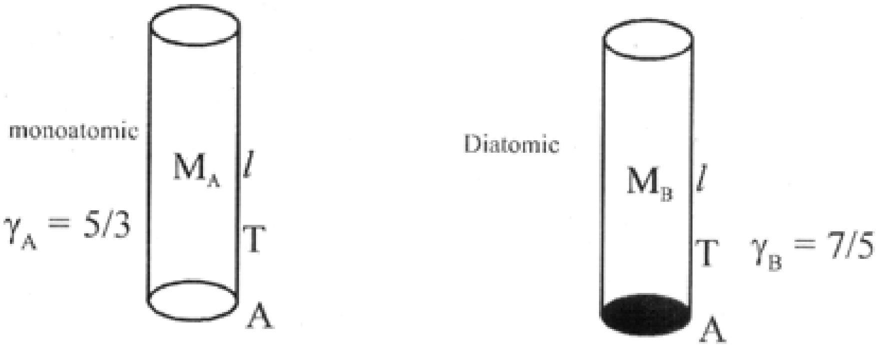
JEE 2002 - SOLUTIONS - PHYSICS

(INDIANET GROUP)

Q.1



(a) Frequency of second harmonic in A is $n_{A_2} = \frac{v_A}{\ell} = \frac{1}{\ell}\sqrt{\frac{\gamma_A RT}{M_A}}$

Frequency of third harmonic in is B is $n_{B_3} = \frac{3v_B}{4\ell} = \frac{3}{4\ell}\sqrt{\frac{\gamma_B RT}{M_B}}$

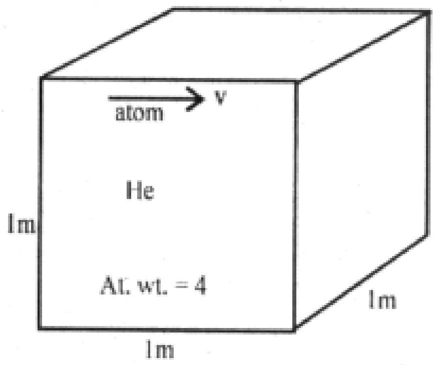
given $n_{A_2} = n_{B_3}$

$$\Rightarrow \sqrt{\frac{\gamma_A}{M_A}} = \sqrt{\frac{9\gamma_B}{16M_B}} \Rightarrow \frac{M_A}{M_B} = \frac{16}{9}\frac{\gamma_A}{\gamma_B} = \frac{16 \times 5 \times 5}{9 \times 3 \times 7} = 2.116$$

(b) Now the fundamental frequency of both the pipes is $\frac{v}{2\ell}$ where v is the respective velocities thus

$$\frac{n_{A_f}}{n_{B_f}} = \frac{v_A}{v_B} = \sqrt{\frac{\gamma_A M_B}{\gamma_B M_A}} = \sqrt{\frac{\gamma_A}{\gamma_B} \times \frac{9\gamma_B}{16\gamma_A}} = \frac{3}{4}$$

Q2.



$P = 100\ Nt/m^2$

given that an atom makes 500 hits /sec.

thus its rms speed is

$$v = \frac{500 \times 1 \times 2}{1} = 10^3 \text{ hits /sec.}$$

(a) temp. of gas can be given as $10^3 = \sqrt{\frac{3RT}{M}}$ or $T = \frac{4 \times 10^{-3} \times 3}{3 \times 25} = 160K$

(b) kinetic energy per atom is on an average $= \frac{3}{2} kT = \frac{3}{2} \times 1.38 \times 10^{-23} \times 160$

$$= 3.312 \times 10^{-21} \text{ Joule}$$

(c) total mass of the can be obtained as

$$PV = nRT$$

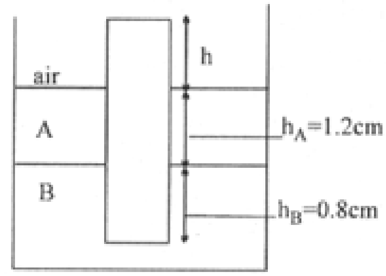
$$\text{or } 100 \times 1 = \frac{m}{4 \times 10^{-3}} = \frac{25}{3} = 160$$

$$\text{or} \quad m = \frac{4 \times 3 \times 10^{-3} \times 100}{25 \times 160} = 3 \times 10^{-4} = 0.3 \text{ gm}$$

Q3. $d_{cyl} = 0.8$ gm/cm³
$d_A = 0.7$ gm/cm³
$d_B = 1.2$ gm/cm³

(a) force exerted by liq. A on cylinder is F = 0 as no vertical part of cylinder is in contact.

(b) If S is the area of cross section of cylinder,
we have for its equilibrium



$$S(h + h_A + h_B)\,d_{cyl.} = h_A S\,d_A + hAS\,h_B$$

$$\text{we have } h = \frac{(h_A d_A + h_B d_B)}{d_{cyl}} - (h_A + h_B)$$

$$= \frac{1.2 \times 0.7 + 0.8 \times 1.2}{0.8} - (2) \quad = \frac{0.84 + 0.96}{0.8} - 2$$

h = 0.25 cm

(c) When cylinder is depressed. The height of cylinder in liquid A & B are
$h_A = 1.2$ cm & $h_B' = 1.05$ cm

$$\text{Thus net buoyancy force on cylinder is } F_{up} = \frac{(h_A d_A g + h_B' d_B g)S}{(h_A + h_B')S d_{cyl}} - g$$

$$= \frac{1.2 \times 0.7 \times 10 + 1.05 \times 1.2 \times 10}{2.25 \times 0.8} - 10 = 1.66 \text{ m/sec}^2$$

Q.4

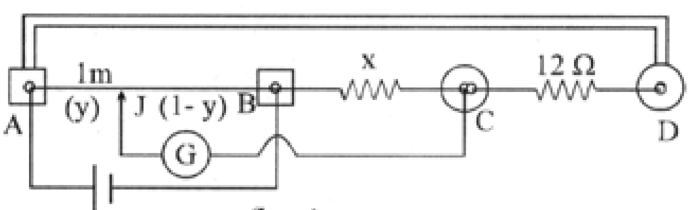


fig - 1

(a) No. As at the time of balancing the bridge, current in galvanometer is zero so we do not need a unidirectional galvanometer. In unidirectional galvanometer it is also difficiult to get null deflection point.

(b) Figure is shown above or it can also be like the

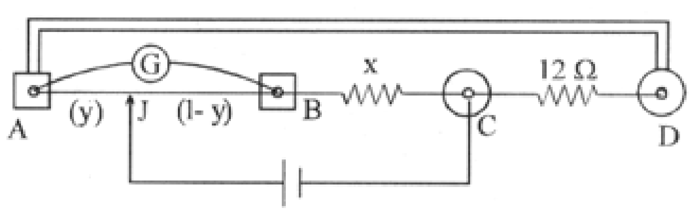


fig - 2

(c) for balanced wheat stone bridge, we must have

$$\frac{y}{1-y} = \frac{12}{x} \quad \Rightarrow \quad x = \frac{12}{y}(1-y) = \frac{12}{0.6} \times 0.4 = 8\ \Omega \quad \textbf{Ans.}$$

Q5.(a) H-like atom is emitting six radiations
let the quantum no. of –0.85 eV shells is n
then that of –0.544 eV must be n + 3
as the transistors between these two levels give six radiations, then diff. must be 3.(eg. from 4 to 1)

we have $\frac{13.6 \text{ x } z^2}{n^2} = 0.85$ and $\frac{13.6z^2}{(n+3)^2} = 0.544$

dividing we get $\frac{(n+3)^2}{n^2} = \frac{0.85}{0.544} \Rightarrow \frac{n+3}{n} = 1.25$

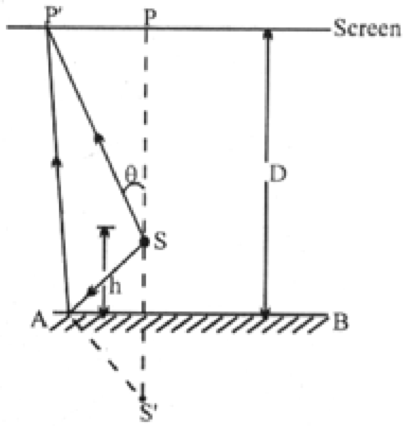
$n + 3 = 1.25\ n$
$0.25n = 3$
$n = 12$
$\Rightarrow \quad n + 3 = 15$

$\Rightarrow \quad 13.6 \text{ x } z^2 = 0.85 \text{ x } (z)^2$
$\Rightarrow \quad z^2 = 9 \Rightarrow z = 3$ ans.

(b) Smaller wavelength corresponds to maximum energy transistor
$\Rightarrow$ n = 15 to n = 12
$\Rightarrow$ energy radiated is $\Delta E = (-0.544) - (-0.85) = 0.306$ eV

$\Rightarrow \lambda = \frac{hc}{\Delta E} = \frac{12400}{0.306} = 40522.87$ Å

Q6.



$\lambda = 6000\text{Å} = 600\text{nm}$

(a) As S is a point source fringes are observed on screen due to light coming from S & its image S′. If at P′ we discuss, what be the phase difference will remain same in a cone of half angle thus fringes will be circular.

(b) Intensity from S is if I, from S′ will be 0.36 I, thus, we have

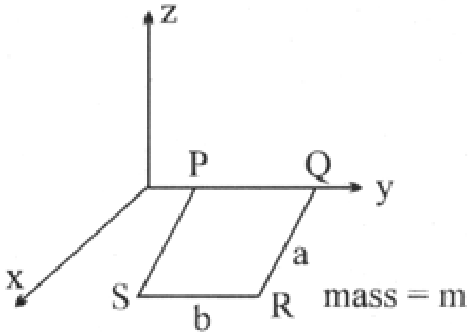
$$\frac{I_{max}}{I_{min}} = \left(\frac{\sqrt{I_1}+\sqrt{I_2}}{\sqrt{I_1}-\sqrt{I_2}}\right)^2 = \left(\frac{1.6}{0.4}\right)^2 = 16$$

(c) If at P there is max ⇒ at P path difference is –

$\Delta = 2h + \lambda/2 \quad = N\lambda$

for again receiving a maxima at P, h must be increased by $\lambda/2$ so that Δ will increase by λ

⇒ disp. of AB is $\lambda/2 = 3000\text{Å}$ Ans.



Q.7 (a) $B = (3\hat{i} + 4\hat{k})B_0$

As loop is in equilibrium

$\Rightarrow \quad \Sigma \tau = 0$

or $\quad \vec{\tau}_{magnetic} + \vec{\tau}_{mg} = 0$

$$\vec{\tau}_{mg} = \left(mg \times \frac{a}{2}\right)\hat{j}$$

If magnetic moment of loop is $\vec{M} = m\hat{k}$ (as $\vec{M}$ is either in z or in – z direction)

$$\Rightarrow \quad \vec{M} \times \vec{B} = -mg \times \frac{a}{2}\hat{j}$$

or $$M\hat{k} \times (3\hat{i} + 4\hat{k})B_0 = -mg\frac{a}{2}\hat{j}$$

$$3MB_0\hat{j} = -mg\frac{a}{2}\hat{j} \quad \text{....(1)}$$

Thus we must have magnitude has M as – ve or $\vec{M}$ is in – z direction. Thus current in loop PQRS is clockwise from P to QRS.

(b) Magnetic force on arm RS is $\vec{F} = I\left(\vec{b} \times \vec{B}\right)$

$$\vec{F} = I\left[(-b\hat{j}) \times (3\hat{i} + 4\hat{k})B_0\right] \quad \text{(as } \vec{b} \text{ is} - b\hat{j})$$

$$\vec{F} = BI_0\left[3b\hat{k} - 4b\hat{i}\right]$$

$$\vec{F} = BI_0 b\ (3\hat{i} - 4\hat{k})$$

$$|\vec{F}| = 5\ BI_0 b \quad \textbf{Ans.}$$

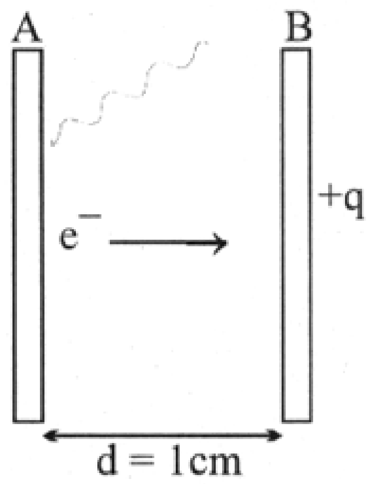
(c) From equation (1) we have

$$3MB_0 = mg\frac{a}{2} \quad \text{in magnitude}$$

$$3\ I\ b\ B_0 = \frac{mg}{2}$$

$$I = \frac{mg}{6bB_0} \quad \textbf{Ans.}$$

Q8.



Area $A = 5 \times 10^{-4}\ m^2$

$q = 33.7 \times 10^{-12}$ C

& $\frac{hc}{\lambda} = 5eV$

given 10^{16} photon falls /sec/ m^2

photo efficiency is $\eta = 1$ out of 10^6 ph

work function of A $\phi = 2eV$

(a) No. of photo electrons upto t = 10 sec.

$$N = \frac{10^{16}}{10^6} \times 5 \times 10^{-4} \times 10 = 5 \times 10^7\ e^-$$

(b) Charge emitted in 10 sec. is $q = 5 \times 10^7 \times 1.6 \times 10^{-19} = 8 \times 10^{-12}$ coul

now charge on plate A is $q_A = +8 \times 10^{-12}$ coul

on plate B is $q_B = +(337 - 8) \times 10^{-12} = 25.7 \times 10^{-12}$ coul

EF between the two plates now is

$$E = \frac{q_B - q_A}{2A \in_0} = \frac{17.7 \times 10^{-12}}{2 \times 5 \times 10^{-4}} = 2000\ V/m$$

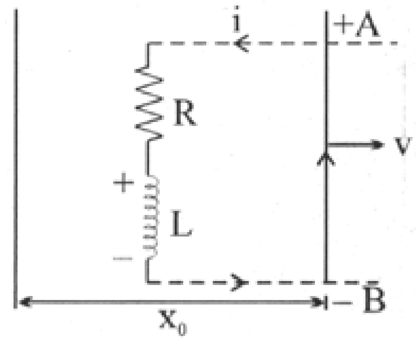
(c) maximum KE of the photo electron just emitted by plate A is $KE_{max} = 5 - 2 = 3eV$

potential difference at this instant between plates A & B is = E.d = 2000 x 1 cm

= 20 volts

$\Rightarrow$ KE of e^- when reaches B is $KE_{at\ B} = 3eV + 20eV = 23\ eV$

Q.9 (a) Let i be the current in circuit when wire AB is sliding at v towards right, emf induced in wire is when it is at dustance x from I_0



$$e_{AB} = \frac{\mu_0 I_0}{2\pi x}.l.v = \frac{d\phi}{dt} \quad \text{(if v is the velocity of AB at this instant)}$$

for circuit loop we can write

$$e_{AB} - iR - L\frac{di}{dt} = 0$$

$$\frac{d\phi}{dt} - iR - L\frac{di}{dt} = 0$$

(b) Charge flown through the resistance is $q = \int_0^T i\,dt$

or for circuit loop we can write total charge flown is

$$\Delta q = \frac{\Delta\phi}{R} = \frac{(\phi_1 - Li_1) - \phi_2}{R}$$

where ϕ_1 = final flux through circuit when $x = 2x_0$

& ϕ_2 = initial flux through circuit when $x = x_0$

$$\Rightarrow \quad \phi_1 - \phi_2 = \frac{\mu_0 I_0 l}{2\pi} \, ln(2)$$

$$\Rightarrow \quad \Delta q = \frac{\frac{\mu_0 I_0 l \, ln(2)}{2\pi} - Li_1}{R}$$

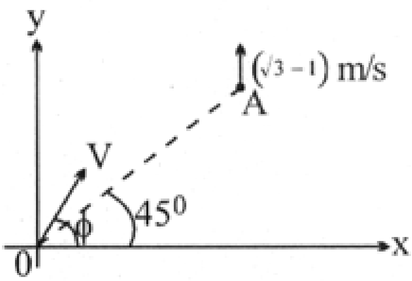
(c) Given that at time t rod is stopped, now transient decays & decaying current is

$i = i_0 e^{-Rt/L}$ where $i_0 = i_1$ & $i = i_1/4$ at $t = 2T$

$$\Rightarrow \quad i_1/4 = i_1 e^{-R(2T)/L}$$

$$2\,ln\,2 = \frac{2RT}{L} \quad \Rightarrow \quad \frac{L}{R} = \frac{T}{ln(2)}$$

Q10.



(a) As ball will hit A, it appears to A that ball is moving towards A from O. Thus the apparent angle will be 45^0

(b) If velocity of ball relative to surface is v. Velocity w.r.t. A is

$$v_x = v\cos\phi$$

$$v_y = v\sin\phi - \left(\sqrt{3}-1\right)$$

we have $\theta = 45^0 = \tan^{-1}\dfrac{v_x}{v_y} = \tan^{-1}\left(\dfrac{v\cos\phi}{v\sin\phi - \left(\sqrt{3}-1\right)}\right)$

given that $\phi = \dfrac{4\theta}{3} = 60^0$

$$\Rightarrow \tan 45^0 = 1 = \frac{v\cos\phi}{v\sin\phi - \left(\sqrt{3}-1\right)}$$

$$v\sin(60^0) - \left(\sqrt{3}-1\right) = v\cos 60^0$$

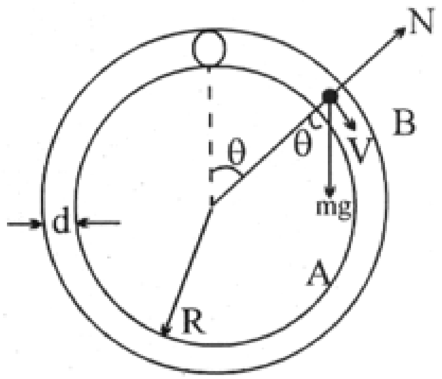
$$\frac{v\sqrt{3}}{2} - \sqrt{3} + 1 = \frac{v}{2}$$

$$v\sqrt{3} - \sqrt{3} \times 2 + 2 = v$$

$$v\left(\sqrt{3}-1\right) = 2\left(\sqrt{3}-1\right)$$

v = 2m/sec.

Q11.



(a) Let when ball is at an angle θ, its velocity is given by

$$V = \sqrt{2gR(1-\cos\theta)}$$

for its radial equilibrium we have

$$mg\cos\theta = N + \frac{mv^2}{R} \Rightarrow N = mg\cos\theta - \frac{m}{R}\,(2gR(1\text{-}\cos\theta))$$

$N = 3mg\cos\theta - 2mg$

(b) We know that N_A wll be zero when

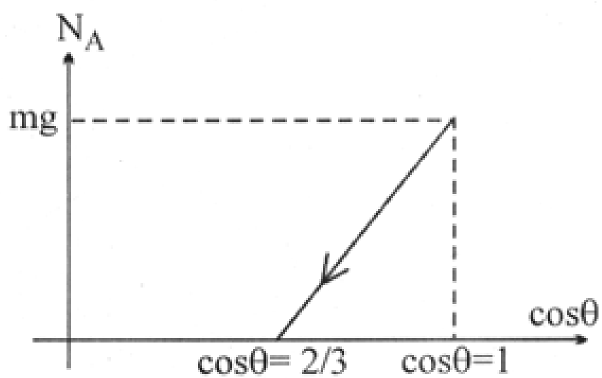
$$\frac{mv^2}{R} = mg\cos\theta \Rightarrow \cos\theta = 2/3$$

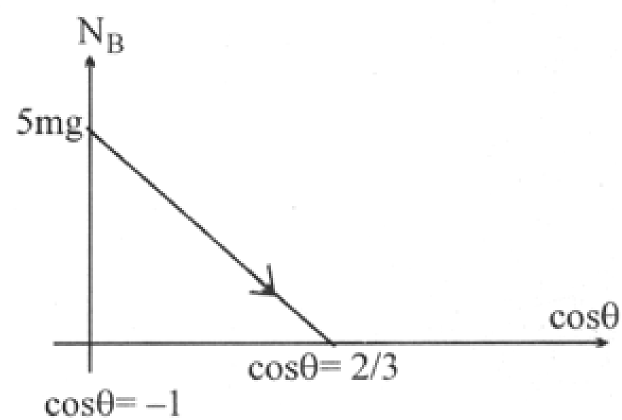
now N_B appears as we will have after this instant

$$N_B + mg\cos\theta \Rightarrow \frac{mv^2}{R} = 2mg - 2mg\cos\theta$$

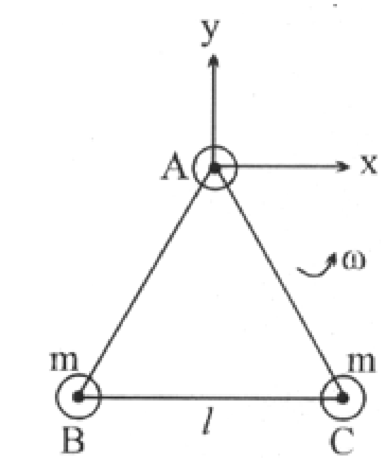
or $N_B = 2mg - 3mg\cos\theta$

graphs are as follows –





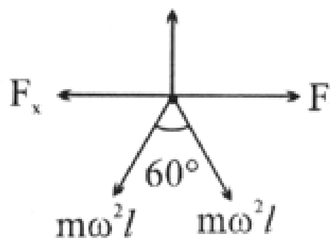
Q.12

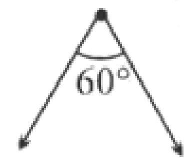


(a) Force exerted by hinge in horizontal direction must be equal to the centripetal force required for circular motions of particle B & C as

$$F_H = 2\ m\ \omega^2 l \cos 30^\circ = \sqrt{3}\, m\ \omega^2 l$$

(b) Now let hinge exerts F_x & F_y force on body. We have

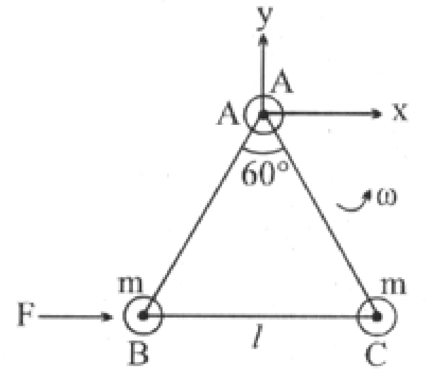




Let body rotates with angular a_{cm}, we have

$$F \times \frac{\sqrt{3}\, l}{2} = 2mt^2.\alpha$$

or $$\alpha = \frac{\sqrt{3}\, F}{2ml}$$



linear acceleration of cm of body is

$a_{cm} = \alpha \times \dfrac{l}{\sqrt{3}} = \dfrac{\sqrt{3}\, F}{4ml} \times \dfrac{l}{\sqrt{3}} = \dfrac{F}{4M}$ in horizontal direction from above F & D we have

$$F - F_x = 3\ m\left(\frac{F}{4M}\right) = \frac{3F}{4}$$

$$F_x = F - \frac{3F}{4} = \frac{F}{4} \qquad \textbf{Ans.}$$

In y direction there is no acceleration of body at this instant thus

$$F_y = 2\ m\ \omega^2 l \cos 30^\circ = \sqrt{3}\ m\ \omega^2 l.$$