PART A - PHYSICS

SECTION I - MULTIPLE ANSWER CORRECT TYPE

1. **a) magnetic field inside cavity is uniform**
   c) magnetic field inside cavity is perpendicular to $\vec{a}$
   d) If an electron is projected with velocity $v_0\vec{j}$ inside the cavity it will move undeviated

   Magnetic field is given by $\vec{B} = \frac{\mu_0\left(\vec{j}\times\vec{a}\right)}{2}$

2. **a) If coil is free to rotate about x axis torque on the coil is given by $\frac{1}{2} iAB_0 \hat{i}$**
   b) If coil is free to rotate about y-axis torque on coil is given by $-\frac{1}{2} iAB_0 \hat{j}$
   c) Resultant force on coil is zero
   d) Equation for the torque $\vec{u}\times\vec{B}$ where μ is magnetic moment of coil is not valid on the coil
   Wire segment (1)

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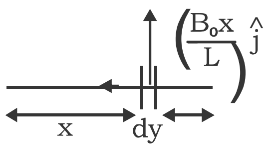
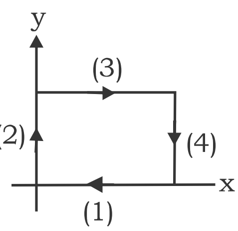




$$\left(d\vec{f}\right) = \int_0^L i dx\left(\frac{B_0 x}{2}\right) = \frac{iB_0 L}{2}$$

$$d\vec{f} = \frac{-iB_0 L}{2}\hat{K}$$

Similary for $\vec{f_2} = -\frac{-iB_0 L}{2}\hat{K}$

$$\vec{f_3} = \frac{iB_0 L}{2}\hat{K}$$

$$\vec{f_4} = \frac{iB_0 L}{2}\hat{K}$$

$$\vec{f_a} = \theta$$

If coil is constrained to rotate about

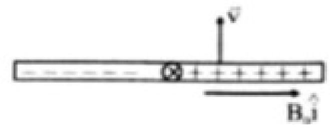
y-axis $|\bar{\tau}| = 1\left(\frac{B_0 L}{2}\right)L$

$$= \frac{iAB_0}{2}$$

$\Rightarrow$ Similarly for torque about has same magnitude

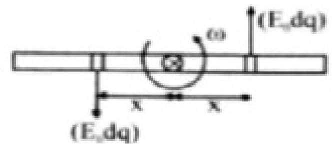
3. **c) An electric field $E_0\left(-\hat{j}\right)$ will slow down rod**
   d) A magnetic field can not show down the rod

A)



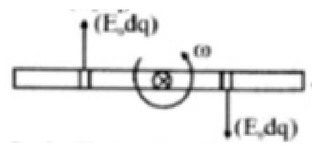
Magnetic force is $\perp$ inward on right half and outward on left body. If is constrained so no effect.

B)



Torque of electric force increases ω.

C)



Torque electric force increases ω.

D) Rod will slow down only if force on any element is opposite to velocity magnetic force is always $\perp$ to velocity vectur.

4. **a) Radius of the loop changes with r as $r = r_0 - vt/\pi$**
   b) EMF induced in the loop as a function of time is $e = 2Bv[r_0 - vt/\pi]$
   d) Current induced in the loop is $I = \frac{Bv}{\pi\lambda}$

$\therefore \quad \frac{d}{dt}(2\pi r) = 2v \quad \Rightarrow \quad \frac{dr}{dt} = \frac{v}{\pi}$

$\therefore \quad r = \left(r_0 - \frac{v}{\pi}t\right)$

$\phi = B \cdot \pi r^2 \quad \Rightarrow \quad 6 = \left|\frac{-d\phi}{dt}\right| = B.\,2\pi.r\frac{dr}{dt}$

$\therefore \quad 6 = 2B\pi\left(r_0 - \frac{v}{\pi}t\right).\frac{v}{\pi} = 2Bv\left(r_0 - \frac{v}{\pi}t\right)$

$I = \frac{\phi}{R} = \frac{2Bvr}{\lambda.2\pi r} = \frac{Bv}{\pi\lambda}$

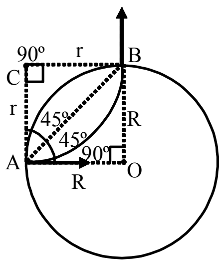
5. **a)** $\mathbf{B = \frac{mv}{qR}}$

b) $\mathbf{T = \frac{\pi R}{2v}}$

c) $\mathbf{T = \frac{\pi m}{2qB}}$

$r = \frac{mv}{qB}$

$\therefore$ r = R [as OACB is a sqaure]



$R = \frac{mv}{qB} \Rightarrow B = \frac{mv}{qR}$

$T = \frac{\theta}{\omega}, \omega = \frac{qB}{m}$

$T = \frac{\pi m}{2qB} \Rightarrow T = \frac{\pi R}{2v}$

6. **b)** $\mathbf{\frac{L_2}{L_1}}$

c) $\mathbf{\frac{I_1}{I_2}}$

$\therefore \quad L_1I_1 = L_2I_2$

$\frac{U_1}{U_2} = \frac{\frac{1}{2}L_1I_1I_1}{\frac{1}{2}L_2I_2I_2} = \frac{I_1}{I_2} = \frac{L_2}{L_1}$

7. **b) the maximum charge on the capacitor will become $\sqrt{2}$ times of its initial value**

c) the maximum current that will appear in the circuit will be $\sqrt{2}$ times of its initial value I_{max}.

d) at the moment energy stored in capacitor and inductor becomes equal the charge on the capacitor will be equal to the initial maximum charge on it.

As there will be no change in either L or C by changing energy of the oscillations $f = 2\pi\left(\frac{1}{\sqrt{LC}}\right)$ will not change. Total energy

$= \frac{\left(\sqrt{2}Qm\right)^2}{2C}$

Therefore maximum charge on the capacitor has become $\sqrt{2}$ times of the initial maximum charge Qm

$\frac{1}{2}Li_m{}^2 = 2 \times \frac{1}{2}Li_m{}^2 \quad Þ \quad i_m = \sqrt{2}\, i_m$

when total energy is equal divided between capacitor and inductor. Charge on capacitor

$= \frac{1}{2}\left[\frac{2Q_m^2}{2C}\right] = \frac{Q_m^2}{2C}$

i.e. it is equal to initial maximum charge on the capacitor.

8. **a)** $\mathbf{q = 10\sqrt{2}\sin\left(10^4 t\left(s^{-1}\right) + \frac{3\pi}{4}\right)}$

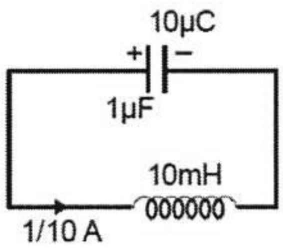
b) $\mathbf{q = 10\sqrt{2}\sin\left(10^2 t\left(s^{-1}\right) + \frac{\pi}{4}\right)}$

After closing S_1, S_2 and S_3:

At t = 0

At any Time t :

$\frac{d^2q}{dt^2} = -\omega^2 q$



$\Rightarrow$ $q = Q_{max} \sin(\omega t + \phi)$

$$\frac{1}{2}(10mH)\left(\frac{1}{10}\right)^2 + \frac{(10\mu C)^2}{2.(1\mu F)} = \frac{Q_{max}^2}{2.(1\mu F)} = \frac{1}{2}(10mH)I_{max}^{\ 2}$$

$\Rightarrow$ $Q_{max} = 10\sqrt{2}\,\mu C$

$I_{max} = \frac{1}{5\sqrt{2}} A$

At t = 0, q = 10 μC so $\phi = \frac{3\pi}{4}$

Also $\frac{di}{dt} = q$

so $\frac{di}{dt}$ will become maximum when charge becomes maximum.

SECTION II - PARAGRAPH TYPE

Paragraph - 1

1. **d)** **zero**

Since $\vec{M} \,||^{r}$ to $\vec{B}$

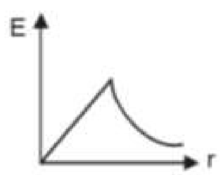
$\therefore$ torqur zero.

2. **d)** **none**

at C direction must be along $t\hat{k}$

Paragraph - 2

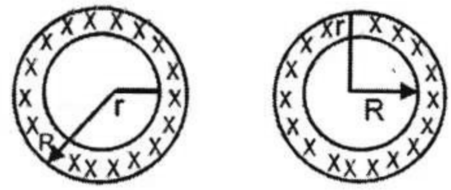
1. **a)**



For r < R $\quad \oint E dl = A\frac{dB}{dt}$

$E\, 2\pi r = (\pi r^2)\alpha$

$E = \frac{r\alpha}{2}$ or $E \propto r$



So, E - r graph is a straight line passing through origin.

At r = B $\quad E = \frac{R\alpha}{2}$

For r > R $\quad E\, 2\pi r = (\pi R^2)\alpha$

Hence, choice (a) is correct and choices (b), (c) and (d) are wrong.

2. **b)** **20 mV**

Perpendicular dostance between BC and center O iis 10 cm. Component of induced electric field along the rod = $\frac{d}{2}\frac{dB}{dt}$

BC O 10cm = $\frac{d}{2}\frac{dB}{dt}$

Where d = Perpendicular distance from center to the rod.

Hence, potential difference between the ends of rod

$v = EI = 1.\frac{d}{2}\frac{dB}{dt}$

$= \frac{10}{2} \times 10^{-2} \times 20 \times 10^{-2} \times 2 = 20$ mv

Hence, choice (b) is correct and choices (a), (c) and (d) are wrong

SECTION III - INTEGER TYPE ANSWER

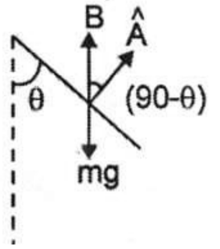
1. **4**

Applying Energy conservation, intialy kinetic energy = 0 gravitational P.E. = 0 (say) & Magnetic P.E. = μB

Where, μ = magnetic moment of the loop

$= i.\left(\frac{\sqrt{3}a^2}{4}\right)$

Finally when the loop becomes horizontal, kinetic energy = 0 gravitation P.E. = mg $\left(\frac{a}{\sqrt{3}}\right)$ (becouse mg acts on the center of mass) magnetic P.E. = 0



$$\Rightarrow \quad 0 + 0 + \mu B = 0 + \frac{mga}{\sqrt{3}} + 0$$

$$\Rightarrow \quad B = \frac{mga}{\sqrt{3}} = \frac{4mg}{3ia} \text{ using values, } B = 400 \text{ mT}$$

2.

$a = 0$

$$F_0 = F_m = ilB = \left(\frac{\varepsilon}{R}\right)lB = \left(\frac{Blv_0}{R}\right)lB$$

v_0 = velocity at point 'P'

Now, retardation $a = \frac{F_m}{m} = \frac{ilB}{m}$

$$a = \frac{B^2l^2}{mR}v$$

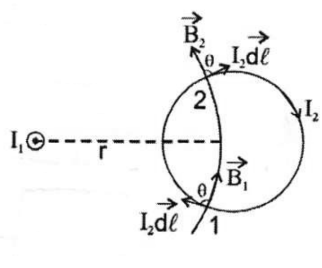
$$\Rightarrow \quad -v\frac{dv}{ds} = \frac{B^2l^2}{mR}v$$

$$\text{or } -\int_{v_0}^{0} dv = \frac{B^2l^2}{mR}\int_0^s ds$$

$$\text{or } v_0 = \frac{B^2l^2}{mR}s$$

$$\text{or } s = \frac{B^2l^2}{mR} = \frac{F_0 mR^2}{B^4l^4} = 320\text{m}$$

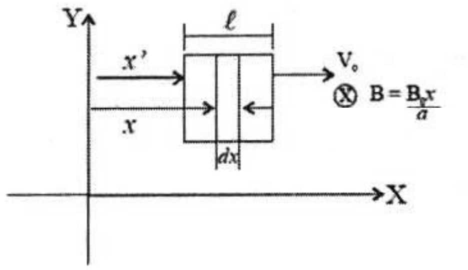
3. **0**



The force on current elements 1 and 2 is equal in magnitude and opposite in direction

$\Rightarrow F_{net} = 0$

4. **3**



$$d\phi = \frac{B_0\ell}{a} \times \ell dx$$

$$\phi = \frac{B_0\ell}{a}\int x\,dx$$

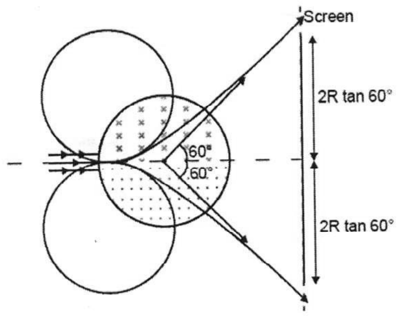
$$\phi = \frac{B_0\ell}{a}\int_x^{x'+\ell} x\,dx$$

$$\Rightarrow \phi = \frac{B_0\ell}{2a}\left[(x'+\ell)^2 - (x')^2\right]$$

$$\varepsilon = \frac{d\phi}{dt} = \frac{B_0\ell}{2a}\left[2(x'+\ell)V_0 - 2x'\,V_0\right]$$

$$\varepsilon = \frac{B_0\ell^2V_0}{a} = 3 \text{ volts}$$

5. **X = 3**



Required

$d = 4R\tan 60^0 = 4\left(\sqrt{3}\right)\sqrt{3} = 12$

6. **4**

Just after the switch is closed, there is no current through the coil and capacitor offers no resistance.

Net Resistance = $\frac{9}{2}$ = 4.5 $\Omega \Rightarrow$ $i_0 = \frac{18}{4.5}$ = 4 A.

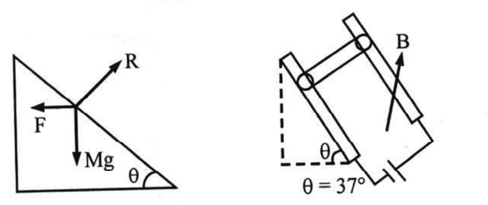
7. **1**

$$\varepsilon = \frac{\Delta\phi}{\Delta t} = \frac{(\phi_2 - \phi_1)}{\Delta t}$$

$$= \frac{\phi_1 - \phi_2}{\Delta t}$$

$$= \frac{BA - 0}{\Delta t} = \frac{0.5 \times \pi (1 \times 10^{-2})^2}{0.5} = \pi \times 10^{-4}\,V$$

8. **3**



F cos θ = Mg sin θ

Bl L cos θ = Mg sin θ

$$B = \frac{Mg}{IL}\tan\theta$$