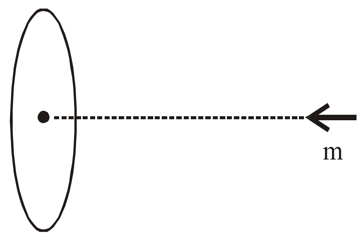
PHYSICS

COMPREHENSION

Material that is able to flow current through it without resistance has a feature that flux through it remains zero. A magnetic dipole of magnetic dipole moment 'm' is brought towards a ring of such a material from infinity along its axis as shown in figure. Radius of ring is a. (a << r)



1. The induced current in the ring is proportional to

(A) $\frac{m}{r^3}$ (B) $\frac{m}{r^2}$ (C) $\frac{m^2}{r^3}$ (D) $\frac{m^2}{r^2}$

Ans. **(A)**

Sol. $\frac{\mu_0 m}{2\pi r^3} = \frac{\mu_0 I}{2a}$

2. The Work done in bringing dipole from infinity to a point at a distance 'r' from the centre of the ring is proportional to

(A) $\frac{m^2}{r^7}$ (B) $\frac{m^2}{r^6}$ (C) $\frac{m^2}{r^5}$ (D) $\frac{m^2}{r^8}$

Ans. **(B)**

Sol Work Done = $-\vec{M}.\vec{B}$

$$= M\left(\frac{\mu_0 I a^2}{2(r^2+a^2)^{\frac{3}{2}}}\right)$$

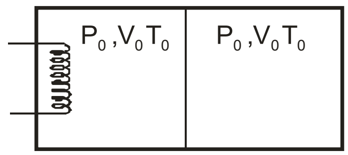
If r >> a,

$$\frac{mI}{r^3}$$

$$= \frac{m^2}{r^6}$$

Comprehension (Q. 3 & 4)

The rectangular non-conducting box shown in figure has a non-conducting partition which can slide without friction. Initially each of two chambers of the box has one mole idal gas with $C_V = 2R$ and pressure P_0, volume V_0, temperature T_0. Now left chamber is heated slowly by heater till right chamber has volume $\frac{V_0}{2}$.



3. If T_R, temperature if right chamber then find out $\frac{T_R}{T_0}$

(A) $\sqrt{2}$ (B) $\frac{1}{\sqrt{2}}$ (C) $\sqrt{3}$ (D) $\frac{1}{\sqrt{3}}$

Ans. **(A)**

Sol. $\gamma = \frac{3}{2}$

$$T_0 V_0^{\frac{3}{2}-1} = T_R \times \left(\frac{V_0}{2}\right)^{\frac{3}{2}-1}$$

$$\frac{T_R}{T_0} = \sqrt{2}$$

4. If heat is supplied by heater ΔQ, then find out $\frac{\Delta Q}{RT_0}$

(A) $4(2\sqrt{2} + 1)$ (B) $4(2\sqrt{2} - 1)$

(C) $2(2\sqrt{2} + 1)$ (D) $2(2\sqrt{2} - 1)$

Ans. **(B)**

Sol. $\Delta Q = \Delta U = \Delta U_1 + \Delta U_2$

$$\Delta U_2 = 1 \times 2R \times \left(\sqrt{2}T_0 - T_0\right) = 2RT_0\left(\sqrt{2}-1\right)$$

For ΔU_2 : Using mole conservation on left side.

$$\frac{P_0V_0}{RT_0} = \frac{2\sqrt{2}P_0 \frac{3V_0}{2}}{RT_L}$$

$$T_L = 3\sqrt{2}T_0$$

$\Delta U_1 = 1 \times 2R \times \left(3\sqrt{2}T_0 - T_0\right) = 2RT_0\left(3\sqrt{2} - 1\right)$

$\Delta Q = 2RT_0\left(\sqrt{2} - 1\right) + 2RT_0\left(3\sqrt{2} - 1\right)$

$= 2RT_0(4\sqrt{2} - 2)$

$\frac{\Delta R}{RT_0} = (8\sqrt{2} - 4)$

Comprehension (Q. 5 & 6)

An ac source (200V, 50 Hz) is applied across a series combination of a bulb and a purely capacitive load of capacitance C μF. The average power consumption of the circuit is 500 W. The voltage across the resistor is 100 V and the phase difference between the current and the voltage is Δϕ. (Take $\sqrt{3}\pi = 5$)

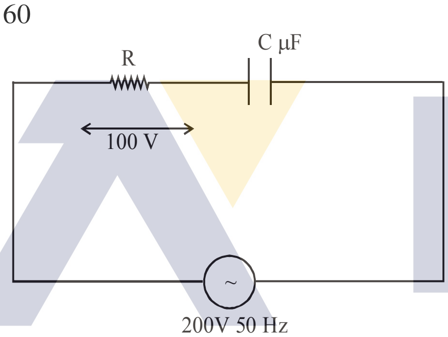
5. The value of C is .... in μF

Ans. 100

6. The value of Δϕ is .... degree.

Ans. 60

Sol



$V_R = \frac{V_{rms}}{Z}R \Rightarrow V_R = V_{rms}\cos\phi \left(\cos\phi = \frac{R}{Z}\right)$

$\Rightarrow 100 = 200 \text{ Cos } \phi$

$\Rightarrow \text{Cos } \phi = \frac{1}{2} \Rightarrow \qquad \phi = \frac{\pi}{3} = 60 \text{ degree.}$

$\text{Power} = \frac{V_{rms}}{Z} I_{rms} \cos\phi = 200 \times \frac{200}{Z} \times \frac{1}{2} = 500$

$\Rightarrow Z = 40$

$\cos\phi = \frac{R}{Z} \Rightarrow \frac{1}{2} = \frac{R}{40} \Rightarrow R = 20\Omega$

$Z^2 = R^2 + X_C^2 \Rightarrow 40^2 = 20^2 + X_C^2 \Rightarrow X_C^2 = 1200$

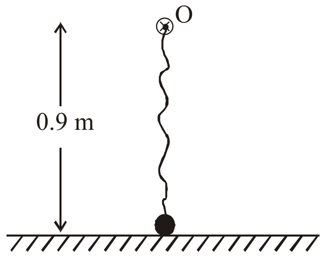
$\Rightarrow X_C = 20\sqrt{3}$

$\Rightarrow \frac{1}{\omega C} = 20\sqrt{3}$

$\Rightarrow C = \frac{1}{20\sqrt{3} \times 2\pi \times 50} = 100\mu F$

Comprehension (Q. 7 & 8)

A Particle of 0.1 kg mass is tied to a string of length 1m whose other end is fixed at point. 'O' which is 0.9 m above the ground. Now mass is given 0.2 kg m/s impulse, in horizontal direction. (Give your answer in SI Unit)

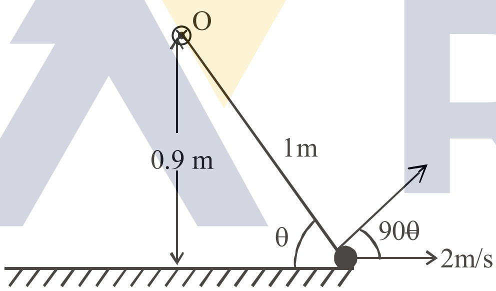


7. Find angular momentum of particle about point 'O' just before string becomes tight.

Ans 0.18

8. Find kinetic energy of particle just after string becomes tight

Ans. 0.16

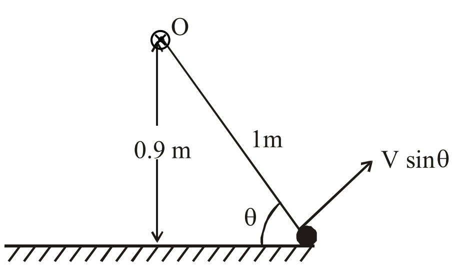


Sol.

$L_O = mv \sin\theta \times 1$

$= 0.1 \times 2 \times 0.9 = 0.18$

After string become tight

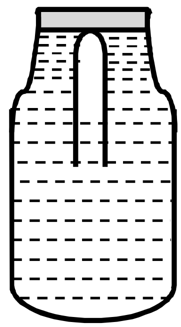


So K.E $= \frac{1}{2} \times 0.1 \times (v \sin\theta)^2$

$= 0.16$ J

Comprehension (Q. 9 & 10)

A thick test tube is inside a container filled with water. In the state shown in figure pressure of gas inside the tube is 10^5 Pa & volume is 3.3 cc. Mass of the tube is 5 gm and density is 2.5 gm /cc. When the container is squeezed it just sinks/ floats. Assume temp remains constant :



9. If final pressure of gas is $P_i + \Delta p$. Then Δp is $x \times 10^3$ Pa. Then x is

Ans. 10

10. If final volume of the gas is $V_i - \Delta V$ then $(10\Delta V)$ in cc

Ans. **3**

Sol When the tube just sinks/ floats then average density = density of water

$$\frac{\text{Mass}}{\text{total volume}} = 1\text{gm/cc}$$

$$\Rightarrow \frac{5\text{gm}}{\text{total volume}} = 1\text{gm/cc}$$

$\Rightarrow$ Total volume = 5 cc

$\Rightarrow$ Volume of tube + final volume of air in the tube = 5cc

$$\Rightarrow \frac{5\text{gm}}{2.5\text{gm/cc}} + V_f = 5$$

$\Rightarrow V_f = 5 - 2 = 3$ cc

$\Rightarrow \Delta V = 0.3$ cc

$P_i V_i = P_f V_f$

$$\Rightarrow Pf = 10^5 \times \frac{3.3}{3}$$

$P_f = 1.1 \times 10^5 - 10^5$

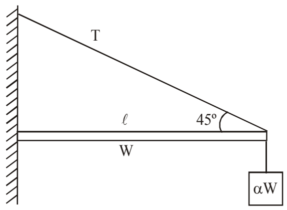
$P_f - P_i = 1.1 \times 10^5 - 10^5$

$= 0.1 \times 10^5$

$= 10 \times 10^3$ Pa

$\Rightarrow x = 10$

11.



IF the maximum tension T that the string can sustain is $2\sqrt{2}W$ then choose the correct options.

(A) The rope will break if α is more than $\frac{3}{2}$

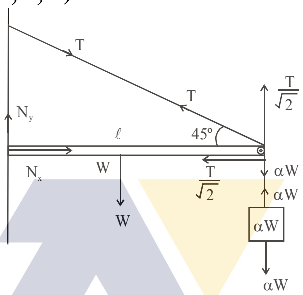
(B) For $\alpha = 1$ horizontal component of normal reaction at the hinge is $\frac{3}{2}W$

(C) For $\alpha = 1$ horizontal component of normal reaction at the hinge is $\frac{1}{2}W$

(D) For $\alpha = 1$ vertical component of normal reaction at the hinge is $\frac{1}{2}W$

Ans. (A,B,D)

Sol



$$\alpha W \ell + W\frac{\ell}{2} = \frac{I}{\sqrt{2}}\ell$$

For string to stay intact

$$T = \sqrt{2}\left(\alpha + \frac{1}{2}\right)W \le 2\sqrt{2}W$$

$$\left(\alpha + \frac{1}{2}\right) \le 2$$

$$\alpha \le \frac{3}{2} \quad \therefore \text{ String breaks for } \alpha \le \frac{3}{2}$$

For $\alpha = 1$

$$\frac{T}{\sqrt{2}} = \frac{3}{2}W \quad \Rightarrow T = \frac{3}{2}\sqrt{2}W$$

$$N_x - \frac{T}{\sqrt{2}} \Rightarrow N_x = \frac{3}{2}W$$

$$N_y + \frac{T}{\sqrt{2}} = W + W$$

$$N_y + \frac{3}{2} = 2W$$

$$N_y = \frac{W}{2}$$

12. Dimensions of $\frac{\vec{E}\times\vec{B}}{\mu_0}$ is same as.

(A) $\frac{\text{Energy}}{\text{Volume}}$ (B) $\frac{\text{Power}}{\text{Area}}$ (C) $\frac{\text{Force}}{\text{Charge x current}}$ (D) $\frac{\text{Force}}{\text{length}\times\text{Time}}$

Ans. (B,D)

13. A source in approaching towards a closed organ pipe of fundamental frequency f_0, frequency of source is f_s and velocity of source is u, velocity of sound is v, then relation between f_0 and f_s for resonance.

(A) $u = 0.5\ v,\ f_s = \frac{3}{2}f_0$ (B) $u = 0.5\ v,\ f_s = f_0$ (C) $u = 0.8\ v\ ,\ f_s = \frac{3}{2}f_0$ (D) $u = 0.8v,\ f_s = f_0$

Ans. **(A, D)**

Sol. Let observed freq. is f'

$$f' = \left[\frac{v}{v-u}\right]f_s$$

for resonance

$f' = (2n-1)\ f_0$

$$\left[\frac{v}{v-u}\right]f_s = (2n-1)\ f_0$$

if $u = 0.5\ v$

$2f_s = (2n-1)\ f_0$

for $n = 1$ $f_s = \frac{f_0}{2}$

$n = 2$ $f_s = \frac{3f_0}{2}$

$n = 3$ $f_s = \frac{5f_0}{2}$

if $u = 0.8\ v$

$5f_s = (2n-1)\ f_0$

if $n = 1$ $f_s = \frac{f_0}{5}$

$n = 2$ $f_s = \frac{3f_0}{5}$

$n = 3$ $f_s = f_0$

14. A radioactive nuclie 'U' initially at rest disintegrates into daughter nuclie 'P' and 'Q'.

Given $M_U - M_P - M_Q = \delta$

(A) Ratio of velocity of P and Q is $\frac{V_P}{V_Q} = \frac{M_Q}{M_P}$

(B) $E_P + E_Q = \delta C^2$, where E_P and E_Q are energy of P and Q.

(C) Momentum of any particle is $\left(\sqrt{2\delta\mu}\right)C$, where $\mu = \frac{M_P M_Q}{M_P + M_Q}$

(D) If total energy released is E, then $E_P = \frac{M_P(E)}{M_P + M_Q}$

Ans. **(A, B, C)**

Sol. $P_i = P_f$

$0 = M_P V_P - M_Q V_Q \quad \Rightarrow \frac{V_P}{V_Q} = \frac{M_Q}{M_P}$

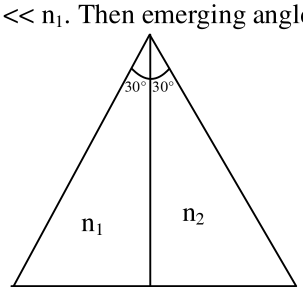
Also, $E_P + E_Q = \Delta m C^2 = \delta C^2$

Now, $\frac{p^2}{2M_P} + \frac{p^2}{2M_Q} = \delta C^2$

$\Rightarrow p = \sqrt{2\mu\delta}\,C$

$E_P \propto \frac{1}{M_P} \Rightarrow E_P = \frac{M_Q}{M_P + M_Q}(E)$

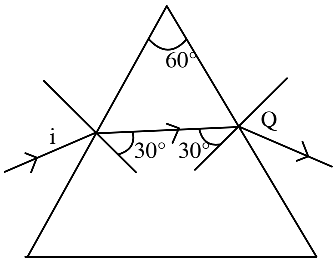
15. For $n_1 = n_2 = \frac{3}{2}$, minimum deviation occurs for angle of incidence i. Now n_2 is changed to $n_1 + \Delta n$, where $\Delta n << n_1$. Then emerging angle e becomes $i + \Delta e$



(A) Δe proportional to Δn
(B) for $\Delta n = 2.8 \times 10^{-3}$ range of Δe will be 2 mrad to 3 mrad
(C) for $\Delta n = 2.8 \times 10^{-3}$ rage of Δe will be 1 mrad to 1.6 mrad
(D) Change in Δn is less than the charge in Δe in terms of mrad.

Ans. **(A,B)**

Sol.



$n_1 = n_2 = \frac{3}{2}$

$\frac{\sin 30°}{\sin e} = \frac{1}{n_1 + \Delta n}$

$\frac{1}{2\sin e} = \frac{1}{n_1 + \Delta n}$

$2\sin e = n_1 + \Delta n$

$2\sin(I + \Delta e) = n_1 + \Delta n$ ....(i)

$2\sin i = n_1$ .....(ii)

By (i) , (ii)

$2[\sin(I + \Delta e) - \sin i] = \Delta n$

$2[\sin\left(\frac{\Delta Q}{2}\right)\cos i] = \Delta n$

$\Delta n = 4\sin\left(\frac{\Delta e}{2}\right)\cos i$

$= 2(\Delta e)\cos i$

(ii) $\Delta n = 2(\Delta e)\cos i$

$2.8 \times 10^{-3} = 2(\Delta e)\cos i$

$1.4 \times 10^{-3} = \Delta e \cos i$

(iv) $Dn = 2\Delta e \cos i$

$\Delta n < 2\Delta e$

$\frac{\sin i}{\sin 30°} = \frac{2}{3}$

$\sin i = \frac{1}{3}$

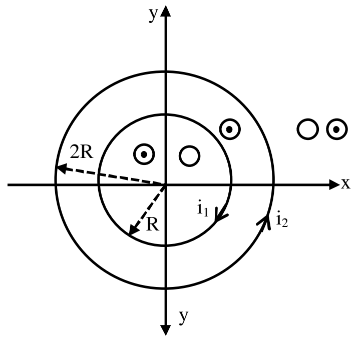
$I = \sin^{-1}\left(\frac{1}{3}\right)$

$2.8 \times 10^{-3} = 4\sin\left(\frac{\Delta e}{2}\right) \times \frac{2\sqrt{2}}{3}$

$\frac{\Delta e}{2} = 0.74 \times 10^{-3}$

$\Delta e = 1.48 \times 10^{-3}$

16. Two concentric circular rings of radii R & 2R lie in x-y plane. They carry currents in opposite directions as shown in diagram. $i_1 > 2i_2$ and r is radial distance from centres of the two rings in xy plane.



(A) for r < R, |B| is never zero

(B) for r < 2R, |B| is in wards

(C) B depends only on radial distance r

(D) B is always perpendicular to the x-y plane.

Ans. (A,C,D)

Sol. At r < R and at r > 2R, |B| can become zero as the two rings produce B in opposite directions.

Also in x-y plane B will be perpendicular to x-y plane

Also because of symmetry B will depend only on r and not on θ.

17. For earth-sun system, earth rotates about sun in a orbit of average radius R. Time period of earth is T_0. For a binary star system having two stars of masses $4M_S$ and $5\ M_S$ and separation 9R, time period is nT_0 . Find n.

Ans. 9

Sol. For earth-sun system

$$T_0^2 = \frac{4\pi^2}{GM_S} \times R^3 \qquad \ldots(i)$$

For binary system

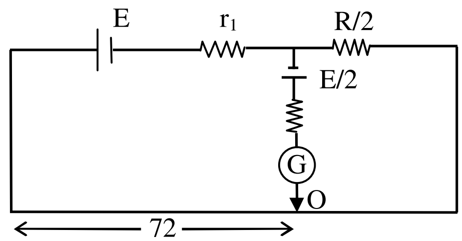
$$T^2 = \frac{4\pi^2}{G[4M_S + 5M_S]} \times (9R)^3 \qquad \ldots(ii)$$

using (i) and (ii)

$$T = 9T_0$$

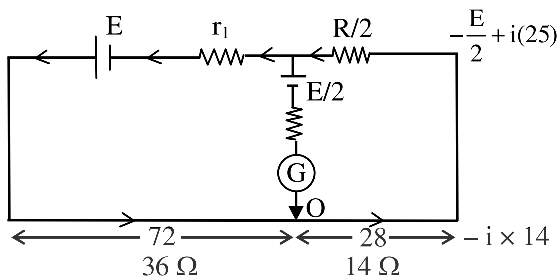
So, $n = 9$

18. In the given circuit galvanometer shows zero deflection for length 72 cm on the potentiometer wire of length 1 meter. Find the internal resistance (in Ω) of the cell if resistance of potentiometer wire is $R = 50\Omega$



Ans. **3**

Sol.



$$-\frac{E}{2} + i(25) = -i(14)$$

$$i(25 + 14) = \frac{E}{2}$$

$$\frac{39E}{r_1 + 75} = \frac{E}{2}$$

$r_1 = 3\ \Omega$

19. Photon of same energy is thrown on metals P, Q while different photon is used for metal R. Maximum kinetic energy in these cases are $E_P = 2\ E_Q = 2E_R$ and work function of P, Q, R are 4 ev, 4.5 ev, 5.5 ev respectively.

Find then energy (ev) of photon that is used in metal R.

Ans. 6

Sol. $h\nu = E_P + 4$

$h\nu = E_Q + 4.5$

$$1 = \frac{E_P + 4}{E_Q + 4.5} \Rightarrow E_Q + 4.5 = E_P + 4$$

$E_Q + 4.5 = 2E_Q + 4$

$E_Q = 0.5$ ev

For metal R

$h\nu_1 = E_R + 5.5$

$h\nu_1 = 0.5 + 5.6$

$h\nu_1 = 6$ ev