RADIANT 2026

Physics

Measurements and Experimentation

Lecture - 02

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Topics *to be covered*

1. Need of Unit for Measurement
2. Unit
3. King of unit
4. Properties of Unit
5. Units of Length, Mass and Time

6) Other Commonly used System of Units-fps and cgs

Fundamental Quantities, Units and Symbols in SI. System

Quantity	Unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Temperature	kelvin	K
Luminous	candela	cd
Electric current	ampere	A
Amount of substance	mole	mol*
Angle	radian	rd
Solid angle	steradian	st-rd

Use of Prefix with a Unit

3×10^{12} m
3 Tm

Some Prefixes Used for big Measurements

7×10^{24} m
7 Ym

Prefix	Symbol	Meaning
deca	da	10^1
hecto	h	10^2
kilo	k	10^3
mega	M	10^6
giga	G	10^9
tera	T	10^{12}
peta	P	10^{15}
exa	E	10^{18}
zetta	Z	10^{21}
yotta	Y	10^{24}

3×10^{12} m
3 tera m

3000 m
3×10^3 m
3 km

Some Prefixes Used for Big Measurements

The various small measurements are expressed by using the *prefixes* deci, centi, milli, micro, etc., with the units. The symbol and meaning of each such prefix are given below.

Some Prefixes Used for Small Measurements

Prefix	Symbol	Meaning
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p (or μμ)	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}
zepto	z	10^{-21}
yoeto	y	10^{-24}

11×10^{-12} m

$11 \times$ pm

1 ym 1×10^{-24} m

14×10^{-9} m

14 nm

12×10^{-3} m

12 mm

UNITS OF LENGTH

S.I. unit of length

The S.I. unit of the length is metre (m).

A metre was originally defined in 1889 as the distance between two marks drawn on a platinum-iridium (an alloy with 90% platinum and 10% iridium) rod kept at 0°C in the International Bureau of Weights and Measures at Sevres near Paris.

UNITS OF LENGTH

1 Sec = 299792458 m

$\frac{1}{299792458} = 1\text{m}$

Later, in 1960, the metre was re-defined as 1,650,763-73 times the wavelength of a specified orange-red spectral line in the emission spectrum of Krypton-86. It is also defined as: 'one metre Later, in 1960, the metre was re-defined as 1,650, 763-73 times the wavelength of a specified orange-red spectral line in the emission spectrum of Krypton-86. It is also defined as: 'one metre is 1,553,164-1 times the wavelength of the red line in the emission spectrum of cadmium'.

In 1983, the metre was re-defined in terms of speed of light according to which one metre is the distance travelled by the light in $\frac{1}{299,792,458}$ of a second in air (or vacuum).

UNITS OF LENGTH

Sub units of metre

For the measurement of small lengths, the metre is considered too big a unit. The most commonly used sub units of metre are

(i) centimetre (cm), 10^{-2}

(ii) millimetre (mm), 10^{-3}

(iii) micron (μ) and 10^{-6}

(iv) nanometre (nm). 10^{-9}

UNITS OF LENGTH

(i) **centimetre (cm):** One centimetre is one-hundredth part of a metre.

i.e., $1\text{ cm} = \frac{1}{100}\text{ m} = 10^{-2}\text{ m}$

(ii) **millimetre (mm):** One millimetre is one-thousandth part of a metre.

i.e., $1\text{mm} = \frac{1}{1000}\text{ m} = 10^{-3}\text{ m} = \frac{1}{10}\text{ cm}$

UNITS OF LENGTH

(iii) **micrometre or micron:** It is one-millionth (10^{-6}) part of a metre. It is expressed by the symbol μ. It is also called micrometre (symbol μm).

$$1 \text{ micron } (\mu) = 10^{-6} \text{ metre}$$

$$= 10^{-4} \text{ cm} = 10^{-3} \text{ mm.}$$

$= 10^{-2} \times 10^{-4}$ meter $= 10^{-4}$ cm

$= 10^{-3}\ 10^{-3} =$ mm

(iv) **nanometer (nm):** It is one billionth (10^{-9} th) part of a metre.

i.e., $1 \text{ nm} = 10^{-9} \text{ m.}$

UNITS OF LENGTH

Multiple units of metre

For the measurement of large lengths (or distances), the metre is considered as too small a unit. The most commonly used multiple unit of metre is kilometre.

kilometre (km): One kilometre is the one-thousand multiple of a metre.

i.e., 1 km = 1000 m (or 10^3 m).

UNITS OF LENGTH

Non-metric units of length

Bigger units: For the measurement of distance between two heavenly bodies, the kilometre is considered a too small unit. The commonly used units for this purpose are:

(i) astronomical unit (A.U.),

(ii) light year (ly) and

(iii) parsec.

UNITS OF LENGTH

(i) **Astronomical unit (A.U.):** One astronomical unit is equal to the mean distance between the earth and the sun. i.e.,

$$1 \text{ A.U.} = 1.496 \times 10^{11} \text{ metre}$$

UNITS OF LENGTH

(ii) **Light year (ly):** A light year is the distance travelled by light in vacuum, in one year. i.e.,

1 light year = speed of light × time 1 year

$= 3 \times 10^8 \text{ m s}^{-1} \times (365 \times 24 \times 60 \times 60\text{s})$

$= 9.46 \times 10^{15} \text{ m} = 9.46 \times 10^{12} \text{ km}$

The distance of stars from earth is generally expressed in light years. However, light minute and light second are its smaller units.

1 light minute $= 3 \times 10^8 \text{ m s}^{-1} \times 60\text{s} = 1.8 \times 10^{10} \text{ m}$

and 1 light second $= 3 \times 10^8 \text{ m s}^{-1} \times 1\text{s} = 3 \times 10^8 \text{ m}$

(1) 1 light year

(i) 9.46×10^{15} km

(ii) 9.46×10^{15} m

(iii) 9.46×10^{15} cm

UNITS OF LENGTH

(iii) **Parsec:** One parsec* is the distance from where the semi major axis of orbit of earth (1 A.U.) subtends an angle of one second.

i.e., Parasec angle × 1 = 1 A.U.

or 1 Parasec $= \frac{1.496 \times 10^{11}\,\text{m}}{(1/3600) \times (\pi/180)} = 3.08 \times 10^{16}\,\text{m}$

$= \frac{3.08 \times 10^{16}}{9.46 \times 10^{15}}\,1\text{y} = 3.26\,1\text{y}$

UNITS OF LENGTH

Smaller units: To express the wavelength of light, size and separation between two molecules (or atoms), radius of orbit of electron, etc. a small size unit called the **Angstrom** (Å) is used, while the size of the nucleus is expressed by a still smaller unit called **fermi** (*f*).

UNITS OF LENGTH

Å → nm

(i) **Angstrom (Å) :** It is 10^{-10} th part of a metre. It is expressed by the symbol Å. i.e.,

$$1 \text{ Angstrom (Å)} = 10^{-10} \text{ metre}$$

$$= 10^{-8} \text{ cm} = 10^{-1} \text{ nm}$$

$\therefore$ 1 micron = 10,000 Å

and 1 nm = 10 Å

Nowadays, Å is outdated and nm is preferred over the Å. The wavelength of light, inter-atomic or inter-molecular separation, etc. are now commonly expressed in nm.

UNITS OF LENGTH

(ii) **fermi (f):** It is 10^{-15} th part of a metre. i.e.,

$$1 \text{ fermi } (f) = 10^{-15} \text{ m}$$

The commonly used smaller and bigger units of length are summarized in the following table.

UNITS OF LENGTH

Smaller and bigger units of length

Klear

Smaller units	Value in metre	Bigger units	Value in metre
Cm	10^{-2} m	km	10^{3} m
		A.U.	1.496×10^{11} m
mm	10^{-3} m	1y	9.46×10^{15} m
μ (or μm)	10^{-6} m	parsec	3.08×10^{16} m
Nm	10^{-9} m		
Å	10^{-10} m		
f	10^{-15} m		

UNITS OF MASS

S.I. unit of mass

The S.I. unit of mass is kilogram (kg).

In 1889, one kilogram was defined as the mass of a cylindrical piece of platinum-iridium alloy kept at International Bureau of Weights and Measures at Sevres near Paris.

However, the mass of 1 litre (= 1000ml) of water at 4 °C is also taken as 1 kilogram.

UNITS OF MASS

Sub units of kilogram

For measurement of small masses, kilogram (kg) is a bigger unit of mass. The smaller units of mass in common use are

(i) gram (g) and (ii) milligram (mg).

UNITS OF MASS

(i) **gram (g):** One gram is the one-thousandth part of a kilogram i.e.,

$$1g = \frac{1}{1000} kg = 10^{-3} kg$$

1gm = 10^{-3} kg

or $1 kg = 1000 g$

$1\ 10^{-6}$ gm

(ii) **milligram (mg):** One milligram is one-millionth (10^{-6}) part of a kilogram or it is one-thousandth (10^{-3}) part of a gram. i.e.,

$$1 mg = 10^{-6} kg \text{ or } 1 mg = 10^{-3} g$$

UNITS OF MASS

Multiple units of kilogram

The bigger common units of mass used in daily life are (i) quintal and (ii) metric tonne.

(i) **quintal:** It is one hundred times a kilogram,

i.e., 1 quintal = 100 kg

(ii) **metric tonne:** It is one-thousand times a kilogram.

i.e, 1 metric tonne = 1000 kg = 10 quintal.

1 Ton

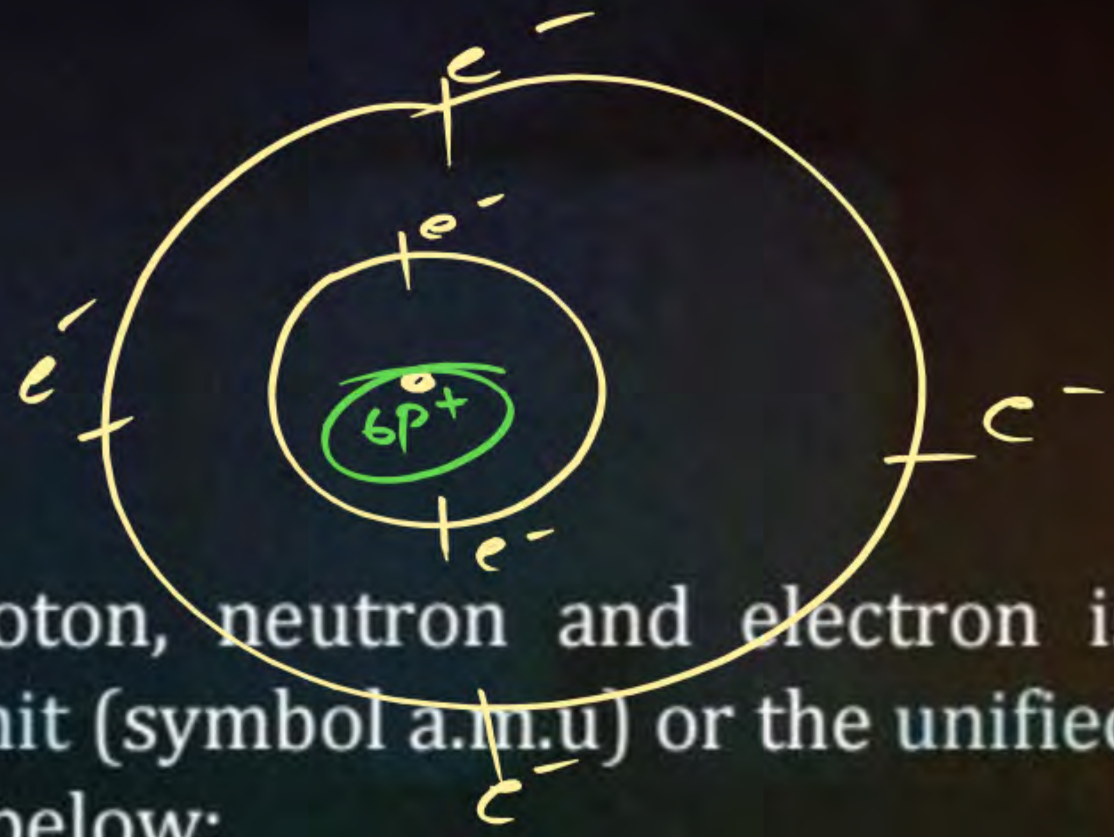
A → 10^3 kg

B → 10^2 kg

C → 10^7 kg

D → 10^3 gm

UNITS OF MASS



Non-metric unit of mass

The mass of atomic particles such as proton, neutron and electron is expressed in a unit called the atomic mass unit (symbol a.m.u) or the unified atomic mass unit (symbol u). It is defined as below:

1 a.m.u. (or u) is $\frac{1}{12}$ th the mass of one carbon-12 atom.

The mass of 6.02×10^{26} atoms of carbon –12 is 12 kg*.

UNITS OF MASS

$$\therefore 1 \text{ a.m.u (or } u) = \frac{1}{12} \times \frac{12}{6.02 \times 10^{26}} \text{ kg}$$

$$= 1.66 \times 10^{-27} \text{ kg}$$

The mass of large heavenly bodies is measured in terms of solar mass where 1 solar mass is the mass of the sun, i.e.,

$$1 \text{ solar mass} = 2 \times 10^{30} \text{ kg}$$

The commonly used smaller and bigger units of mass are summarized in the following table.

UNITS OF MASS

Smaller and bigger units of mass

Smaller units	Value in kg	Bigger units	Value in kg
g	10^{-3} kg	quintal	100 kg
mg	10^{-6} kg	metric tonne	1000 kg
u (or a.m.u.)	1.66×10^{-27} kg	solar mass	2×10^{30} kg

UNITS OF TIME

1 Day = 24 × 60 × 60 s

1 Day = 86400 sec

1 sec = $\frac{1}{86400}$ Day

Unit of time

The S.I. unit of time is second (s).

A second is defined as 1/86400 th part of a mean solar day. i.e.,

$$1\ s = \frac{1}{86400} \times \text{one mean solar day}$$

One solar day is the time taken by the earth to complete one rotation on its own axis.

UNITS OF TIME

For many years, the above definition of second remained in use. But mean solar day varies over the years, therefore in 1956, scientists agreed to consider one year 1900 and 12 hours as the ephemeris time and one year 1900 to be equal to 365-2422 days. Thus,

$$1 \text{ year } 1900 = 365.2422 \text{ days}$$
$$= 365.2422 \times 86400 \text{ s}$$
$$= 31556925.9747 \text{ s}$$

Hence one second is defined as $\frac{1}{31556925.9747}$ th part of the year 1900. i.e.,

$$1 \text{ s} = \frac{1}{31,556,925.9747} \text{th part of the year 1900.}$$

UNITS OF TIME

In 1964, a second was defined in terms of energy change in cesium atom as follows:

One second is the time interval of 9,192,631,770 vibrations of radiation corresponding to the transition between two hyperfine levels of the ground state of the cesium - 133 atom.

UNITS OF TIME

Smaller units of time

The common smaller units of time are millisecond (ms), microsecond (μs), shake and nanosecond (ns) where

$1\ ms = 10^{-3}\ s$; $1\ \mu s = 10^{-6}\ s$;

$1\ shake = 10^{-8}\ s$ and $1\ ns = 10^{-9}\ s$.

UNITS OF TIME

Bigger units of time

Sometimes second is a smaller unit of time and so we use other units of time such as (i) minute, (ii) hour, (iii) day, (iv) month, (v) lunar month, (vi) year, (vii) leap year, (viii) decade, (ix) century and (x) millennium. They are defined as below.

UNITS OF TIME

(i) **minute (min):** One minute is the duration of 60 second.

i.e., $1 \text{ min} = 60 \text{ s}$

(ii) **hour (h):** One hour is the duration of 60 minutes.

repit

i.e., $1 \text{ h} = 60 \text{ min}$

$= 60 \times 60 \text{ s} = 3600 \text{ s}$

(iii) **day:** The time taken by the earth to rotate once on its own axis is called a day. One day is divided in 24 hours. Thus,

$1 \text{ day} = 24 \text{ h}$

$= 24 \times 60 \text{ min} = 1440 \text{ min}$

$= 24 \times 60 \times 60 \text{ s} = 86400 \text{ s}$

UNITS OF TIME

(iv) **month:** The western or Gregorian Calendar has January, March, May, July, August, October and December each of 31 days; April, June, September and November each of 30 days and Feburary of 28 days (or 29 days in a leap year). To an approximation, a month is considered to be of 30 days and a year of 12 months to be of 365 days.

UNITS OF TIME

(v) **lunar month:** The western or Gregorian Calendar is based on the period of revolution of earth around the sun, but our Hindu (Vikram and Shak) and Muslim (Hizri) Calendars are based on the phases of moon as seen from our earth. In these calendars, one month is the time of one lunar cycle which is nearly 29.5 days. The period of 12 lunar months is 354-37 days.

UNITS OF TIME

(vi) **year (yr):** One year is defined as the time in which the earth completes one revolution around the sun. The period of revolution of earth around the sun is nearly 365 days. Thus,

$$1 \text{ yr} = 365 \text{ days}$$

$$= 365 \times 86400 \text{ s} = 3.1536 \times 10^7 \text{ s}$$

UNITS OF TIME

(vii) **Leap year:** A leap year is the year in which the month of February is of 29 days,

i.e., 1 Leap year = 366 days.

(viii) **Decade:** A decade is of 10 years. Thus,

$$1 \text{ Decade} = 10 \text{ years} = 3.1536 \times 10^8 \text{ s}$$

UNITS OF TIME

(ix) **Century:** A century is of 100 years. In a century, there will be 24 years each of 366 days and 76 years each of 365 days. Thus,

$$
\begin{aligned}
1 \text{ Century} &= 100 \text{ years} \\
&= (24 \times 366 + 76 \times 365) \text{ days} \\
&= 36524 \text{ days} \\
&= 3.16 \times 10^9 \text{ s.}
\end{aligned}
$$

UNITS OF TIME

(x) **Millennium:** A millennium is of 1000 years,
i.e. 1 Millennium = 3.16×10^{10} s

The commonly used bigger units of time are summarized in the following table.

Bigger units of time

Smaller units	Value in second	Bigger units	Value in second
min	60 s	year	3.1536×10^{7} s
h	3600 s	Decade	3.1536×10^{8} s
day	86400 s	Century	3.16×10^{9} s
Month	2.592×10^{6} s	Millennium	3.16×10^{10} s

Derived Units of Some Physical Quantities

Sr. No.	Quantity	Definition	Derived Unit	Abbreviation /symbol
1.	Area	length × breadth	metre × metre	m^2
2.	Volume	length × breadth × height	metre × metre × metre	m^3
3.	Density	$\frac{\text{mass}}{\text{volume}}$	$\frac{\text{kilogram}}{(\text{metre})^3}$	$kg\ m^{-3}$
4.	Speed or velocity	$\frac{\text{distance}}{\text{time}}$	$\frac{\text{metre}}{\text{second}}$	$m\ s^{-1}$
5.	Acceleration	$\frac{\text{velocity}}{\text{time}}$	$\frac{\text{metre/second}}{\text{second}}$	$m\ s^{-2}$
6.	Force	mass × acceleration	kilogram × $\frac{\text{metre}}{(\text{second})^2}$ or newton	$kg\ m\ s^{-2}$ or N

Derived Units of Some Physical Quantities

Sr. No.	Quantity	Definition	Derived Unit	Abbreviation /symbol
7.	Work or energy	force × displacement	kilogram × $\frac{\text{metre}}{(\text{second})^2}$ × metre or joule	kg m^2 s^{-2} or J
8.	Momentum	mass × velocity	kilogram × $\frac{\text{metre}}{\text{second}}$ or newton × second	kg m s^{-1} or N s
9.	Moment of force or torque	force × distance	kilogram × $\frac{\text{metre}}{(\text{second})^2}$ × metre or newton-metre	kg m^2 s^{-2} or N m
10.	Power	$\frac{\text{work}}{\text{time}}$	$\frac{\text{kilogram}(\text{metre})^2}{(\text{second})^2}$ / second or joule/second or watt	kg m^2 s^{-3} or J s^{-1} or W
11.	Pressure	$\frac{\text{force}}{\text{area}}$	kilogram × $\frac{\text{metre}}{(\text{second})^2}$ / $(\text{metre})^2$ or newton/$(\text{metre})^2$ or pascal	kg m^{-1} s^{-2} or N m^{-2} or Pa

Question

Which of the following is a fundamental unit in the Sl system?

(A) Newton

(B) Joule

(C) Kilogram

(D) Pascal

Question

Which of the following is a fundamental unit in the SI system?

(A) Newton

(B) Joule

(C) Kilogram

(D) Pascal

Ans. (C) Kilogram

Question

The SI unit of time is:

(A) Minute

(B) Hour

(C) Second

(D) Millisecond

Question

The Sl unit of time is:

(A) Minute

(B) Hour

(C) Second

(D) Millisecond

Ans. (C) Second

Question

One nanometer is equal to:

(A) 10^{-3} m

(B) 10^{-6} m

(C) 10^{-9} m

(D) 10^{-12} m

Question

One nanometer is equal to:

(A) 10^{-3} m

(B) 10^{-6} m

(C) 10^{-9} m

(D) 10^{-12} m

Ans. (C) 10^{-9} m

Question

Which of the following pairs are both derived units?

(A) Kilogram and meter

(B) Newton and joule

(C) Second and candela

(D) Kelvin and mole

Question

Which of the following pairs are both derived units?

(A) Kilogram and meter

(B) Newton and joule

(C) Second and candela

(D) Kelvin and mole

Ans. (B) Newton and joule

Question

Fill in the Blanks

i. The Sl unit of length is ________ .

ii. One litre is equal to ________ cubic centimetres.

iii. A physical quantity which has only magnitude and no direction is called a ________ quantity.

iv. The Sl unit of force is ________ .

Question

Fill in the Blanks

i. The Sl unit of length is ________.

ii. One litre is equal to ________ cubic centimetres.

iii. A physical quantity which has only magnitude and no direction is called a ________ quantity.

iv. The Sl unit of force is ________.

Ans.
i. metre
ii. 1000
iii. scalar
iv. newton

Question

Define a fundamental unit with one example.

Question

Define a fundamental unit with one example.

Solution.

A fundamental unit is the unit of a basic physical quantity which is independent and cannot be derived from other units. Example: metre (unit of length).

Question

What is the difference between fundamental and derived units? Give one example of each.

Question

What is the difference between fundamental and derived units? Give one example of each.

Solution.

Fundamental units are the basic units for quantities like length (metre), mass (kilogram), and time (second). Derived units are formed from the fundamental units, like velocity (m/s), force (newton).

Question

Convert 5 km into metres.

Question

Convert 5 km into metres.

Solution.

$5 \times 1000 = 5000$ m.

Question

A box weighs 2500 g. Convert this into kilograms.

Question

A box weighs 2500 g. Convert this into kilograms.

Solution.

$$2500 \div 1000 = 2.5 \text{ kg}$$

Question

How many units are fundamental and complementary?

(A) 2 fundamental, 7 complementary

(B) 3 fundamental, 6 complementary

(C) 7 fundamental, 2 complementary

(D) 4 fundamental, 5 complementary

Question

How many units are fundamental and complementary?

(A) 2 fundamental, 7 complementary

(B) 3 fundamental, 6 complementary

(C) 7 fundamental, 2 complementary

(D) 4 fundamental, 5 complementary

Ans. (C) 7 fundamental, 2 complementary

Question

The fundamental unit is-

(A) Newton

(B) Pascal

(C) Hertz

(D) Second

Question

The fundamental unit is-

(A) Newton

(B) Pascal

(C) Hertz

(D) Second

Ans. **(D)** Second

Question

Which of the following unit is not a fundamental unit:

(A) Metre

(B) Litre

(C) Second

(D) Kilogram

Question

Which of the following unit is not a fundamental unit:

(A) Metre

(B) Litre

(C) Second

(D) Kilogram

Ans. (B) Litre

Question

Name the S.I unit of mass and define it.

Question

The S.I. unit of energy is:

(A) Joule

(B) $Kg\ m^2$

(C) $Kg\ m^2 s^{-3}$

(D) $Kg\ m^2 s^{-1}$

Question

The S.I. unit of energy is:

(A) Joule

(B) Kg m^2

(C) Kg m^2s^{-3}

(D) Kg m^2s^{-1}

Ans. (A) Joule

Question

Which one of the following is a derived unit?

(A) Metre

(B) Kelvin

(C) $Metre^3$

(D) Mole

Question

Which one of the following is a derived unit?

(A) Metre

(B) Kelvin

(C) $Metre^3$

(D) Mole

Ans. (C) $Metre^3$

Question

What is meant by measurement?

Question

What is meant by measurement?

Solution.

It is comparison of the specified physical quantity with the known standard quality of the equivalent nature.

Question

What do you understand by the term unit?

Question

What do you understand by the term unit?

Solution.

Unit is quantity of a constant magnitude which is used to measure the magnitudes of other quantities of the same nature.

Question

What are the three requirements for selecting a unit of a physical quantiy?

Question

What are the three requirements for selecting a unit of a physical quantiy?

Solution.

The three requirements for selecting a unit of a physical are:

- It should be reproducible
- Is required to be of convenient size
- No ambiguity while defining the unit
- The value of unit should not change with space and time.

Question

Name the three fundamental quantities.

Question

Name the three fundamental quantities.

Solution.

The three fundamental quantities are:

- Length
- Mass
- Time

Question

The condition(s) essential for a unit to be accepted internationally:

(A) The unit should be of convenient size and without any ambiguity.

(B) The unit should be reproducible.

(C) The value of the unit should not change with space and time.

(D) All of the above.

Question

The condition(s) essential for a unit to be accepted internationally:

(A) The unit should be of convenient size and without any ambiguity.

(B) The unit should be reproducible.

(C) The value of the unit should not change with space and time.

(D) All of the above.

Ans. **(D)** All of the above.

Question

In mechanics, the three fundamental quantities are:

(A) Length, mass, velocity

(B) Mass, time, density

(C) Mass, time, pressure

(D) Length, mass, time

Question

In mechanics, the three fundamental quantities are:

(A) Length, mass, velocity

(B) Mass, time, density

(C) Mass, time, pressure

(D) Length, mass, time

Ans. (D) Length, mass, time


Thank You