Sure shots (1 Mark) Solution

1.
Ans. ***Given:*** $M = 1.5$ H, $I_1 = 0$ A, $I_2 = 20$ A

$\therefore \quad dI = I_2 - I_1$
$= 20 - 0 = 20$ A
$dt = 0.5$ sec.

To find: $d\phi = ?$

Formula: $d\phi = M\,dI$

$\therefore \quad d\phi = 1.5 \times 20 = 30$ Wb *(1 mark)*

2.
Ans. ***Given:*** $a = 3$ cm, $a_{max} = 27\,cm/s^2$.

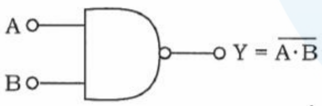
To find: Angular velocity (ω) = ?

Formula: $a_{max} = a\omega^2$

$\therefore \quad \omega^2 = \frac{a_{max}}{a} = \frac{27}{3} = 9$

$\therefore \quad \omega = 3$ rad/sec. *(1 mark)*

3.
Ans. • ***Schematic symbol for NAND gate:***



(½ mark)

• ***Boolean expression for NAND gate:***
$Y = \overline{A \cdot B}$ *(½ mark)*

4.
Ans. Magnetic field (B) = $\frac{F}{Il}$

$\therefore$ Dimension of B $= \frac{[L^1 M^1 T^{-2}]}{[I^1][L^1]}$
$= [L^0 M^1 T^{-2} I^{-1}]$ *(1 mark)*

5.
Ans. • ***Velocity gradient:*** The rate of change of velocity (dv) with distance (dx) measured from a stationary layer is called velocity gradient.

$\therefore$ Velocity gradeint $= \frac{dv}{dx}$ *(1 mark)*

6.
Ans. • ***Wien's displacement law:*** It is observed that the wavelength for which emissive power of a blackbody is maximum, is inversely proportional to the absolute temperature of the blackbody.

i.e. $\lambda_{max} \propto \frac{1}{T}$ *(1 mark)*

7.
Ans. • ***Isobaric process:*** A process which takes place at constant pressure is called as an isobaric process. *(1 mark)*

8.
Ans. • ***Radius of Gyration:*** The radius of gyration of a body about a given axis of rotation is defined as the distance between the axis of rotation and a point at which the whole mass of the body can be supposed to be concentrated so as to possess the same moment of inertia as that of the body. *(1 mark)*

9.
Ans. $n = \frac{4}{3}$, $i = 90 - 40° = 50°$

$\therefore \quad n = \frac{\sin i}{\sin r}$

$\therefore \quad \sin r = \frac{\sin i}{n}$
$= \frac{\sin 50°}{4/3} = \frac{0.7660}{4/3}$
$= 0.5745$

The angle of refraction,
$r = \sin^{-1}(0.5745) = 35°4'$ *(1 mark)*

10.
Ans. Excess of pressure,

$p - p_0 = \frac{4T}{R} = \frac{4 \times 30}{3} = 40$ dyne/cm^2 *(1 mark)*

11.
Ans. The force experienced by moving charge in a magnetic field is the electromagnetic force. *(1 mark)*

12.
Ans. Magnetic potential energy,
$U_m = -mB\cos\theta$
where, m is magnetic moment
B is magnetic field *(1 mark)*

13.
Ans. Kinetic friction will be there between the road and the tyres, but it will not determine the grip, as grip is determined by static friction. *(1 mark)*

14.
Ans. Since restoring force, $f = -kx$, the spring constant k has the dimensions of $\left(\frac{f}{x}\right)$. Since f and x have different dimensions, k is a dimensional constant. *(1 mark)*

15.
Ans. The lowest temperature of $-273.15°C$ at which a gas is supposed to have zero volume and at which entire molecular motion stops is called the absolute zero of temperature. *(1 mark)*

16.

Ans. (3) Adiabatic curve slope = γ × isothermal curve slope *(½ mark)*

For isothermal process, PV = constant

$$\therefore \left(\frac{dp}{dv}\right) = \frac{\gamma P}{V} = \text{slope of adiabatic curve}$$

$$\left(\frac{dp}{dv}\right)_{\text{adiabotic}} = \gamma\left(\frac{dp}{dv}\right)_{\text{isothermal}}$$ *(½ mark)*

17.

Ans. A two wheeler is moving along a level curve of radius r with speed v must lean at an angle θ with respect to the vertical,

where $\theta = \tan^{-1}\left(\frac{v^2}{rg}\right)$.

Therefore, for a given radius r, angle θ should be more, for higher velocity v. *(1 mark)*

18.

Ans. ***Given:*** I_E = 6.28 mA, I_C = 6.20 mA, α = ?

We know, $\alpha = \frac{I_C}{I_E} = \frac{6.20}{6.28} = 0.987$ *(1 mark)*

19.

Ans. $E = \frac{1}{2}kA^2 = \frac{1}{2} \times 10\,(3 \times 10^{-2})^2$

$= 4.5 \times 10^{-3}$ J *(1 mark)*

20.

Ans. ***Ionization energy:*** It is minimum amount of energy required to be given to an electron in the ground state of that atom to set the electron free. *(1 mark)*

21.

Ans. 1 tesla = 10^4 gauss *(1 mark)*

22.

Ans. The liquid pressure at a point is independent of quantity of liquid and depends upon the depth of point below the liquid surface. This is known as hydrostatic paradox. *(1 mark)*

23.

Ans. (1) Melting of ice

(2) Boiling of water *(Any one - 1 mark)*

24.

Ans. Resistance only *(1 mark)*

25.

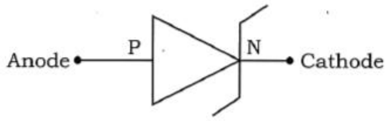
Ans. Velocity gradient,

$$\frac{dv}{dx} = \frac{12}{0.8} = 15\ s^{-1}$$ *(1 mark)*

26.

Ans. The gas molecules are always in a state of random motion i.e. the gas molecules are moving in all possible directions with all possible velocities. This motion of gas molecules is known as Brownian motion. *(1 mark)*

27.



Ans. The name of given symbol is Zener diode *(1 mark)*

28.

Ans. $E = \frac{1}{2}LI^2 = \frac{1}{2} \times 20 \times 10^{-3} \times (1)^2$

$= \frac{1}{2} \times 20 \times 10^{-3}\ J = 10^{-2}$ J

= 10 mJ *(1 mark)*

29.

Ans. A wave is propagating along –ve direction of X-axis. *(1 mark)*

30.

Ans. Surface charge density, $\sigma = \frac{\lambda}{2\pi R}$

where λ is the linear charge density. *(1 mark)*

31.

Ans. $[M^0L^{-1}T^0I^1]$ *(1 mark)*

32.

Ans. $f = \frac{qB}{2\pi m}$, *(1 mark)*

where, B = magnetic field

q = charge on particle

m = mass of the particle.

33.

Ans. SI unit of surface energy = J *(½ mark)*

Dimensions of surface energy = $[L^2M^1T^{-2}]$ *(½ mark)*

34.

Ans. *Given:* Q = 10 J, Force = 3N,

Displacement = 2 m

Work done (W) = Force × Displacement

= 3 × 2 = 6J

By first law of thermodynamics,

$\Delta U = |Q| - |W|$

= 10 – 6 = 4 J *(1 mark)*

35.

Ans. When a charged particle moves through a region in which both electric and magnetic fields are present, then the net force experienced by that charged particle is the sum of electrostatic force and magnetic force and is called as Lorentz force. *(1 mark)*

36.

Ans. ***Statement:*** Magnetization of paramagnetic sample is directly proportional to the external magnetic field and inversely proportional to the absolute temperature.

i.e. $M_z \propto \frac{B_{ext}}{T}$ *(1 mark)*

37.

Ans. ***Given:*** L_1 = 75 mH, L_2 = 55 mH, K = 0.75

To find: M = ?

Formula:

$$M = K\sqrt{L_1 L_2}$$
$$= 0.75\sqrt{75 \times 75}$$
$$= 0.75\sqrt{4125}$$
$$= 0.75 \times 64.23$$
$$= 48.17\text{mH}$$

(1 mark)

38.

Ans. Peak value of an alternating current or emf is the maximum value of the current or emf in either direction *(1 mark)*

39.

Ans. Half life period of a radioactive substance is defined as the time in which the half of substance is disintegrated. *(1 mark)*

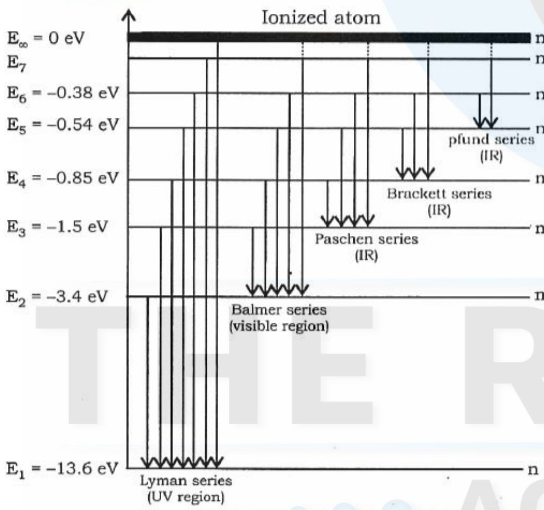
40.

Ans. The output of rectifier consist of a small fraction of an AC component along with DC is called as ripple. *(1 mark)*

Sure shots (2 Marks) Solution

41.

Ans. • ***Energy level diagram for hydrogen atom:***



(Diagram - 1 mark; Labellings - 1 mark)

42.

Ans. • ***Eddy currents:*** The circulating currents induced in a metal block (or plate}, when it is placed or moved in a changing magnetic field are called eddy currents. *(1 mark)*

• ***Applications:***

(i) Dead beat galvanometer: When a galvanometer is used for measuring current, the coil is wound on a light aluminium frame to make it dead beat i.e. to bring the coil quickly to rest. The eddy current opposes the motion and brings the coil to rest quickly. *(½ mark)*

(ii) Electric brake: When the train is to be stopped, the power supplied to rotate the axel is switched off. At the same time, the stationary magnetic field is applied to the rotating drum giving rise to strong eddy currents in the drum. These eddy currents produce a torque which opposes the rotation of the drum and hence the axle. Thus train is brought to rest quickly. *(½ mark)*

43.

Ans. ***Given:*** Radius of a big drop (R) = 8 mm,

Radius of a small drop (r) = 1 mm.

To find: Number of droplets (n) = ?

Formula: Number of droplets,

$$n = \frac{\text{Volume of big drop}}{\text{Volume of each droplet}}$$

$$= \frac{\frac{4}{3}\pi R^3}{\frac{4}{3}\pi r^3}$$ *(1 mark)*

$$n = \left(\frac{R}{r}\right)^3 = \left(\frac{8}{1}\right)^3$$

$$\therefore \quad n = 512$$ *(1 mark)*

44.

Ans. ***Given:*** L = 100 mH = 100×10^{-3} H = 10^{-1} H

f = 50 Hz

To find: Reactance of coil (X_L) = ?

Formula:

$$X_L = 2\pi f L$$ *(½ mark)*

$$= 2 \times 3.14 \times 50 \times 10^{-1}$$
$$= 6.28 \times 5$$ *(½ mark)*

$$\therefore \quad X_L = 31.4\ \Omega$$ *(1 mark)*

45.

Ans. Consider the two pipes of same diameter but different lengths of l_1 and l_2.

Let n_1 and n_2 be the frequencies of tunning fork.

We know, for a pipe closed at one end

$$V = 4n_1L_1 = 4n_2L_2$$ *(½ mark)*

$$n_1L_1 = n_2L_2$$

$$n_1(l_1 + e) = n_2(l_2 + e)$$

where, e = end correction.

$$\therefore \quad n_1l_1 + n_1e = n_2l_2 + n_2e$$ *(½ mark)*

$$n_1e - n_2e = n_2l_2 - n_1l_1$$

$$e(n_1 - n_2) = n_2l_2 - n_1l_1$$

$$\therefore \quad e = \frac{n_2l_2 - n_1l_1}{n_1 - n_2}$$ *(1 mark)*

46.

Ans. ***Given:*** $v = 5 \times 10^6$ m/s, $m_e = 9.1 \times 10^{-31}$ kg

Planck's constant, $h = 6.63 \times 10^{-34}$.

To find: de Broglie wavelength (λ) = ?

Formula:

$$\lambda = \frac{h}{mv} \quad \text{(½ mark)}$$

$$= \frac{6.63 \times 10^{-34}}{9.1 \times 10^{-31} \times 5 \times 10^6} \quad \text{(½ mark)}$$

$$= 0.1457 \times 10^{-9} \text{ m}$$

$$= 1.457 \times 10^{-10} \text{ m}$$

$$\therefore \quad \lambda = 1.457 \text{ Å} \quad \text{(1 mark)}$$

47.

Ans. ***Given:***

$A = 100 \text{ cm}^2 = 100 \times 10^{-4} \text{ m}^2 = 10^{-2} \text{ m}^2$,

$T = 227\,°C = 227 + 273 = 500$ K

$\sigma = 5.67 \times 10^{-6}$ J/m²sK⁴

t = 1 min = 60 sec.

To find: Energy radiated (Q) = ?

Formula: $Q = \sigma A t T^4$ *(½ mark)*

$\therefore Q = 5.67 \times 10^{-6} \times 10^{-2} \times 60 \times (500)^4$ *(½ mark)*

$= 5.67 \times 60 \times (5)^4$

$= 212625$ J *(1 mark)*

48.

Ans. ***Given:*** r = 5 m, g = 9.8 m/s².

To find: ω = ?

The motor cyclist will not loose contact with the sphere at the highest point if

Centripetal force

= Weight of the motor and rider

i.e. $mr\omega^2 = mg$ *(½ mark)*

$$\therefore \quad \omega^2 = \frac{g}{r}$$

$$\omega = \sqrt{\frac{g}{r}}$$

$$= \sqrt{\frac{9.8}{5}} \quad \text{(½ mark)}$$

$$= \sqrt{1.96}$$

$$\therefore \quad \omega = 1.4 \text{ rad/s} \quad \text{(1 mark)}$$

49.

Ans. • ***Kirchhoff's current law:***

Statement: The algebraic sum of the currents at a junction is zero in an electrical network.

i.e. $\sum_{t=1}^{n} I_t = 0$ *(1 mark)*

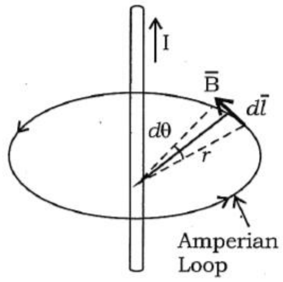
• ***Sign conventions:***

(i) The currents arriving at the junction are considered positive. *(½ mark)*

(ii) The currents leaving the junction are considered negative. *(½ mark)*

50.

Ans. Consider a long wire carrying a current I as shown in the figure.



(½ mark)

$\vec{B}$ and $d\vec{l}$ are tangential to the Amperian loop

By Ampere's law,

$$B \oint \vec{B} \cdot d\vec{l} = \mu_0 I$$

$$\oint B\, dl \cos\theta = \mu_0 I$$

$$B \oint dl = \mu_0 I \quad (\text{As } \theta = 0°, \cos 0° = 1)$$

$$\therefore \quad B \oint dl = \mu_0 I \quad \text{(½ mark)}$$

But, $\oint dl$ = Total length of the loop

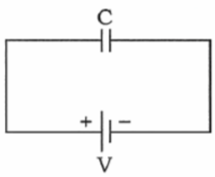
$= 2\pi r$ *(½ mark)*

$$\therefore \quad B \times 2\pi r = \mu_0 I$$

$$\therefore \quad \boxed{B = \frac{\mu_0 I}{2\pi r}} \quad \text{(½ mark)}$$

51.

Ans. Consider a capacitor of capacitance C being charged by a DC source of V volt as shown in figure.



During the process of charging, let q be the charge on the capacitor and V be the P .D. between the plates.

By definition of capacity,

$$C = \frac{q}{V}$$

$$\therefore \quad V = \frac{q}{C} \quad \ldots\text{(i)} \quad \text{(½ mark)}$$

A small amount of work is done if a small charge dq is further transferred between the plates.

$$\therefore \quad dw = V dq$$

$$\text{i.e.} \quad dw = \frac{q}{C} dq \quad \ldots\text{[From (i)]} \quad \text{(½ mark)}$$

Integrating, with limit 0 to Q we get total work done.

$$\therefore \quad W = \int_0^Q dw = \int_0^Q \frac{q}{C} dq$$

$$W = \frac{1}{C} \int_0^Q q\, dq \quad \text{(½ mark)}$$

$$W = \frac{1}{C} \left[\frac{q^2}{2}\right]_0^Q$$

$$W = \frac{1}{C} \left[\frac{Q^2}{2} - 0\right]$$

$$W = \frac{1}{2} \frac{Q^2}{C}$$

Putting Q = CV, we get

$$\therefore \quad \boxed{W = \frac{1}{2} CV^2} \quad \text{(½ mark)}$$

52.

Ans. • ***Zeroth law of thermodynamics:***

If two systems are each in thermal equilibrium with a third system, they are also in thermal equilibrium with each other. *(1 mark)*

- ***Significance of zeroth law::***

(i) The zeroth law enables us to use a thermometer to compare the temperatures of different objects.

(ii) When we use a thermometer, the thermometer and the object are in thermal equilibrium and thermometer indicates the temperature of the object.

(iii) Temperature is defined on the basis of zeroth law of thermodynamics.

(Any two - ½ mark each)

53.

Ans.

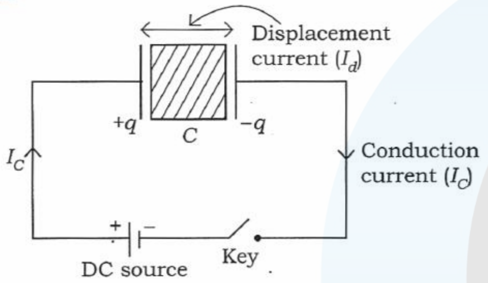


Fig. Displacement current in the space between the plates of the capacitor

(Correct Diagram - 1 mark; Labellings - 1 mark)

54.

Ans. ***Sphere of Death:*** This is a popular show in a circus. During this, two-wheeler rider (or riders) undergo rounds inside a hollow sphere. Starting with small horizontal circles, they eventually perform revolutions along a vertical circles. *(½ mark)*

The dynamics of this vertical circular motion is the same as that of the point mass tied to the string, except that the force due to tension T is replaced by the normal reaction force N.

(½ mark)

The linear speed is more for larger circles but angular speed (frequency) is more for smaller circles (while starting or stopping). *(1 mark)*

55.

Ans. ***Given:*** E = 9×10^4 N/C, r = 2 cm = 0.02 m.

To find: λ = ?

$$E = \frac{\lambda}{2\pi\varepsilon_0 r} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2\lambda}{r} \quad (½\ mark)$$

$$\therefore \lambda = \frac{4\pi\varepsilon_0 E \cdot r}{2} = \frac{9 \times 10^4 \times 0.02}{9 \times 10^9 \times 2} \quad (½\ mark)$$

$$= 10^{-7}\ Cm^{-1} \quad (1\ mark)$$

$\therefore$ The linear charge density is 10^{-7} Cm^{-1}

56.

Ans. ***Given:*** T_1 = 527°C = 527 + 273 = 800 K

T_2 = 127°C = 127 + 273 = 400 K

T_0 = 27°C = 27 + 273 = 300 K

To find: $\frac{(dQ/dt)_1}{(dQ/dt)_2}$ = ?

$$\left(\frac{dQ}{dt}\right)_1 = \sigma Ae\,[T_1^4 - T_0^4]$$

(½ mark)

and $$\left(\frac{dQ}{dt}\right)_2 = \sigma Ae\,[T_2^4 - T_0^4]$$

$\therefore$ The ratio of the rates of loss of heat,

$$\frac{(dQ/dt)_1}{(dQ/dt)_2} = \frac{T_1^4 - T_0^4}{T_2^4 - T_0^4} = \frac{(800)^4 - (300)^4}{(400)^4 - (300)^4} \quad (½\ mark)$$

$$= \frac{4096 - 81}{256 - 81} = \frac{4015}{175}$$

$$\therefore \frac{(dQ/dt)_1}{(dQ/dt)_2} = 22.94 \quad (1\ mark)$$

57.

Ans. When a spherical conductor of radius r carries a charge q, the surface charge density is given by,

$$\sigma = \frac{q}{4\pi r^2} \quad (1\ mark)$$

For a pointed end, r is very small, therefore σ is very large. The particles of air coming in contact with pointed ends gets charged and repelled. In this way an electric wind is set up which takes away the charge continuously from the pointed ends of conductor. This process of spraying the charge is called corona discharge. *(1 mark)*

58.

Ans. We know that, $r_n \propto n^2$ *(½ mark)*

$$\therefore \frac{r_1}{r_4} = \left(\frac{1}{4}\right)^2 \quad (½\ mark)$$

$$= \frac{1}{16} \quad (1\ mark)$$

59.

Ans. ***Given:*** P = 100 W, e_{rms} = 220 V, f = 50 Hz

To find: R = ?

$$P = \frac{e_{rms}^2}{R} \quad (½\ mark)$$

$$\therefore R = \frac{e_{rms}^2}{P} = \frac{220 \times 220}{100} \quad (½\ mark)$$

$$\therefore R = 484\ \Omega \quad (1\ mark)$$

60.

Ans. ***Given:*** $v_1 = v_2 = v = 330$ m/s

$n_1 = n_2 = n = 540$ Hz

$x_1 = 3.5$ m, $x_2 = 3$ m,

To find: $\delta = ?$

We have, $\delta = \frac{2\pi x}{\lambda}$

$= 2\pi(x_1 - x_2) \times \frac{n}{v} \quad \left(\text{As } \lambda = \frac{v}{n}\right)$ *(½ mark)*

$= 2\pi(3.5 - 3) \times \frac{540}{330}$ *(½ mark)*

$= \pi \times \frac{54}{33} = \pi \times 1.6363$

$\therefore \boxed{\delta = 1.64\pi}$ *(1 mark)*

61.

Ans.

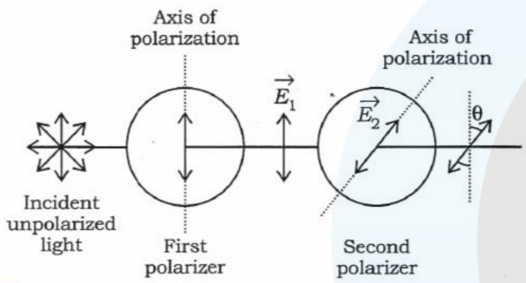


Fig. **Unpolarized light passing through two polarizers**

(Correct diagram - 1 mark; Labellings - 1 mark)

62.

Ans. $T = \frac{f}{l}$, SI unit is N/m

Its dimensions $= \frac{[L^1M^1T^{-2}]}{[L^1M^0T^0]}$

$= [L^0M^1T^{-2}]$ ... (i) *(½ mark)*

Also, $T = \frac{dW}{dA}$, SI unit is J/m^2

Its dimensions, $= \frac{dW}{dA} = \frac{\text{Force} \times \text{displacement}}{\text{Area}}$

$= \frac{[L^1M^1T^{-2}]\,[L^1M^0T^0]}{[L^2M^0T^0]} = \frac{[L^2M^1T^{-2}]}{[L^2M^0T^0]}$

$= [L^0M^1T^{-2}]$ ... (ii) *(½ mark)*

From (i) and (ii),

$T = \frac{f}{l} = \frac{W}{A}$ *(½ mark)*

SI unit of surface tension i.e. N/m and J/m^2 are equivalent. *(½ mark)*

63.

Ans. (i) The air inside the inflated ballon is under high pressure. *(½ mark)*

(ii) When an inflated ballon is suddenly burst air inside comes out from the high pressure to outside environment which is at low pressure. *(½ mark)*

(iii) According to the principle of Joule-Thomson effect, when a gas at high pressure moves an area of low pressure, the gas cools down. Hence, the emerging air is slightly cooled. *(1 mark)*

64.

Ans. (i) Before the current in the coil is turned on the magnetic flux through the ring is zero. *(½ mark)*

(ii) Afterwards, the flux appears in the coil in upward direction. This change in flux causes an induced emf as well as induced current in the ring. *(½ mark)*

(iii) The direction of induced current in the ring will be opposite to the direction of current in the coil, as dictated by Lenz's law. *(½ mark)*

(iv) As the opposite currents repel, the ring flies off in air. *(½ mark)*

65.

Ans. In a pipe closed at one end, only odd harmonics survives

$\therefore \quad 640 = (2p + 1)n_0$

$896 = (2q + 1)n_0$

$1152 = (2r + 1)n_0$

where p, q, r denotes the overtone number and n_0 represents fundamental frequency.

But $896 - 640 = 1152 - 896 = 256$ *(½ mark)*

As every frequency is the multiple of fundamental frequency (also the even one) *(½ mark)*

Thus, fundamental frequency $= \frac{256}{2} = 128$ Hz

$\therefore$ Fundamental frequency is 128 Hz *(1 mark)*

66.

Ans. *Given:* $R = 100\ \Omega$, $Z = 100\sqrt{2}\ \Omega$

To find: $\phi = ?$

$\cos\phi = \frac{R}{Z} = \frac{100}{100\sqrt{2}} = \frac{1}{\sqrt{2}}$ *(1 mark)*

$\phi = \cos^{-1}\left(\frac{1}{\sqrt{2}}\right) = \frac{\pi}{4}$ rad $= 45^\circ$ *(1 mark)*

This is the phase difference between the emf and the current.

67.

Ans. *Given:* $v_1 = 2$ m/s, $v_2 = 3$ m/s, $v_3 = 4$ m/s, $v_4 = 5$ m/s, $v_5 = 6$ m/s

To find: $v_{rms} = ?$

$\therefore v_{rms} = \sqrt{\overline{v^2}} = \sqrt{\frac{v_1^2 + v_2^2 + \dots + v_N^2}{N}}$ *(½ mark)*

$= \sqrt{\frac{v_1^2 + v_2^2 + v_3^2 + v_4^2 + v_5^2}{5}}$

$= \sqrt{\frac{2^2 + 3^2 + 4^2 + 5^2 + 6^2}{5}}$ *(½ mark)*

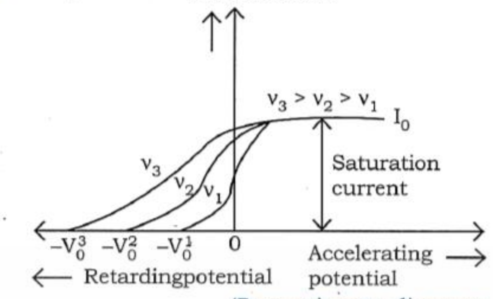
$= \sqrt{\frac{4 + 9 + 16 + 25 + 36}{5}}$

$= \sqrt{\frac{90}{5}} = \sqrt{18}$

$\therefore \quad v_{rms} = 4.242$ m/s *(1 mark)*

68.

Ans. ***Diagram:***



(Proportionate diagram - 1 mark; Labellings - 1 mark)

69.

Ans. The coefficient of magnetic coupling between two coils depends on –

(i) the permeability of the core on which the coils are wound.

(ii) the distance between the coils.

(iii) the angle between the coil axes.

(Any two factors - 1 mark each)

70.

Ans. *Given:* P = Q = R = 4 Ω

To find: Resistance = X = ?

$\because \quad \frac{P}{Q} = \frac{R}{S}$

Let resistance connected across 12 Ω be X.

Equivalent resistance for 12 Ω and X in parallel is given by

$X' = \frac{12 \times X}{12 + X}$ *(½ mark)*

$\therefore \quad X' = S = \frac{12X}{12 + X}$

From formula,

$\frac{4}{4} = \frac{4}{\frac{12X}{12+X}}$ *(½ mark)*

$1 = \frac{4(12 + X)}{12X}$

$12X = 48 + 4X$

$\therefore \quad X = 6\ \Omega$ *(1 mark)*

The resistance connected across 12 Ω resistance to balance the network is 6 Ω.

71.

Ans. $I_1 = I_2 = 300$ A

$l_1 = l_2 = L = 70$ cm $= 0.7$ m

$d = 1.5$ cm $= 1.5 \times 10^{-2}$ m

Since $d << l_1$ and l_2, each wire may be considered to have infinite length.

Force per unit length $= \frac{F}{L} = ?$

$\frac{F}{L} = \frac{\mu_0}{2\pi} \times \frac{I_1 I_2}{d}$ *(½ mark)*

$\therefore \quad \frac{F}{L} = \frac{4\pi \times 10^{-7} \times 300 \times 300}{2\pi \times 1.5 \times 10^{-2}}$ *(½ mark)*

$= 1.2 \times 10^5 \times 10^{-5}$

∴ The force per unit length is 1.2 N/m *(1 mark)*

72.

Ans. The kinetic energy of a body of moment of inertia I and rotating with a constant angular velocity ω is given by

$K.E. = \frac{1}{2} I\omega^2$ *(½ mark)*

But the angular momentum of a rotating body is given by

$L = I\omega$ *(½ mark)*

$\because \quad K.E. = \frac{1}{2} I\omega \cdot \omega$

$\therefore \quad K.E. = \frac{1}{2} L\omega$ *(1 mark)*

This is the required equation.

73.

Ans. Consider an electron moving with constant speed v in a circular orbit of radius r about the nucleus as shown in figure.

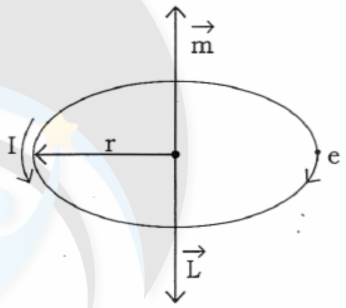


Fig. **Single electron revolving arnound the nucleus**

(Dig. - ½ mark)

If the electron travels a distance of $2\pi r$ (circumference) in time T, then its orbital speed, $v = \frac{2\pi r}{T}$. *(½ mark)*

Thus the current I associated with this orbiting electron of charge e is

$I = \frac{e}{T} = \frac{e\omega}{2\pi} = \frac{ev}{2\pi r}$ *(½ mark)*

$\ldots \left(\because T = \frac{e\omega}{2\pi} \text{ and } \omega = \frac{v}{r}\right)$

The orbital magnetic moment associated with orbital current loop is

$m_{orb} = I.A = \frac{ev}{2\pi r} \times \pi r^2$

$= \frac{1}{2} evr$ *(½ mark)*

74.

Ans. The following theories were proposed to explain nature of light.

(i) Newton's corpuscular theory of light.

(ii) Wave theory of light

(iii) Maxwell's theory of light

(iv) Planck's quantum theory of light.

(½ mark for each)

75.

Ans. ***(a) Range of molecular attraction:*** The maximum distance from molecule upto which the molecular force is effective is called the range of molecular attraction.

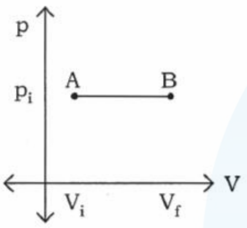
It is of the order of 10^{-9} m in solid and liquids so it is called short range force. *(1 mark)*

(b) Sphere of influence: An imaginary sphere with a molecular range is called the sphere of influence of the molecule. *(1 mark)*

The inter-molecular force is effective only within the sphere of influence.

76.

Ans. (i) The p-V diagram for an isobaric process is called isobar. It is shown in figure below.



(1 mark)

(ii) The different curves shown on the maps provided by the meteorology department are isobars. They indicate the locations having same pressure in a region. *(1 mark)*

77.

Ans. • ***Definition:*** The minimum amount of energy required to release all the nucleons from the nucleus is called binding energy per nucleon. *(1 mark)*

Thus, the binding energy per nucleon is

$$\frac{E_B}{A}$$

• ***Significance:***

(i) It allows us to compare the relative strengths with which nucleolus are bound in a nucleus for different species and therefore, compare their stabilities. *(½ mark)*

(ii) Nuclei with higher values of E_B/A are more stable as compared to nuclei having smaller values of this quantity. *(½ mark)*

78.

Ans. • ***The rotational analogue of Newton's second law of motion:***

The time rate of change in the angular momentum of a body is equal to the net external torque acting on the body.

Mathematically,

$$\vec{\tau}_{external} = \frac{d\vec{L}}{dt}$$ *(1 mark)*

• ***Angular momentum:*** The quantity in rotational mechanics analogue to linear momentum is angular momentum or moment of linear momentum. It is similar to the torque being moment of force.

i.e. $\vec{L} = \vec{r} \times \vec{p}$ *(1 mark)*

79.

Ans. • ***Heat engine:*** A heat engine is a device which takes a system through a repeated thermodynamic cycle that converts part of the heat supplied by a hot reservoir into work (mechanical energy) and release the remaining part to a cold reservoir. *(1 mark)*

• ***Elements of heat engine:***

(i) A working substance

(ii) Hot and cold reservoir

(iii) Cylinder *(1 mark)*

80.

Ans. *Given:* I = 10 A, N = 5, B = 0.5×10^{-4} T

To find: d = ?

We have,

$$B = \frac{\mu_0 NI}{2R} = \frac{\mu_0 NI}{d}$$ *(½ mark)*

$$\therefore d = \frac{4\pi \times 10^{-7} \times 5 \times 10}{0.5 \times 10^{-4}}$$ *(½ mark)*

$\therefore$ d = 1.257 m

$\therefore$ The diameter of the coil is 1.257 m *(1 mark)*

81.

Ans. *Given:* $V_f = 0.8\ V_i$; $T_i = 27 + 273 = 300$ K,

To find: T_f = ?

$$\gamma = \frac{5}{3} \quad \text{... (Mono-atomic)}$$ *(½ mark)*

$$\therefore (T_iV_i)^{\gamma-1} = (T_fV_f)^{\gamma-1}$$ *(½ mark)*

$$\therefore T_f = T_i\left(\frac{V_i}{V_f}\right)^{\gamma-1} = 300(1.25)^{\frac{5}{3}-1}$$ *(½ mark)*

...($\because V_f = 0.8V_i$)

$$= 300(1.25)^{\frac{2}{3}}$$

$$= (300)(1.161)$$

$$= 348.3 \text{ K} = (348.3 - 273)^\circ\text{C}$$

$\therefore$ T_f = 75.3°C is the final temperature of the gas *(½ mark)*

82.

Ans. • ***Diagram:***

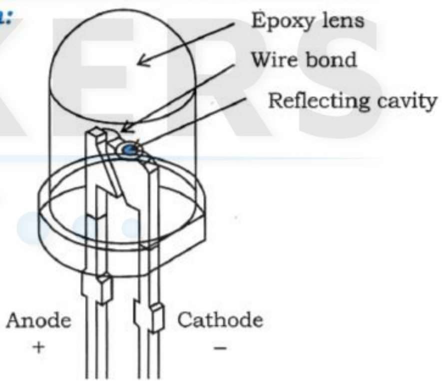


Fig. Schematic structure of LED

(Correct diagram - 1 mark, Labellings - 1 mark)

83.

Ans. *Given:* $T_2 = 4T_1$, $l_2 = \frac{l_1}{2}$

To find: $n_1 : n_2 = ?$

$\because \quad n = \frac{1}{2l}\sqrt{\frac{T}{m}}$ (½ mark)

$\therefore \quad \frac{n_1}{n_2} = \frac{l_2}{l_1}\sqrt{\frac{T_1}{T_2}}$

$\frac{n_1}{n_2} = \frac{1}{2}\sqrt{\frac{1}{4}}$ (½ mark)

$= \frac{1}{2} \times \frac{1}{2}$

$= \frac{1}{4}$

$\therefore \quad \boxed{n_1 : n_2 = 1 : 4}$ (1 mark)

84.

Ans. *Given:* $C = 0.5\ \mu F = 0.5 \times 10^{-6}$ F, $f = 100$ Hz

To find: Capacitive reactance $(X_C) = ?$

$\therefore X_C = \frac{1}{2\pi f C}$ (½ mark)

$\therefore X_C = \frac{1}{2 \times 3.142 \times 100 \times 0.5 \times 10^{-6}}$ (½ mark)

$= \frac{10^6}{314.2} = 3183\ \Omega$

$= 3.183\ k\Omega$ (1 mark)

$\therefore$ The capacitive reactance of a capacitor is 3.183 kΩ

85.

Ans. A steel blade floats on the surface of pure water due to the surface tension. When detergent is added in a pure water its surface tension decreases, steel blade sinks because of weight of the blade is greater than reaction force provided by the detergent solution. Hence, steel blade sinks in detergent water. (1 mark)

- ***Capillarity:*** The phenomenon of rise or fall of a liquid inside a capillary tube when it is dipped in the liquid is called capillarity. (1 mark)

86.

Ans. *Given:* $l_1 = 2.7$ m, $l_2 = 0.3$ m,

To find: $\frac{E_1}{E_2} = ?$

$\because \frac{E_1}{E_2} = \frac{l_1 + l_2}{l_1 - l_2}$ (½ mark)

$= \frac{2.7 + 0.3}{2.7 - 0.3}$ (½ mark)

$= \frac{3.0}{2.4} = \frac{5}{4} = 1.25$ (1 mark)

$\therefore$ The ratio of emits of two cells is 1.25

87.

Ans. The unit of mutual inductance is henry (H)

$\text{Henry} = \frac{\text{volt}}{\text{A s}} = \text{ohm}\cdot\text{s}$ (1 mark)

1 henry = 1 ohm·s

If rate of change of current in the primary circuit is 1 A/s, the induced emf produced in the secondary circuit is 1 volt then the mutual inductance (M) of the two circuits is 1 H. (1 mark)

88.

Ans. A quality that describes electrical behaviour of a dielectric is called as electrical susceptibility of dielectric medium. (1 mark)

It is denoted by χ_e (½ mark)

It is constant for a dielectric but has different values for different dielectric.

For vacuum $\chi_e = 0$ (½ mark)

89.

Ans.

	Centripetal force	Centrifugal force
(i)	Centripetal force is directed along the radius towards the centre of a circle.	Centrifugal force is directed along the radius away from the centre of a circle.
(ii)	It is a real force.	It is a pseudo force.
(iii)	$\vec{F} = -m\omega^2 \vec{r}$	$\vec{F} = +m\omega^2 \vec{r}$
(iv)	It is considered in inertial frame of reference.	It is considered in non-inertial frame of reference.

(Each point - ½ mark)

90.

Ans. • ***Statement:*** For streamline flow, the viscous force acting on any layer is directly proportional to the area (A) and the velocity gradient $\left(\frac{dv}{dx}\right)$. (1 mark)

• ***Explanation:***

Let A be the area of layer.

$\frac{dv}{dx}$ be the velocity gradient

F be the viscous force.

$\therefore$ By Newton's law of viscosity,

$F \propto A\left(\frac{dv}{dx}\right)$

$F = \eta A \frac{dv}{dx}$

where η is constant called coefficient of viscosity of the liquid.

$\therefore \eta = \frac{F}{A\left(\frac{dv}{dx}\right)}$ (1 mark)

$\eta = F$, if $A = 1\ m^2$ and $\frac{dv}{dx} = 1\ m \cdot s^{-1}$.

91.

Ans. Let P - be the pressure exerted by the gas

V - be the volume of the gas

N - be the number of molecule of gas

m - be the mass of each molecule of gas.

$\therefore$ Total mass of the gas, $M = Nm$.

From kinetic theory of gases,

$P = \frac{1}{3}\frac{Nm}{V}\bar{v}^2$ (½ mark)

$\therefore$ Pressure exerted by gas in an enclosed vessel is

$$P = \frac{2}{3}\frac{N}{V}\left(\frac{1}{2}m\overline{v}^2\right)$$

But $\frac{1}{2}m\overline{v}^2 = \left(\begin{array}{c}\text{Kinetic energy at}\\ \text{constant temperature}\end{array}\right)$

= constant (½ mark)

N is number which is also constant.

$$\therefore \quad P = \frac{\text{constant}}{V}$$

$$\therefore \quad P \propto \frac{1}{V}$$ (½ mark)

Hence, at constant temperature, if pressure of the gas is increased then its volume is reduced. (½ mark)

92.

Ans. ***Given:*** $W = 4.8 \times 10^8 J$, $Q_H = 1.2 \times 10^9 J$

To find: Efficiency (η) = ?

Formula: $\eta = \frac{W}{Q_H}$ (½ mark)

From formula,

$$\eta = \frac{4.8 \times 10^8}{1.2 \times 10^9} = 0.4$$ (½ mark)

$\therefore$ Percentage = $0.4 \times 100 = 40\%$

The percentage efficiency of the steam engine is 40%. (1 mark)

93.

Ans. ***Given:*** $B = 0.6 \text{ Wb/m}^2$, 0

$m_p = 1.673 \times 10^{-27}$ kg,

$e = 1.6 \times 10^{-19}$ C

To find: Frequency (n) = ?

Formula: $n = \frac{qB}{2\pi m} = \frac{eB}{2\pi m}$ (½ mark)

From formula,

$$n = \frac{1.6 \times 10^{-19} \times 0.6}{2 \times 3.142 \times 1.673 \times 10^{-27}}$$ (½ mark)

$$= \frac{0.96}{10.513} \times 10^8 = 9.13 \times 10^6$$

$\therefore$ Frequency $n = 9.13 \times 10^6$ Hz (1 mark)

94.

Ans. ***Given:*** $v = 330$ m/s, $\eta = 540$ Hz,

$x_1 = 3.5$ m, $x_2 = 3$ m.

To find: Phase difference ($\Delta\phi$) = ?

Formulae:

(i) $\lambda = \frac{v}{\eta}$ **(ii)** $\Delta\phi = \frac{2\pi}{\lambda} \times \Delta x$ (½ mark)

From formula (i),

$$\lambda = \frac{330}{540} = \frac{11}{18} \text{ m}$$ (½ mark)

From formula (ii),

$$\Delta\phi = \frac{2\pi}{\frac{11}{18}} \times (3.5 - 3)$$ (½ mark)

$$= \frac{2 \times \pi \times 18}{11} \times \frac{1}{2}$$

$$= \frac{18\pi}{11} = 1.64\pi$$ (½ mark)

$\therefore$ The phase difference between the wave is 1.64π.

95.

Ans. ***Given:*** $q = 0.5\ \mu C$, $r = 0.05$ m, $n = 125$

To find: Electrical Potential (V) = ?

Formula: $V = \frac{Q}{4\pi\varepsilon_0 R}$ (½ mark)

As single drop is formed by coalescing, the big drop will have charge

$Q = nq = 125 \times 0.5 \times 10^{-6}$ C

Radius $= 125^{1/3} \times 0.05$ ...(As $R = n^{1/3} r$)

$= (5^3)^{1/3} \times 0.05$

$= 5 \times 0.05$

Radius r = 0.25 m (½ mark)

From formula,

$$V = \frac{9 \times 10^9 \times 125 \times 0.5 \times 10^{-6}}{0.25}$$ (½ mark)

$= 2250 \times 10^3$

$= 2.25 \times 10^6$ V

$\therefore$ Electric potential is 2.25×10^6 V (½ mark)

96.

Ans. ***Given:*** $n_1 = 1$ (first orbit), $n_3 = 3$ (third orbit),

$h = 6.33 \times 10^{-34}$ Js

To find:

Change in angular momentum $(L_3 - L_1)$ = ?

Formula: $L = m_e v r = \frac{nh}{2\pi}$ (½ mark)

From formula,

$L_1 = m_e v_1 r_1 = \frac{n_1 h}{2\pi}$ and $L_3 = m_e v_3 r_3 = \frac{n_3 h}{2\pi}$

$\therefore L_3 - L_1 = m_e v_3 r_3 - m_e v_1 r_1$

$$\therefore L_3 - L_1 = \frac{n_3 h}{2\pi} - \frac{n_1 h}{2\pi}$$

$$= \frac{h}{2\pi}(n_3 - n_1)$$ (½ mark)

$$= \frac{h}{2\pi}(3 - 1)$$

$$= \frac{h}{\pi}$$

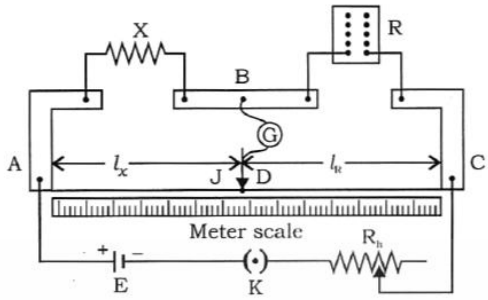
$$= \frac{6.33 \times 10^{-34}}{3.142}$$

$\therefore L_3 - L_1 = 2.11 \times 10^{-34}\ \text{kgm}^2/\text{s}$ (1 mark)

The change in angular momentum of electron when it jump from 3rd orbit to 1st orbit in hydrogen atom is $2.11 \times 10^{-34}\ \text{kgm}^2/\text{s}$.

97.

Ans. • ***Diagram:***



(1 mark)

• ***Labellings:***

X - Unknown resistance	R_h - Rheostat
R - Resistance box	K - Plug key
G - Galvanometer	D - Null point
E - Battery	J - Jocky

(1 mark)

98.

Ans. • ***Faraday's first law:*** Whenever there is a change of magnetic flux in a closed circuit, an induced emf is produced in the circuit. *(1 mark)*

• ***Faraday's second law:*** The magnitude of induced emf produced in the circuit is directly proportional to the rate of change of magnetic flux linked with the circuit. *(1 mark)*

99.

Ans. • ***AC circuit with resistance:***

Suppose an alternating source of emf is applied between the terminals of a resistor of resistance R as shown in Fig. (a).

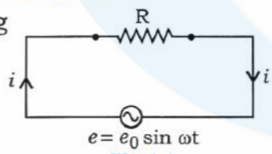


Fig. (a)

The instantaneous value of emf is given by

$e = e_0 \sin \omega t$ ...(i) *(½ mark)*

Let e be the potential drop across the resistance.

$\therefore \quad e = iR$ ...(ii)

But, Instantaneous emf

= Instantaneous value of potential drop.

$\therefore$ From equations (i) and (ii), we have,

$iR = e_0 \sin \omega t$

$i = \dfrac{e_0 \sin \omega t}{R}$ ...(iii) *(½ mark)*

We know, peak current $i_0 = \dfrac{e_0}{R}$

Substituting in equation (iii) we have,

$i = i_0 \sin \omega t$ ...(iv)

From equation (i) and (iv) there is no phase difference between alternating current and emf i.e. there is zero phase difference between current and emf. *(½ mark)*

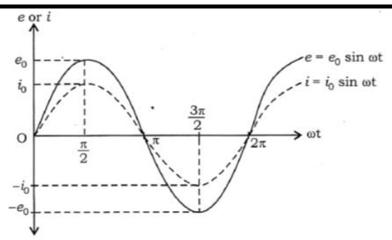


Fig.(b) *(½ mark)*

100.

Ans. **(a)** ***Threshold frequency:*** The minimum frequency of incident radiation required to start a photoemission in any photosensitive material is known as threshold frequency. *(1 mark)*

(b) ***Work function:*** The minimum amount of energy required to be provided to an electron to pull it out of the metal from the surface is called the work function of the metal. *(1 mark)*

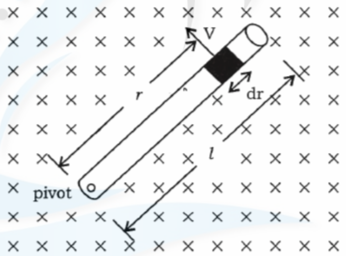
Sure shots (3 Marks) Solution

101.

Ans. Consider a conducting rod rotating around a pivot at one end in a uniform magnetic field that is perpendicular to the plane of rotation.

Refer figure →

Now consider a small element dr of the rod at a distance r from the pivot moving with velocity v in magnetic field $\overline{B}$ and has an induced emf generated in it like a sliding rod. *(½ mark)*



(Diagram - ½ mark)

The induced emf (de) in the element dr is given by

$de = Bv dr$ ...(i) *(½ mark)*

Integrating eqn. (i) with limit 0 to l we get total induced emf

$\therefore \quad e = \int_0^l de = \int_0^l Bv dr$ *(½ mark)*

Putting $v = r\omega$, we get

$e = \int_0^l Br\omega dr$

$e = B\omega \int_0^l r dr$

$e = B\omega \left[\dfrac{r^2}{2}\right]_0^l$

$e = \dfrac{1}{2} B\omega [l^2 - 0]$

$e = \dfrac{1}{2} B\omega l^2$ ...(ii) *(1 mark)*

102.

Ans. ***Given:*** $R = 1.097 \times 10^7\ m^{-1}$

For the first member of Balmer series,

$p = 2$ and $n = 3$

To find: (a) Wavelength (λ) = ?

(b) Wave number ($\bar{v}$) = ?

(a) We have

$$\frac{1}{\lambda} = R\left[\frac{1}{p^2} - \frac{1}{n^2}\right] \quad (\tfrac{1}{2}\ mark)$$

$$\therefore \quad \frac{1}{\lambda} = R\left[\frac{1}{4} - \frac{1}{9}\right] \quad (\tfrac{1}{2}\ mark)$$

$$\therefore \quad \frac{1}{\lambda} = R\left[\frac{5}{36}\right]$$

$$\therefore \quad \lambda = \frac{36}{5R}$$

$$= \frac{36}{5} \times \frac{1}{(1.097 \times 10^7)}$$

$$= \frac{36}{5.485} \times 10^{-7}$$

$$= 6.563 \times 10^{-7}\ m$$

$$\therefore \quad \lambda = 6563\ Å \quad (1\ mark)$$

(b) Wave number ($\bar{v}$) $= \frac{1}{\lambda}$ *(½ mark)*

$$= \frac{1}{6.563 \times 10^{-7}}$$

$$= 1.524 \times 10^6\ m^{-1} \quad (\tfrac{1}{2}\ mark)$$

103.

Ans. ***Given:*** $n = 50$

$A = 6 \times 10^{-4}\ m^2,\ B = 3 \times 10^{-2}\ Wb/m^2,$

$\theta = 60° = \frac{\pi}{3} = 1.047$ rad

$K = 3.82 \times 10^{-6}$ SI unit.

To find: I = ?

Formula:

$$I = \frac{K\theta}{nAB} \quad (1\ mark)$$

$$= \frac{3.82 \times 10^{-6} \times 1.047}{50 \times 6 \times 10^{-4} \times 3 \times 10^{-2}} \quad (1\ mark)$$

$$= \frac{3.82 \times 1.047}{50 \times 6 \times 3}$$

$$\therefore \quad I = \frac{3.9995}{900}$$

$$\therefore \quad = 0.004443\ A = 4.4\ mA \quad (1\ mark)$$

104.

Ans. ***Given:*** $n = 2.0$ mol, $T_A = 300K$, $T_B = 500K$,

$Q = -1200\ J$, $R = 8.3\ J/mol\ K$.

To find: Work done (W_{BC}) = ?

Formula: (1) $Q = \Delta U + W$

(2) $W = P\Delta V = nR\Delta T$

$\because \quad Q = \Delta U + W$

$\therefore \quad Q = W_{ABCA}$ ...(As internal energy $\Delta U = 0$)

$Q = W_{AB} + W_{BC} + W_{CA}$ *(½ mark)*

As, the volume remains constant during path CA,

$\therefore \quad W_{CA} = 0$

$-1200 = W_{AB} + W_{BC} + 0$

$\therefore \quad W_{AB} + W_{BC} = -1200$ ...(i) *(½ mark)*

We know,

$W_{AB} = nR\Delta T$

$= nR(T_B - T_A)$

$= 2.0 \times 8.3(500 - 300)$

$\therefore \quad W_{AB} = 3320\ J$ *(½ mark)*

From equation (i)

$3320 + W_{BC} = -1200$

$\therefore \quad W_{BC} = -4520\ J$ *(½ mark)*

Negative sign indicates that the work is done on the gas.

$\therefore$ Work done by the gas in part BC = + 4520 J.

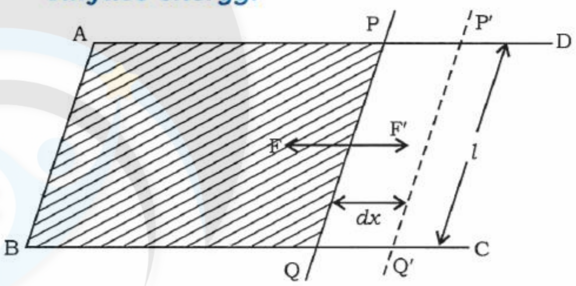
(1 mark)

105.

Ans. • ***Surface Tension:*** It is defined as the tangential force acting per unit length on both sides of an imaginary line drawn on the free surface of liquid. *(1 mark)*

$\therefore$ Surface Tension (T) $= \frac{F}{l}$

• ***Relation between surface tension and surface energy:***



(Diagram - ½ mark)

Let ABCD be a rectangular frame of wire fitted with a movable arm PQ. The frame held in horizontal position and dipped into soap solution and taken out so that soap film is formed. Due to surface tension a force F will acts on the wire PQ which tending to pull it towards AB. Magnitude of force is calculated as

$$T = \frac{F}{2l}$$

$$F = T \cdot 2l \quad (\tfrac{1}{2}\ mark)$$

where l is length of wire PQ and 2 is used because soap film has two free surfaces.

Due to this force work is done

$dw = F \cdot dx$

$dw = 2Tl dx$

$dw = T \times dA$ *(½ mark)*

where $dA = 2l dx$ = surface area

This work done is stored in the form of potential energy (P.E.)

$\therefore \quad P.E. = T \times dA$

$$\frac{P.E.}{dA} = T \quad (\tfrac{1}{2}\ mark)$$

i.e. surface energy per unit area is equal to surface tension.

106.

Ans. ***Given:*** $\lambda_R = 6400$ Å

To find: $\lambda_B = ?$

Formula:

For bright band $x_n = \dfrac{nD\lambda}{d}$ *(½ mark)*

For red light, distance of 3rd bright band is

$$x_3 = \frac{3D\lambda_R}{d} \quad \ldots\text{(i)}$$ *(½ mark)*

For blue light, distance of 4th bright band is

$$x_4 = \frac{4D\lambda_B}{d} \quad \ldots\text{(ii)}$$ *(½ mark)*

By condition,

(Distance of 3rd bright band of red light i.e. x_3) = (Distance of 4th bright band of red light i.e. x_4)

$$\therefore \quad \frac{3D\lambda_R}{d} = \frac{4D\lambda_B}{d}$$ *(½ mark)*

$$\frac{3}{4}\lambda_R = \lambda_B$$

$$\therefore \quad \lambda_B = \frac{3}{4} \times 6400$$

$$\therefore \quad \lambda_B = 4800 \text{ Å}$$ *(1 mark)*

107

Ans. ***Given:*** $r = 0.53$ Å $= 0.53 \times 10^{-10}$ m,

$v = 2 \times 10^6$ m/s,

$e = 1.6 \times 10^{-19}$ C,

$m = 9.1 \times 10^{-31}$ kg.

To find:

(1) Orbital magnetic moment (M_{orb}) =?

(2) Angular momentum (L) = ?

Formulae: (1) $M_{orb} = \dfrac{evr}{2}$ (2) $L = mvr$

(1) $M_{orb} = \dfrac{evr}{2}$ *(½ mark)*

$$= \frac{1.6 \times 10^{-19} \times 2 \times 10^6 \times 0.53 \times 10^{-10}}{2}$$

$$= 1.6 \times 0.53 \times 10^{-23}$$

$$= 0.848 \times 10^{-23}$$

$$= 8.48 \times 10^{-24} \text{ Am}^2$$ *(1 mark)*

(2) $L = mvr$ *(½ mark)*

$$= 9.1 \times 10^{-31} \times 2 \times 10^6 \times 0.53 \times 10^{-10}$$

$$= 18.2 \times 0.53 \times 10^{-35}$$

$$= 9.65 \times 10^{-35} \text{ J.s}$$ *(1 mark)*

108.

Ans.

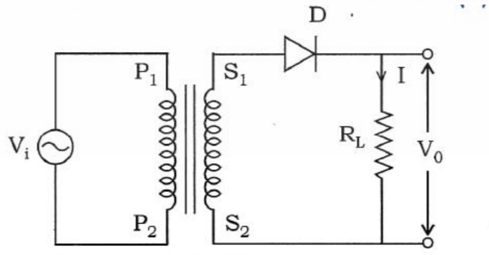


Fig. (a)

P_1P_2 – Primary of transformer,

S_1S_2 – Secondary of transformer,

D – Diode, R_L – Load resistance,

V_i – AC input, V_0 – DC output.

(Diagram - 1 mark)

(i) The experimental circuit for half wave rectifier is as shown in above Fig. (a). The AC voltage which is to be rectified is applied across the primary P_1P_2 of transformer. The secondary S_1S_2 of transformer is connected in series with diode D and resistance R_L. The output is taken across the load resistance.

(ii) When we apply AC input across primary P_1P_2 then AC voltage is developed across secondary S_1S_2.

(iii) During the positive half cycle of input voltage, S_1 is positive with respect to S_2, therefore the diode D is forward biased. It conducts current and current flows through the circuit and we get output across load resistance. The output voltage V_0 is, $V_0 = IR_L$. *(½ mark)*

(iv) During the negative half cycle of input voltage, S_1 is negative with respect to S_2, therefore the diode D is reverse biased. It does not conduct current. No current flows through the circuit. Therefore output voltage across R_L is zero i.e. $V_0 = 0$. *(½ mark)*

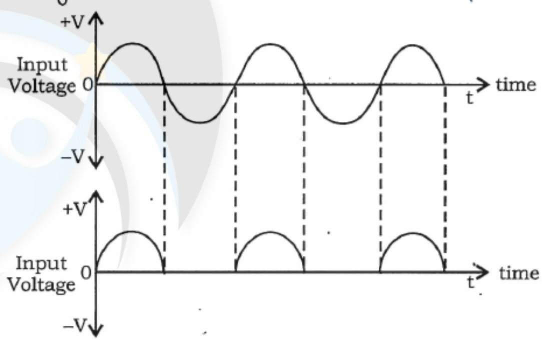


Fig. (b) *(Diagram - ½ mark)*

(v) The diode conducts only in the positive half cycle of AC input. The current flows through R_L only in one direction and only half part of wave is rectified. Therefore it is called as half wave rectifier. *(½ mark)*

(vi) The variation of AC input and DC output with time is as shown in Fig. (b).

109.

Ans. • ***Principle of conservation of angular momentum:*** Angular momentum of an isolated system is conserved in the absence of an external unbalanced torque. *(1 mark)*

• ***Proof:***

Angular momentum (L) of a system is given by $\bar{L} = \bar{r} \times \bar{p}$ ...(i)

where,

$\bar{r}$ is the position vector from the axis of rotation.

$\bar{p}$ is the linear momentum.

Differentiating equation (i) w.r. to time, we get

$$\frac{d\bar{L}}{dt} = \frac{d(\bar{r} \times \bar{p})}{dt}$$

$$= \bar{r} \times \frac{d\bar{p}}{dt} + \frac{d\bar{r}}{dt} \times \bar{p}$$ *(½ mark)*

Now, $\frac{d\overline{r}}{dt} = \overline{v}$ and $\frac{d\overline{p}}{dt} = \overline{F}$ *(½ mark)*

$\therefore \quad \frac{d\overline{L}}{dt} = \overline{r} \times \overline{F} + \overline{v} \times m\overline{v}$ (As $p = mv$)

$= \overline{r} \times \overline{F} + m(\overline{v} \times \overline{v})$

We know $\overline{v} \times \overline{v} = 0$

$\therefore \quad \frac{d\overline{L}}{dt} = \overline{r} \times \overline{F} + 0$ *(½ mark)*

But $\overline{r} \times \overline{F} = \overline{\tau}$ = moment of force or torque

$\therefore \quad \overline{\tau} = \frac{d\overline{L}}{dt}$

Thus, if $\overline{\tau} = 0$ then $\frac{d\overline{L}}{dt} = 0$

$\Rightarrow \quad \overline{L}$ = constant. *(½ mark)*

110.

Ans. Let, $e = e_0 \sin\omega t$ be applied emf across a resistance R as shown in the following figure.

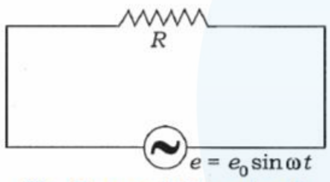


Fig. Pure resistive circuit

(Diagram - ½ mark)

At time t, current $i = i_0 \sin\omega t$ is flowing through the resistor.

In this case e and i are in phase.

$\therefore$ Power in circuit is given by

$P = ei$

$P = (e_0 \sin\omega t)\,(i_0 \sin\omega t)$

$P = e_0 i_0 \sin^2\omega t$ ...(i) *(½ mark)*

Average power for one cycle can be obtained as follows:

$$P_{av} = \frac{\text{Work done by emf in one cycle}}{\text{Time for one cycle (period)}}$$

$$\therefore \quad P_{av} = \frac{\int_0^T P\,dt}{T}$$ *(½ mark)*

$$= \frac{\int_0^T e_0 i_0 \sin^2\omega t\,dt}{T}$$

$$P_{av} = \frac{e_0 i_0}{T}\int_0^T \sin^2\omega t\,dt$$

$$P_{av} = \frac{e_0 i_0}{T}\left(\frac{T}{2}\right)$$

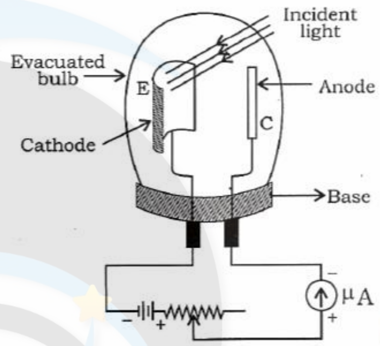
$$\left[\because \int_0^T \sin^2\omega t\,dt = \frac{T}{2}\right]$$ *(½ mark)*

$$P_{av} = \frac{e_0}{\sqrt{2}} \times \frac{i_0}{\sqrt{2}}$$

$$P_{av} = e_{rms} \times i_{rms}$$ *(1 mark)*

111.

Ans. • ***Diagram:***



(Diagram-1 mark)

- ***Construction:*** It consist of an evacuated glass bulb or tube containing two electrodes anode and cathode. The cathode is semi-cylindrical photosentitive metal plate (E) and the anode is in the form of metal rod. The glass bulb is fitted on nonconducting base provided with two pins for external connection as shown in figure given below. *(1 mark)*
- ***Working:*** The experimental circuit is as shown in the figure. The cathode is connected to negative terminal and anode is connected to positive terminal of battery (HT) with microammeter. When light of suitable wavelength falls on the cathode, photoelectrons are emitted. These electrons are attracted towards the anode due to applied electric field. The generated photocurrent is noted from the microammeter. This current is directly proportional to the intensity of incident light. *(1 mark)*

112.

Ans. ***Given:*** At STP, $T_1 = 273$ K;

$v_2 = 4v_1$

To find: Temperature (T_2) = ?

Formula: $v_{rms} = \sqrt{\frac{3RT}{M}}$ *(½ mark)*

$\therefore \quad v \propto \sqrt{T}$

$$\frac{v_1}{v_2} = \sqrt{\frac{T_1}{T_2}}$$ *(½ mark)*

$$\frac{v_1}{4v_1} = \sqrt{\frac{273}{T_2}}$$ *(1 mark)*

Squaring on both side,

$$\frac{1}{16} = \frac{273}{T_2}$$

$$\therefore \quad T_2 = 16 \times 273$$

$$T_2 = 4368 \text{ K} \quad \textit{(1 mark}$$

113.

Ans. *Given:* $l = 25$ m, $R = 25\Omega$,

$\rho = 3.142 \times 10^{-7}\ \Omega$m,

To find: $r = ?$,

We have,

$$R = \frac{\rho l}{A} = \frac{\rho l}{\pi r^2} \quad \textit{(1 mark)}$$

$$\therefore \quad r^2 = \frac{\rho l}{\pi R} = \frac{3.142 \times 10^{-7} \times 25}{3.142 \times 25} \quad \textit{(1 mark)}$$

$$r^2 = 10^{-7} = 10 \times 10^{-8}$$

$$\therefore \quad r = \sqrt{10 \times 10^{-8}}$$

$$r = 3.162 \times 10^{-4} \text{ m} \quad \textit{(1 mark)}$$

114.

Ans. *Given:* B = 1.7 T, $q = 1.6 \times 10^{-19}$ C

$m = 1.66 \times 10^{-27}$ kg, $r_{max} = 0.5$ m

To find: $K.E._{max} = ?$

$$KE_{max} = \frac{q^2B^2}{2m} r^2_{max} \quad \textit{(1 mark)}$$

$$KE_{max} = \frac{(1.6 \times 10^{-19})^2 \times 1.7 \times 1.7 \times 0.5 \times 0.5}{2 \times 1.66 \times 10^{-27}} \quad \textit{(1 mark)}$$

$$= \frac{1.8496 \times 10^{-38}}{3.32 \times 10^{-27}}$$

$$= 0.5571 \times 10^{-11}$$

$$\therefore \quad KE_{max} = 5.5 \times 10^{-12} \text{ J}$$

or $KE_{max} = 34 \times 10^6$ eV *(1 mark)*

115.

Ans. *Given:* $\bar{p} = 25$ W, $e_0 = 100$ V

To find: $I_{rms} = ?$

$$\because \quad \bar{p} = \frac{e_0 I_0}{2} \quad \textit{(½ mark)}$$

$$\therefore \quad I_0 = \frac{2\bar{p}}{e_0} = \frac{2 \times 25}{100} \quad \textit{(½ mark)}$$

$$\therefore \quad I_0 = 0.5 \text{ A} \quad \textit{(1 mark)}$$

$$\text{But } I_{rms} = \frac{I_0}{\sqrt{2}} = \frac{0.5}{1.414} = 0.3536 \text{ A} \quad \textit{(1 mark)}$$

116.

Ans. (i) Size of a nucleus depends on number of nucleons present in it. *(½ mark)*

(ii) The size of an atom is decided by the size of the orbits of the electrons in the atom. Larger the number of electrons in an atom, higher are the orbits occupied by them and larger is the size of the atom. *(1 mark)*

(iii) A nucleus of mass number A has radius of $R = R_0A^{1/3}$ where R_0 is constant and has the value of 1.2×10^{-15} m. *(1 mark)*

(iv) This implies that all nuclei do not have same size. *(½ mark)*

117.

Ans. **Given:** $n_1 = 300$ rpm

$$\therefore \quad n_1 = \frac{300}{60} = 5 \text{ rps} = 5 \text{ Hz}$$

$n_2 = 0$, $t = 20$ s

Angular acceleration,

$$\alpha = \frac{\omega_2 - \omega_1}{t} \quad \textit{(½ mark)}$$

$$\alpha = \frac{2\pi n_2 - 2\pi n_1}{20} \quad \textit{(½ mark)}$$

$$\therefore \quad \alpha = \frac{0 - 2\pi \times 5}{20} = \frac{-\pi}{2} \text{ rad/s}^2 \quad \textit{(1 mark)}$$

$$\alpha = \frac{-3.14}{2} \text{ rad/s}^2$$

$$\therefore \quad \alpha = -1.57 \text{ rad/s}^2 \quad \textit{(1 mark)}$$

118.

Ans. **Given:** $V = V_N$, $m_O = m_N$, $M_O = 32$, $M_N = 28$

$T_1 = T_2 = T = 127°C = (127 + 273)$ K = 400K

To find: $\frac{P_O}{P_N} = ?$

We know,

$PV = nRT$

$P_OV = n_ORT$ ...(i) (For oxygen)

$P_NV = n_NRT$ ...(ii) (For nitrogen) *(½ mark)*

Dividing eqn (i) by eqn (ii), we get,

$$\frac{P_OV}{P_NV} = \frac{n_ORT}{n_NRT}$$

$$\frac{P_O}{P_N} = \frac{n_O}{n_N}$$

$$\frac{P_O}{P_N} = \frac{m_O}{M_O} \div \frac{m_N}{M_N} \quad \textit{(½ mark)}$$

... ($\because m_O = n_OM_O$ & $m_N = n_NM_N$)

$$\frac{P_O}{P_N} = \frac{m_O}{M_O} \times \frac{M_N}{m_N} \quad \textit{(½ mark)}$$

But $m_O = m_N$ ...(given)

$$\therefore \quad \frac{P_O}{P_N} = \frac{M_N}{m_N} \quad \textit{(½ mark)}$$

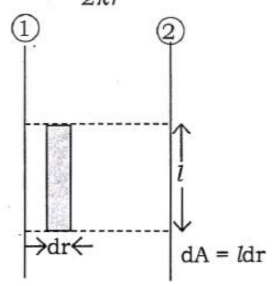
$$= \frac{28}{32}$$

119.

Ans. Using Ampere's law, (for a single wire)

$$B = \frac{\mu_0 I}{2\pi r} \quad \textit{(½ mark)}$$

$$\therefore \quad d\phi = BdA = \frac{\mu_0 I}{2\pi r} l dr \quad \textit{(½ mark)}$$



Total flux is two times flux generated by one wires, (due to symmetry)

$$\phi_{total} = 2\int_a^{d-a} BdA = 2\int_a^{d-a}\left(\frac{\mu_0 I}{2\pi r}\right)l\,dr \quad (½ \text{ mark})$$

$$= \frac{\mu_0 Il}{\pi}\int_a^{d-a}\frac{dr}{r}$$

$$= \frac{\mu_0 Il}{\pi}[\ln r]_a^{d-a}$$

$$= \frac{\mu_0 Il}{\pi}\ln\left[\frac{d-a}{a}\right] \quad (½ \text{ mark})$$

$$\therefore \quad L = \frac{\phi_{total}}{I} = \frac{\mu_0 l}{\pi}\ln\left(\frac{d-a}{a}\right) \quad (½ \text{ mark})$$

If $a << d$, then $d - a \approx d$

$$\therefore \; L = \frac{\mu_0 l}{\pi}\ln\left(\frac{d}{a}\right) \quad (½ \text{ mark})$$

120.

Ans.

	Streamline flow		Turbulent flow
(i)	The smooth flow of a fluid with velocity smaller than certain critical velocity (limiting value of velocity) is called streamline flow or laminar flow of a fluid	(i)	The irregular and unsteady flow of a fluid when its velocity increases beyond critical velocity is called turbulent flow.
(ii)	In a streamline flow, velocity of a fluid at a given point is always constant.	(ii)	In a turbulent flow, the velocity of a fluid at any point does not remain constant.
(iii)	Two streamlines can never intersect i.e. they are always parallel.	(iii)	In a turbulent flow, at some points, the fluid may have rotational motion which gives rise to eddies.
(iv)	Streamline flow over a plane surface can be assumed to be divided into a number of plane layers. In a pipe, all the streamlines will be parallel to the axis of the tube.	(iv)	A flow tube loses its order and particles move in random direction.

(Any three points - 1 mark each)

121.

Ans. ***Characteristics of a single-slit diffraction pattern:***

(i) The image cast by a single slit is not the expected purely geometrical image.

(ii) For a given wavelength, the width of the diffraction pattern is inversely proportional to the slit width.

(iii) For a given slit width 'a', the width of the diffraction pattern is proportional to the wavelength.

(iv) The intensities of the non central i.e. secondary, maxima are much less than the intensity of the central maximum.

(v) The minima and the non-central maxima are of the same width, $D\lambda/a$.

(vi) The width of the central maximum is $2D\lambda/a$. It is twice the width of the non central maxima or minima. *(½ mark for each point)*

122.

Ans. An electric current in a circular loop establishes a magnetic field similar in every respect to the field of a magnetic dipole (or a bar magnet)

Consider a circular conducting loop of radius R, axis along the X-axis and carrying a current I. The area of the loop is $A = \pi R^2$ and $\vec{A}$ has the direction given by right hand rule. The axial magnetic induction of the current loop at a distance x from its centre is *(½ mark)*

$$\vec{B} = \left(\frac{\mu_0}{4\pi}\right)\frac{2I\vec{A}}{(R^2 + x^2)^{3/2}}$$

$$= \left(\frac{\mu_0}{4\pi}\right)\frac{2\vec{M}}{(R^2 + x^2)^{3/2}} \quad (½ \text{ mark})$$

where $\vec{M} = I\vec{A}$ is the magnetic moment of the current loop and μ_0 is the permeability of free space.

For $x >> R$, ignoring R^2 in comparison with x^2)

123.

$$\therefore \quad B = \left(\frac{\mu_0}{4\pi}\right)\frac{2\vec{M}}{x^3} \quad (½ \text{ mark})$$

This equation also gives the magnetic induction on the axis of a short magnetic dipole (or a bar magnet) of magnetic moment $\vec{M}$.

For a magnetic dipole, the dipole moment is directed from the south pole of the dipole to its north pole. For a current loop, the mangetic dipole moment has the direction of the axial field of the current loop as given by the right hand rule.

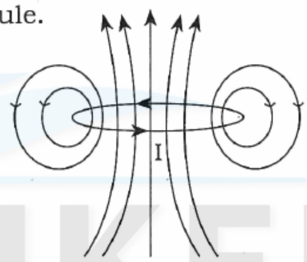


Fig. **Magnetic field lines for a current loop**

(½ mark)

When an observer looking at a current carrying circular loop finds the direction of the current anticlockwise, the face of the loop towards the observer acts as the north pole. When an observer looking at a current carrying circular loop finds the direction of the current clockwise, the face of the loop towards the observer acts as the south pole. This rule is known as the **clock rule.** *(½ mark)*

(a) Anticlockwise current **(b)** Clockwise current

(½ mark)

123.

Ans. • ***Definition:*** Potential gradient is defined as potential difference per unit length of wire.

$\therefore$ Potential gradient $= \frac{V}{L}$ *(1 mark)*

- ***SI Unit:*** V/m *(½ mark)*
- ***Dimensions:*** $[M^1L^1I^{-1}T^{-3}]$ *(½ mark)*
- ***Applications of potentiometer:***

(i) **Voltage divider:** To continuously change the output of a voltage supply.

(ii) **Audio control:** Used in modern low power audio systems as audio control devices.

(iii) **Sensor:** Connected to the moving part of machine, it can work as a motion sensor.

(Any two - ½ mark each)

124.

Ans. ***Limitations of first law of thermodynamics:***

(i) Fist law of thermodynamics does not tell us whether any particular process can actually occur. *(1 mark)*

(ii) According to the first law of thermodynamics, heat may, on its own, flow from an object at higher temperature to one at lower temperature as well as it can flow from an object at lower temperature to one at higher temperature. Practically, heat cannot flow from an object at lower temperature to another at higher temperature. The first law of thermodynamics does not predict this practical observation. *(1 mark)*

(iii) According to the first law, all (100%) of the heat available could be converted into work. Similarly, all the work could be converted into heat. This is practically impossible. *(1 mark)*

125.

Ans.

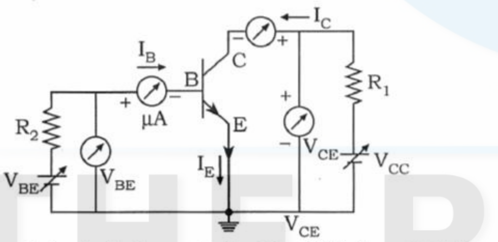


Fig. **Circuit to study Common Emitter (CE) characteristic**

(Diagram - ½ mark)

The variation of the collector current I_C with variation in the collector emitter voltage, V_{CE} is called the output characteristics of a transistor.

The base current I_B is constant at this time. From the curve we can see that the collector current I_C is independent of V_{CE} as long as the collector emitter junction is reverse biased. Also, the collector current I_C is large for large values of the base current I_B when V_{CE} is constant. *(1 mark)*

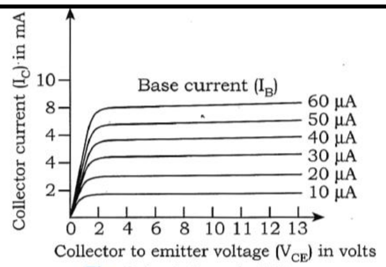


Fig. **Output characteristics**

(Diagram - ½ mark)

The output dynamic resistance R_D of CE configuration is defined as the ratio of the change in the collector-emitter voltage V_{CE} and the change in the collector current I_C for constant base current I_B.

$$R_D = \frac{\Delta V_{CE}}{\Delta I_C}$$ *(1 mark)*

126.

Ans. *Data:* $\frac{C_1}{C_2} = \frac{1}{2}$, U_1 (for parallel) = U_2 (for series)

$\because \frac{C_1}{C_2} = \frac{1}{2} \quad \therefore C_2 = 2C_1$

For the parallel combination of C_1 and C_2,

$C_p = C_1 + C_2 = 3\,C_1$ *(½ mark)*

and charged to a potential V_1, the energy stored is

$U_1 = \frac{1}{2}C_pV_1^2 = \frac{3}{2}C_1V_1^2$ *(½ mark)*

For the series combination of C_1 and C_2,

$C_S = \frac{C_1C_2}{C_1 + C_2} = \frac{2C_1^2}{3\,C_1} = \frac{2}{3}C_1$ *(½ mark)*

and a charged to a potential V_2, the energy stored is,

$U_2 = \frac{1}{2}C_SV_2^2 = \frac{1}{3}C_1V_2^2$ *(½ mark)*

For $U_1 = U_2$,

$\frac{3}{2}C_1V_1^2 = \frac{1}{3}C_1V_2^2$ *(½ mark)*

$\therefore \left(\frac{V_1}{V_2}\right)^2 = \frac{2}{9}$

$\therefore \frac{V_1}{V_2} = \frac{\sqrt{2}}{3} = \frac{1.414}{3} = 0.471$ *(½ mark)*

This is the required ratio.

127.

Ans. Given: $v = 2.3 \times 10^6$ m/s,

$r = 0.53\text{Å} = 0.53 \times 10^{-10}$ m,

To find: M = ?

Period of revolution of electron

$$T = \frac{2\pi r}{v} = \frac{2\pi \times 0.53 \times 10^{-10}}{2.3 \times 10^6}$$

$$= \frac{2 \times 3.142 \times 0.53 \times 10^{-10}}{2.3 \times 10^6}$$

$\therefore T = 1.448 \times 10^{-16}$ sec *(½ mark)*

Current, $I = \frac{e}{T}$ (½ mark)

$= \frac{1.6 \times 10^{-19}}{1.448 \times 10^{-16}}$

$= 1.105 \times 10^{-3}$ A (½ mark)

Magnetic moment of the revolving electron,

$M = IA$ (½ mark)

$= I \cdot \pi r^2$

$= 1.105 \times 10^{-3} \times 3.142 \times (0.53 \times 10^{-10})^2$ (½ mark)

$= 0.9753 \times 10^{-23}$

$\therefore$ $M = 9.753 \times 10^{-24}$ Am² (½ mark)

128.

Ans. *Given:* $\nu_0 = 1.7 \times 10^{15}$ Hz, $\nu = 2.2 \times 10^{15}$ Hz

K.E.$_{max} = 3.3 \times 10^{-19}$ J,

To find: h = ?

$\frac{1}{2}mV_{max}^2 = h(\nu - \nu_0)$ (1 mark)

$\therefore \quad h = \frac{\frac{1}{2}mV_{max}^2}{\nu - \nu_0} = \frac{K.E._{max}}{\nu - \nu_0}$ (½ mark)

$= \frac{3.3 \times 10^{-19}}{2.2 \times 10^{15} - 1.7 \times 10^{15}}$ (½ mark)

$\therefore \quad h = 6.6 \times 10^{-34}$ Js (1 mark)

129.

Ans. *Given:* r = 1 mm = 10^{-3} m,

h = 0.536 cm = 0.536×10^{-2} m

T = 0.485 N/m , $\rho = 13.6 \times 10^3$ kg/m³

To find: θ = ?

$\because \quad T = -\frac{h\rho g r}{2\cos\theta}$ (1 mark)

$\therefore \quad -\cos\theta = \frac{h\rho g r}{2T}$

$= \frac{0.536 \times 10^{-2} \times 13.6 \times 10^3 \times 9.8 \times 10^{-3}}{2 \times 0.485}$ (1 mark)

$= \frac{71.38 \times 10^{-2}}{0.97}$

$\therefore \quad -\cos\theta = 0.7359$

$\cos(\pi - \theta) = 0.7359 \quad [\because \cos(\pi - \theta) = -\cos\theta]$

$\pi - \theta = \cos^{-1}(0.7359)$

$\therefore \quad \pi - \theta = 42°34'$

$\theta = \pi - 42°34'$

$\therefore \quad \theta = 180° - 42°34'$

$\theta = 179°60' - 42°34'$

$\therefore \quad \theta = 137°26'$ (1 mark)

130.

Ans. *Given:* l_1 = 0.25 m, $\quad v$ = 350 m/s,

e = 0.015 m,

To find: l_2 = ?

$\because$ Given that, $\quad n_1 - n_2 = 5$

$\therefore \quad \frac{v}{2(l_1 + 2e)} - \frac{v}{2(l_2 + 2e)} = 5$ (½ mark)

$\frac{v}{2}\left[\frac{1}{0.25 + 2 \times 0.015} + \frac{1}{l_2 + 2e}\right] = 5$ (1 mark)

$v\left[\frac{1}{0.25 + 0.030} + \frac{1}{l_2 + 2e}\right] = 10$

$350\left[\frac{1}{0.280} + \frac{1}{l_2 + 2e}\right] = 10$

$\frac{1}{0.280} + \frac{1}{l_2 + 2e} = \frac{1}{35}$

$\frac{1}{0.280} - \frac{1}{35} = \frac{1}{l_2 + 2e}$

$3.574 - 0.02857 = \frac{1}{l_2 + 2e}$ (½ mark)

$3.5424 = \frac{1}{l_2 + 2e}$

$l_2 + 2e = 0.2829$

$\therefore \quad l_2 = 0.2829 - 0.030$

$= 0.2523$ m (1 mark)

131.

Ans. Consider a thermodynamic system consisting of an ideal gas confined to a cylinder with a movable, frictionless, and massless piston.

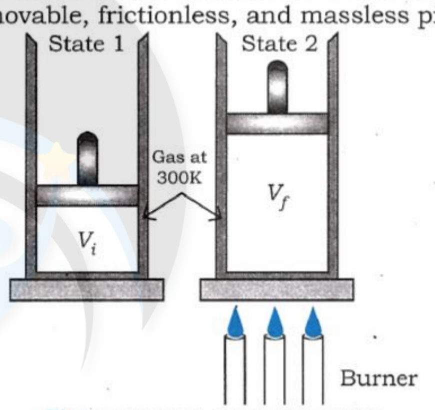


Fig. Isothermal expansion of gas

(Diagram - 1 mark)

When a gas is heated slowly in a controlled manner it expands at a constant temperature. It reaches the final volume V_f isothermally. (1 mark)

The system absorbs a finite amount of heat during this process but as the process is very slow, the temperature remains constant.

In this way, the gas expands and reaches final volume V_f at constant temperature. (1 mark)

132.

Ans. ***Choke coil:*** If we use a resistance to reduce the current passing through an AC circuit, there will be loss of electrical energy in the form of heat (I^2RT) due to Joule heating. A choke coil helps to minimize this effect. (½ mark)

A choke coil is an inductor, used to reduce AC passing through a circuit without much loss of energy. It is made up of thick insulated copper wires wound closely in a large number of turns over a soft iron laminated core. Choke coil offers large resistance $X_L = \omega L$ to the flow of AC and hence current is reduced. Laminated core reduces eddy current loss. (1 mark)

Average power dissipated in the choke is $P = I_{rms} E_{rms} \cos\phi$

where the power factor,

$$\cos\phi = \frac{R}{\sqrt{R^2 + \omega^2 L^2}}$$ *(½ mark)*

For a choke coil L is very large. Hence R is very small, so $\cos\phi$ is nearly zero and power loss is very small. The only loss in the iron core which can be reduced using a soft iron core. *(1 mark)*

133.

Ans. • ***Limitations of cyclotron:***

(i) Cyclotron cannot accelerate uncharged particles like neutron. *(½ mark)*

(ii) Cyclotron cannot accelerate electrons because they have small mass. Electrons start moving at a very high speed, when they gain small energy in the cyclotron. Oscillating electric field makes them to go quickly out of step because of their very high speed. *(½ mark)*

(iii) The positively charged particles having large mass i.e. ions cannot move at limitless speed in a cyclotron. *(½ mark)*

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

where,

m_0 = mass of ion at rest

m = mass of ion at velocity v

c = velocity of light

• ***Advantages of cyclotron:***

(i) It produces high energetic positively charged particles of energy about 50 MeV.

(ii) The size of cyclotron is small.

(iii) It operates on low voltage.

(iv) It provides continuous stream of charged particles. *(Any three - ½ mark each)*

134.

Ans. The electrostatic potential energy of a system of point charges is defined as the work required to assemble the system of charges by bringing them from infinity to their present locations.

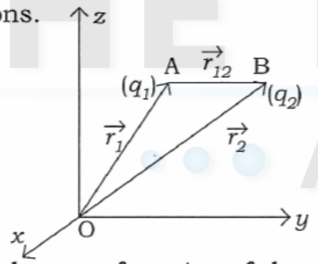


Fig. **Potential energy of a system of charges q_1 and q_2**

(Diagram - ½ mark)

Consider first the simple case of two charges q_1 and q_2 lying at points A and B with position vectors r_1 and r_2 relative to same origin. To calculate the electric potential energy of the two charges. We consider the charges q_1 and q_2 initially at infinity and determine the work done by an external agency to bring the charges to the given locations.

Suppose first the charge q_1 is brought from infinity to the point A. There is no external field against which work needs to be done, so work done in bringing q_1 from infinity to point A is zero. *(1 mark)*

Now, move charge q_2 from infinity to point B. When charge q_2 is moved, the electric field due to the charge q_1 at point A opposes it. Hence, work has to be done. The work done in bringing charge q_2 from infinity to the point B in the electric field of charge q_1 is given by

$$W = \begin{pmatrix}\text{Electric potential at} \\ \text{B due to charge } q_1\end{pmatrix} \times q_2$$

$$= \left(\frac{1}{4\pi\epsilon_0}\cdot\frac{q_1}{AB}\right)\cdot q_2$$ *(½ mark)*

Since, $AB = |\vec{r}_1 - \vec{r}_2| = r_{12}$

We have, $W = \dfrac{1}{4\pi\epsilon_0}\cdot\dfrac{q_1 q_2}{r_{12}}$ *(½ mark)*

This work done in bringing the two charges to their respective location is stored as the potential energy of the configuration of two charges.

$$\therefore \quad U = \frac{1}{4\pi\epsilon_0}\cdot\frac{q_1 q_2}{r_{12}}$$ *(½ mark)*

135.

Ans. The path difference between two light waves interfering at a point is given by -

Path difference $= \dfrac{xd}{D}$ *(½ mark)*

The distance of n^{th} bright band from central bright band is given by

$x_n = \dfrac{D}{d} n\lambda$ *(½ mark)*

Distance of first bright band ($n = 1$),

$x_1 = \dfrac{D}{d}\lambda$ *(½ mark)*

Similarly, distance of second bright band ($n = 2$),

$x_2 = \dfrac{D}{d} 2\lambda$ *(½ mark)*

$\therefore$ Band width $= B = x_2 - x_1 = \dfrac{D}{d} 2\lambda - \dfrac{D}{d}\lambda$

$= \dfrac{D}{d}\lambda\,(2 - 1) = \dfrac{D}{d}\lambda$ *(1 mark)*

Similarly, we can find distance between two consecutive dark band and it is called Band width and is given by

Band width $= \dfrac{D\lambda}{d}$

136.

Ans. For a particle in SHM velocity at any instant is $v = \sqrt{a^2 - x^2}$ *(½ mark)*

$\therefore \quad v_1 = \omega\sqrt{a^2 - x_1^2}$ and $v_2 = \sqrt{a^2 - x_2^2}$

$\therefore \quad v_1^2 = \omega^2(a^2 - x_1^2)$ and $v_2^2 = \omega^2(a^2 - x_2^2)$

$\therefore \quad \dfrac{v_1^2}{\omega^2} = (a^2 - x_1^2)$ ...(i)

and $\dfrac{v_2^2}{\omega^2} = (a^2 - x_2^2)$ ...(ii) *(½ mark)*

Subtracting equation (i) from equation (ii) gives,

$$\frac{v_1^2}{\omega^2} - \frac{v_2^2}{\omega^2} = x_2^2 - x_1^2$$

$$\frac{v_1^2 - v_2^2}{\omega^2} = x_2^2 - x_1^2$$

$$\therefore \quad \omega^2 = \frac{v_1^2 - v_2^2}{x_2^2 - x_1^2}$$

$$\omega = \sqrt{\frac{v_1^2 - v_2^2}{x_2^2 - x_1^2}}$$ *(½ mark)*

But $\omega = \frac{2\pi}{T}$ *(½ mark)*

$$\therefore \quad \frac{2\pi}{T} = \sqrt{\frac{v_1^2 - v_2^2}{x_2^2 - x_1^2}}$$

$$\therefore \quad T = 2\pi\sqrt{\frac{x_2^2 - x_1^2}{v_1^2 - v_2^2}}$$ *(1 mark)*

137.

Ans.

LED	Photo-diode
(1) It is forward biased pn-junction diode.	(1) It is special purpose reverse biased pn-junction diode.
(2) It emits light due to direct radioactive recombination of excess electron hole pairs.	(2) It generates charge carriers in response to photons and high energy particles.
(3) The intensity of the emitted light is directly proportional to the diode forward current.	(3) The photocurrent in the external circuit is proportional to the intensity of the incident radiation.

(3 points - 1 mark for each)

138.

Ans. (a)

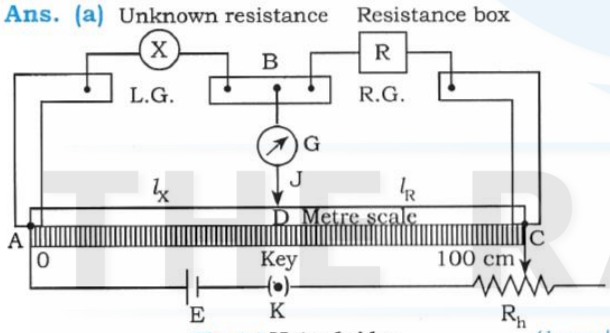


Fig. (a) Meter bridge *(1 mark)*

(b)

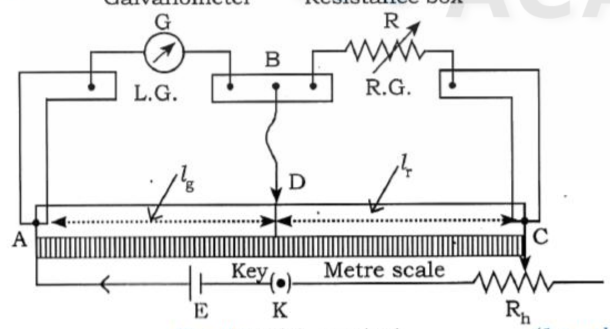


Fig. (b) Kelvin Method *(1 mark)*

(c)

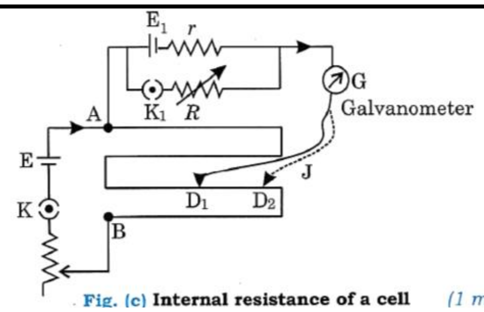


Fig. (c) Internal resistance of a cell *(1 mark)*

139.

Ans. ***Given:*** $v = 330$ m/s, $n_0 = 600$ Hz $L_0 = ?$ $L_c = ?$

For an open pipe, the fundamental frequency,

$$n_0 = \frac{v}{2L_0}$$ *(½ mark)*

$\therefore$ The length of an open pipe is

$$L_0 = \frac{v}{2n_0} = \frac{330}{2 \times 600}$$

$$= 0.275 \text{ m} = 27.5 \text{ cm}$$ *(1 mark)*

Now, it is given that,

$$\begin{pmatrix}\text{Frequency of} \\ \text{First overtone} \\ \text{of open pipe}\end{pmatrix} = \begin{pmatrix}\text{Frequency of} \\ \text{First overtone} \\ \text{of closed pipe}\end{pmatrix}$$

$$\therefore \quad 2\left(\frac{v}{2L_0}\right) = 3\left(\frac{v}{4L_C}\right)$$ *(½ mark)*

$$2 \times 600 = 3 \times \frac{330}{4L_C}$$

$$1200 = \frac{990}{4L_C}$$

$$\therefore \quad L_C = \frac{990}{4 \times 1200}$$

$$= 0.20625 \text{ m}$$

$$= 20.625 \text{ cm}$$ *(1 mark)*

140.

Ans. *Given:* F = 1N, A = 10^{-2} m², $v_0 = 2 \times 10^{-2}$ m/s

$y = 1.5 \times 10^{-3}$ m

To find: $\eta = ?$

$$\text{Velocity gradient} = \frac{dv}{dy} = \frac{2 \times 10^{-2}}{1.5 \times 10^{-3}} = \frac{40}{3} \text{ s}^{-1}$$ *(1 mark)*

$$\therefore \text{ Viscous force, } F = \eta\frac{dv}{dy}$$ *(½ mark)*

$$\therefore \quad \eta = \frac{F}{A(dv/dy)} = \frac{1\text{N}}{(10^{-2}\text{m}^2)\left(\frac{40}{3}\text{s}^{-1}\right)}$$ *(½ mark)*

$$= \frac{30}{4} \text{ N}\cdot\text{s/m}^2$$

$$\eta = 7.5 \text{ Pa.s or N}\cdot\text{s/m}^2$$ *(1 mark)*

141.

Ans. $T_{1/2} = 4.5 \times 10^9$ y

$= 4.5 \times 10^9 \times 3.16 \times 10^7$ s

$= 1.42 \times 10^{17}$ s *(½ mark)*

238 g of isotope contains Avogadro's number of atoms, and so 1 gm of $^{238}_{92}U$ contains

$$N = \frac{1}{238} \times 6.022 \times 10^{23} \text{ atoms/kmol}$$

$$\therefore \quad N = 25.3 \times 10^{20} \text{ atoms}$$ *(½ mark)*

The decay rate R is,

$$R = \lambda N$$ *(½ mark)*

$$= \frac{0.693}{T_{1/2}} N$$

$$= \frac{0.693 \times 25.3 \times 10^{20}}{1.42 \times 10^{17}} \text{ s}^{-1}$$ *(½ mark)*

$$= 1.23 \times 10^4 \text{ s}^{-1}$$

$$= 1.23 \times 10^4 \text{ Bq}$$ *(1 mark)*

142.

Ans. ***Data:*** C $= 20\ \mu\text{F} = 20 \times 10^{-6}$ F, $k = 2$

d $= 2$ mm $= 2 \times 10^{-3}$ m,

$t = 1$ mm $= 1 \times 10^{-3}$ m

To find: Capacitance when slab is inserted between the plates = ?

Formulae: (i) $C = \frac{A\varepsilon_0}{d}$ *(½ mark)*

and (ii) $C' = \frac{A\varepsilon_0}{d - t + \frac{t}{k}}$ *(½ mark)*

Dividing (ii) by (i), we get

$$\frac{C'}{C} = \frac{d}{d - t + \frac{t}{k}}$$

$$C' = \left[\frac{2 \times 10^{-3}}{\left(2 - 1 + \frac{1}{2}\right) \times 10^{-3}}\right] \times 20 \times 10^{-6}$$ *(1 mark)*

$$\therefore \quad C' = 26.67 \times 10^{-6} \text{ F} = 26.67\ \mu\text{F}$$

∴ The new capacitance is 26.67 µF *(1 ma*

143.

Ans. $\theta_1 = 0.20°$, $n_w = 1.33$

$D \sin \theta_1 = y_1$ and $D \sin \theta_2 = y_2$

$$\therefore \frac{\sin \theta_1}{\sin \theta_2} = \frac{y_1}{y_2} \quad \text{... (i)}$$ *(½ mark)*

$\therefore\ y\ \mu\ \frac{\lambda D}{d}$ so that given d and D, $y\ \mu\ \lambda$

$$\therefore \frac{y_2}{y_1} = \frac{\lambda_2}{\lambda_1} \quad \text{... (ii)}$$ *(½ mark)*

Also, $$n_w = \frac{\lambda_1}{\lambda_2} \quad \text{... (iii)}$$ *(½ mark)*

From eqn (i), (ii) and (iii) we get,

$$\therefore \frac{\sin \theta_2}{\sin \theta_1} = \frac{\lambda_2}{\lambda_1} = \frac{1}{n_w}$$ *(½ mark)*

$$\therefore \sin \theta_2 = \frac{\sin \theta_1}{n_w} = \frac{\sin (0.2)}{1.33} = \frac{0.0035}{1.33}$$

$$\therefore \sin \theta_2 = 0.0026$$

$$\therefore \theta_2 = \sin^{-1}(0.0026) = 9' = 0.15°$$ *(1 mark)*

This is the required angular fringe separation.

144.

Ans. ***Derivation:***

(i) Changing magnetic flux in a coil causes an induced emf.

(ii) The induced emf is produced opposes the change and hence the energy has spent to overcome it to built-up the magnetic field. *(½ mark)*

(iii) This energy may be recovered as heat in a resistance of the circuit.

(iv) The induced emf is given as $e = -L\frac{dI}{dt}$ *(½ mark)*

(v) The work done in moving a charge dq against this emf is

$$dw = -edq = L\frac{dI}{dt} \cdot dq = L \cdot \frac{dIdq}{dt}$$ *(½ mark)*

$$\therefore \quad dw = L \cdot IdI \quad \text{...} \left[\because \frac{dq}{dt} = I\right]$$ *(½ mark)*

Therefore, total work:

$$W = \int dw = \int_0^I LIdI = \frac{1}{2}LI^2 = U_B \quad \text{... (i)}$$ *(½ mark)*

(vi) Equation (i) gives the energy stored (U_B) in magnetic field and is analogous to the energy stored (U_E) in the electric field in a capacitor. *(½ mark)*

145.

Ans. • ***Diagram:***

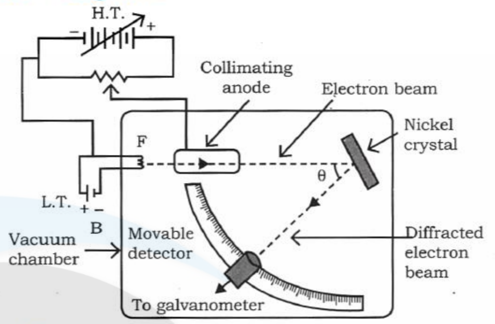


Fig. Schematic of Davission and Germer experiment

(Diagram - 1 mark)

- ***Construction:*** A schematic of the experimental arrangement of the Davisson and Germer experiment is shown in figure. The whole set-up is enclosed in an evacuated chamber. It uses an electron gun - a device to produce electrons by heating a tungsten filament F using a battery B. Electrons from the gun are accelerated through vacuum to a desired velocity by applying suitable accelerating potential across a cylindrical anode and are collimated into a focused beam. This beam of electrons falls on a nickel crystal and is scattered in different directions by the atoms of the crystal. Thus, in the Davisson and Germer experiment, electrons were used in place of light waves. *(1 mark)*
- ***Working:*** Scattered electrons were detected by an electron detector and the current was measured with the help of a galvanometer. By moving the detector on a circular scale that is by changing the scattering angle θ (angle between the incident and the scattered electron beams), the intensity of the scattered electron beam was measured for different values of scattering angle. Scattered intensity was not found to be uniform in all directions (as predicted by classical theory). The intensity pattern resembled a diffraction pattern with peaks corresponding to constructive interference and troughs to regions of destructive interference. Diffraction is a property of waves. Hence, above observations implied that the electrons formed a diffraction pattern on scattering and that particles could show wave-like properties. *(1 mark)*

146.

Ans. ***Perfect blackbody:*** A body which absorbs the entire radiant energy incident on it, is called an ideal or perfect black body. *(1 mark)*

In practice a simple arrangement illustrated in following figure which was designed by Ferry, can be used as a perfect black body. It consists of a double walled hollow sphere having tiny hole or aperture, through which radiant heat can enter (Fig.). The space between the walls is evacuated and outer surface of the sphere is silvered. The inner surface of sphere is coated with lamp-black. There is a conical projection on the inner surface of sphere opposite the aperture. The projection ensures that a ray travelling along the axis of the aperture is not incident normally on the surface and is therefore not reflected back along the same path. Radiation entering through the small hole has negligible chance of escaping back through the small hole. A heat ray entering the sphere through the aperture suffers multiple reflections and is almost completely absorbed inside. Thus, the aperture behaves like a perfect blackbody. *(1 mark)*

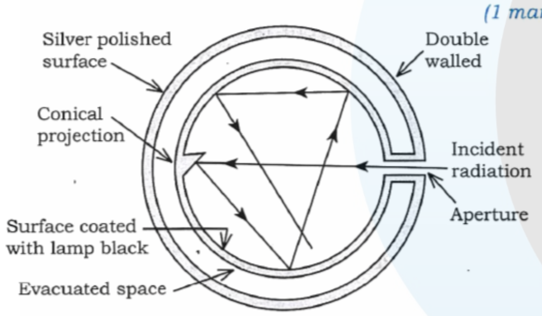


Fig. Ferry's Black body *(Diagram- 1 mark)*

147.

Ans.

(i) LC circuit is also called as a resonant circuit. It oscillates with the natural resonant frequency. *(½ mark)*

(ii) Therefore, natural frequency of LC circuit is the resonant frequency.

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$ *(1 mark)*

(iii) At resonance, as $X_L = X_C$ total reactance is given as

$|X_L - X_C| = 0$ ... ($\because X_L = X_C$) *(1 mark)*

(iv) Therefore, the reactance of the LC circuit at natural frequency is zero. *(½ mark)*

148.

Ans. • ***Construction:*** Moving Coil Galvanometer (MCG) consists of a coil of several turns mounted (suspended or pivoted) in such a way that it can freely rotate about a fixed axis, in a radial uniform magnetic field. A soft iron cylindrical core makes the field radial and strong. *(½ mark)*

• ***Working:*** The coil rotates due to a torque acting on it as the current flows through it. This torque is given by

$\tau = N\, I\, A.B$ ...(i) *(½ mark)*

where, A is the area of the coil,

B is the strength of the magnetic field,

N is the number of turns of the coil

and I is the current in the coil.

Here, $\sin\phi = 1$ as the field is radial (plane of the coil will always be parallel to the field). However, this torque is counter balanced by a torque due to a spring fitted as shown in the figure. *(½ mark)*

This counter torque balances the magnetic torque, so that a fixed steady current I in the coil produces a steady angular deflection ϕ. Larger the current is, larger is the deflection and larger is the torque due to the spring. If the deflection is ϕ, the restoring torque due to the spring is equal to $K\phi$ where K is the torsional constant of the spring.

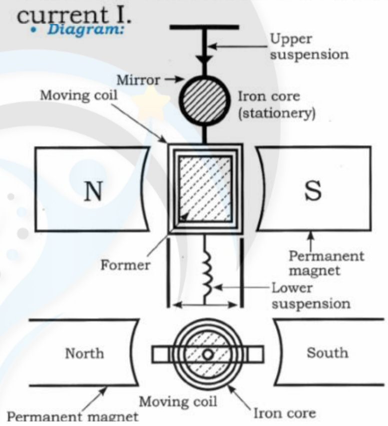
Thus, $K\phi = NIAB$,

and the deflection $\phi = \left(\frac{NAB}{K}\right) I$ ... (ii) *(½ mark)*

$\therefore \phi \propto I$

Thus the deflection ϕ is proportional to the current I.

• *Diagram:*



149.

Ans. Due to surface tension free liquid drops and bubbles are spherical in shape, if effect of gravity and air resistance are negligible. A bubble or drop does not collapse because the resultant of the external pressure and the force of surface tension is smaller than the pressure inside a bubble or drop i.e. $P_0 < P_1$.

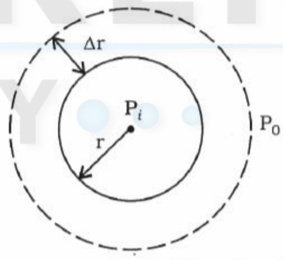


Fig. Excess pressure inside a liquid soap.

(Diagram - ½ mark)

Let P_i - be the pressure inside the bubble or drop.

P_0 - be the pressure outside the bubble or drop.

$\therefore$ Excess pressure = $P_i - P_0$ *(½ mark)*

Let radius of the drop increase from r to $(r + \Delta r)$ where Δr is very small, so that the inside pressure remains constant.

Initial surface area $(A_1) = 4\pi r^2$

Final surface area $(A_2) = 4\pi(r + \Delta r)^2$

$= 4\pi(r^2 + 2\Delta r \cdot r + \Delta r^2)^2$

As Δr is small therefore Δr^2 is neglected.

$\therefore \quad A_2 = 4\pi r^2 + 8\pi r \Delta r$

Increase in surface area (dA) = $A_2 - A_1$

$\therefore \quad dA = 4\pi r^2 + 8\pi r\Delta r - 4\pi r^2$

$dA = 8\pi r \Delta r$ *(½ mark)*

We know, $T = \dfrac{dw}{dA}$.

Work done in increase in surface area

i.e. $dw = TdA$

i.e. $dw = T \times 8\pi r \Delta r$ ...(i) *(½ mark)*

Excess pressure is given by

$$\text{Excess pressure} = \frac{\text{Excess force}}{\text{Area}}$$

i.e. Excess force = Excess pressure × Area

$dF = (P_i - P_0) \times 4\pi r^2$ ...(ii)

Work done due to excess force is

$dw = dF \times \Delta r$

$dw = (P_i - P_0)\, 4\pi r^2 \Delta r$ ...(iii)

(½ mark)

From equations (i) and (iii),

$(P_i - P_0) \times 4\pi r^2 \Delta r = T \times 8\pi r \Delta r$

$$\therefore \quad P_i - P_0 = \frac{2T}{r} \quad \text{...(iv)}$$ *(½ mark)*

This is Laplace's law of spherical membrane. Equation (iv) gives excess pressure inside a drop.

[**Note:** *In case of soap bubble there are two free surfaces in contact with air i.e.* $dA = 2 \times (8\pi r \Delta r)$

$$\therefore \quad P_i - P_0 = \frac{4T}{r} \quad \text{...(v)}$$

Equation (v) gives excess pressure inside a soap bubble.]

150.

Ans. • ***Mechanism of a refrigerator:***

(i) A refrigerator extracts heat from a cold region (inside the chamber, or the compartments) and delivers it to the surrounding (the atmosphere) thus, further cooling the cold region. *(½ mark)*

(ii) Figure shows the schematics of the mechanism used in a typical refrigerator. It consists of a compressor, an expansion valve, and a closed tube which carries the refrigerant. *(½ mark)*

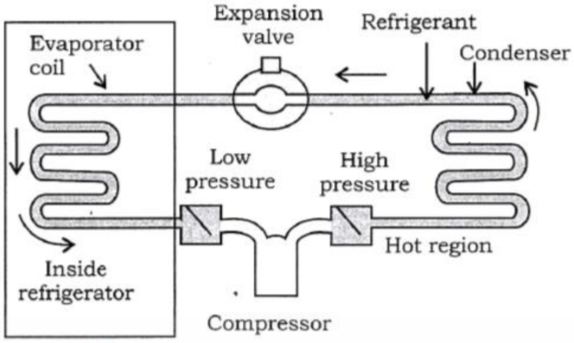


Fig. Schematics of a refrigerator.

(Diagram - 1 mark)

(iii) A fluid such as fluorinated hydrocarbons is used as refrigerant.

(iv) Part of the tube, called the cooling coil, is in the region which is to be cooled at lower temperature and lower pressure. *(½ mark)*

(v) The other part which is exposed to the surrounding (generally, the atmosphere) is at a higher temperature and higher pressure. *(½ mark)*

(vi) Normally, the cold and the hot part of the coil contain the refrigerant as a mixture of liquid and vapour phase in equilibrium.

151.

Ans. **(i)** ***Fundamental mode:***

The lowest frequency with which a string vibrate is called a fundamental frequency and the corresponding mode is called as fundamental mode. This mode contains only one loop as shown in fig. (a)

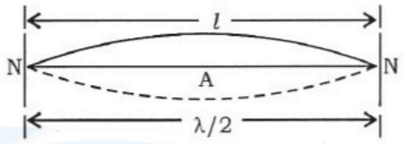


Fig.(a) Fundamental mode or first harmonic.

(Diagram - ½ mark)

Let l be the length of string, n and λ be the frequency and wavelength for this mode.

Length of loop = Length of vibrating string

$$\frac{\lambda}{2} = l \quad \Rightarrow \lambda = 2l$$

We know, $v = n\lambda$

$$n = \frac{v}{\lambda}$$

Substituting $v = \sqrt{\dfrac{T}{m}}$ and $\lambda = 2l$

$\lambda = l$

$$\text{we get} \quad n = \frac{\sqrt{\dfrac{T}{m}}}{2l}$$

$$\therefore \quad n = \frac{1}{2l}\sqrt{\frac{T}{m}} \quad \text{...(i)}$$ *(½ mark)*

This is the equation for fundamental frequency.

(ii) *First overtone:*

This mode contain two loops as shown in Fig. (b).

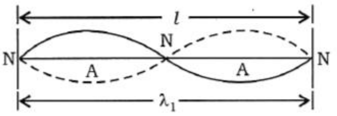


***Fig.(b)* First overtone** *(Diagram - ½ mark)*

Let l be the length of vibrating string.

Let n_1 and λ_1 be the frequency and wavelength for this mode respectively.

∴ Length of loop = Length of vibrating string

$$\lambda_1 = l$$

We know, $n_1 = \dfrac{v}{\lambda_1}$

Putting $v = \sqrt{\dfrac{T}{m}}$ and $\lambda_1 = l$, we get

$$n_1 = \frac{\sqrt{\dfrac{T}{m}}}{l}$$

∴ $n_1 = 2 \times \dfrac{1}{2l}\sqrt{\dfrac{T}{m}}$ ...(ii) *(½ mark)*

∴ $n_1 = 2n$

Thus, the first overtone is second harmonic.

151.

(iii) *Second overtone:*

This mode contain three loops as shown in Fig. (c).

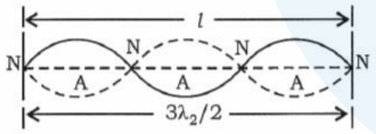


***Fig.(c)* Second overtone** *(Diagram - ½ mark)*

Let l be the length of vibrating string.

Let n_2 and λ_2 be the frequency and wavelength for this mode respectively.

∴ Length of loop = Length of vibrating string

$$\frac{3\lambda_2}{2} = l$$

$$\lambda_2 = \frac{2l}{3}$$

We know, $n_2 = \dfrac{v}{\lambda_2}$

Putting $v = \sqrt{\dfrac{T}{m}}$ and $\lambda_2 = \dfrac{2l}{3}$, we get

∴ $n_2 = \dfrac{\sqrt{\dfrac{T}{m}}}{2l/3}$

∴ $n_2 = 3 \times \dfrac{1}{2l}\sqrt{\dfrac{T}{m}}$ ...(iii)

∴ $n_2 = 3n$

Thus, the second overtone is third harmonic.

From equations (i), (ii) and (iii) we can say that all harmonic are present in case of a stretched string and the frequencies given by

$n_p = (p+1)\,n$ *(½ mark)*

152.

Ans. ***Given:*** $d = 100\lambda$, D = 50 cm.

To find:

(i) Angular separation between the central maximum and an adjacent minima (θ) = ?

(ii) Distance between maxima (X) = ?

Formula: (i) $\theta = \dfrac{\lambda}{d}$ (ii) $X = \dfrac{\lambda D}{d}$

(i) $\theta = \dfrac{\lambda}{d}$ *(½ mark)*

$= \dfrac{\lambda}{100\lambda} = \dfrac{1}{100}$

∴ θ = 0.01 rad. *(1 mark)*

(ii) $X = \dfrac{\lambda D}{d}$ *(½ mark)*

$= \theta \cdot D = 0.01 \times 50$

∴ X = 0.5 cm. *(1 mark)*

153.

Ans. • ***Diagram:***

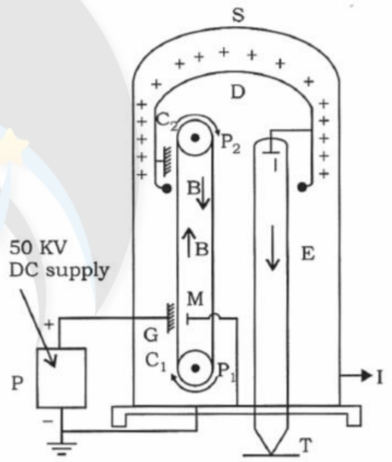


***Fig.* van de Graaff generator**

D	- Dome	T	- Target
$C_1 C_2$	- Metallic comb	M	- Earth metal plate
$P_1 P_2$	- Pulleys	E	- Gas discharge tube
I	- Iron cell		*(Diagram - 1 mark)*

• ***Construction:***

van de Graaff generator consist of hollow metallic sphere (D) of radius about 5 m. This sphere is called as **dome**. This dome is supported by two insulated support. Inside the dome there are two metallic combs C_1 and C_2.

Comb C_1 is connected to high voltage supply about 10,000 V and C_2 is connected to dome. There is a rubber belt which passes over two pulleys P_1 and P_2. Pulley P_1 is rotated using a motor, so that belt can rotate. Speed of belt is about 20 to 50 cm / sec. Inside the dome there is a gas discharge tube (E). In this tube charge particles are produced (e.g. proton, deuteron).Other end of tube is earthed and pointed on the target (T). *(1 mark)*

- ***Working:***

When motor connected to the pulley P_1 is switched on, the pulley begins to rotate and belt start rotating. Charges from metal comb C_1, are transfered to belt and moves in upward direction. Comb C_2 collects these charges and are then spread over the surface of the dome. These charges are stored on the surface of the dome.

To store maximum charges on the dome, it is enclosed in a metal (iron) shell containing high pressure gas about 15 atmosphere. Due to this high pressure gas, charge from the dome cannot leak and therefore potential of the dome increases to very large extent, about one million volt.

The charge particles are produced in the discharge tube E. Due to high P.D. between dome and target these charged particles travels towards target with very high speed and strikes on the target. *(1 mark)*

154.

Ans. • ***Individual Method:***

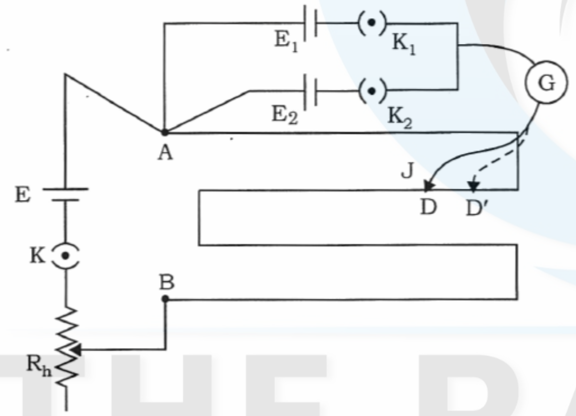


Fig. *Potentiometer*

- ***Notations:***

AB - Potentiometer wire J - Jockey
E - Battery G - Galvanometer
E_1, E_2 - Cells R_h - Rheostat
K, K_1, K_2 - Keys *(Diagram - 1 mark)*

- ***Construction:***

The experimental circuit of potentiometers is as shown in the figure. A battery having emf E greater than E_1 and E_2 is connected between A and B of the wire with a plug key K_1 and K_2. Series combination of cell E, plug key K and rheostat R_h. On closing the key, a steady current flows through the wire. A jockey J is connected to common terminal of K_1 and K_2 through galvanometer.

- ***Working:***

First of all close the circuit and check the deflection in galvanometer on both side of zero by touching jockey to A and B terminal of wire AB.

(i) Now close key K and K_1 and open K_2. Therefore the cell of emf E_1 comes into circuit. The null point D is obtained by touching the jockey at various points on the wire AB such that galvanometer shows null deflection. Measure length of wire AD. Let AD = l_1.

By principle of potentiometer,

$$E_1 \propto l_1$$

$$E_1 = (\text{constant})\, l_1 \qquad \ldots\text{(i)}$$ *(1 mark)*

(ii) Similarly close key K and K_2 and open K_1. Therefore the cell of emf E_2 comes into circuit. The null point D′ is obtained by touching the jockey at various points on wire AB. Measure length of wire AD′. Let AD′ = l_2.

By principle of potentiometer,

$$E_2 \propto l_2$$

$$E_2 = (\text{constant})\, l_2 \qquad \ldots\text{(ii)}$$

Dividing equation (i) by (ii), we get

$$\frac{E_1}{E_2} = \frac{l_1}{l_2}$$ *(1 mark)*

155.

Ans. • ***Principle:*** When a coil carrying an electric current is suspended in a uniform magnetic field, a torque acts on it. This torque tends to rotate the coil about the axis of suspension so that the magnetic flux passing through the coil is maximum. *(1 mark)*

- ***Diagram:***

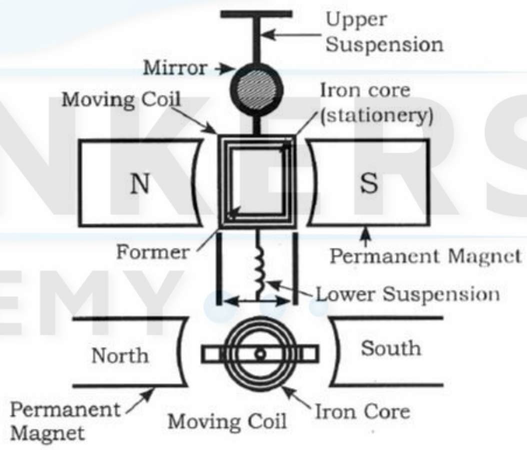


Fig. *Moving Coil Galvanometer (M. C. G.)* *(1 mark)*

- ***Construction:*** A rectangular coil of thin insulated copper of N-turns wound over a non-magnetic frame. It is suspended between the concave poles of strong horse shoe magnet. The lower end of the coil is connected to a light spring. The current enters the coil through the fiber and leave through the spring.

A small mirror attached to the suspension wire is used to measure the deflection of the coil by lamp and scale arrangement. The upper end of the wire is connected to a rotating screw head so that plane of the coil can be adjusted in any desired position. A soft iron cylinder is fixed inside the coil such that the coil rotate freely between the poles of the magnet and the concave pole pieces. Soft iron cylinder produces strong radial magnetic field. The soft iron cylinder increases the strength of the magnetic field. *(1 mark)*

156.

Ans. ***Given:*** $M = 2 \times 10^{-2}\ Am^2$, $I = 7.2 \times 10^{-7}\ kg\ m^2$,

$$T = \frac{6}{10} = \frac{3}{5}\ sec$$

...(As there are 10 oscillations per 6 sec.)

To find: Magnetic field (B) = ?

Formula: $T = 2\pi\sqrt{\frac{I}{MB}}$ *(1 mark)*

Squaring and rearranging, we get

$$B = \frac{4\pi^2 I}{MT^2}$$

$$= \frac{4 \times (3.142)^2 \times 7.2 \times 10^{-7}}{2 \times 10^{-2} \times \left(\frac{3}{5}\right)^2}$$ *(1 mark)*

$$= \frac{4 \times 9.872 \times 7.2 \times 10^{-7} \times 25}{2 \times 10^{-2} \times 9}$$

$\therefore$ B = $3.948 \times 10^{-3}\ Wb/m^2$. *(1 mark)*

157.

Ans. ***Given:*** P_{av} = 100 W, e_{rms} = 220 V, f = 50 Hz.

To find: (i) Resistance (R) = ?

(ii) rms current (i_{rms}) = ?

Formulae: (i) $P_{av} = e_{rms} \times i_{rms}$

(ii) $i_{rms} = \frac{e_{rms}}{R}$

From formula (i),

$$P_{av} = e_{rms} \times i_{rms}$$ *(½ mark)*

$$100 = 220 \times i_{rms}$$

$$\therefore \quad i_{rms} = \frac{100}{220} = \frac{10}{22}$$

$$i_{rms} = 0.4545\ A$$ *(1 mark)*

From formula (ii),

$$\therefore \quad R = \frac{e_{rms}}{i_{rms}}$$ *(½ mark)*

$$= \frac{220}{0.4545} = 484\ \Omega$$ *(1 mark)*

158.

Ans. ***Given:*** $E = 5 \times 10^{-21}$ J, $m_n = 1.67 \times 10^{-27}$ kg.

To find: (i) Speed of neutron (v) = ?

(ii) Wavelength of neutron (λ) = ?

Formulae: **(i)** $E = \frac{1}{2} m_n v^2$ **(ii)** $\lambda = \frac{h}{m_n v}$

(i) $E = \frac{1}{2} m_n v^2$

$$\therefore \quad v = \sqrt{\frac{2E}{m_n}}$$ *(½ mark)*

$$= \sqrt{\frac{2 \times 5 \times 10^{-21}}{1.67 \times 10^{-27}}}$$ *(½ mark)*

$$= \frac{10^{-10}}{\sqrt{1.67 \times 10^{-27}}} = 0.2447 \times 10^4\ m/s$$

$\therefore$ $v = 2.45 \times 10^3$ m/s *(½ mark)*

(ii) $\lambda = \frac{h}{m_n v}$ *(½ mark)*

$$= \frac{6.63 \times 10^{-34}}{1.67 \times 10^{-27} \times 2.45 \times 10^3}$$ *(½ mark)*

$$= \frac{6.63 \times 10^{-34}}{1.67 \times 2.45} \times 10^{-10}$$

$$= 1.620 \times 10^{-10}\ m$$

$\therefore$ λ = 1.62 Å *(½ mark)*

159.

Ans. ***Given:*** Z = 95, N(p) = 95, N(n) = 224 – 95 = 149

M = 244.06428 u, 1 u = 931.5 MeV/C^2

m_p = 1.00728 u, m_n = 1.00866 u

To find: B.E. per nucleon $\frac{E_B}{A}$ = ?

The binding energy per nucleon,

$$\frac{E_B}{A} = \frac{(Zm_p + Nm_n - M)C^2}{A}$$ *(1 mark)*

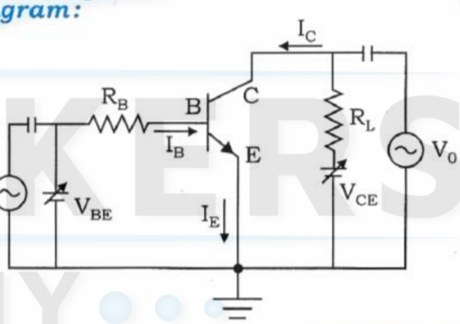
$$= \left(\frac{95 \times 1.00728 + 147 \times 1.00866 - 244.06428}{244}\right)C^2$$ *(½ mark)*

$$= \left(\frac{95.6916 + 150.29034 - 244.06428}{244}\right) \times 931.5\ MeV$$ *(½ mark)*

$$\therefore \quad \frac{E_B}{A} = 7.3209\ MeV/nucleon$$ *(1 mark)*

160.

Ans. • ***Diagram:***



(Diagram - 1 mark)

• ***Working:***

The circuit of an amplifier using a n-p-n transistor in common emitter configuration is as shown in the above figure.

When the input voltage V_{in} is not applied, by applying KVL to the output loop, we can write

$$V_{CC} = V_{CE} + I_C R_L$$

Similarly, for input loop, we have

$$V_{BB} = V_{BE} + I_B R_B$$

When input AC signal is applied, V_{in} is not zero.

Thus, the potential across the input loop will be,

$V_{BB} + V_{in} = V_{BE} + I_B R_B + \Delta I_B(R_B + r_i)$ ...(i)

(½ mark)

The AC signal applied adds the current of ΔI_B to the original current flowing through the circuit. Therefore the additional potential in the input loop will be across resistor R_B i.e. $\Delta I_B R_B$ and across the input dynamic resistance of the transistor (= $\Delta I_B r_i$)

From equation(i)

$V_{in} = \Delta I_B (R_B + r_i)$

$\therefore \quad V_{in} = \Delta I_B r_i$ ...(ii)

...(As R_B is very small, neglecting R_B)

(½ mark)

The changes in the base current I_B cause changes in the collector current I_C. This changes potential across the load resistance because V_{CC} is constant. We can write,

$\Delta V_{CC} = \Delta V_{CE} + I_C R_L = 0$

$\therefore \quad \Delta V_{CE} = -I_C R_L$

The change in output voltage ΔV_{CE} is the output voltage V_0 hence we can write,

$V_0 = \Delta V_{CE} = \beta_{AC} R_L \Delta I_B$ *(1 mark)*

Sure shots (4 Marks) Solution

161.

Ans. • ***Ideal Simple Pendulum:*** An ideal simple pendulum is a heavy particle suspended by a massless, inextensible, flexible string from a rigid support. *(1 mark)*

• ***Expression for period of simple pendulum:***

Consider a simple pendulum of length L.

Let m be the mass of bob and is balanced by the tension in the string (T').

If the bob is in displaced position with very small angle θ, then the displacement x of the bob may be treated as a straight line. When the bob is at B, the forces acting on bob are:

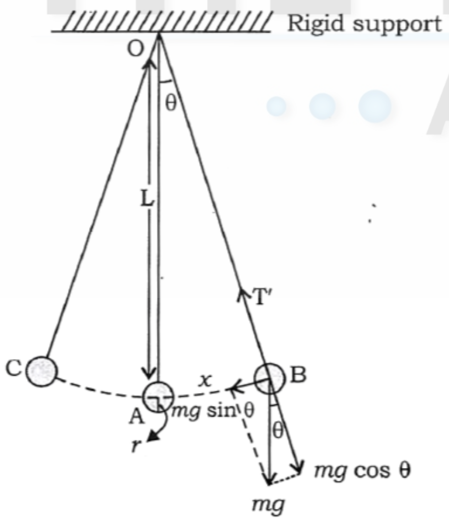


Fig. Simple pendulum

(i) the weight of bob (mg) acting vertically downwards.

(ii) the tension (T') in the string acting along BO.

The weight mg resolved into two components.

(a) $mg\sin\theta$ - perpendicular to the string

(b) $mg\cos\theta$ - along the string balanced by T'.

(½ mark)

The $mg\sin\theta$ is along tangent to arc at B.

The force tries to restore the bob. It opposes to the angular displacement θ.

$\therefore$ Restoring force (F) = $-mg\sin\theta$

$\therefore$ F = $-mg\theta$ ...(As θ is small $\sin\theta = \theta$)

From figure,

$\theta = \frac{\text{arc AB}}{\text{radius}} = \frac{x}{L}$ ...(i) *(½ mark)*

$\therefore \quad F = -mg\frac{x}{L}$

But, $F = ma$

$\therefore$ Equation (i) becomes,

$ma = -mg\frac{x}{L}$

$\therefore \quad a = -g\frac{x}{L}$ ...(ii)

We know,

Acceleration (a) = $-\omega^2 x$ *(½ mark)*

$\therefore$ Equation (ii) becomes,

$-\omega^2 x = -g\frac{x}{L}$

$\therefore \quad \omega = \sqrt{\frac{g}{L}}$

The equation for the period is

$T = \frac{2\pi}{\omega}$

$= \frac{2\pi}{\sqrt{g/L}}$

$\therefore$ Period (T) = $2\pi\sqrt{\frac{L}{g}}$ ...(iii) *(½ mark)*

From Eqn (iii)

Period of simple pendulum depends on the length of the pendulum and acceleration due to gravity. *(½ mark)*

162.

Ans. When the stationary waves are produced in a pipe closed at one end, a node is formed at the closed end and anti-node is formed at open end. This is called as boundary condition.

The different modes of vibrations are as follows:

(i) Fundamental mode of vibration:

The first mode of vibration of air column closed at one end is called fundamental mode. This mode contains half loop as shown in Fig. (a).

Let l be the length of pipe.

$L = l + e$

where,

$e \rightarrow$ be the end correction.

$n \rightarrow$ be the frequency of first mode,

$\lambda \rightarrow$ be the wavelength.

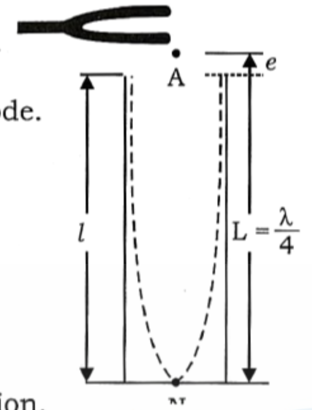


Fig. (a)

(Diagram - ½ mark)

$\because$ (Length of air column) = (Length of loop)

$$L = \frac{\lambda}{4}$$

$$\therefore \lambda = 4L$$

We know,

$$v = n\lambda$$

$$n = \frac{v}{\lambda} = \frac{v}{4L}$$

$$n = \frac{v}{4(l+e)} \quad \text{...(i)}$$ *(½ mark)*

where $L = l + e$

This is the frequency of fundamental mode or first harmonic.

(ii) First overtone:

This mode contains one full loop and one half loop as shown in Fig. (b).

$n_1 \rightarrow$ be the frequency

$\lambda_1 \rightarrow$ be the wavelength

$\because$ (Length of air column) = (Length of loop)

$$L = \frac{3\lambda_1}{4}$$

$$\therefore \lambda_1 = \frac{4L}{3}$$

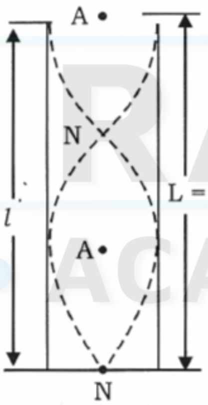


Fig. (b)

(Diagram - ½ mark)

We know,

$$n_1 = \frac{v}{\lambda_1}$$

$$n_1 = \frac{v}{4L/3}$$

$$n_1 = 3\frac{v}{4L}$$

$$n_1 = 3n \quad \text{...(ii)}$$ *(½ mark)*

Thus, the first overtone is third harmonic (and 2^{nd} harmonic is absent).

(iii) Second overtone: This mode contain two full loops and one half loop as shown in Fig. (c).

$n_2 \rightarrow$ be the frequency

$\lambda_2 \rightarrow$ be the wavelength

$\because$ (Length of air column) = (Length of loop)

$$L = \frac{5\lambda_2}{4}$$

$$\therefore \lambda_2 = \frac{4L}{5}$$

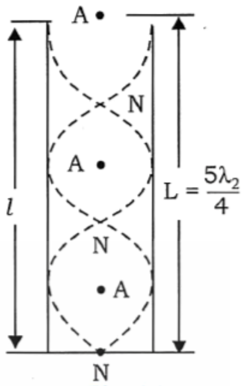


Fig. (c)

(Diagram - ½ mark)

We know,

$$n_2 = \frac{v}{\lambda_2}$$

$$n_2 = \frac{v}{4L/5}$$

$$n_2 = 5\frac{v}{4L}$$

$$n_2 = 5n \quad \text{...(iii)}$$

Thus, the second overtone is 5^{th} harmonic (and 4^{th} harmonic is absent).

Continuing in similar way, for p^{th} overtone the frequency n_p is

$$n_p = (2p+1)n$$

Thus, for a pipe closed at one end only odd harmonics are present. *(½ mark)*

- ***Problem:***

Given: $n_0 = 440$ Hz

To find: n_1 and $n_2 = ?$

Formula: $n_p = (p+1)n_0$

$\therefore \quad n_1 = (1+1) \times 440$

$= 880$ Hz *(½ mark)*

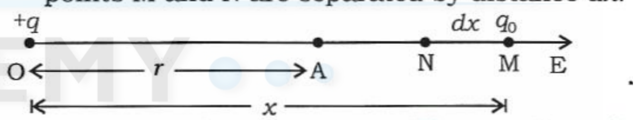
Similarly $n_2 = (2+1) \times 440$

$= 1320$ Hz *(½ mark)*

163.

Ans. • ***Relation between electric intensity and electric potential:***

Consider a point charge $+q$ at point 'O'. The points M and N are separated by distance dx.



(Diagram - ½ mark)

Let q_0 be the test charge at point M. When it is displaced from M to N small work is done and it is given by

$$dw = -F\,dx \quad \text{...(i)}$$

Negative sign indicates force and displacement are in opposite direction.

By definition of electric intensity

$$E = \frac{F}{q_0}$$

$$F = E q_0$$ *(½ mark)*

∴ Equation (i) becomes

$$dw = -E q_0 dx$$

$$\frac{dw}{q_0} = -E dx$$ *(½ mark)*

$$\therefore \quad dV = -E dx, \quad \text{where } dV = \frac{dw}{q_0}$$

$$\therefore \quad E = -\frac{dV}{dx}$$ *(½ mark)*

Thus the electric intensity at a point in an electric field is the negative potential gradient at that point.

- ***Problem:***

Given: $C = 20\mu F$, $d' = 2d$

To find: New capacitance (C′) = ?

Formula: $C = \frac{A\varepsilon_0 k}{d}$ …(i) *(½ mark)*

The distance between plates is double

∴ $d' = 2d$

∴ The new capacitance is

$$C' = \frac{A\varepsilon_0 k}{d'} = \frac{A\varepsilon_0 k}{2d}$$ …(ii) *(½mark)*

Dividing equation (ii) by (i),

$$\frac{C'}{C} = \frac{A\varepsilon_0 k}{2d} \times \frac{d}{A\varepsilon_0 k}$$

$$C' = \frac{1}{2}C = \frac{1}{2} \times 20$$

∴ $C' = 10\mu F$ *(1 mark)*

164.

Ans. • ***Advantages of a potentiometer over a voltmeter:***

(i) Potentiometer is more sensitive than a voltmeter. *(½ mark)*

(ii) A potentiometer can be used to measure a potential difference as well as emf of a cell. A voltmeter always measures terminal potential difference and as it draws some current, it cannot be used to measure an emf of a cell. *(½ mark)*

(iii) Measurement of P.D. or emf is very accurate in the case of a potentiometer as compare to voltmeter. *(½ mark)*

(iv) A potentiometer is used to measure a very small P.D. of order 10^{-6} volt and to determine internal resistance of a cell while a voltmeter can not be used to measure small PD and to determine internal resistance of a cell. *(½ mark)*

- ***Problem:***

Given: $S = 3\Omega$, $G = 297\Omega$.

To find: Fraction of current $\left(\frac{I_g}{I}\right)$ = ?

Formula: $I_g G = (I - I_g) S$ *(½ mark)*

From formula,

$$\frac{G}{S} = \frac{I - I_g}{I_g} = \frac{I}{I_g} - 1$$

$$\frac{G}{S} + 1 = \frac{I}{I_g}$$

$$\therefore \quad \frac{G+S}{S} = \frac{I}{I_g}$$

$$\therefore \quad \frac{I_g}{I} = \frac{S}{S+G}$$

$$= \frac{3}{3+297}$$ *(½ mark)*

$$\therefore \quad \frac{I_g}{I} = \frac{3}{300} = \left[\frac{3}{300} \times 100\right]\%$$

$$\therefore \quad \frac{I_g}{I} = 1\%$$ *(1 mark)*

The fraction of current passing through the galvanometer is 1%.

165.

Ans. Let PQ be a plane reflecting surface. A plane wavefront AB bounded by two parallel rays EA and FC is incident on the surface PQ.

AB touches the surface PQ at point A at $t = 0$. According to Huygen's principle point A acts as secondary source and emit secondary waves in the same medium. Draw normal AN to surface PQ.

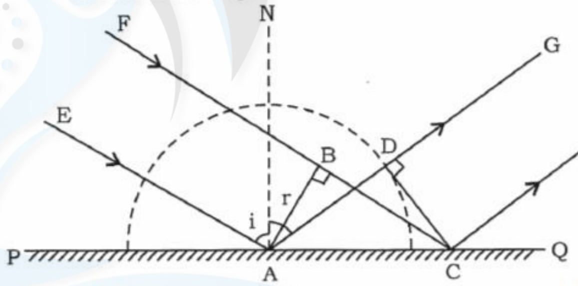


Fig. Reflection at a plane surface *(1 mark)*

Let the incident wavefront move from the point B to C in time $t = T$ with velocity v.

∴ $BC = vT$

During, the same time, the secondary wave starting from A will travel the same distance vT. Taking A as center and vT as radius, draw semi circle. Then draw tangent CD to this semi circle. Hence CD represent the reflected wavefront bounded by AG and CH i.e. $AD = vT$.

Let $\angle EAN = i$ = Angle of incidence and

$\angle NAD = r$ = Angle of reflection. *(½ mark)*

In ΔABC and ΔADC,

AC	≅	AC	...(Common)
AD	≅	BC = vT	...(Construction)
∠BAC	≅	∠ADC = 90°	
∴ ΔABC	≅	ΔADC	
∠BAC	≅	∠DCA	...(CACT)...(i) *(½ mark)*

From figure,

$$i + \angle NAB = 90°$$

$$\angle NAB + \angle BAC = 90°$$

Comparing above equations,

$$\angle BAC = i \quad ...(ii)$$

Also,

$$r + \angle DAC = 90°$$

$$\angle DAC + \angle DCA = 90°$$

Comparing above equations,

$$\angle DCA = r \quad ...(iii)$$

Putting the values of equations (ii) and (iii) in equation (i), we get

$$i = r$$ *(1 mark)*

i.e. Angle of incidence = Angle of reflection

- ***Laws of Reflection:***

(i) Angle of incidence is equal to angle of reflection.

(ii) The incident ray, reflected ray and normal lies in the same plane.

(iii) The incident ray and reflected ray lies on the opposite side of normal. *(1 mark)*

166.

Ans. When a zener diode is operated in the breakdown region, voltage across it remains almost constant even if the current through it changes by a large amount. A voltage regulator maintains a constant voltage across a load regardless of variations in the applied input voltage and variations in the load current. Following figure shows a typical circuit diagram of a voltage regulator using a zener diode.

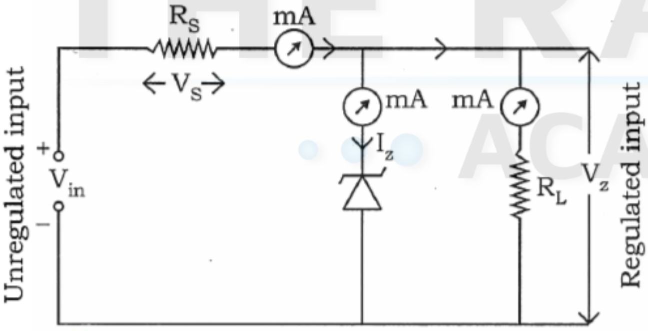


Fig. Voltage regulator using a Zener diode

(Diagram - 1 mark)

A zener diode of breakdown voltage V_Z is connected in reverse bias to an input voltage source V_i. The registor R_S connected in series with the zener diode limits the current flow through the diode. The load resistance R_L is connected in parallel with the zener diode, so that the voltage across R_L is always the same as the zener voltage ($V_R = V_Z$) *(1 mark)*

Variations in the applied input voltage: When the input voltage increases, the voltage across the series resistance R_S also increases. This causes an increase in the current through the load resistance remains constant. Hence the output voltage remains constant irrespective of the change in the input voltage. *(½ mark)*

Variations in the load current: When the input voltage is constant but the load resistance R_L decreases. The load current increases. This extra current cannot come from the source because the drop across R_S will not change as the zener is within its regulating range. The additional load curret is due to a decrease in the zener current I_Z.

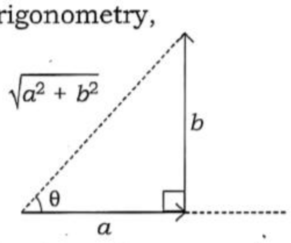
(½ mark)

When load is infinite ($R_L \to \infty$): When there is no load in the circuit, the load current will be zero ($I_1 = 0$) and all the circuit current passes through the zener diode. This results in maximum dissipation of power across the zener diode. Similarly, a small value of R_S results in a large diode current when R_L of the large value is connected across it. This will increases the power dissipation requirement of the diode. The value of R_S is so selected that the maximum power rating of the zener diode is not exceeded when there is not load or when the load is very high. *(½ mark)*

Thus, the voltage across the zener diode remains constant at its breakdown voltage V_Z for all the values of zener current I_Z as long as the current persists in the breakdown region. Hence, a resulated DC output voltage $V_0 = V_Z$ is obtained across R_L whenever the input voltage remains within a minimum and maximum voltage. *(½ mark)*

167.

Ans. Using trigonometry,



From the above diagram,

$$\frac{a}{\sqrt{a^2+b^2}} = \cos\theta, \text{ and } \frac{b}{\sqrt{a^2+b^2}} = \sin\theta$$ *(½ mark)*

Displacement of a particle performing oscillation,

$x = a\sin\omega t + b\cos\omega t$ *(½ mark)*

$$= \sqrt{a^2+b^2}\left[\frac{a}{\sqrt{a^2+b^2}}\sin\omega t + \frac{b}{\sqrt{a^2+b^2}}\cos\omega t\right]$$

$$= \sqrt{a^2+b^2}\,[\cos\theta\sin\omega t + \sin\theta\cos\omega t]$$

$$= \sqrt{a^2+b^2}\,\sin(\omega t + \theta)$$ *(½ mark)*

On comparing it with general equation of SHM

$x = A\sin(\omega t + \phi)$ we get

Amplitude as, $A = \sqrt{a^2+b^2}$ *(½ mark)*

- ***Numerical:***

Given: $m = 50$ kg, $x = 20$ cm $= 0.2$ m,

$T = 0.6$ sec.

To find: Weight $W = mg = ?$

We have, $T = 2\pi\sqrt{\frac{m}{k}}$ *(½ mark)*

Since, $f = mg$

$= 50 \times 9.8 = kx$

$\therefore k = \frac{50 \times 9.8}{0.2} = 2450\ \text{Nm}^{-1}$ *(½ mark)*

From formula,

$m = \frac{T^2k}{4\pi^2} = \frac{(0.6)^2 \times 2450}{4 \times 9.87}$

$= 22.34$ kg *(½ mark)*

$\therefore W = mg = 22.34 \times 9.8$

$= 219$ N

$\therefore$ The weight of the body is 219 N *(½ mark)*

168.

Ans. • ***Numerical:***

Given: $H = 1200\ \text{Am}^{-1}$, $\chi = 599$

To find: $\mu = ?$, $B = ?$

Permeability, $\mu = \mu_0(1 + \chi)$ *(½ mark)*

$= 4\pi \times 10^{-7} \times (1 + 599)$

$\mu = 7.536 \times 10^{-4}\ \text{T mA}^{-1}$ *(½ mark)*

Magnetic field, $B = \mu H$ *(½ mark)*

$= 7.536 \times 10^{-4} \times 1200$

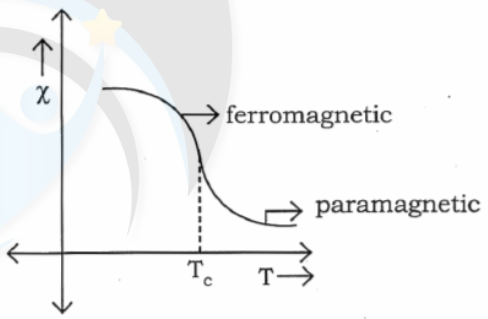
$\therefore B = 0.904$ T *(½ mark)*

- ***Variation of magnetic susceptibility:***

An increase in the temperature of a ferromagnetic material weakens the exchange coupling between neighbouring moments which results in the domain structure setting distorted. At a certain temperature, depending upon the material. The domain structure collapses totally and the material behaves like paramagnetic material. The temperature at which a ferromagnetic material behaves like paramagnetic material transforms into a paramagnetic substance is called **Curie temperature** (T_c) of that material. The relation between the magnetic susceptibility of a material when it has acquired paramagnetic property and the temperature T is given by

$$\chi = \frac{C}{T - T_c} \text{ for } T > T_c \quad \dots \text{(i)}$$ *(1 mark)*

where C is a constant.



(Graph- 1 mark)

169.

Ans. • ***Numerical:***

Given: $V = 120$ V

To find: de-Broglie wavelength of electron $\lambda = ?$

$\therefore \lambda(\text{nm}) = \frac{1.228}{\sqrt{V}}$ *(½ mark)*

$\lambda = \frac{1.228}{\sqrt{120}} = \frac{1.228}{10.954}$

$\lambda = 0.1121$ nm *(½ mark)*

The de-Broglie wavelength of electron is 0.1121 nm.

- ***Types of electron emission:***

Depending on the physical ways to provide the energy to the electrons to know them off the metal surface; there are following type of emissions.

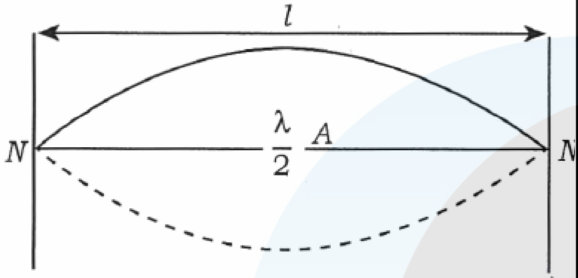
(i) Thermionic emission: Carried out by heating the metal to temperatures ≈ 2000°C i.e. by providing thermal energy. *(1 mark)*

(ii) Field emission: Carried out by establishing strong electric fields ≈ 10^6 V/m at the surface of a metal tip i.e. by providing electrical energy. *(1 mark)*

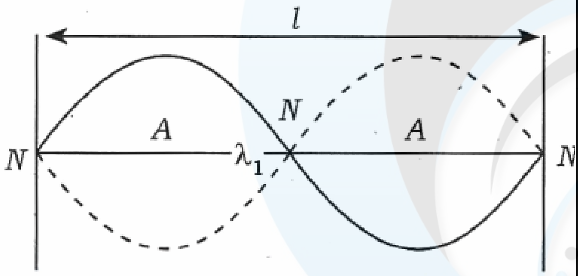
(iii) Photoelectron emission: Carried out by shining radiation of suitable frequency (ultraviolet or visible) on a metal surface i.e. by providing light energy. *(1 mark)*

170.

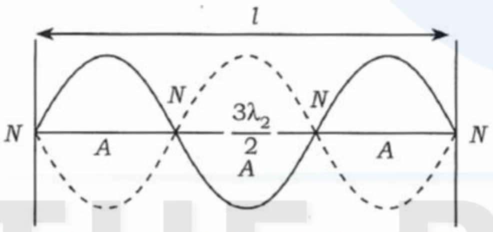
Ans.



(a) Fundamental mode or first harmonic



(b) First overtone or second harmonic



(c) Second overtone or third harmonic

Fig. Different modes of vibrations of a stretched string.

(Diagram - ½ mark each)

Consider a string of length 'l' stretched between two rigid supports. Let the linear density is m and T be the tension acts on the string due to stretching. A string is made to vibrate by plucking up any point.

The different modes of vibrations are as shown in above figure. Stationary waves are observed in the string due to the reflection of wave form rigid end which are displaced nodes.

The velocity of transverse wave in the string is given by

$$v = \sqrt{\frac{T}{m}} \quad \ldots(i) \quad (½\ mark)$$

A simple mode of vibration consisting of one loop called as fundamental mode. If n and λ are the frequency and wavelength of fundamental mode then,

$$l = \frac{\lambda}{2}$$

$$\therefore \quad \lambda = 2l$$

$$\because \quad v = n\lambda$$

$$n = \frac{v}{\lambda} = \frac{\sqrt{T/m}}{2l}$$

$$n = \frac{1}{2l} = \sqrt{\frac{T}{m}} \quad \ldots(ii) \quad (½\ mark)$$

This is equation for fundamental frequency.

The next possible mode of vibrations consisting of two loops pattern called as second harmonics or first overtone. If n_1 and λ_1 are the frequency and wavelength of second harmonics, then

$$l = 2 \cdot \frac{\lambda_1}{2}$$

$$\lambda_1 = \frac{2l}{2} = l$$

$$\therefore \quad n_1 = \frac{v}{\lambda_1} \frac{\sqrt{T/m}}{l}$$

$$\therefore \quad n_1 = 2 \cdot \frac{1}{2l}\sqrt{\frac{T}{m}} \quad \ldots(iii)$$

From (ii) and (iii)

$$n_1 = 2n \quad \ldots(iv) \quad (½\ mark)$$

Similarly, a three loops pattern is calld third harmonics or second overtone. If n_2 and λ_2 are the frequency and wavelength of second overtone, then,

$$l = 3 \cdot \frac{\lambda_2}{2}$$

$$\therefore \quad \lambda_2 = \frac{2l}{3}$$

$$\therefore \quad n_2 = \frac{v}{\lambda_2} = \frac{\sqrt{T/m}}{2l/3}$$

$$\therefore \quad n_2 = 3 \times \frac{1}{2l}\sqrt{\frac{T}{m}} \quad \ldots(v)$$

From (ii) and (v)

$$n_2 = 3n \quad \ldots(vi) \quad (½\ mark)$$

From equations (ii), (iv) and (vi), the possible frequencies are n, $2n$, $3n$ ....

Hence, all (even as well odd) harmonics are present as overtones in mode of vibration of string. *(½ mark)*

171.

Ans. (a) The necessity of radius of gyration:

(i) To measure the distribution of masses in a body about the given axis of rotation. *(½ mark)*

(ii) To measure moment of inertia of the body of any shape. *(½ mark)*

(b) Definition:

Radius of gyration of a body about an axis of rotation is the distance between the axis of rotation and a point at which the whole mass of the body is supposed to be concentrated so as to have the same moment of inertia as that of the body about the same axis of rotation. *(½ mark)*

(c) Factors on which it depends:

(i) Shape and size of the body.

(ii) Position and configuration of axis of rotation.

(iii) Distribution of masses in the body with respect to axis of rotation.

(iv) Moment of inertia of the body. *(1 mark)*

(d) Factors on which it does not depend:

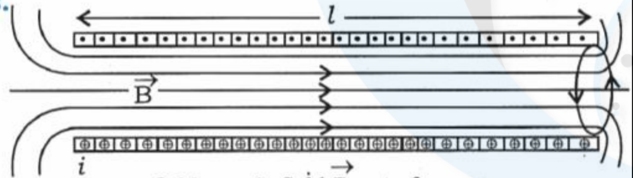
Mass of the body *(½ mark)*

(e) Axis of rotation of a body passing through centre of mass and radius of gyration are parallel to each other. *(½ mark)*

(f) No, K is not same for a ring and a disc. *(½ mark)*

172.

Ans.



⊙ Magnetic field $\vec{B}$ out of paper

⊕ Magnetic field $\vec{B}$ into the paper

Fig. A current carrying solenoid produces uniform magnetic field in the interior region

(Diagram - 1 mark)

Consider a long solenoid having length and cross-section area A and carrying a current. Volume associated with the solenoid = A × l

The energy stored will be uniformly distributed within the volume, as the magnetic field $\overline{B}$ is uniform everywhere inside the solenoid.

Thus, the energy stored, per unit volume in the magnetic field is,

$$u_B = \frac{U_B}{A \cdot l} \quad \text{... (i)} \qquad \textit{(½ mark)}$$

We know energy stored in magnetic field is

$$U_B = \frac{1}{2}LI^2$$

$$\therefore \quad u_B = \frac{1}{2}LI^2 \times \frac{1}{A \cdot l} = \left(\frac{L}{l}\right)\frac{I^2}{2A} \quad \text{... (ii)} \qquad \textit{(½ mark)}$$

For a long solenoid, the inductance (L) per unit length is given by,

$$\left(\frac{L}{l}\right) = \mu_0 n^2 A \qquad \textit{(½ mark)}$$

Equation (ii) becomes

$$\therefore \quad u_B = \mu_0 n^2 A \cdot \frac{I^2}{2A}$$

$$= \frac{1}{2}\mu_0 n^2 I^2 \quad \text{... (iii)} \qquad \textit{(½ mark)}$$

For a solenoid, the magnetic field at the interior points is

$$B = \mu_0 n I \qquad \textit{(½ mark)}$$

$$\therefore \quad u_B = \frac{B^2}{2\mu_0} \quad \text{... (iv)} \qquad \textit{(½ mark)}$$

This gives the energy density stored at any point where magnetic field is B.

173.

Ans. • *Numerical:*

Given: Initial atomic mass A_m = 227

Initial atomic number Z_i = 89

Final atomic mass A_d = 211

Final atomic number = 82

To find: x = ?, y = ?

x = number of ${}^4_2He$ i.e. α-particles

y = number of ${}^{0}_{-1}e$ i.e. β-particles

$$\therefore \quad 4 \times \alpha\,({}^4_2He) = A_m - A_d \qquad \textit{(1 mark)}$$

$$\therefore \quad \alpha = \frac{A_m - A_d}{4}$$

$$\therefore \quad \alpha = \frac{227 - 211}{4} = \frac{16}{4} = 4 = x \qquad \textit{(1 mark)}$$

$$\therefore \quad 82 + 2x - 1y = 89$$

$$82 + 2 \times 4 - y = 89$$

$$82 + 8 - y = 89$$

$$y = 90 - 89 \Rightarrow y = 1 \qquad \textit{(1 mark)}$$

$\therefore$ $x = 4$ and $y = 1$.

• ***Binding Energy of nucleus:***

The minimum amount of energy required to separate all the nucleons from the nucleus is called binding energy of nucleus. *(1 mark)*

174.

Ans. • *Proof:*

The expression for the pressure exerted by a gas on the basis of kinetic theory of gas is given by

$$P = \frac{1}{3}\frac{Nm}{V}v_{rms}^2 \qquad \textit{(½ mark)}$$

$$PV = \frac{1}{3} \times 2 \times \frac{1}{2} \times Nmv_{rms}^2$$

$$\therefore \quad PV = \frac{2}{3}E, \qquad \left(\because E = \frac{1}{2} \times Nmv_{rms}^2\right) \qquad \textit{(½ mark)}$$

By definition,

PV = RT (for one mole)

$$\therefore \quad RT = \frac{2}{3}E$$

$$E = \frac{3}{2}RT$$

$$E = \frac{3}{2}Nk_BT \quad \ldots (\because R = Nk_B) \qquad (½ \text{ mark})$$

$$\therefore \frac{E}{N} = \frac{3}{2}k_BT \qquad \therefore \frac{E}{N} \propto T \qquad (½ \text{ mark})$$

∴ Average energy, per molecule is directly proportional to absolute temperature T of the gas.

- ***Numerical:***

Given: Q = 2000 cal, Q_a = 550 cal

To find e = ?

We have,

$$a = \frac{Q_a}{Q} = \frac{550}{2000}$$

$$= \frac{11}{40} = 0.275 \qquad (½ \text{ mark})$$

By Kirchhoff's law of radiation

$a = e$ *(½ mark)*

$\therefore$ $\boxed{e = 0.275}$ *(1 mark)*

175.

Ans. ***(a) Demerits of potentiometer:***

(i) Potentiometer is not portable

(ii) Direct measurement of potential difference or emf is not possible. *(½ mark each)*

(b) Diagram:

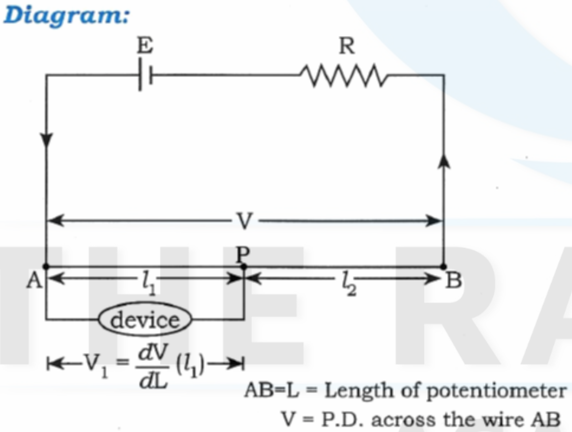


Fig. Potentiometer as voltage divider

(Labelled diagram - 1 mark)

- ***Numerical:***

Given: V_g = 20 V, G = 500 Ω,

V = 200 V

To find: R = ?

$$V_g = I_g \cdot G$$

$$I_g = \frac{V_g}{G}$$

$$= \frac{20}{500}$$

$$= 0.04 \text{ A} \qquad (½ \text{ mark})$$

Now,

$$R = \frac{V - V_g}{I_g}$$

$$= \frac{200 - 20}{0.04} \qquad (½ \text{ mark})$$

$$= \frac{180}{0.04}$$

$$= 4500\ \Omega \qquad (½ \text{ mark})$$

∴ Resistance of 4500 Ω should be connected in series with the coil. *(½ mark)*

176.

Ans. • **Statement:** It states that, "*The moment of inertia (I_O) of an object about any axis is the sum of its moment of inertia (I_C) about an axis parallel to the given axis, and passing through the centre of mass and the product of the mass of the object and the square of the distance between the two axes (Mh^2).*" *(1 mark)*

i. e. $I_O = I_C + M \cdot h^2$

- **Proof:** In order to apply this theorem to any object, we need two axes parallel to each other with one of them passing through the centre of mass of the object.

The figure shows an object of mass M. Axis MOP is any axis passing through point O. Axis ACB is passing through the centre of mass C of the object, parallel to the axis MOP, and at a distance h from it ($\therefore h = CO$).

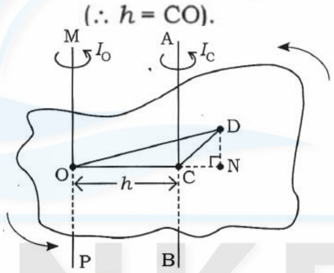


Fig. Theorem of parallel axes *(Diagram - ½ mark)*

Consider a mass element dm located at point D. Perpendicular on OC (produced) from point D is DN.

Moment of inertia of the object about the axis ACB is $I_C = \int (DC)^2\, dm$, and about the axis MOP it is $I_O = \int (DO)^2\, dm$.

$$\therefore I_O = \int (DO)^2\, dm \qquad (½ \text{ mark})$$

$$= \int ([DN]^2 + [NO]^2)\, dm$$

$$= \int [(DN)^2 + [(OC + CN)]^2]\, dm$$

$$= \int [(DN)^2 + (OC)^2 + + 2 \cdot OC \cdot CN + (CN)^2]\, dm$$

$$= \int [(DN)^2 + (CN)^2 + + 2 \cdot CN \cdot OC + (OC)^2]\, dm$$

$= \int([DC])^2 + 2NC.h + h^2)\, dm$ *(½ mark)*

$= \int(DC)^2\, dm + 2h \int NC.dm + h^2 \int dm$

Now, $\int(DC)^2\, dm = I_C$ and $\int dm = M$ *(½ mark)*

NC is the distance of a point from the centre of mass. Any mass distribution is symmetric about the centre of mass.

Thus, from the definition of the centre of mass, $\int NC.dm = 0$.

$\therefore I_O = I_C + M \cdot h^2$ *(1 mark)*

This is the mathematical form of the theorem of parallel axes.

177.

Ans. Consider an electron revolving around positively charged nucleus in a circular orbit as a simple model. A (negatively charged) electron revolving in an orbit is equivalent to a tiny current loop. The magnetic dipole moment due to an orbit is equivalent to a tiny current loop. The magnetic dipole moment due to a current loop is given by

$m_{orb} = IA$ *(½ mark)*

where, A is the area enclosed by the loop and I is the current of an atom and is referred to as orbital magnetic moment.

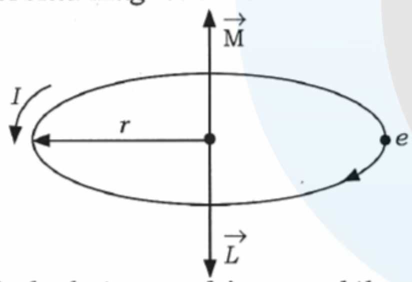


Fig. **Single electron revolving around the nucleus**

(Dig. - ½ mark)

Consider an electron moving with constant speed v in a circular orbit of radius r about the nucleus as shown in above figure. If the electron travels a distance of $2\pi r$ (circumference of the circle) in time T, then its orbital speed

$v = 2\pi r/T$ *(½ mark)*

Thus the current I associated with this orbiting electron of charge e is

$I = \frac{e}{T}$ *(½ mark)*

But $T = \frac{2\pi}{\omega}$ and $\omega = \frac{v}{r}$, the angular speed

$\therefore I = \frac{e\omega}{2\pi} = \frac{ev}{2\pi r}$ ... (i) *(½ mark)*

The orbital magnetic moment associated with orbital current loop is

$m_{orb} = IA = \frac{ev}{2\pi r} \times \pi r^2 = \frac{1}{2} evr$ ... (ii) *(½ mark)*

For this electron, orbital angular momentum is

$L = m_e vr,$ *(½ mark)*

where m_e is the mass of an electron.

Hence the orbital magnetic moment, can be written as

$m_{orb} = \left(\frac{e}{2m_e}\right)(m_e vr)\left(\frac{e}{2m_e}\right) L$ ... (iii) *(½ mark)*

178.

Ans. • ***Laws of simple pendulum:***

(a) The period of a simple pendulum is directly proportional to the square root of its length.

i.e. $T \propto \sqrt{l}$ *(½ mark)*

(b) The period of a simple pendulum is inversely proportional to the square root of acceleration due to gravity.

i.e. $T \propto \frac{1}{\sqrt{g}}$ *(½ mark)*

(c) The period of a simple pendulum does not depend on its mass. *(½ mark)*

(d) The period of a simple pendulum does not depend on its amplitude (for small amplitude) *(½ mark)*

• ***Numerical:***

Given: $v_1 = 8$ units, $v_2 = 6$ units, $x_1 = 6$ cm, $x_2 = 8$ cm

We know that,

$v = \omega\sqrt{(A^2 - x^2)}$

$\therefore \frac{v_1}{v_2} = \frac{8}{6} = \frac{\sqrt{A^2 - 6^2}}{\sqrt{A^2 - 8^2}}$ *(½ mark)*

i.e. $\frac{4}{3} = \frac{\sqrt{A^2 - 6^2}}{\sqrt{A^2 - 8^2}}$

$\therefore \frac{16}{9} = \frac{A^2 - 36}{A^2 - 64}$

$\therefore 16(A^2 - 64) = 9(A^2 - 36)$

$\therefore 16A^2 - 9A^2 = 1024 - 324$

$7A^2 = 700$

$A^2 = 100$

$\therefore A = 10$ cm *(½ mark)*

Now, consider

$\therefore v_1 = \omega\sqrt{A^2 - x_1^2}$

$8 = \frac{2\pi}{T}\sqrt{10^2 - 6^2}$ $\left(\because \omega = \frac{2\pi}{T}\right)$ *(½ mark)*

$T = \frac{2 \times 3.142}{8} \times 8$

$\therefore T = 6.284$ sec. *(½ mark)*

179.

Ans. ***(a) Primary sources of light:*** Primary sources are sources that emit light of their own, because of –

(i) their high temperature (e.g. the Sun, the stars, objects heated to high temperatures, flame of any kind, etc),

(ii) the effect of current being passed through them (e.g. tube light, TV, etc.), and

(iii) chemical or nuclear reactions (e.g. firecrackers, nuclear energy generators). Light originates in these sources. *(1 mark)*

(b) Secondary sources of light: Secondary sources are those sources which do not produce light of their own but receive light from some other source and either reflect or scatter it around. *(½ mark)*

Examples include the moon, the planets, objects like humans, animals, plants, etc., which we see due to reflected light. Majority of the sources that we see in our daily life are secondary sources. *(½ mark)*

- ***Numerical:***

Given: D = 1.22 m, λ = 5000 Å = 5×10^{-7} m

To find: Resolving power of the telescope = ?

$$\text{R.P.} = \frac{D}{1.22\lambda}$$ *(½ mark)*

$$= \frac{1.22}{1.22 \times 5 \times 10^{-7}}$$ *(½ mark)*

$$= \frac{10 \times 10^6}{5}$$

$$= 2 \times 10^6$$ *(1 mark)*

180.

Ans. ***Work done by a gas in an isothermal process:*** Consider n moles of a gas enclosed in a cylinder fitted with a movable, light and frictionless piston. Let P_i, V_i and T be the initial pressure, volume and absolute temperature respectively of the gas.

Consider an isothermal expansion (or compression) of the gas in which P_f, V_f and T are respectively the final pressure, volume and absolute temperature of the gas. *(½ mark)*

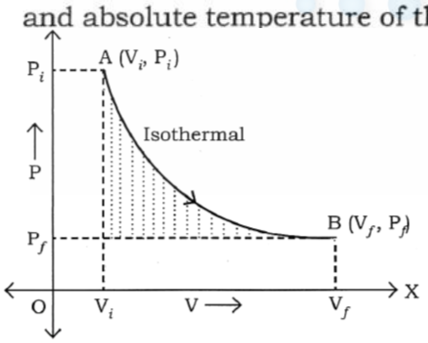


Fig. P–V digram for an isothermal process

(Digram - 1 mark)

For an isothermal change,

$$P_iV_i = P_fV_f = \text{constant}$$

Assuming the gas to behave as an ideal gas, its equation of state is

$$PV = nRT = \text{constant} \quad \text{...(i)}$$

...(as T = constant, R is universal gas constant)

The work done in an infinitesimally small isothermal expansion is given by

$$dW = PdV \quad \text{...(ii)}$$ *(½ mark)*

The total work done in bringing out the expansion from initial volume V_i to the final volume V_f is given by

$$W = \int_{V_i}^{V_f} PdV$$ *(½ mark)*

$$\therefore W = nRT \int_{V_i}^{V_f} \frac{dV}{V} \quad \text{...[from (i)]}$$

$$\therefore W = nRT\,[ln\,V_f - ln\,V_i]$$

$$\therefore W = nRT\,ln\,\frac{V_f}{V_i}$$

$$\therefore W = 2.303\,nRT \log_{10} \frac{V_f}{V_i}$$ *(½ mark)*

- ***Numerical:***

Given: C_v = 12.47 J/mol.K, n = 2, $T_f - T_i$ = 10 K

To find: The increase in the internal energy of the gas (ΔU) = ?

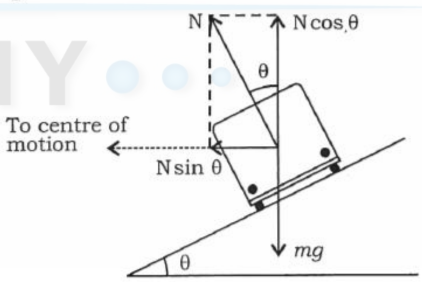
$$\Delta U = nC_v (T_f - T_i)$$ *(½ mark)*

$$= 2 \times 12.47 \times 10$$

$$= 249.4 \text{ J}$$ *(½ mark)*

181.

Ans. • ***Expression for Angle of Banking:*** The following figure shows the vertical section of vehicle on curved road of radius 'r' banked at an angle 'θ' with the horizontal.



(Diagram - ½ mark)

Consider the vehicle to be a point and ignoring friction and non-conservative forces like air resistance.

There are two forces acting on vehicle:

(i) Weight (mg) vertically downwards.

(ii) Normal reaction (N) perpendicular to surface of road.

N resolved into two components:

(i) $N\sin\theta$ - horizontal component being resultant force, must be the necessary centripetal force.

(ii) $N\cos\theta$ - vertical component balances weight (mg)

$\therefore \quad N\sin\theta = \dfrac{mv^2}{r} \quad \ldots$(i)

$N\cos\theta = mg \quad \ldots$(ii) *(½ mark)*

Dividing equation (i) by (ii),

$$\frac{N\sin\theta}{N\cos\theta} = \frac{\frac{mv^2}{r}}{mg}$$

$$\therefore \quad \tan\theta = \frac{v^2}{rg}$$

$$\theta = \tan^{-1}\left(\frac{v^2}{rg}\right)$$ *(1 mark)*

- ***Problem:***

Given: $r = 60$ m, $\theta = 27°$

To find: $v = ?$

Formula: $v = \sqrt{rg\tan\theta}$ *(½ mark)*

$\therefore \quad v = \sqrt{60 \times 9.8 \times \tan 27°}$

$= \sqrt{60 \times 9.8 \times 0.5095}$ *(½ mark)*

$= \sqrt{588 \times 0.5095}$

$= \sqrt{299.5}$

$\therefore \quad v = 17.31$ m/s *(1 mark)*

182.

Ans. • ***Stefan's law:*** The radiant energy emitted per unit time per unit area by a perfectly black body is directly proportional to the fourth power of its absolute temperature. *(½ mark)*

Let R - be the quantity of radiant energy emitted per unit time per unit area by the blackbody

T - be the absolute temperature.

Then, $R \propto T^4$

$R = \sigma T^4 \quad \ldots$(i) *(½ mark)*

where, σ is constant called as Stefan's constant and $\sigma = 5.7 \times 10^{-8}\ J\ m^{-1} s^{-2} K^{-4}$ or $J\ Wm^{-2} K^{-4}$.

Dimension of $\sigma = [L^0 M^1 T^{-3} K^{-4}]$

Thus, the power radiated by a perfectly black body depends only on its temperature and not on colour, materials, nature of surface, etc.

By definition of emissive power,

$$R = \frac{Q}{At}$$ *(½ mark)*

$\therefore$ Equation (i) becomes

$$\frac{Q}{At} = \sigma T^4$$

For body which is not blackbody, the energy radiated per unit area per unit time is still proportional to the fourth power of absolute temperature.

$R = e\sigma A T_0^4 \quad \ldots$(iii) *(½ mark)*

- ***Problem:***

Given: $\dfrac{dQ}{dt} = 20\,W$

$T = 727°C = 727 + 273 = 1000$ K

$\sigma = 5.7 \times 10^{-8}\ J\ m^{-1} s^{-2} K^{-4}$.

To find: Area of the hole (A) = ?

$\because \quad \dfrac{dQ}{dt} = e\sigma A T_0^4$ *(½ mark)*

Consider given hole to be a perfect blackbody.

$\therefore \quad e = 1$

From formula,

$20 = 5.7 \times 10^{-8} \times A \times (1000)^4$ *(½ mark)*

$$\therefore \quad A = \frac{20}{5.7 \times 10^{-8} \times 10^{-12}}$$

$$= \frac{20}{5.7} \times 10^{-3}$$

$= 0.35 \times 10^{-3}\ m^3$

$= 3.5 \times 10^{-4}\ m^2$

$\therefore$ The area of the hole is $3.5 \times 10^{-4}\ m^2$. *(1 mark)*

183.

Ans. Consider a particle of mass m performing linear SHM with its mean position 'O' between two extreme position A and B as shown in figure.

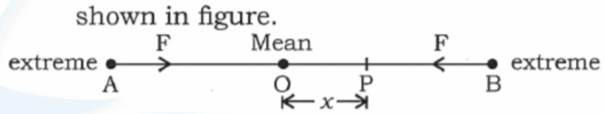


Fig. A particle performing linear SHM

Let P - be the any position of particle at distance x from point O.

F - be the force acting on particle towards mean position.

By definition of linear SHM

$F = -kx \quad \ldots$(i) *(½ mark)*

where k is force constant. Negative sign indicates force and displacement are in opposite direction.

By Newton's 2nd law

$F = ma$

$= m\dfrac{d^2x}{dt^2} \quad \ldots$(ii) *(½ mark)*

where $a = \dfrac{d^2x}{dt^2}$ is the acceleration.

Comparing equations (i) and (ii),

$$\therefore \quad m\frac{d^2x}{dt^2} = -kx$$

$$\frac{d^2x}{dt^2} = -\frac{k}{m}x$$

$\therefore \quad \frac{d^2x}{dt^2} + \frac{k}{m}x = 0$ *(½ mark)*

Substituting $\frac{k}{m} = \omega^2$

$\therefore \quad \frac{d^2x}{dt^2} + \omega^2 x = 0$ ...(iii) *(½ mark)*

Equation (iii) is the differential equation of linear SHM.

- ***Problem:*** ***Given:*** Path length = 10 cm

$\therefore$ Amplitude (A) = $\frac{\text{Path length}}{2} = \frac{10}{2} = 5$ cm

$$v = \frac{v_{max}}{2}$$

To find: Distance (x) = ?

Formulae: (i) $v_{max} = \omega A$

(ii) $v = \omega\sqrt{A^2 - x^2}$

From formula (ii),

$v = \omega\sqrt{A^2 - x^2}$ *(½ mark)*

$\frac{v_{max}}{2} = \omega\sqrt{A^2 - x^2}$

But $v_{max} = \omega A$ *(½ mark)*

$\therefore \quad \frac{\omega A}{2} = \omega\sqrt{A^2 - x^2}$

$\therefore \quad \frac{A}{2} = \sqrt{A^2 - x^2}$

Squaring,

$\therefore \quad \frac{A^2}{4} = A^2 - x^2$

$\therefore \quad x^2 = A^2 - \frac{A^2}{4} = \frac{3}{4}A^2$

$\therefore \quad x = \frac{\sqrt{3}}{4}A = \frac{\sqrt{3}}{4} \times 5$

$\therefore \quad x = 0.866 \times 5 = 4.33$ cm *(1 mark)*

$\therefore$ The distance at which speed of particle is half of its maximum value is 4.33 cm.

184.

Ans. Let S_1 and S_2 be the two sources of light separated by distance d. A screen is placed at a distance D from the two sources of light.

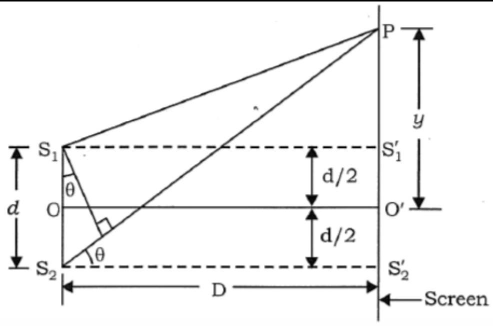
Let λ be the wavelength of light.

Draw $S_1S'_1$ and $S_2S'_2$ perpendicular to screen.

Let O be the midpoint of $S'_1S'_2$.

$\therefore \quad O'S'_1 = O'S'_2 = \frac{d}{2}$

Let 'P' be the point at distance y from point 'O' on screen. To find whether the point P to be a bright or dark is depending upon the path difference. The path difference is $S_2P - S_1P$.



(Diagram - 1 mark)

In $\Delta S_1S'_1P$,

$(S_1P)^2 = (S_1S'_1)^2 + (S'_1P)^2$

$(S_1P)^2 = D^2 + \left(y - \frac{d}{2}\right)^2$

$(S_1P)^2 = D^2 + y^2 - yd + \frac{d^2}{4}$ ...(i)

In $\Delta S_2S'_2P$,

$(S_2P)^2 = (S_2S'_2)^2 + (S'_2P)^2$

$(S_2P)^2 = D^2 + \left(y + \frac{d}{2}\right)^2$

$(S_2P)^2 = D^2 + y^2 + yd + \frac{d^2}{4}$ ...(ii)

Subtracting equation (i) from (ii),

$(S_2P)^2 - (S_1P)^2$

$= \left(D^2 + y^2 + yd + \frac{d^2}{4}\right) - \left(D^2 + y^2 - yd + \frac{d^2}{4}\right)$

$\therefore \quad (S_2P - S_1P)(S_2P - S_1P) = 2yd$

$\therefore \quad S_2P - S_1P = \frac{2yd}{(S_2P + S_1P)}$

$\therefore$ Path difference $= \frac{2yd}{(S_2P + S_1P)}$ *(½ mark)*

Now D is very large as compared to y and d i.e. D >> y and D >> d.

$\therefore \quad S_2P \approx S_1P \approx D$

$\therefore$ Path difference $= \frac{2yd}{D + D} = \frac{2yd}{2D}$

$\therefore$ **Path difference = $\frac{yd}{D}$** ...(iii) *(½ mark)*

Case - I: The point P will be bright if path difference = $n\lambda$.

$\therefore \quad \frac{yd}{D} = n\lambda$

$$y = \frac{Dn\lambda}{d}$$

Equation for position of n^{th} bright band is

$$\therefore \quad \boxed{y_n = \frac{Dn\lambda}{d}} \quad \ldots(iv)$$ *(½ mark)*

Case-II: The point P will be dark if path difference = $(2n-1)\frac{\lambda}{2}$

$$\therefore \quad \frac{yd}{D} = (2n-1)\frac{\lambda}{2}$$

$$\therefore \quad y = \frac{D(2n-1)\lambda}{2d}$$

Equation for position of n^{th} dark band is

$$\therefore \quad \boxed{y_n = \frac{D(2n-1)\lambda}{2d}} \quad \ldots(v)$$ *(½ mark)*

- ***Fringe width:*** The distance between any two successive fringes or any two successive dark fringes in an interference pattern is called fringe width or band width.

$\therefore$ Fringe width (W) $= y_{n+1} - y_n$ *(½ mark)*

We know the equation of n^{th} bright band

$$y_n = \frac{Dn\lambda}{d}$$

Equation for $(n+1)^{th}$ bright band

$$y_{n+1} = \frac{D(n+1)\lambda}{d}$$

$$\therefore \text{ Fringe width (W)} = y_{n+1} - y_n = \frac{D(n+1)\lambda}{d} - \frac{Dn\lambda}{d} = \frac{D\lambda}{d}(n+1-n)$$

$$\therefore \text{ Fringe width (W)} = \frac{D\lambda}{d}$$ *(½ mark)*

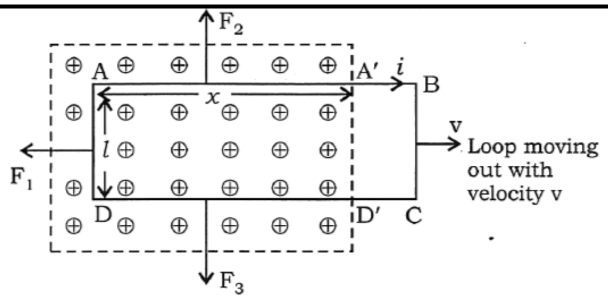
Similarly, we can determine distance between two successive dark fringes is same,

i.e. $\quad W = \frac{D\lambda}{d}$

185.

Ans. Consider a loop ABCD moving with constant velocity in a uniform magnetic field B as shown in the figure.

A current i is induced in the loop in clockwise direction. Let F_1, F_2 and F_3 be the forces acting on side AD, AA′ and DD′ respectively. The dashed line shows limit of magnetic field.



⊕ Magnetic field $\vec{B}$ into plane of the paper

Fig. (a)

(1 mark)

To pull the loop at constant velocity towards right, it is required to apply external force $\overline{F}$ on loop so as to over come the magnetic force of equal magnitude but opposite in direction.

The rate of work done on loop is

$$\text{Power} = \frac{\text{Work done}}{\text{Time}}$$

$$\therefore \quad \text{Power} = \frac{\text{Force} \times \text{displacment}}{\text{Time}} = \text{Force} \times \text{velocity}$$

$$\therefore \quad P = \overline{F} \cdot \overline{v}$$ *(½ mark)*

Let us find the expression for P in terms of $\vec{B}$, resistance, area and width. When the loop is moved to the right, the distance x decreases i.e. area of loop inside the field decreases, causing magnetic flux decreases and it reduces current in the loop.

The magnitude of magnetic flux through loop is

$$\phi = BA = Blx \quad \text{where } A = lx$$

By Faraday's law, the induced emf is

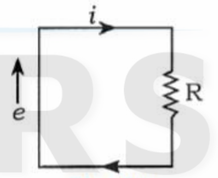


Fig. (b)

$$\therefore \quad e = \frac{-d\phi}{dt}$$

$$\therefore \quad e = \frac{-d}{dt}(Blx)$$

$$\therefore \quad e = -Bl\frac{-dx}{dt}$$

$$\therefore \quad e = -Bl(-v) \quad \ldots\left(\text{As } -v = \frac{-dx}{dt}\right)$$

$$\therefore \quad e = Blv \quad \ldots(i)$$ *(½ mark)*

v is negative, as time increases distance x decreases,

The magnitude of induced current is

$$i = \frac{|e|}{R} = \frac{Blv}{R} \quad \ldots(ii)$$

The force acting on AA′ and DD′ i.e. F_2 and F_3 are equal in magnitude and opposite in direction. Therefore they cancel each other.

The force F_1 is directed opposite to F.

$$\therefore \overline{F} = -\overline{F_1}$$

The magnitude of F_1 is

$$F_1 = ilB\sin\theta$$

$$F_1 = ilB$$

(As $F \perp l \perp B$, $\therefore \theta = 90°$ and $\sin 90° = 1$)

$$\therefore |F| = |F_1| = ilB$$ *(½ mark)*

Putting the value of i in equation (ii),

$$|F| = \left(\frac{Blv}{R}\right)lB$$

$$|F| = \frac{B^2 l^2 v}{R} \quad \ldots\text{(iii)}$$

The rate of mechanical work, i.e. power is

$$P = Fv$$

$$P = \frac{B^2 l^2 v^2}{R} \quad \ldots\text{(iv)}$$ *(½ mark)*

The rate of production of heat energy in the loop is

$$P = i^2 R$$

Putting $i = \frac{Blv}{R}$

$$P = \frac{B^2 l^2 v^2}{R} \quad \ldots\text{(v)}$$ *(½ mark)*

Comparing equations (iv) and (v) we find that the rate of doing mechanical work is exactly same as the rate of production of heat energy in the loop. Thus the work done in loop appears as heat energy in the loop. *(½ mark)*