CHAPTER 2 – UNITS AND MEASUREMENT

Question 2.1

Fill in the blanks

a) The volume of a cube of side 1 cm is equal to…..m^3

b) The surface area of a solid cylinder of radius 2.0 cm and height 10.0 cm is equal to … $(mm)^2$

c) A vehicle moving with a speed of 18 km h^{-1}covers….m in 1 s

d) The relative density of lead is 11.3. Its density is ….g cm^{-3}or . …kg m^{-3}.

Answer

a) 1 cm = $\frac{1}{100}$ m

Volume of the cube = 1 cm^3

But, 1 cm^3 = 1 cm × 1 cm × 1 cm = $\left(\frac{1}{100}\right)$m × $\left(\frac{1}{100}\right)$m × $\left(\frac{1}{100}\right)$m

∴ 1 cm^3 = **10^{-6} m^3 Ans.**

Hence, the volume of a cube of side 1 cm is equal to 10^{-6} m^3.

b) The total surface area of a cylinder of radius *r* and height *h* is

$S = 2\pi r\,(r + h)$.

Given that,

r = 2 cm = 2 × 1 cm = 2 × 10 mm = 20 mm

h = 10 cm = 10 × 10 mm = 100 mm

∴ S = 2 × 3.14 × 20 × (20 + 100) = 15072 = **1.5×10^4 mm^2 Ans.**

c) Using the conversion,

1 km/h = $\frac{5}{8}$ m/s

18 km/h = $\left(18 \times \frac{5}{18}\right)$ m/s = 5 m/s

Therefore, distance can be obtained using the relation:

Distance = Speed × Time = 5 × 1 = 5 m

Hence, the vehicle covers 5 m in 1 s. Ans.

d) Relative density of a substance is given by the relation,

Relative density = $\frac{Density\ Of\ Substance}{Density\ Of\ Water}$

Density of water = 1 g/cm^3

Density of lead = Relative density of lead × Density of water

= 11.3 × 1 = 11.3 g/cm^3

Again, 1 g = $\frac{1}{1000}$ kg ; 1 cm^3 = 10^{-6} m^3

1 g/cm^3 = $\frac{10^{-3}}{10^{-6}}$ kg/m^3 = 10 kg/m^3

∴ 11.3 g/cm^3 = **11.3×10^3 kg/m^3 Ans.**

Question 2.2

Fill in the blanks by suitable conversion of units:

a) $1\ kg\ m^2 s^{-2} = ...g\ cm^2\ s^{-2}$

b) $1\ m = ...\ ly$

c) $3.0\ m\ s^{-2} = ...\ km\ h^{-2}$

d) $G = 6.67 \times 10^{-11}\ N\ m^2\ (kg)^{-2} = ...\ (cm)^3 s^{-2}\ g^{-1}$.

Answer

a) $1\ kg = 10^3\ g$

$1\ m^2 = 10^4\ cm^2$

$1\ kg\ m^2\ s^{-2} = 1\ kg \times 1\ m^2 \times 1\ s^{-2}$

$= 10^3\ g \times 10^4\ cm^2 \times 1\ s^{-2}$

$= \mathbf{10^7\ g\ cm^2\ s^{-2}}$ **Ans.**

b) Light year is the total distance travelled by light in one year.

1 ly = Speed of light × One year

$= (3 \times 10^8\ m/s) \times (365 \times 24 \times 60 \times 60\ s)$

$= 9.46 \times 10^{15}\ m$

$\therefore\quad 1\ m = \dfrac{1}{9.46 \times 10^{15}} = \mathbf{1.057 \times 10^{-16}\ ly.}$ **Ans.**

c) $1\ m = 10^{-3}\ km$

Again, $1\ s = \dfrac{1}{3600}\ h$

$1\ s^{-1} = 3600\ h^{-1}$

$1\ s^{-2} = (3600)^2\ h^{-2}$

$\therefore\quad 3\ ms^{-2} = (3 \times 10^{-3}\ km) \times ((3600)^2\ h^{-2}) = \mathbf{3.88 \times 10^4\ km\ h^{-2}}$ **Ans.**

d) We know,

$1\ N = 1\ kgms^{-2}$

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

$1\ m^3 = 10^6\ cm^3$

$\therefore\quad 6.67 \times 10^{-11}\ N\ m^2\ kg^{-2} = 6.67 \times 10^{-11} \times (1\ kg\ m\ s^{-2})\ (1\ m^2)\ (1\ s^{-2})$

$= 6.67 \times 10^{-11} \times (1\ kg \times 1\ m^3 \times 1\ s^{-2})$

$= 6.67 \times 10^{-11} \times (10^{-3}\ g^{-1}) \times (10^6\ cm^3) \times (1\ s^{-2})$

$= \mathbf{6.67 \times 10^{-8}\ cm^3\ s^{-2}\ g^{-1}}$ Ans.

Question 2.3

A calorie is a unit of heat or energy and it equals about 4.2 J where $1J = 1\ kg\ m^2 s^{-2}$. Suppose we employ a system of units in which the unit of mass equals α kg, the unit of length equals β m, the unit of time is γ s. Show that a calorie has a magnitude $4.2\ \alpha^1 \beta^2 \gamma^2$ in terms of the new units.

Answer

Given that,

$1\ calorie = 4.2\ (1\ kg)\ (1\ m^2)\ (1\ s^{-2})$

New unit of mass = α kg

Hence, in terms of the new unit, 1 kg = $\frac{1}{\alpha} = \alpha^{-1}$

In terms of the new unit of length,

$$1\ \text{m} = \frac{1}{\beta} = \beta^{-1} \text{ or } 1\ \text{m}^2 = \beta^{-2}$$

And, in terms of the new unit of time,

$$1\ \text{s} = \frac{1}{\gamma} = \gamma^{-1}$$
$$1\ \text{s}^2 = \gamma^{-2}$$
$$1\ \text{s}^{-2} = \gamma^2$$

∴ 1 calorie = 4.2 $(1\ \alpha^{-1})\ (1\ \beta^{-2})\ (1\ \gamma^2)$ = **$4.2\ \alpha^{-1}\ \beta^{-2}\ \gamma^2$ Ans.**

Question 2.4

Explain this statement clearly:

"To call a dimensional quantity 'large' or 'small' is meaningless without specifying a standard for comparison". In view of this, reframe the following statements wherever necessary:

a) Atoms are very small objects
b) A jet plane moves with great speed
c) The mass of Jupiter is very large
d) The air inside this room contains a large number of molecules
e) A proton is much more massive than an electron
f) The speed of sound is much smaller than the speed of light.

Answer

The given statement is true because a dimensionless quantity may be large or small in comparison to some standard reference. For example, the coefficient of friction is dimensionless. The coefficient of sliding friction is greater than the coefficient of rolling friction, but less than static friction.

a) An atom is a very small object in comparison to a soccer ball.
b) A jet plane moves with a speed greater than that of a bicycle.
c) Mass of Jupiter is very large as compared to the mass of a cricket ball.
d) The air inside this room contains a large number of molecules as compared to that present in a geometry box.
e) A proton is more massive than an electron.
f) Speed of sound is less than the speed of light.

Question 2.5

A new unit of length is chosen such that the speed of light in vacuum is unity. What is the distance between the Sun and the Earth in terms of the new unit if light takes 8 min and 20 s to cover this distance?

Answer

Distance between the Sun and the Earth:

= Speed of light × Time taken by light to cover the distance

Given that in the new unit, speed of light = 1 unit

Time taken, t = 8 min 20 s = 500 s

∴ Distance between the Sun and the Earth = 1 × 500 = **500 units Ans.**

Question 2.6

Which of the following is the most precise device for measuring length:

a) A Vernier callipers with 20 divisions on the sliding scale.
b) A screw gauge of pitch 1 mm and 100 divisions on the circular scale.
c) An optical instrument that can measure length to within a wavelength of light?

Answer

A device with minimum count is the most suitable to measure length.

a) Least count of vernier callipers

= 1 standard division (SD) – 1 vernier division (VD)

$$= 1 - \frac{9}{10} = \frac{1}{10} = \mathbf{0.01\ cm}$$

b) Least count of screw gauge $= \dfrac{Pitch}{Number\ Of\ Divisions}$

$$= \frac{1}{1000} = \mathbf{0.001\ cm}$$

c) Least count of an optical device = Wavelength of light ~ 10^{-5} cm

= 0.00001 cm

Hence, it can be inferred that an optical instrument is the most suitable device to measure length.

Question 2.7

A student measures the thickness of a human hair by looking at it through a microscope of magnification 100. He makes 20 observations and finds that the average width of the hair in the field of view of the microscope is 3.5 mm. What is the estimate on the thickness of hair?

Answer

Magnification of the microscope = 100

Average width of the hair in the field of view of the microscope = 3.5 mm

∴ Actual thickness of the hair is $\frac{3.5}{100}$ = **0.035 mm.**

Question 2.8

Answer the following:

a) You are given a thread and a meter scale. How will you estimate the diameter of the thread?
b) A screw gauge has a pitch of 1.0 mm and 200 divisions on the circular scale. Do you think it is possible to increase the accuracy of the screw gauge arbitrarily by increasing the number of divisions on the circular scale?