IV. Multiple Choice Questions

Question 1. The SI units of magnetic field is

(a) weber per metre^2

(b) newton per coulomb per (metre per second)

(c) newton per ampere per metre

(d) all the above

Question 2. The dimensions of energy per unit volume are the same as those of

(a) pressure

(b) force

(c) modulus of elasticity

(d) all the above

Question 3. The SI units of the universal gravitational constant G are

(a) kg m^2 s^{-2}

(b) kg^{-1} m^3 s^{-2}

(c) N kg^2 m^{-2}

(d) N kg^2 m^{-2}

Question 4. The number of particles crossing per unit area perpendicular to X-axis in unit time is N = -D n_2-n_1/x_2-x_1 where n_1 and n_2 are number of particles per unit volume for the value of x_1 and x_2 respectively. The dimensions of diffusion constant D are

(a) M°L T^2

(b) M°L^2 T^{-4}

(c) M°L T^3

(d) M°L^{2}T^3

Question 5. A physical quantity is represented by X = MaLb TA If percentage error in the measurement of M, L and T are α%, (3% and γ% respectively, then total percentage error is

(a) (αa - βb +γc)%

(b) (αa + βb +γc)%

(c) (αa - βb — γc)%

(d) none of the above

Question 6. 'Parsec' is the unit of:

(a) Time

(b) Distance

(c) Frequency

(d) Angular acceleration

Question 7. The density of a cube is measured by measuring its mass and the length of its sides. If the maximum errors in the measurement of mass and length are 3% and 2% respectively, then the maximum error in the measurement of density is

(a) 9% (b) 7% (c) 5% (d) 1%

Question 8. A wire has a mass 0.3 ± 0.003 g, radius 0.5 ± 0.005 mm and length 6 ± 0.06 cm. The maximum percentage error in the measurement of its density is

(a) 1 (b) 2 (c) 3 (d) 5

9. The velocity of a body moving in viscous medium is given by $v = \frac{A}{B}\left[1 - e^{\frac{-t}{B}}\right]$ where t is time, A and B are constants.
Then the dimensions of A are

(a) $M^0 L^0 T^0$ (b) $M^0 L^1 T^0$ (c) $M^0 L^1 T^{-2}$ (d) $M^1 L^1 T^{-1}$

10. The dimensions of entropy are

(a) $M^0 L^{-1} T^0 K$ (b) $M^0 L^{-2} T^0 K^2$ (c) $ML T^{-2} K$ (d) $M L^2 T^{-2} K^{-1}$

Answer:

1.—(d)
2.—(d)
3 —(b) and (c)
4.—(d)
5.—(b)
6.—(b)
7.—(a)
8.—(d)
9.—(b)
10.—(d)

V. Question On High Order Thinking Skills (Hots)
Question 1. A laser light beam sent to the moon takes 2.56 s to return after reflection at the Moon's surface. Calculate the radius of the lunar orbit around the eazth.
Answer:
Radius of the lunar orbit around the earth = Distance between the moon and the earth
Time taken by the laser beam from earth to moon and then back to the earth = 2.56 s.

$\therefore$ Time taken by the laser beam to go from earth to the moon is $t = \frac{2.56}{2} = 1.28$ s

Speed of the laser beam (*i.e.*, light),

$$c = 3 \times 10^8 \text{ ms}^{-1}$$

$\therefore$ Distance between moon and earth,

$$S = c\,t = 3 \times 10^8 \times 1.28$$
$$= 3.84 \times 10^8 \text{ m} = 3.84 \times 10^5 \text{ km.}$$

Question 2. The parallactic angle subtended by a distant star is 0.76 on the earth's orbital diameter (1.5 x 10^{11} m). Calculate the distance of the star from the earth.
Answer:

The parallactic angle, $\phi = 0.76 = \frac{0.76 \times \pi}{180 \times 60 \times 60}$ radians

$$= \frac{19\,\pi}{1.62 \times 10^7} \text{ radians}$$

The orbital diameter, say $D = 1.5 \times 10^{11}$ m

$\therefore$ The required distance, $d = \frac{D}{\phi}$

$$= \frac{1.5 \times 10^{11} \times 1.62 \times 10^7}{19\,\pi} \text{ m}$$
$$= \frac{2.43 \times 10^{18}}{19 \times 3.14} \text{ m}$$
$$= \frac{243 \times 10^{16}}{59.66} \text{ m}$$
$$= 4.073 \times 10^{16} \text{ m}$$

Since, 1 light year $= 9.5 \times 10^{15}$ m

$$d = \frac{4.073 \times 10^{16}}{9.5 \times 10^{15}} \text{ light year}$$
$$= 4.29 \text{ light year.}$$

Question 3. The heat dissipated in a resistance can be obtained by the measurement of resistance, the current and time. If the maximum error in the measurement of these quantities is 1 %, 2 % and 1 % respectively, what is the maximum error in determination of the dissipated heat?
Answer:

Heat produced H is given by

$$H = \frac{I^2 R t}{J}$$

$$\therefore \qquad \frac{\Delta H}{H} = 2\frac{\Delta I}{I} + \frac{\Delta R}{R} + \frac{\Delta t}{t} - \frac{\Delta J}{J}$$

For maximum percentage error,

$$\frac{\Delta H}{H} \times 100 = 2\frac{\Delta I}{I} \times 100 + \frac{\Delta R}{R} \times 100 + \frac{\Delta t}{t} \times 100 + \frac{\Delta J}{J} \times 100$$

$$= 2 \times 2\% + 1\% + 1\% + 0\% = \mathbf{6\%}$$

Question 4. E, m, 1 and G denote energy, mass, angular momentum and gravitational constant respectively.Determine the dimensions of El^2/m^5G^2.

Answer:

$$\text{Dimensions of } E = [M L^2 T^{-2}]$$

$$\text{Dimensions of } l = [M L^2 T^{-1}]$$

$$\text{Dimensions of } m = [M]$$

$$\text{Dimensions of } G = [M^{-1} L^3 T^{-2}]$$

$\therefore$ **Dimensions of El^2/m^5G^2**

$$= \frac{[M L^2 T^{-2}][M L^2 T^{-2}]^2}{[M]^5 [M^{-1} L^3 T^{-2}]^2} = 1$$

Thus El^2/m^5G^2 is dimensionless.

Question 5. The Reynold's number n_R for a liquid flowing through a pipe depends upon:

(i) the density of the liquid ρ,

(ii) the coefficient of viscosity η,

(iii) the speed of flow of the liquid v, and

(iv) the f radius of the tube r.Obtain dimensionally an expression for n_R. Given, n_R is directly proportional to r.

Answer:

$$\text{Let} \qquad n_R = \rho^x \eta^y v^z r$$

Note in Eqn. (1) we have used the information that n_R is directly proportional to r. If this information was not available there will be four unknowns. By equating powers of M, L and ' T only three independent equations will be obtained and they cannot give values of the four

unknowns. Now

$$[n_R] = M^0 L^0 T^0$$

$$[\rho] = M L^{-3}$$

$$[\eta] = M L^{-1} T^{-1}$$

$$[r] = L$$

Substituting dimensions of parameters involved in Eqn. (1), we have

$$M^0 L^0 T^0 = (M L^{-3})^x (M L^{-1} T^{-1})^y (L T^{-1})^z L^{+1}$$

$$= M^{x+y} L^{-3x-y+z+1} T^{-y-z}$$

By the principle of homogeneity of dimensions

$$x + y = 0 \qquad ...(2)$$

$$-3x - y + z + 1 = 0 \qquad ...(3)$$

$$-y - z = 0 \qquad ...(4)$$

Solving these equations, we get

$$x = 1, \quad y = -1, \quad z = 1$$

Hence, $\qquad n_R = k\, r\, \rho^1 \eta^{-1} v^1$

or $\qquad n_R = \dfrac{k\, r\, \rho\, v}{\eta}.$

Question 6.

The period of oscillation of a simple pendulum is $T = 2\pi\sqrt{4g}$. Measured value of L is 20.0 cm known to 1 mm accuracy and time for 100 oscillations of the pendulum is found to be 90 s using a wrist watch of 1 s resolution. What is the accuracy in the determination of g?

Answer:

$$g = \frac{4\pi^2 L}{T^2}$$

Here, $$T = \frac{t}{n} \quad \text{and} \quad \Delta T = \frac{\Delta t}{n}$$

Therefore, $$\frac{\Delta T}{T} = \frac{\Delta t}{t}$$

The errors in both L and t are the least count errors.

$$\left(\frac{\Delta g}{g}\right) = \left(\frac{\Delta L}{L}\right) + 2\left(\frac{\Delta T}{T}\right)$$

$$= \frac{0.1}{20.0} + 2\left(\frac{1}{90}\right) = 0.032$$

Thus, the percentage error in g is

$$100\left(\frac{\Delta g}{g}\right) = 100\left(\frac{\Delta L}{L}\right) + 2 \times 100\left(\frac{\Delta T}{T}\right)$$

$$= 3\%.$$

Question 7. The speed of light in air is 3.00 x 108 ms 1. The distance travelled by light in one year (i.e., 365 days = 3.154 x 10^7 s) is known as light year. A student calculates one light year = 9.462 x 10^{15} m. Do you agree with the student? If not, write the correct value of one light year.

Answer: One light year = speed x time = 9.462 x 10^{15} m. When two physical quantities are multiplied, the significant figures retained in the final result should not be greater than the least number of significant figures in any of the two quantities. Since, in this case significant figures in one quantity (3.00 x 10^8 ms^{-1}) are 3 and the significant figures in the other quantity (3.154 x 10^7 s) are 4, therefore, the final result should have 3 significant figures. Thus, the correct value of one light year = 9.46 x 10^{15} m.

Question 8.

A physical quantity $X = \frac{a^2 b^{-3/2}}{c^4}$. *A student says that the relative error in* $X = 2\frac{\Delta a}{a} - \frac{3}{2}\frac{\Delta b}{b} - 4\frac{\Delta c}{c}$. *Do you agree with the student? If not, what is the relative error in X?*

Answer:

Errors are always additive. Therefore, the relative error in $X = 2\frac{\Delta a}{a} + \frac{3}{2}\frac{\Delta b}{b} + 4\frac{\Delta c}{c}$.

Question 9. If velocity of sound in a gas depends on its elasticity and density, derive the relation for the velocity of sound in a medium by the method of dimensions.

Answer: If v be the velocity of sound, E the elasticity of the medium and p the density of the medium, then

$$v \propto E^a \rho^b$$

or $$v = k\, E^a \rho^b$$

where k is a dimensionless constant of proportionality. Writing down the dimensions of both sides of equation (i), we get

$$[M^0 L T^{-1}] = [M L^{-1} T^{-2}]^a [M L^{-3}]^b$$
$$[M^0 L T^{-1}] = [M^{a+b} L^{-a-3b} T^{-2a}]$$

Comparing powers of M, L and T, we get

$$a + b = 0, \quad -a - 3b = 1, \quad -2a = -1 \quad \text{or} \quad a = \frac{1}{2}$$

$$\therefore \qquad \frac{1}{2} + b = 0 \quad \text{or} \quad b = \frac{-1}{2}$$

From eqn. (i), $\quad v = k\, E^{1/2} \rho^{-1/2}$

or $\quad v = k\sqrt{\frac{E}{\rho}}$

where the value of k can be determined experimentally.

Question 10. Reynold's number N_R (a dimensionless quantity) determines the condition of laminar flow of a viscous liquid through a pipe. N_R is a function of the density of the liquid r, its average speed is v and the coefficient of viscosity of the liquid is h. If N_R is given directly proportional to d

diameter of the pipe), show from dimensional consideration that $N_R \propto \frac{d\rho v}{\eta}$ *the unit of* η *in S.I. system is* $kgm^{-1}\, s^{-1}$.

Answer: As the Reynold's number N_R depends on density p, average speed v and coefficient of viscosity η, then let us say

$$N_R \propto \rho^a v^b \eta^c$$

Again N_R is proportional to d, the diameter of the pipe, combining the two quantities we have,

$$N_R \propto \rho^a v^b \eta^c d$$

or
$$N_R = k\rho^a v^b \eta^c d \qquad ...(i)$$
$$[N_R] = [M^0 L^0 T^0]$$
$$[\rho] = [LT^{-3}]$$
$$[\eta] = [ML^{-1} T^{-1}]$$
$$[d] = [L]$$

Substituting the dimension in (i), we have,

$$[M^0 L^0 T^0] = [ML^{-3}]^a [LT^{-1}]^b [ML^{-1} T^{-1}]^c [L]$$
$$= [M^{a+c} L^{-3a+b-c+1} T^{-b-c}]$$

Comparing the dimensions of M, L and T, we have,

$$a + c = 0$$
$$-3a + b - c + 1 = 0$$
$$-b - c = 0$$

On simplifying, we get $c = -1$, $b = 1$, $a = 1$

Therefore, the relation (i) becomes

$$N_R = k\rho^1 v^1 \eta^{-1} d$$

or
$$N_R = k \cdot \rho \frac{vd}{\eta}$$

or
$$N_R \propto \rho \frac{vd}{\eta}$$

Question 11. It is required to find the volume of a rectangular Mock. A Vernier Caliper is used to measure the length, width and height of the Mock. The measured values are found to be 1.37 cm, 4.11 cm and 2.56 cm respectively.

Answer:

The measured (nominal) volume of the block is,

V = l x w x h

= (1.37 x 4.11 x 2.56) cm^3

= 14.41 cm^3

The least count of Vernier Caliper is ± 0.01 cm Uncertain values can be written as

l = (1.37 ± 0.01) cm w

= (4.11 ± 0.01) cm h
= (2.56 ± 0.01) cm
Lower limit of the volume of the block is,
$V_{(min)}$ = (1.37 - 0.01) x (4.11 - 0.01) x (2.56 - 0.01) cm^3
= (1.36 x 4.10 x 2.55) cm^3
= 14.22 cm^3
This is 0.19 cm^3 lower than the nominal measured value.
Similarly the upper limit can also be calculated as follows.
$V_{(max)}$ = (1.37 + 0.01) x (4.11 + 0.01) x (2.56 + 0.01) cm^3
= (1.38 x 4.12 x 2.57) cm^3
= 14.61 cm^3
This is 0.20 cm^3 higher than the measured value.
But we choose the higher of these two values as the uncertainty i.e.
(14.41 ± 0.20) cm^3

Question 12. In an experiment on determining the density of a ectangular Mock, the dimensions of the Mock are measured with a Venier Caliper (with a least count of 0.01 cm) and its mass is measured with a beam balance of least count of 0.1 gm. How do we report our result for the density of the block?
Answer: Let the measured values be:
Mass of the block (m) = 39.3 g
length (1) = 5.12 cm
breadth (b) = 2.56 cm
thickness (f) = 0.37 cm
The density of the block is given by

$$d = \frac{\text{mass}}{\text{volume}} = \frac{m}{l \times b \times h}$$

$$= \frac{39.3}{5.12 \times 2.56 \times 0.37} = 8.1037 \text{ gram/cm}^3$$

Now the uncertain values are

$$l = \pm 0.01 \text{ cm}$$

$$b = \pm 0.01 \text{ cm}$$

$$t = \pm 0.01 \text{ cm}$$

Maximum relative error, in the density, value is given by

$$\frac{\Delta d}{d} = \frac{\Delta l}{l} + \frac{\Delta b}{b} + \frac{\Delta t}{t} + \frac{\Delta m}{m}$$

$$= \frac{0.01}{5.12} + \frac{0.01}{2.56} + \frac{0.01}{0.37} + \frac{0.1}{39.3}$$

$$= 0.0019 + 0.0039 + 0.027 + 0.0024$$

$$= 0.0358$$

$$\therefore \quad \Delta d = 0.0358 \times 8.1037 = 0.3 \text{ g/cm}^3 \text{ (approx)}$$

VI. Value-Based Questions
Question 1. Suresh went to London to his elder brother Lalit who is a Civil Engineer there. Suresh found there f the currency is quite different from his country. He could not understand pound and how it is converted into rupees. He asked there an Englishman how far is the Central London from here.He replied that it is 16 miles. Suresh again got confused because he never used these units in India.
In the evening Suresh inquired all about it. His brother told him about the unit system used in England. He explained his brother that here F.P.S. system is used. It means, distance is measured in foot, mass in pound and time in seconds whereas in India it is MKS system.
(i) What values are displayed by Suresh?
(ii) How many unit system are there?
Answer:
(i) Sincerity, Curiosity, dedicated and helping nature
(ii) Unit system are:

(a) FPS system
(b) MKS system
(c) CGS system

*********** END **********