UNIT-1 NATURE OF PHYSICAL WORLD AND ENVIRONMENT

MY REVISION TIMELINE:-

SUMMARY:-

- Physics is an experimental science in which measurements must be expressed in units.
- All physical quantities have a magnitude and a unit.
- The SI unit of length is metre, mass is kilogram, time is second, temperature is kelvin, electric current is ampere, amount of substance is mole, luminous intensity is candela.
- Units of all mechanical, electrical, magnetic and thermal quantities are derived in terms of base units.
- For measurements of length in case of small distances – Screw gauge and Vernier methods are available.
- For measurements of length in case of long distances – Parallax, Radar methods are available
- The uncertainty in a measurement is called error.
- The accuracy is a measure of how close the measured value is to the true value of the quantity.
- Every accurate measurement is precise but every precise measurement need not be accurate.
- When two or more quantities are added or subtracted, the result can be precise as the least of individual precisions.
- When the quantities are multiplied or divided, the result has same number of significant figures as the quantity with smallest number of significant figures.
- Dimensional analysis is used to perform quick check on validity of equations.
- Whenever quantities are added, subtracted or equated, they must have some dimension.
- A dimensionally correct equation may not be a true equation but every true equation is necessarily dimensionally correct.

FORMULAS:-

- Π radian = $180°$
- 1 radian = $\frac{180°}{\Pi} = 57.27°$
- $1° = 60´$
- $1´ = 60´´$
- $1° = \frac{\Pi}{180°}$ rad = $1.745 * 10^{-2}$ rad
- $1´ = \frac{1°}{60} = 2.91 * 10^{-4}$ rad

- $1'' = \frac{1^\circ}{3600} = 4.85 * 10^{-6}$ rad
- Triangular method:- Large distance is given by $n = x \tan\theta$
- Parallax method:- Distance of moon from earth is given by $MC = \frac{AB}{\theta}$, also $x = \frac{b}{\theta}$
- Radar method = $d = \frac{v*t}{2}$
- 1 fermi 1fm = 10^{-15}m
- 1 angstrom = 1 A° = 10^{-10}m
- 1 nanometre = 1 nm = 10^{-9}nm
- 1 micron = 1 µm = 10^{-6}m
- 1 light year = $9.467 * 10^{15}$ m
- 1 astronomical unit = 1AU = $1.496 * 10^{11}$ m
- 1 parsec = $3.08 * 10^{16}$ m = 3.26 light year
- 1 Chandrasekhar unit = 1 CSL = 1.4 time the mass of sun
- 1 Shake = 10^{-8} s
- Mass of electron = $9.11 * 10^{-31}$ kg
- Mass of observable universe = 10^{55} kg
- Arithmetic mean:- $a_m = \frac{a1+a2+a3+....+an}{n} = \frac{\sum a_i}{n}$
- Absolute error:- $|\Delta a_n| = |a_m - a_n|$
- Mean absolute error = $\frac{|\Delta a1|+|\Delta a2|+|\Delta a3|+....+|\Delta an|}{n} = \frac{\sum \Delta a_i}{n}$
- Relative error = $\frac{\Delta a_m}{a_m}$
- Percentage error = $\frac{\Delta a_m}{a_m} * 100\%$
- Error in sum of two quantities = $\Delta Z = \Delta A + \Delta B$
- Error in difference of two quantities = $\Delta Z = \Delta A + \Delta B$
- Error in product of two quantities = $\frac{\Delta Z}{Z} = \pm(\frac{\Delta A}{A} + \frac{\Delta B}{B})$
- Error in division of two quantities = $\frac{\Delta Z}{Z} = (\frac{\Delta A}{A} + \frac{\Delta B}{B})$
- Error in power of a quantity = $\frac{\Delta Z}{Z} = n(\frac{\Delta A}{A})$
- Percentage error:- If $Z = \frac{A^p B^q}{C^r}$ then, Percentage error in Z is $\frac{\Delta Z}{Z} *100 = \frac{p\Delta A}{A} * 100 + \frac{q\Delta B}{B} * 100 + \frac{r\Delta C}{C} * 100$
- Frequently used dimensional formulas in problems
    - Volume = $[L^3]$ (V)
    - Density = $[ML^{-3}]$ (ρ)
    - Velocity = $[LT^{-1}]$ (c), (v)
    - Force = $[MLT^{-2}]$ (F)
    - Charge = [AT] (q)
    - Mass = [M] (m)
    - Length = [L] (n), (l), (r)
    - Time = [T] (t)

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- Temperature = [K] (T)
- Frequency = $[T^{-1}]$
- Acceleration = $[LT^{-2}]$ (q), (a)
- Energy = $[ML^2T^{-2}]$ (E)
- Pressure = $[ML^{-1}T^{-2}]$ (P)
- Gravitational constant = $[M^{-1}L^3T^{-2}]$ (G)
- Boltzmann constant = $[ML^2T^{-2}K^{-1}]$ (k_b)
- Magnetic permeability = $[MLT^{-2}A^{-2}]$ (μ_o)
- Electric permeability = $[M^{-1}L^{-3}T^4A^2]$ (ε_0)
- Planck's constant = $[ML^2T^{-1}]$ (h)
- No. per unit volume = $[L^{-3}]$ (n)

MULTIPLE CHOICE QUESTIONS:-

1. One of the combinations from the fundamental physical constants is $\frac{hc}{G}$. The unit of this expression is

a) kg^2

Solution:

$h = [ML^2T^{-1}]$ $c = [LT^{-1}]$ $G = [M^{-1}L^3T^{-2}]$

$= [ML^2T^{-1}]$ $[LT^{-1}]$ / $[M^{-1}L^3T^{-2}]$

$= [ML^3T^{-2}] / [M^{-1}L^3T^{-2}]$

$= [M^2]$

Unit = kg * kg = kg^2

2. If the error in the measurement of radius is 2%, then the error in the determination of volume of the sphere will be

d) 6%

Solution:

% error of r = 2%

Volume of sphere = $\frac{4}{3}\pi r^3$

$\frac{\Delta v}{v} * 100 = 3*(\frac{\Delta r}{r})*100$

$= 3 * 2\%$

= 6%

3. If the length and time period of an oscillating pendulum have errors of 1% and 3% respectively then the error in measurement of acceleration due to gravity is

d) 7%

Solution:

% error of l = 1%, % error T is 3%

$T = k\sqrt{(l/g)} \Rightarrow T^2 \alpha (l/g) \Rightarrow g = (l/T^2)$

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$\frac{\Delta g}{g} * 100 = \frac{\Delta l}{l} * 100 + 2\frac{\Delta t}{t} * 100$

$= 1\% + 2 * 3\%$

$= 7\%$

4. The length of a body is measured as 3.51m, if the accuracy is 0.01m, then the percentage error in the measurement is

c) 0.28%

Solution:

$l = 3.51m, \Delta l = 0.01m$

$\frac{\Delta l}{l} * 100 = \frac{0.01}{3.51} * 100$

$= 0.28\%$

5. Which of the following has the highest number of significant figures?

d) 6.3200 J

Solution:

a) 0.007 m^2 = 1

*b) 2.64 * 10^{24} kg = 3*

c) 0.0006032 m^2 = 4

d) 6.3200 J = 5

6. If π = 3.14, then the value of π^2 is

c) 9.86

Solution:

$\pi = 3.14$

$\pi^2 = 9.8596$

$\pi^2 = 9.86$

7. Which of the following pairs of physical quantities have same dimension?

b) Torque and energy

Solution:

a) Force and Power :- $[MLT^{-2}]$ and $[ML^2T^{-3}]$

b) Torque and Energy :- $[ML^2T^{-2}]$ and $[ML^2T^{-2}]$

c) Torque and Power :- $[ML^2T^{-2}]$ and $[ML^2T^{-3}]$

d) Force and Torque :- $[MLT^{-2}]$ and $[ML^2T^{-2}]$

8. The dimensional formula of Planck's constant h is

a) $[ML^2T^{-1}]$

Solution:

$h = E / f = \frac{E}{1/t} = \frac{W}{1/t} = \frac{F*d}{1/t} = \frac{m*a*d}{1/t} = \frac{m*(v/t)*d}{1/t} = m*v*d$

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$h = [ML^2T^{-1}]$

9. The velocity of a particle v at an instant t is given by $v = at + bt^2$. The dimension of b is

d) $[LT^{-3}]$

Solution:

$v = at + bt^2$

$v = [LT^{-1}]$ $a = [LT^{-2}]$ $t = [T]$

$[LT^{-1}] = [LT^{-2}][T] + b\,[T^2]$

$[LT^{-1}] = [LT^{-2}][T] + [LT^{-3}]\,[T^2]$

$[LT^{-1}] = [LT^{-1}] + [LT^{-1}]$

$b = [LT^{-3}]$

10. The dimensional formula for gravitational constant G is

b) $[M^{-1}L^3T^{-2}]$

Solution:

$G = (F * d^2) / m^2 = (m*a*d^2) / (m^2) = \{[m*(v/t)*d^2] / (m^2)\} = \{[m*[(d/t) / t]* d^2] / (m^2)\}$

$G = [M^{-1}L^3T^{-2}]$

11. The density of a material in CGS system of units is 4 gcm^{-3}. In a system of units in which unit of length is 10 cm and unit of mass is 100g, then the value of density of material will be

c) 40

Solution:

Dimension of density $= [ML^{-3}]$

$P_1 = [M_1^a L_1^b T_1^c]$ $P_2 = [M_2^a L_2^b T_2^c]$

$P_2 = P_1 \left[\frac{M1}{M2}\right]^a \left[\frac{L1}{L2}\right]^b \left[\frac{T1}{T2}\right]^c$

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

$M_1 = 1g$ $M_2 = 100g$

$L_1 = 1cm$ $L_2 = 10cm$

$P_1 = 4gcm^{-3}$

$P_2 = 4 \left[\frac{1g}{100g}\right]^1 \left[\frac{1cm}{10cm}\right]^{-3} \left[\frac{1s}{1s}\right]^0$

$P_2 = 4\,(10^{-2})^1\,(10^{-1})^{-3}$

$P_2 = 4\ (10)^1$

$$\boldsymbol{P_2 = 40}$$

12. If the force is proportional to square of velocity, then the dimension of proportionally constant is

d) $[ML^{-1}T^0]$

Solution:

$F \alpha v^2$

$F = kv^2$

$[MLT^{-2}] = k\ [LT^{-1}]^2$

$[MLT^{-2}] = k\ [L^2T^{-2}]$

$k = [MLT^{-2}] / [L^2T^{-2}]$

$$\boldsymbol{k = [ML^{-1}T^0]}$$

13. The dimension of $(\mu_o\varepsilon_o)^{-(1/2)}$ is

c) Velocity

Solution:

$\mu_o = [MLT^{-2}A^{-2}]$

$\varepsilon_0 = [M^{-1}L^{-3}T^4A^2]$

$$(\mu_o\varepsilon_o)^{-(1/2)} = \frac{1}{\sqrt{\mu o \varepsilon_o}}$$

$$= \frac{1}{\sqrt{[MLT^{-2}A^{-2}][M^{-1}L^{-3}T^4A^2]}}$$

$$= \frac{1}{\sqrt{L^{-2}T^{-2}}}$$

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

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

$$\boldsymbol{= [L^1T^{-1}]\ (Velocity)}$$

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14. Planck's constant (h), speed of light in vacuum (c) and Newton's Gravitational constant (G) are taken as three fundamental constants. Which of the following combinations of these has the dimension of length?

a) $\sqrt{(hG)} / (c)^{3/2}$

Solution:

$c = [LT^{-1}]$ $h = [ML^2T^{-1}]$ $G = [M^{-1}L^3T^{-2}]$

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

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

$$= \frac{\left[L^{\frac{5}{2}}T^{\frac{-3}{2}}\right]}{L^{\frac{3}{2}}T^{\frac{-3}{2}}}$$

= [L] (Length)

15. A length – scale (l) depends on the permittivity (ε) of a dielectric material, Boltzmann constant (K_b), the absolute temperature (T), the number per unit volume (n) of certain charged particles and the charge (q) carried by each of the particles. Which of the following expression for l is dimensionally correct?

b) $l = \sqrt{(\varepsilon K_b T)} / \sqrt{(nq^2)}$

Solution:

$\varepsilon_0 = [M^{-1}L^{-3}T^4A^2]$ $K_b = [ML^2T^{-2}K^{-1}]$ $T = [K]$ $n = [L^{-3}]$ $q = [AT]$

$$l = \frac{\sqrt{([M^{-1}L^{-3}T^4A^2][ML^2T^{-2}K^{-1}][K])}}{\sqrt{([L^{-3}]\,[AT])}}$$

$$l = \sqrt{([L^2])}$$

$$l = ([L^2])^{1/2}$$

l = [L]

NUMERICAL PROBLEMS:-

1. Given:

$t = 80s$, $v = 1480ms^{-1}$, $d = ?$

Formula used:

$d = (vt) / 2$

Solution:

$d = \frac{[(1460ms^{-1})(80s)]}{2}$

= 58400m or 58.40km

2. Given:

r = 3.12m, area of circle with significant figures = ?

Formula used:

Area of circle = πr^2

Solution:

*Area of circle with significant figures = (3.14) * $(3.12m)^2$ = $30.566m^2$*

= $30.6m^2$

3. Given:

$\gamma \alpha F^x l^y m^z$

To prove:

$\gamma \alpha \frac{\sqrt{F}}{l\sqrt{m}}$

Solution:

$\gamma \alpha F^x l^y m^z$ → ①

$[T^{-1}] = [MLT^{-2}]^x [L]^y [ML^{-1}]^z$

$[M^0L^0T^{-1}] = [M^{x+z} L^{x+y-z} T^{-2x}]$

Comparing the powers of M, L, T on both sides

x+z = 0,	*x+y-z = 0,*	*-2x = -1*
(1/2)+z =0,	*(1/2)+y+(1/2) = 0,*	*x = ½*
z = -1/2,	*1+y = 0,*	
	y = -1	

Substitute the values of x, y and z in ①

$\gamma \alpha F^{1/2} l^{-1} m^{-1/2}$

$\gamma \alpha \frac{\sqrt{F}}{l\sqrt{m}}$ Hence proved.

4. Given:

*Distance of Jupiter = 824.7 * 10^6km*

Angular diameter = 35.72´

Formula used:

*Diameter of Jupiter b = x*Q [x = b/Q]*

Solution:

*1´´ = 4.85 * 10^{-6}rad*

*Q = 35.72 * 4.85 * 10^{-6}rad*

*= 173.242 * 10^{-6}rad*

*Diameter of Jupiter b = 824.7 * 10^6 * 173.242 * 10^{-6}*

= 142872.6

= 1.428 * 10^5km

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5. Given:

*Length of a simple pendulum = 20cm = 20 * 10^{-2}m*

*Accuracy = 2mm = 2 * 10^{-3}m*

Time for 50 oscillations = 40s

Time for 1 oscillation = 40/50 = 0.88s

Percentage accuracy in the determination of g = ?

Formula used:

$g = (4\pi^2 l)/ T^2$

Solution:

$$\frac{\Delta g}{g} * 100 = \frac{\Delta l}{l} * 100 + 2\,\frac{\Delta T}{T} * 100$$

$$\frac{\Delta g}{g} = \frac{\Delta l}{l} + 2\,\frac{\Delta T}{T}$$

l = 20cm, T = 40s, Δl = 0.2, ΔT = 1

$$= \frac{0.2}{20} + 2\,\frac{1}{40}$$

$$= 0.01 + 0.05$$

$$= 0.06$$

$$\boxed{\boldsymbol{Percentage\ accuracy\ in\ the\ determination\ of\ g = 0.06 * 100 = 6\%}}$$

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