CHAPTER 1

UNITS AND MEASUREMENTS

CLASS 11TH

NCERT EXERCISE AND SOLUTIONS - PHYSICS

1.1 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}.

SOLUTION:

(a) The volume of a cube of side 1 cm is equal to $\mathbf{10^{-6}\ m^3}$.

Length of cube (l) = 1cm

Using formula $V = l^3$

Volume of cube, $V = (1\text{ cm})^3$

$V = (10^{-2}\text{ m})^3$ {1cm = 10^{-2} m}

$V = 10^{-6}\text{ m}^3$.

(b) The surface area of a solid cylinder of radius 2.0 cm and height 10.0 cm is equal to $\mathbf{1.5\times10^4}$ $(mm)^2$.

Radius (r) = 2 cm, height = 10 cm

Using formula for surface area of cylinder-

Surface area (A) = $2\pi rh + 2\pi r^2 = 2\pi r(h+r)$

$$A = 2\times\frac{22}{7}\times2\times10(10\times10+2\times10)\text{mm}^2 \quad \{1\text{cm} = 10\text{mm}\}$$

$A = 1.5\times10^4\text{ mm}^2$

(c) A vehicle moving with a speed of 18 km h^{-1} covers 5 m in 1 s.

Speed of vehicle (s) =18 km/h = 18×1000/3600 m/s {1km = 1000 m, 1h = 3600 sec}

Therefore, the vehicle covers 5 m in 1 sec.

(d) The relative density of lead is 11.3. Its density is 11.3 g cm^{-3} or d = 11.3×10^3 kg m^{-3}.

Density of lead (ρ_{lead}) = 11.3

Using formula:

$$\text{Relative density, } R = \frac{\text{Density of lead}\left(\rho_{\text{lead}}\right)}{\text{Density of water}\left(\rho_{\text{water}}\right)}$$

Density of water, ρ_{water} = 1000 kg/m^3 = 1 g/cm^3

$\rho_{lead} = 11.3\times\rho_{water}$

ρ_{lead} (in g/cm^3) = 11.3×1

ρ_{lead} (in g/cm^3) = 11.3 g/cm^3

Density (ρ) = 11.3×10^3 kg m^{-3})

1.2 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 × 10^{-11} N m^2 (kg)$^{-2}$ = ... (cm)^3 s^{-2} g^{-1}.

SOLUTION:

(a) 1 kg m^2 s^{-2} = 10^7 g cm^2 s^{-2}

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

$$= \frac{1\times1000\times\left(10^2\right)^2}{s^2}\text{gcm}^2$$

$= 10^7$g cm^2 s^{-2}

(b) 1 m = 10^{-16} ly (1 ly = Distance travelled by light in 1 year)

(c) 3.0 m s^{-2} = 3.888 × 10^4 km h^{-2}

$$3\text{ms}^{-2} = \frac{3\times10^{-3}\text{km}}{\left(\frac{1}{3600}\right)^2\text{h}^2}$$

3 ms^{-2} = 3×3600×3600×10^{-3} km h^{-2}

3 ms^{-2} =3.888×10^4 km h^{-2}

(d) G = 6.67 × 10^{-11} N m^2 (kg)$^{-2}$

$$G = 6.67\times10^{-11}\text{Nm}^2\text{kg}^{-2} = 6.67\times10^{-11}\frac{\text{kgm}}{\text{s}^2}\text{m}^2\text{kg}^{-2}$$

$$\text{G} = 6.67\times10^{-11}\text{kg}^{-1}\text{m}^3\text{s}^{-2}$$

$$\text{G} = 6.67\times10^{-11}\frac{\text{m}^3}{\text{kgs}^2} = \frac{6.67\times10^{-11}\times\left(10^2\right)^3}{\left(10^8\right)^2}$$

$$\text{G} = 6.67\times10^{-8}\text{cm}^3\text{s}^{-2}\text{g}^{-1}.$$

1.3 A calorie is a unit of heat (energy in transit) and it equals about 4.2 J where 1 J = 1 kg m^2 s^{-2}. Suppose we employ a system of units in which the unit of mass equals a kg, the unit of length equals b m, the unit of time is g s. Show that a calorie has a magnitude 4.2 a^{-1} b^{-2} g^{2} in terms of the new units.

SOLUTION:

Given – 1 calorie = 4.2 J = 4.2 kg m^2 s^{-2}

Using the standard formula for the conversion:

$$\frac{\text{Given unit}}{\text{new unit}} = \left(\frac{M_1}{M_2}\right)^x \left(\frac{L_1}{L_2}\right)^y \left(\frac{T_1}{T_2}\right)^z$$

Dimensional formula for energy = $[M^1L^2\,T^{-2}]$

Here, $x = 1$, y = 2 and z = –2

$M_1 = 1$ kg, $L_1 = 1$ m, $T_1 = 1$ s

and $M_2 = \alpha$ kg, $L_2 = \beta$ m, $T_2 = \gamma$ s

$$\frac{\text{Calorie}}{\text{new unit}} = 4.2\left(\frac{1}{\alpha}\right)^1 \left(\frac{1}{\beta}\right)^2 \left(\frac{1}{\gamma}\right)^{-2}$$

Calorie = $4.2\alpha^{-1}\,\beta^{-2}\,\gamma^2$

1.4 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.

SOLUTION:

The statement means that terms like "large" and "small" depend on what you're comparing something to. Without a reference point, it's hard to judge the size of something. For example, a 10-meter tree might be large compared to a 1-meter plant, but small compared to a 100-meter skyscraper.

(a) The size of an atom is much smaller than even the sharp tip of a pin.

(b) A Jet plane moves with a speed greater than that of a super-fast train.

(c) The mass of Jupiter is very large compared to that of the earth.

(d) The air inside this room contains more number of molecules than in one mole of air.

(e) This is a correct statement.

(f) This is a correct statement.

1.5 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?

SOLUTION:

Given – time taken (t) = 8 min 20s

Need to find – Distance between Sun and Earth (d)

Speed of light in vacuum (c) = 3×10^8 m/s

Distance (d) = Speed of light in vacuum (c) × time taken by light to travel from sun to Earth (t)

$$d = 3\times\frac{10^8\,\text{m}}{\text{s}}\times 8\text{min}20\text{s}$$

$$d = 3\times\frac{10^8\,\text{m}}{\text{s}}\times 500\text{s}$$

$$d = 500\times3\times10^8\,\text{m}.$$

d = 500 units {new unit of length is 3×10^8 m/s}

In the new system, the speed of light in vacuum is unity. So, the new unit of length is.

1.6 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?

SOLUTION:

(a) Least count of vernier callipers:

Given- Number of divisions = 20(n), Value of main scale division=1mm

$$\text{Using formula: Least Count (L.C.)} = \frac{\text{Value of one main scale division}}{\text{Number of divisions on the vernier scale}}$$

$$\text{L.C.} = \frac{1}{20}$$

L.C. = 0.05 mm = 5×10^{-5} m

(b) Least count of screw gauge:

Given- pitch = 1 mm = 10^{-3}m, number of divisions= 100 divisions

Least count (L.C.) = Pitch/No. of divisions on circular scale

L.C. = $1\times10^{-3}/100 = 1\times10^{-5}$m

(c) Least count of optical instrument = (average wavelength of visible light as 6000 A) = 6×10^{-7}m
As the least count of optical instrument is least, it is the most precise device out of three instruments given to us.

1.7 **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?**

SOLUTION:

Given – (magnification) m = 100, observed width = 3.5 mm

Need to find – Estimate on the thickness of hair (real width, r)

Using formula: Magnification (m) $= \dfrac{\text{observed width}}{\text{real width}}$

real width = 3.5mm/100 = 0.035 mm

real width = 0.035 mm

Hence, thickness of hair = 0.035 mm

1.8 **Answer the following:**

(a) **You are given a thread and a metre 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?**

(c) **The mean diameter of a thin brass rod is to be measured by vernier callipers. Why is a set of 100 measurements of the diameter expected to yield a more reliable estimate than a set of 5 measurements only?**

SOLUTION:

(a) To determine the thickness of the thread, wrap it several times around a round pencil to form a coil, ensuring the turns are closely packed together. Measure the total length of the coil using a meter scale. Let *n* represent the number of turns in the coil and *l* the total length of the coil. The length occupied by each individual turn (which corresponds to the thickness of the thread) is given by *l*/*n*. This value represents the diameter of the thread.

(b) The least count is calculated as the pitch divided by the number of divisions on the circular scale. When the number of divisions on the circular scale increases, the least count decreases, leading to greater accuracy. However, this is only a theoretical consideration. In practice, increasing the number of divisions can introduce difficulties. For instance, the limited resolution of the human eye can make it hard to distinguish between very closely spaced divisions. Additionally, it would be technically challenging to maintain a consistent pitch along the entire length of the screw.

(c) Due to random errors, taking a larger number of measurements yields more reliable results than taking fewer measurements. This is because the probability of a positive random error is equal to the probability of a negative random error of the same magnitude. Therefore, in a large set of measurements, positive and negative errors are likely to cancel each other out, leading to a more accurate and reliable result.

1.9 The photograph of a house occupies an area of 1.75 cm2 on a 35 mm slide. The slide is projected on to a screen, and the area of the house on the screen is 1.55 m2. What is the linear magnification of the projector-screen arrangement.

SOLUTION:

Given – Area of the house on slide (A') = 1.75 cm^2 = 1.75×10^{-4} m^2, Area of the house of projector screen (A) = 1.55 m^2

Need to find – Liner magnification (M)

$$\text{Areal magnification} = \frac{\text{Area on screen}}{\text{Area on slide}} = 1.55\text{m}^2 / 1.75\times10^{-4}\text{m}^2 = 8.857\times10^3$$

$$\text{Linear magnification}(M) = \sqrt{\text{Areal magnification}}$$

$$M = \sqrt{(8.857)\times10^3}$$

$$M = 94.1$$

Hence linear magnification is 94.1

1.10 State the number of significant figures in the following:

(a) 0.007 m^2

(b) 2.64 × 1024 kg

(c) 0.2370 g cm^{-3}

(d) 6.320 J

(e) 6.032 N m^{-2}

(f) 0.0006032 m^2

SOLUTION:

(a) 0.007 m^2: The leading zeros are not significant. The significant figure here is the 7 .
Number of significant figures: 1

(b) 2.64×10^{24} kg: All digits in this number are significant (2,6, and 4).
Number of significant figures: 3

(c) 0.2370 g cm^{-3}: The leading zero is not significant, but the digits 2,3,7 and the trailing zero are significant. Number of significant figures: 4

(d) 6.320 J: All digits are significant (6,3,2, and 0).
Number of significant figures: 4

(e) 6.032 N m^{-2}: All digits are significant .
Number of significant figures: 4

(f) 0.0006032 m^2: The leading zeros are not significant. The digits 6,0,3,2 are significant.
Number of significant figures: 4

1.11 The length, breadth and thickness of a rectangular sheet of metal are 4.234 m, 1.005 m and 2.01 cm respectively. Give the area and volume of the sheet to correct significant figures.

SOLUTION:

Given – length (l) = 4.234 m, breadth (b) = 1.005 m, thickness (t) = 2.01 cm

Need to find – Area (A) and volume (V)

Area = l × b

$A = (4.234 \times 1.005)$

$A = 4.255 = 4.3\ m^2$

Volume = l × b × h

$V = (4.234 \times 1.005) \times (2.01 \times 10^{-2})$

$V = 8.55289 \times 10^{-2} = 0.0855\ m^3$

1.12 The mass of a box measured by a grocer's balance is 2.30 kg. Two gold pieces of masses 20.15 g and 20.17 g are added to the box. What is (a) the total mass of the box, (b) the difference in the masses of the pieces to correct significant figures?

SOLUTION:

Given – mass of the box (m)= 2.30 kg, Two gold pieces mass: m_1= 20.15g and m_2 = 20.17g

Need to find – Total mass of the box(M)

(a) Total mass of the box (M) = $m + m_1 + m_2$

M = (2.3+0.0217+0.0215) kg = 2.3442 kg

Since the least number of decimal places is 1, therefore, the total mass of the box .

(b) Difference of mass = 2.17 – 2.15 = 0.02 kg

Since the least number of decimal places is 2 so the difference in masses to the correct significant figures is 0.02 g.

1.13 A famous relation in physics relates 'moving mass' *m* to the 'rest mass' m_o of a particle in terms of its speed *v* and the speed of light, *c*. (This relation first arose as a consequence of special relativity due to Albert Einstein). A boy recalls the relation almost correctly but forgets where to put the constant c. He writes:

$$m = \frac{m_0}{\left(1 - v^2\right)^{1/2}}$$

Guess where to put the missing *c*.

SOLUTION:

From the given equation, $\frac{m_o}{m} = \sqrt{1 - v^2}$

Left hand side is dimensionless.

Therefore, right hand side should also be dimensionless.

It is possible only when $\sqrt{1-v^2}$ should be $\sqrt{1-\frac{v^2}{c^2}}$

Thus, the correct formula is $m = m_o\left(1-\frac{v^2}{c^2}\right)^{-1/2}$

1.14 The unit of length convenient on the atomic scale is known as an angstrom and is denoted by Å: 1 Å = 10^{-10} m. The size of a hydrogen atom is about 0.5 Å. What is the total atomic volume in m^3 of a mole of hydrogen atoms?

SOLUTION:

Given – Size of hydrogen atom (r) = 0.5 Å

Need to find – Total atomic volume of a mole of hydrogen atom (V)

Volume of one hydrogen atom = $\frac{4\pi r3}{3}$ (volume of sphere)

$= 4/3\times3.14\times(0.5\times10^{-10})m^3 = 5.23\times10–31\ m^3$

According to Avogadro's hypothesis, one mole of hydrogen contains 6.023×10^{23} atoms.

Atomic volume of 1 mole of hydrogen atoms (V) = $6.023\times10^{23}\times5.23\times10^{-31}$

$V = 3.15\times10^{-7})\ m^3$

Therefore volume of a mole of hydrogen is $3.15\times10^{-7}\ m^3$

1.15 One mole of an ideal gas at standard temperature and pressure occupies 22.4 L (molar volume). What is the ratio of molar volume to the atomic volume of a mole of hydrogen? (Take the size of hydrogen molecule to be about 1 Å). Why is this ratio so large?

SOLUTION:

Given – Volume of one mole of ideal gas, $V_g = 22.4$ litre $= 22.4\times10^{-3}\ m^3$

Need to find – Ratio of molar volume to the atomic volume. V_g/V_H

Radius of hydrogen molecule = 1 Å/2 = 0.5 Å = 0.5×10^{-10} m

Volume of hydrogen molecule (V) = $(4/3)\pi r^3$

$V = 4/3\times22/7(0.5\times10^{-10})^3\ m^3$

$V = 0.5238\times10^{-30})\ m^3$

One mole contains 6.023×10^{23} molecules.

Volume of one mole of hydrogen, $V_H = V\times6.023\times10^{23}$

$V_H = 0.5238\times10^{-30}\times6.023\times10^{23}\ m^3$

$V_H = 3.1548\times10^{-7}\ m^3$

Now $V_g/V_H = 22.4\times10^{-3}/3.1548\times10^{-7} = 7.1\times10^4$

The ratio is very large. This is because the interatomic separation in the gas is very large compared to the size of a hydrogen molecule.

1.16 Explain this common observation clearly: If you look out of the window of a fast-moving train, the nearby trees, houses etc. seem to move rapidly in a direction opposite to the train's motion, but the distant objects (hill tops, the Moon, the stars etc.) seem to be stationary. (In fact, since you are aware that you are moving, these distant objects seem to move with you).

SOLUTION:

When you're in a fast-moving train, nearby objects like trees and houses seem to move rapidly in the opposite direction because they are close to you, and their relative motion is more noticeable. Distant objects like hills, the Moon, and stars appear stationary because they are far away, and their relative motion is too small to notice. Although they seem still, you know that these distant objects are moving with you through space, since you are aware of your own motion.

1.17 The Sun is a hot plasma (ionized matter) with its inner core at a temperature exceeding 10^7 K, and its outer surface at a temperature of about 6000 K. At these high temperatures, no substance remains in a solid or liquid phase. In what range do you expect the mass density of the Sun to be, in the range of densities of solids and liquids or gases? Check if your guess is correct from the following data: mass of the Sun = 2.0×10^{30} kg, radius of the Sun = 7.0×10^8 m.

SOLUTION:

Given – M = 2×10^{30} kg, r = 7×10^8 m

Need to find – Range of mass density of the sun

Volume of Sun = $\frac{4}{3}\pi r^3 = \frac{4}{3}.3.14 \times (7\times10^8)^3 = 1.437\times10^{27}$ m^3

As p = M/V, $\therefore$ $p = 2\times10^{30}/1.437\times10^{27}$ = 1391.8 kg m^{-3} = 1.4×10^3 kg m^{-3}

Mass density of Sun is in the range of mass densities of solids/liquids and not gases.