14	Peco	10^{-12}	p
15	Femto	10^{-15}	f
16	Atto	10^{-18}	a

4.3 English System of Units

English system of units uses the foot (ft), the pound-mass (lb) and the second (s) as the three fundamental units of length, mass and time respectively. Table 4.4 lists some of common conversion factors from English into SI units:

Table 4.4 English units into SI Units Conversions

No.	Quantity	English Unit	Symbol	SI unit
1	Length	Foot	ft	0.3048 m
		Yard	Yd	0.9144 m
		Inch	In	25.4 mm
		Mile	Mi	1.609 Km

2	Mass	Pound	lb	0.4539237 Kg
		(international avoirdupois) Ounce	Oz	28.35 g
		(international Tory) Ounce	Oz	31.1034768 g
3	Force	Poundal	Pdl	0.138255 N
4	Power	Horsepower	Hp	745.7 W
5	Work, Energy	Foot-poundal	ft.pdl	0.0421401 J
6	Temperature	Fahrenheit	^oF	C= 5/9 (F-32) K= 5/9 (F+459.67)

4.4 Measurement Standards

In general, there are four levels of standards of measurement:

1. International Standards

The international standards are defined by international agreements. They represent certain units of measurement to the closest possible accuracy that production and measurement technology allow. International standards are periodically evaluated and checked by absolute measurement in terms of the fundamental units. These standards are maintained at the international Bureau of Weights and Measures at sevres, near Paris.

2. Primary Standards

The primary standards are preserved by national standard laboratories in different parts of the world. For example, the National Bureau of Standards (NBS) in Washington and the National Physical Laboratory (NPL) in Great Britain. The primary standard representing the fundamental units and some of the derived units. One of the main function of the primary standards is the verification and calibration of secondary standards.

3. Secondary Standards

The secondary standards are maintained as reference standards in industrial measurement laboratories. These standards are periodically sent to national standards laboratories for calibration with the primary standards.

4. Working Standards

The working standards are the principal tools of a measurement laboratories. Working standards are used to check and calibrate the laboratory instruments and the manufacturing components. The working standards are preserved in the quality control department of the measurement laboratory.

The standard units for the measurement have been defined and progressively improved over the years. The latest standards for defining the units used for measuring a range of physical quantities or variable are given in table 4.5 shown below:

Table 2.5 Definition of Standard Units

No.	Physical Quantity	Standard units	Definition
1	Length	Meter	The length of path travelled by light in an interval of 1/299792458.
2	Mass	Kilogram	The mass of platinum-iridium cylinder kept in the BWM at Sevres, Paris.
3	Time	Second	9.192631770×10^9 cycles of radiation from vaporized Ceasium-133.
4	Current	Ampere	Is the current flowing through two infinity long parallel conductors of negligible cross-section placed one meter apart in a vacuum and producing a force of 2×10^{-7} newton per meter length of the conductor.
5	Temperature	Kelvin	The temperature difference between absolute zero and the triple point of water is defined as 273.16 kelvin.
6	Luminous	Candela	Is the luminous intensity in a given direction

	intensity		from a source emitting monochromatic radiation at a frequency of 540 terahertz and with a radiant density in that direction of 1.464 mW/sr.
7	Matter	Mole	The number of atoms in a 12 g mass of Carbon-12.

Examples – L4

Ex4.1 Define the following terms:
(1) Unit (2) Standard

Sol. (1) Unit: is the standard measure of each kind of the physical quantities.
(2) Standard: is the physical representation of the unit.

Ex4.2 Give the SI units for the following quantities:
(1) Length (2)Volume (3) Resistivity (4) Permeability (5) Permittivity (6) Power (7) Current density (8) Momentum (9) Magnetic flux density (10) Acceleration.

Sol.

No.	Quantity	Unit
1	Length	meter
2	Volume	cubic meter
3	Resistivity	ohm-meter
4	Permeability	henry per meter
5	Permittivity	farad per meter
6	Power	watt
7	Current density	ampere per square meter
8	Momentum	kilogram-meter/second
9	Magnetic flux density	Tesla

10	Acceleration	meter per square second

Ex4.3 Describe the following measurements as follows:

1. 8540.33 ^oF in ^oK.
2. 500 oz in Kg.
3. 0.0001 Km/s in ft/hr.
4. 62.5. lb/ft^3 in g/cm^3

Sol.

1. 8540.33 ^oF in ^oK.

From tables we get:

$$K = 5/9\ (F + 459.67)$$

Therefore,

$$K = 5/9\ (8540.33 + 459.67)$$

Or $K = 5000\ ^oK$.

2. 500 oz in Kg.

From tables we get:

$$Oz = 28.35\ g$$

But,

$$g = \frac{Kg}{1000}$$

Therefore,

$$Oz = 28.35\ \frac{Kg}{1000}$$

or

$$Oz = 0.02835\ Kg$$

Thus,

$$500\ Oz = 500\ \times 0.02835\ Kg$$

$$= 14.175\ Kg$$

3. 0.0001 Km/s in ft/hr.

From tables we get:

ft = 0.3048 m

But,

$$m = \frac{Km}{1000}$$

Therefore,

$$ft = 0.3048\ \frac{Km}{1000}$$

or

$$ft = 0.0003048\ Km$$

or

$$Km = \frac{ft}{0.0003048}$$

Also,

$$hr = 3600\ s$$

or

$$s = \frac{hr}{3600}$$

Therefore,

$$0.0001\frac{Km}{s} = 0.0001\ \frac{\frac{ft}{0.0003048}}{\frac{hr}{3600}}$$

$$= 1181.1\ ft/hr$$

4. 62.5 lb/ft^3 in g/cm^3

From tables we get:

$$\text{lb} = 0.454\ Kg$$

But,

$$Kg = 1000\ g$$

Therefore,

$$lb = 454\ g$$

Also,

$$ft = 0.3048\ m$$

But,

$$m = 100\ cm$$

Therefore,

$$ft = 30.48\ cm$$

Or,

$$ft^3 = (30.48\ cm)3$$

Or,

$$ft^3 = 28316.846592\ cm^3$$

Therefore,

$$62.5\,\frac{lb}{ft^3} = 62.5\,\frac{454\ g}{28316.846592\ cm^3}$$

$$= 1\ \ g/cm^3$$

Ex4.4 Tabulate and classify the SI units

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Class	No.	Quantity	Unit	Symbol
Primary Fundamental Units	1	Length	meter	M
	2	Mass	kilogram	Kg
	3	Time	second	S
Auxiliary Fundamental Units	4	Electric current	Ampere	A
	5	Temperature	Kelvin	K
	6	Luminous intensity	candela	cd
	7	Matter	mole	mol
Supplementary Fundamental Units	8	Plane angle	radian	rad
	9	Solid angle	steradian	sr

Ex4.5 List the levels of the measurements standards.

Sol.

1. International standards.
2. Primary standards.
3. Secondary standards.
4. Working standards.