JEE Main Exercise

1. (B)

$$\left|\varepsilon_{avg}\right| = \left|\frac{\Delta\phi}{\Delta t}\right| = \left|\frac{0-2}{6}\right| = \frac{1}{3}\text{ V}$$

2. (D)

$$\varepsilon = -\frac{d\phi}{dt} = -3(3at^2 - 2bt)$$

$$i = \frac{\varepsilon}{R} = -(3at^2 - 2bt)$$

$$\frac{di}{dt} = -(6at - 2b) = 0$$

$$\Rightarrow \quad t = \frac{b}{3a}$$

At $t = \frac{b}{3a}$;

$$i_{\max} = -\left[3a\left(\frac{b}{3a}\right)^2 - 2b\left(\frac{b}{3a}\right)\right] = \frac{b^2}{3a} = 6\text{ A}$$

3. (C)

$$|\varepsilon| = \left|\frac{d\phi}{dt}\right| = \frac{d\left(B\pi R^2\right)}{dt} = B\pi 2R\frac{dR}{dt} = 2\pi(R_0 + t)B$$

As radius increases, magnetic flux through the loop increases.
To oppose that induced current will be anti-clockwise.

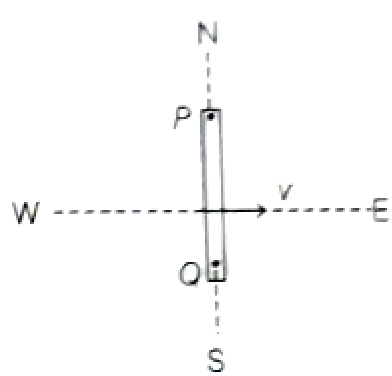
4. (A)

$$\varepsilon = Blv\sin 90^\circ$$

$$\Rightarrow V_P - V_Q = 4(0.3)(10)$$

$$\Rightarrow V_P - 0 = 12$$

$$\Rightarrow V_P = 12\text{ V}$$



5. (A)

$\varepsilon = (\mathbf{v} \times \mathbf{B}) \cdot \mathbf{I}$

$= \left(2\hat{\mathbf{i}} \times \left(3\hat{\mathbf{j}} + 4\hat{\mathbf{k}}\right)\right) \cdot \left(5\cos 53^\circ \hat{\mathbf{i}} + 5\sin 53^\circ \hat{\mathbf{j}}\right)$

$= \left(-8\hat{\mathbf{j}} + 6\hat{\mathbf{k}}\right) \cdot \left(3\hat{\mathbf{i}} + 4\hat{\mathbf{j}}\right)$

$= -32 \text{ V}$

6. (B)

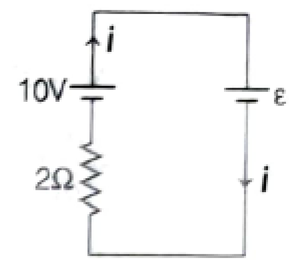
$F_{\text{ext}} = Bil$

$\Rightarrow \quad 0.5 = 0.5 \times i \times 0.25$

$\Rightarrow \quad i = 4 \text{ A}$

$i = \dfrac{10 - \varepsilon}{2} \Rightarrow 4 = \dfrac{10 - Blv}{2}$

$\Rightarrow \quad v = 16 \text{ m/s}$



7. (A)

Let velocity be v at any time.

$\varepsilon = Blv = 0.02 \times 0.5 \times v$

$\Rightarrow \quad \varepsilon = 0.01v$

$i = \dfrac{1 - \varepsilon}{10} = \dfrac{1 - 0.01v}{10}$

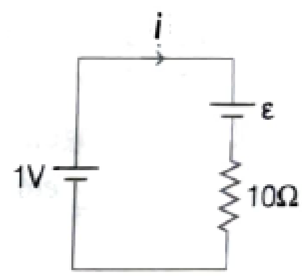
$F = Bil$

$\Rightarrow \quad m\dfrac{dv}{dt} = Bil$

$\Rightarrow \quad 0.002\dfrac{dv}{dt} = 0.02\left(\dfrac{1 - 0.01v}{10}\right)(0.5)$

$\Rightarrow \quad \int_0^v \dfrac{dv}{100 - v} = \dfrac{1}{200}\int_0^t dt$

$\Rightarrow \quad v = 100(10 - e^{-t/200})$



8. (D)

$\varepsilon = \int (\mathbf{v} \times \mathbf{B}) \cdot d\,\mathbf{I}$

$\mathbf{v} = \omega(x \sin\theta)\hat{\mathbf{k}}$

$\mathbf{B} = -B\,\hat{\mathbf{j}}$

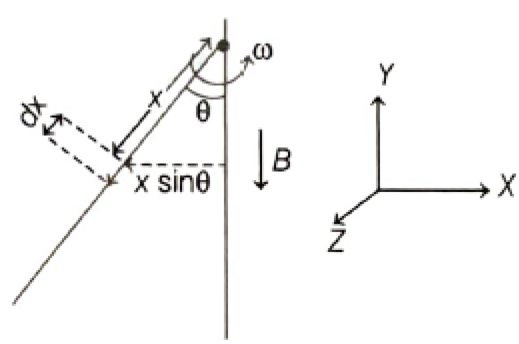
$\mathbf{dl} = -dx \sin\theta\,\hat{\mathbf{i}}$

$\quad -dx \cos\theta\,\hat{\mathbf{j}}$

$\varepsilon = \int\left[\omega\left(x\sin\theta\hat{\mathbf{k}}\right) \times \left(-B\hat{\mathbf{j}}\right)\right] \cdot \left(dx\sin\theta\hat{\mathbf{i}} - dx\cos\theta\hat{\mathbf{j}}\right)$

$= \int\left[\left(B\omega x \sin\theta\hat{\mathbf{i}}\right) \cdot \left(-dx\sin\theta\,\hat{\mathbf{i}} - dx\cos\theta\,\hat{\mathbf{j}}\right)\right]$

$= -B\omega\sin^2\theta\int_0^L x\,dx = \dfrac{-1}{2}B\omega L^2\sin^2\theta$



9. (A)

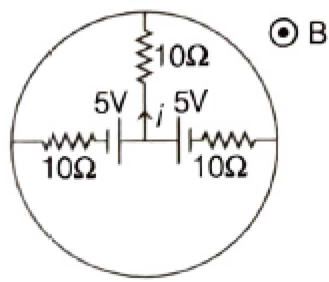
$$\varepsilon = \int Bvdx = \int_0^{L/2} B_0\left(v_0 + \frac{v_0}{L}x\right)dx = \frac{5}{8}B_0v_0L$$

10. (A)

About instantaneous axis of rotation through Q, ring is in pure rotation.

So, $\varepsilon = \frac{1}{2}B\omega I^2 = \frac{1}{2}B\omega(\sqrt{2}R)^2 = B\omega R^2$

11. (C)



$$\varepsilon = \frac{1}{2}B\omega R^2 = \frac{1}{2}\times 50\times 20\times (0.1)^2$$

$$= 5\,\text{V}$$

$$\varepsilon_{eq} = \frac{\frac{5}{10}+\frac{5}{10}}{\frac{1}{10}+\frac{1}{10}} = 5\,\text{V}\,;$$

$$r_{eq} = \frac{10(10)}{10+10} = 5\Omega$$

$$i = \frac{\varepsilon_{eq}}{R+r_{eq}} = \frac{5}{10+5} = \frac{1}{3}\text{A}$$

12. (C)

$$\varepsilon = \frac{1}{2}B\omega r^2, i = \frac{\varepsilon}{R} = \frac{1}{2}\frac{B\omega r^2}{R}$$

$$F_b = Bir$$

$$\sum \tau = 0$$

$$\Rightarrow \quad Fr - (Bir)\frac{r}{2} = 0$$

$$\Rightarrow \quad F = \frac{B^2\omega r^3}{4R}$$

13. (C)

For $r \le R$,

$$E(2\pi r) = \frac{d}{dt}\left(\int_0^r B(2\pi)dr\right)$$

$$\Rightarrow \quad Er\frac{d}{dt}\left(\frac{ktr^3}{3}\right)$$

$$\Rightarrow \quad E = \frac{kr^2}{3}$$

For $r > R$,

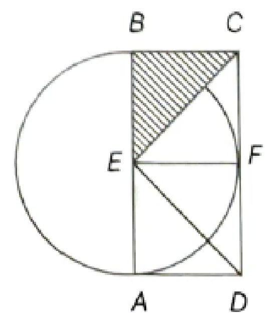
$$E(2\pi r) = \frac{d}{dt}\left(\int_0^R B2\pi r\,dr\right) \Rightarrow E = \frac{kR^3}{3r}$$

At $r = \frac{R}{2}, E_1 = \frac{kR^2}{12}$ and $r = 2R, E_2 = \frac{kR^2}{6}$

$\therefore \quad \frac{E_2}{E_1} = 2$

14. (C)

For loop EBC,



$$\phi = BA = B\left(\frac{R^2}{2}\left(\frac{\pi}{4}\right)\right)$$

$$|\varepsilon| = \left|\frac{d\phi}{dt}\right|$$

$$\Rightarrow \oint \mathbf{E}\cdot\mathbf{dl} = \left(\frac{\pi R^2}{8}\right)\frac{dB}{dt}$$

$$\Rightarrow \int_E^B \mathbf{E}\cdot\mathbf{dl} + \int_B^C \mathbf{E}\cdot\mathbf{dl} + \int_C^E \mathbf{E}\cdot\mathbf{dl} = \left(\frac{\pi R^2}{8}\right)\frac{dB}{dt}$$

$$\Rightarrow 0 + \int_E^B \mathbf{E}\cdot\mathbf{dl} + 0 = \left(\frac{\pi R^2}{8}\right)b = \varepsilon_{BC} = \frac{\pi R^2 b}{8}$$

$$\Rightarrow \varepsilon_{AB} = \int_A^B \mathbf{E}\cdot\mathbf{dl} = 0$$

$\therefore \quad \mathbf{E} \perp \mathbf{dl}$

15. (C)

$$L = \mu_0 n^2 V = \mu_0\left(\frac{N}{I}\right)^2 \pi r^2 I \text{ and } N = \frac{I}{2\pi r}$$

$$\Rightarrow L = \frac{\mu_0 I}{4\pi} \Rightarrow L \propto I$$

Since length is same, self-inductance will be same.

16. (B)

$$\phi = Mi \Rightarrow 1.8\times10^{-3} = M(2) \Rightarrow M = 9\times10^{-4}\text{ H}$$

$$\phi = Mi \Rightarrow \phi = (9\times10^{-4})(3) = 2.7\times10^{-3}\text{ Wb}$$

17. (C)

$$V_A - 5(1) - 15 - 5\times10^{-3}\left(-10^{-3}\right) = V_B$$

$$\Rightarrow V_B - V_A = -15\text{ V}$$

18. (B)

$$V_A - V_B = iR + L\frac{di}{dt}$$

$$140 = 5R + 10L \Rightarrow R + 2L = 28 \qquad \text{...(i)}$$

$$60 = 5R - 10L \Rightarrow R - 2L = 12 \qquad \text{...(ii)}$$

Solving Eqs. (i) and (ii), we get

$$L = 4\,\text{H}$$

19. (C)

$$U = \frac{1}{2}Li^2 \Rightarrow \frac{dU}{dt} = \frac{1}{2}L\left(2i\frac{di}{dt}\right) = 2\times2\times4 = 16\ \text{J/s}$$

20. (A)

$$P = 8i^2 \Rightarrow \left(8\frac{di}{dt}\right)i = 8i^2$$

$$\Rightarrow \int_{i_0}^{2i_0}\frac{di}{i} = \int_0^t dt \Rightarrow t = \ln 2$$

21. (A)

Current in inductor branch will gradually increase to its steady state value.

22. (D)

$$(2L)\left(\frac{E}{R}\right) + L\left(-\frac{E}{R}\right) = (2L + L)i$$

$i = \dfrac{E}{3R}$, anti-clockwise

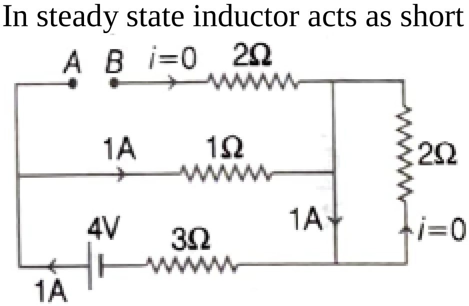
23. (A)

$$V = L\frac{di}{dt} = L\left(\frac{\varepsilon}{L}e^{-\frac{Rt}{L}}\right) = \varepsilon e^{-\frac{Rt}{L}}$$

At $t = \ln\sqrt{2}; V = 6e^{-\left(\frac{10\ln\sqrt{2}}{5}\right)} = 3\,\text{V}$

24. (B)

In steady state inductor acts as short circuit and capacitor acts as open circuit.



$$V_A - V_B = 1(1) = 1\,\text{V}$$

$$U_L = \frac{1}{2}Li^2 = \frac{1}{2}(0.1)(1)^2 = \frac{1}{20}\text{ J}$$

$$U_C = \frac{1}{2}CV^2 = \frac{1}{2}\times 1\times 10^{-60}\times(1)^2$$

$$= \frac{10^{-6}}{2}\text{ J}$$

$$\Rightarrow \quad \frac{U_L}{U_C} = 10^5$$

25. (A)

Charge on capacitor in steady state $= C\varepsilon$

Current through inductor in steady state = 0

$$E = (C\varepsilon)\varepsilon = C\varepsilon^2$$

$$U = U_L + U_C = 0 + \frac{(C\varepsilon)^2}{2C} = \frac{1}{2}C\varepsilon^2$$

$$Q = E - U = \frac{1}{2}C\varepsilon^2$$

26. (C)

Using KVL,

$$+E - iR - L\frac{di}{dt} - \frac{q}{C} = 0$$

$$\Rightarrow \quad +4 - 2(1) - 1(4) - \frac{q}{3\times 10^{-6}} = 0$$

$$\Rightarrow \quad q = 6\,\mu\text{C}$$

27. (D)

$$i_{AB} = \frac{10}{2}\left(1 - e^{-\frac{2t}{2}}\right) = 5\left(1 - e^{-t}\right)$$

$$i_{CD} = \frac{10}{1}e^{-\frac{t}{(1)(1)}} = 10e^{-t}$$

$$i_{AB} = i_{CD} \Rightarrow 5\left(1 - e^{-t}\right) = 10e^{-t}$$

$$\Rightarrow \quad t = \ln 3\text{s}$$

28. (D)

$$i = \frac{E}{R}e^{-\left(\frac{Rt}{L}\right)}$$

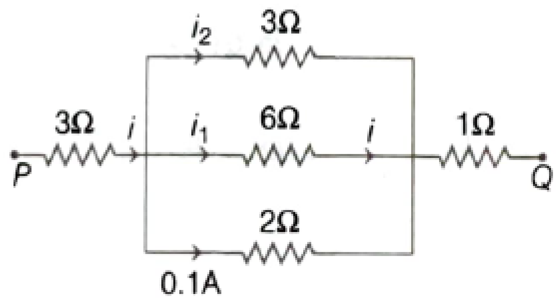
At $\quad t = 0; i_1 = \frac{E}{R}$

At $\quad t = \frac{2L}{R}; i_2 = \frac{E}{e^2 R}$

Heat dissipated in resistor = Loss in energy of inductor

$$= \frac{1}{2}Li_1^2 - \frac{1}{2}Li_2^2$$
$$= \frac{LE^2}{2R^2}\left(\frac{e^4-1}{e^4}\right)$$

29. (5.00)



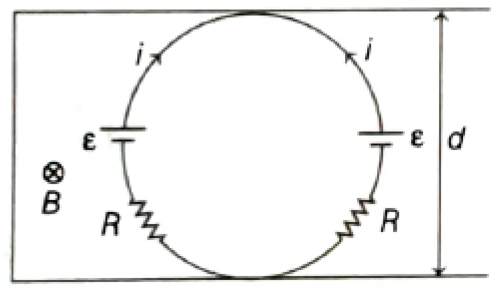
$$i = i_1 + i_2 + 0.1$$
$$= \frac{0.1}{3} + \frac{(0.1)2}{3} + 0.1 = 0.2\,\text{A}$$
$$V_P - V_Q = i\left(3+1+\left(\frac{1}{3}+\frac{1}{6}+\frac{1}{2}\right)^{-1}\right) = 1\text{V}$$
$$V_P - V_Q = BIv = 1$$
$$\Rightarrow\ 2\times 0.1\times v = 1$$
$$\Rightarrow\ v = 5\ \text{m/s}$$

30. (8)

$$i = \frac{BIv}{R},\ \ F = Bil = ma$$
$$\Rightarrow\ \frac{B^2I^2v}{R} = -mv\frac{dv}{dx}$$
$$\Rightarrow\ \int_0^x dx = -\frac{mR}{B^2I^2}\int_{v_0}^{0} dv$$
$$\Rightarrow\ x = \frac{mv_0R}{B^2I^2} = 8\,\text{m}$$

31. (4)

$$\varepsilon = Bvd\ \text{ and }\ R = \lambda\left(\frac{\pi d}{2}\right)$$
$$i = \frac{\varepsilon}{R} = \frac{2Bv}{\pi\lambda}$$
$$F = Bid + Bid = \frac{4B^2vd}{\pi\lambda}$$
So, $N = 4$

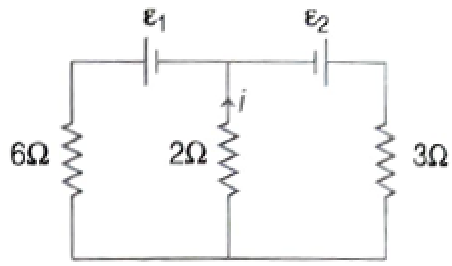


32. (2.36)

$$\varepsilon_1 = A_1 \frac{dB}{dt} = \pi(0.1)^2(100) = \pi\,\text{V}$$

$$\varepsilon_2 = A_2 \frac{dB}{dt} = \pi(0.2)^2(100) = 4\pi\,\text{V}$$

$$r_{eq} = \frac{6(3)}{6+3} = 2\Omega$$



$$\varepsilon_{eq} = \frac{\frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2}}{\frac{1}{r_1} + \frac{1}{r_2}}$$

$$= \frac{\frac{\pi}{6} + \frac{4\pi}{3}}{\frac{1}{6} + \frac{1}{3}} = 3\pi\,\text{V}$$

$$= i = \frac{\varepsilon_{eq}}{R + r_{eq}} = \frac{3\pi}{2+2} = \frac{3\pi}{4}\,\text{A} = 2.36\,\text{A}$$

33. (3)

$$\phi = BA\cos\theta = \left(\frac{\mu_0 NIR^2}{2\left(R^2 + x^2\right)^{3/2}}\right)\pi r^2 \cos 0°$$

$$\varepsilon = \left|\frac{d\phi}{dt}\right| = \left(\frac{\mu_0 NIR^2 \pi r^2}{2}\right)\left(-\frac{3}{2}\frac{2x}{(R^2+x^2)^{5/2}}\frac{dx}{dt}\right)$$

To maximize $\varepsilon, \frac{d\varepsilon}{dt} = 0$

$$\Rightarrow \quad -\frac{3}{2}\mu_0 NIR^2\, \pi r^2 v$$

$$\left(\frac{(R^2+x^2)^{5/2} v - \frac{5}{2}(R^2+x^2)^{3/2}(2x^2)v}{(R^2+x^2)^5}\right) = 0$$

$$\Rightarrow \quad R^2 + x^2 - 5x^2 = 0$$

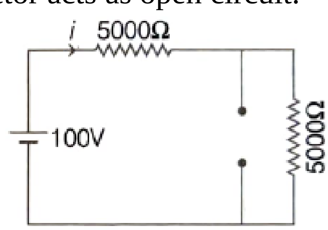
$$\Rightarrow \quad x = \frac{R}{2} = 3\,\text{m}$$

34. (1)

Just after closing the switch inductor acts as open circuit.

$$i = \frac{100}{(5000+5000)} = \frac{1}{100}\,\text{A}$$

$$P = Vi = 100 = 1\,\text{W}$$



35. (100)

$$L=\mu_0 n^2 V=\mu_0\left(\frac{N}{I}\right)^2 \pi r^2 I=\frac{\mu_0 (Nr)^2 \pi}{I}$$

$$1\times 10^{-3}=\frac{4\pi\times 10^{-7}(Nr)^2\pi}{1} \Rightarrow N\pi r=50$$

Length of wire $=N(2\pi r)=2\times 50=100\text{ m}$

36. (1)

$$P=i^2R=\left[\frac{V}{R}\left(1-e^{-t/\tau}\right)\right]^2 R$$

$$\frac{dP}{dt}=\frac{V^2}{R}\left[2\left(1-e^{-t/\tau}\right)\left(-e^{-t/\tau}\right)\left(-\frac{1}{\tau}\right)\right]$$

$$\frac{d^2P}{dt^2}=\frac{2V^2}{\tau R}\left[e^{-t/\tau}\left(-\frac{1}{\tau}\right)-e^{-2t/\tau}\left(-\frac{2}{\tau}\right)\right]=0$$

$$\Rightarrow t=\tau \ln 2=\frac{10}{6.93}(0.693)=1\text{ s}$$

37. (3)

$V_1=L_1\frac{di}{dt}$ and $V_2=L_2\frac{di}{dt}$

$$\frac{V_1}{V_2}=\frac{L_1}{L_2}=\frac{\mu_0 N_1^2 A/I}{\mu_0\mu_r N_2^2 A/I}=\left(\frac{600}{200}\right)^2\left(\frac{1}{3}\right)=\frac{3}{1}$$

38. (2)

When only S_1 is closed, $T_1=RC=0.05$ ...(i)

When only S_2 is closed, $T_2=\frac{L}{R}=2$ ...(ii)

From Eqs. (i) and (ii), we get

$LC=0.1$

When only S_3 is closed, $T=2\pi\sqrt{LC}$

$=2\sqrt{10}\sqrt{0.1}=2\text{ s}$

39. (5)

$i_1=\frac{V}{R}e^{-\frac{t}{RC}}$ and $i_2=\frac{V}{R}\left(1-e^{-\frac{Rt}{L}}\right)$

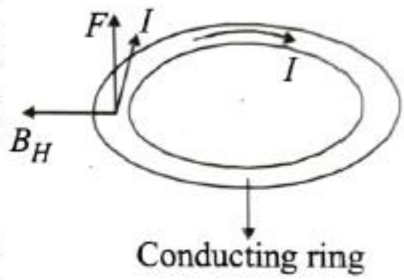
$$i=i_1+i_2=\frac{V}{R}\left(1+e^{-\frac{t}{RC}}-e^{-\frac{Rt}{L}}\right)$$

Since i is constant $\Rightarrow e^{-\frac{t}{RC}}-e^{-\frac{Rt}{L}}=0$

$$\Rightarrow R=\sqrt{\frac{L}{C}}=5\,\Omega$$

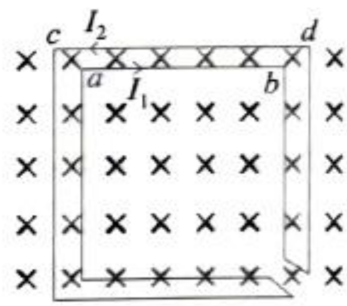
1. (A)

(a) The horizontal component of the magnetic field B_H interacts with the induced current produced in the conducting ring which produces an average force in the upward direction. This is an accordance with Fleming's left hand rule.



2. (D)

(d) The magnetic field is increasing in the downward direction. Therefore, according to Lenz's law the current I_1 will flow in the direction ab and I_2 in the direction dc.



3. (A)

(a) According to Faraday's law of electromagnetic induction, $\varepsilon = \frac{d\phi}{dt}$

Also, $\varepsilon = iR$

$\therefore \quad iR = \frac{d\phi}{dt} \quad \Rightarrow \quad \int d\phi = R\int idt$

Magnitude of change in flux $(d\phi) = R \times$ area under current vs time graph

or, $d\phi = 100 \times \frac{1}{2} \times \frac{1}{2} \times 10 = 250$ Wb

4. (A)

(a) As we know, Magnetic flux, $\phi = B.A$

[Trick: In such case we assume that current is flowing through bigger coil and flux due to magnetic field of bigger coil on smaller coil is determined.]

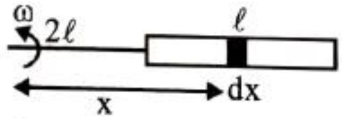
$$\frac{\mu_0(2)(20\times10^{-2})^2}{2[(0.2)^2+(0.15)^2]^{1.5}}\times\pi(0.3\times10^{-2})^2$$

On solving

$= 9.216 \times 10^{-11} = 9.2 \times 10^{-11}$ weber

5. (D)

(d) Here, induced e.m.f.



$de = (\omega x) B dx$

$$e = \int_{2\ell}^{3\ell} (\omega x) B dx = B\omega \frac{[(3\ell)^2 - (2\ell)^2]}{2} = \frac{5B\ell^2\omega}{2}$$

6. (C)

(c) Charge on he capacitor at any time t is given by $q = CV(1 - e^{-t/\tau})$

at $t = 2\tau$

$q = CV(1 - e^{-2})$

7. (A)

(a) Inside the sphere field varies linearly i.e., $E \propto r$ with distance and outside varies according to $E \propto \frac{1}{r^2}$

Hence the variation is shown by curve (a).

8. (A)

(a) Given: No. of turns $N = 1000$

Face area, $A = 4\ cm^2 = 4 \times 10^{-4}\ m^2$

Change in magnetic field,

$\Delta B = 10^{-2}\ wbm^{-2}$

Time taken, $t = 0.01 s = 10^{-2}$ sec

Emf induced in the coil $e = ?$

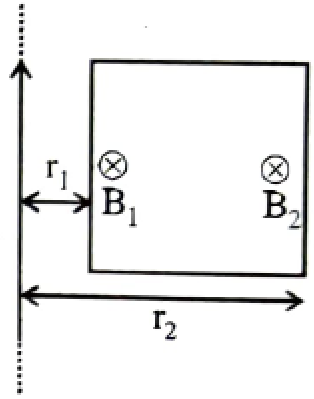
Applying formula,

Induced emf, $e = \frac{-d\phi}{dt} = N\left(\frac{\Delta B}{\Delta t}\right) A \cos\theta$

$$= \frac{1000 \times 10^{-2} \times 4 \times 10^{-4}}{10^{-2}} = 400\ mV$$

9. (B)

(b) Time in which left arm reach at x = 10 cm



$$t = \frac{0.1}{10} = \frac{1}{100} = 0.01\,\text{sec}$$

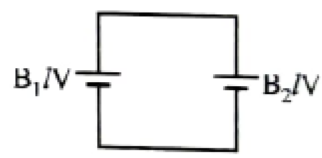
$r_1 = 10 \times 0.01 = 0.1$ m

$e = lV(B_1 - B_2)$

$$= 0.1 \times 10\left(\frac{\mu_0 i}{2\pi r_1} - \frac{\mu_0 i}{2\pi r_2}\right)$$

$$= 0.1 \times 10 \times 2 \times 10^{-7} \times 1\left(\frac{1}{0.1} - \frac{1}{2 \times 0.1}\right)$$

$$= 2 \times 10^{-7}\left(\frac{2-1}{2 \times 0.1}\right) = 10^{-6}\,\text{V}$$

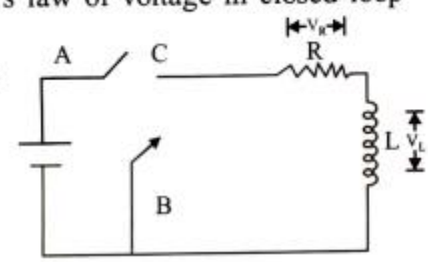


10. (C)

Hence damping will be faster for lesser self inductance.

(c) Applying Kirchhoff's law of voltage in closed loop

$$-V_R - V_C = 0 \Rightarrow \frac{V_R}{V_C} = -1$$



11. (D)

(d) According to Faraday's law of electromagnetic induction,

Induced emf, $e = \frac{Ldi}{dt}$

$$50 = L\left(\frac{5-2}{0.1\,\text{sec}}\right) \Rightarrow L = \frac{50 \times 0.1}{3} = \frac{5}{3} = 1.67\ \text{H}$$

12. (B)

(b) $I(0)=\dfrac{15\times100}{0.15\times10^3}=0.1A$

$I(\infty)=0$

$I(t)=[\mathrm{I}(0)-\mathrm{I}(\infty)]\ e^{\frac{-t}{L/R}}+i(\infty)$

$I(t)=0.1\ e^{\frac{-t}{L/R}}=0.1\,e^{\frac{R}{L}}$

$I(t)=0.1\ e^{\frac{0.15\times1000}{0.03}}=0.67mA$

13. (B)

(b) Electric flux is given by

$\phi=\mathrm{B.A}$

$\phi=\mathrm{B_0\pi r^2e^{-t/\tau}}$ $\left(\because \mathbf{B}=\mathrm{B_0e^{-t/\tau}}\right)$

Induced E.m.f. $\varepsilon=\dfrac{d\phi}{dt}=\dfrac{\mathrm{B_0\pi r^2}}{\tau^2}\mathrm{e}^{-t/\tau}$

Heat $=\displaystyle\int_0^\infty\frac{\varepsilon^2}{\mathrm{R}}=\frac{\pi^2\mathrm{r^4B_0^2}}{2\tau\mathrm{R}}$

14. (A)

(a) Given: Capacitance, $C=0.2\ \mu\mathrm{F}=0.2\times10^{-6}\,\mathrm{F}$

Inductance $\mathrm{L}=0.5\ \mathrm{mH}=0.5\times10^{-3}\ \mathrm{H}$

Current I = ?

Using energy conservation

$\frac{1}{2}CV^2=\frac{1}{2}CV_1^2+\frac{1}{2}LI^2$

$\Rightarrow\frac{1}{2}\times0.2\times10^{-6}\times10^2+0=\frac{1}{2}\times0.2\times10^{-6}\times5^2+\frac{1}{2}\times0.5\times10^{-3}I^2$

$\therefore\quad I=\sqrt{3}\times10^{-1}\,\mathrm{A}=0.17\,\mathrm{A}$

15. (A)

(a) $\phi=BA=(\mu_0n_i)A=\mu_0n\,(kt\,e^{-\alpha t})A$

$e=-\dfrac{d\phi}{dt}=-\mu_0nAk\dfrac{d}{dt}(te^{-\alpha t})$

$=-\mu_0nAk[t(-\alpha)e^{-\alpha t}+e^{-\alpha t}\times1]=-\mu_0nAk[e^{-\alpha t}(1-\alpha t)]$

$i=\dfrac{e}{R}=\dfrac{-\mu_0nAk}{R}[e^{-\alpha t}(1-t)]$

At $t=0$, $i\Rightarrow$ –ve

16. (B)

(b) According to faraday's law of electromagnetic induction, $e = \frac{-d\phi}{dt}$

$$L \times \frac{di}{dt} = 25 \Rightarrow L \times \frac{15}{1} = 25 \text{ or } L = \frac{5}{3} H$$

Change in the energy of the inductance,

$$\Delta E = \frac{1}{2} L\left(i_1^2 - i_2^2\right) = \frac{1}{2} \times \frac{5}{3} \times (25^2 - 10^2) = \frac{5}{6} \times 525 = 437.5 J$$

17. (None)

(None)

Net charge $Q = \frac{\Delta\phi}{R} = \frac{1}{10} A(B_f - B_i)$

$$= \frac{1}{10} \times 3.5 \times 10^{-3} \left(0.4 \sin\frac{\pi}{2} - 0\right)$$

$$= \frac{1}{10}(3.5 \times 10^{-3})(0.4 - 0) = 1.4 \times 10^{-4}$$

No option matches, So it should be a None.

18. (B)

(b) Induced emf,

$e = Bv\ell = 1 \times 10^{-2} \times 0.05 = 5 \times 10^{-4}$ V

Equivalent resistance,

$$R = \frac{4 \times 2}{4 + 2} + 1.7 = \frac{4}{3} + 1.7 \simeq 3\,\Omega$$

$$\text{Current, } i = \frac{e}{R} = \frac{5 \times 10^{-4}}{3} \simeq 170\,\mu A$$

19. (D)

Inductance $= \frac{\mu_0 N^2 A}{L}$

20. (A)

(a) Induced emf, $\varepsilon = Bv\ell$

$$= 0.3 \times 10^{-4} \times 5 \times 10$$
$$= 1.5 \times 10^{-3} \text{ V}$$

21. (D)

(d) The rate of mutual inductance is given by

$M = \mu_0 n_1 n_2 \pi r_1^2$ ...(i)

The rate of self inductance is given by

$L = \mu_0 n_1^2 \pi r_1^2$ ...(ii)

Dividing (i) by (ii)

$$\Rightarrow \frac{M}{L} = \frac{n_2}{n_1}$$

22. (C)

(c) $L = \mu_0 n^2 A l$

$L \propto l$

$$\therefore \quad \frac{L_2}{L_1} = \frac{l_2}{l_1}$$

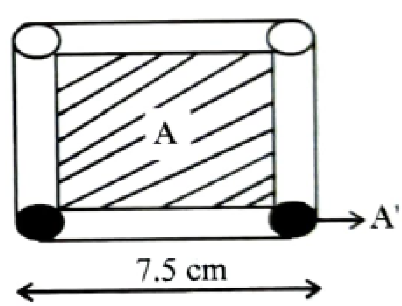
$\Rightarrow \quad L_2 = 3L_1 \qquad [\because l_2 = 3l_1]$

23. (B)

(b) $e = -\frac{d\phi}{dt} = -\frac{d}{dt}(BA\cos 0°) = -A\frac{dB}{dt}$

$$i = \frac{l}{R} = A\frac{dB}{dt} \times \frac{A'}{\rho l'}$$

$$= l^2 \frac{dB}{dt} \times \frac{\pi r^2}{Pl'}$$



Here, $l = 7.5 \times 10^{-2}$ m

$l' = 0.30$ m

$r = 2 \times 10^{-3}$ m

$$\frac{dB}{dt} = 0.032 \text{ T/s}$$

Putting above value; we get

$i = 0.61$A

24. (D)

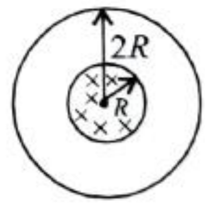
(d) According to question,

$I(t) = I_0 t(1-t)$

$\therefore I = I_0 t - I_0 t^2$

$\phi = B.A$

$\phi = (\mu_0 nI) \times (\pi R^2)$



$(\because\ B = \mu_0 \text{ nI } and\ A = \pi R^2)$

$$V_R = \frac{-d\phi}{dt}$$

$$V_R = \mu_0 n\pi R^2 (I_0 - 2I_0 t) \Rightarrow V_R = 0 \text{ at } t = \frac{1}{2} s$$

after $t > \frac{1}{2}$ sec, V_R is – Ve

i.e. current will change direction after $t > \frac{1}{2}$ sec.

25. (D)

(d) Magnetic field at a distance r from the wire

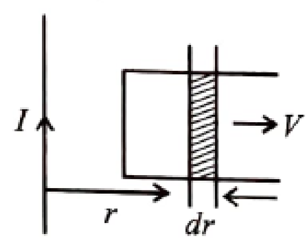
$$B = \frac{\mu_0 I}{2\pi r}$$

Magnetic flux for small displacement dr,

$\phi = B \cdot A = Bldr$

$[\because A = l\,dr \text{ and } B.A = BA\cos 0°]$

$$\Rightarrow \phi = \frac{\mu_0 I}{2\pi r} l\, dr$$



Emf, $e = \frac{d\phi}{dt} = \frac{\mu_0 Il}{2\pi r} \cdot \frac{dr}{dt} \Rightarrow e = \frac{\mu_0}{2\pi} \cdot \frac{Ivl}{r}$

Induce current in the loop, $i = \frac{e}{R} = \frac{\mu_0}{2\pi} \cdot \frac{Ivl}{Rr}$

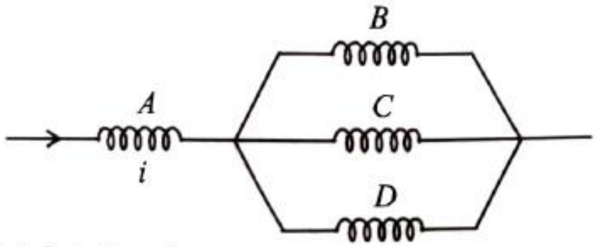
26. (A)

From Lenz law direction of induced current can be found, induced current will oppose the decrease in outward magnetic field, by producing its own outward magnetic field.

27. (C)

(c) From figure,

$B_A = 3T$



$I_B + I_C + I_D = I_A$

By symmetry, $I_B = I_C = I_D = i_0$ (let) $\Rightarrow i_0 = \frac{i}{3}$

We have $B_A = \mu_0 ni$

and, $B_C = \mu_0 ni_0 = \frac{\mu_0 ni}{3} = \frac{B_A}{3} = 1T$

28. (D)

(d) From question, $U = 25\%$ of U_0

$$U = \frac{1}{2}LI^2 = \frac{1}{4} \times \frac{1}{2}LI_0^2 \Rightarrow I = \frac{I_0}{2}$$

Also, $I = I_0\left(1 - e^{-\frac{Rt}{L}}\right) \Rightarrow \frac{I_0}{2} = I_0\left(1 - e^{-\frac{Rt}{L}}\right)$

$$\Rightarrow e^{\frac{-Rt}{L}} = \frac{1}{2} \Rightarrow (t)\frac{R}{L} = \ln 2 \quad \therefore t = \frac{L}{R}\ln 2$$

29. (C)

(c) Given,

Magnetic field, $B = 1T$

At $t = 0$s, the centre of circular ring will touch the boundary.

$\therefore$ Induced emf $= Blv$, $l =$ length $\perp_r$ to $\vec{B}$ and $\vec{V}$.

$= 1.(2R).1 = 2V$.

30. (D)

(d) $P = \frac{e^2}{R} = \frac{\left(-NA\frac{dB}{dt}\right)^2}{\rho l} \times A_C$,

A = area of coil

A_c = area of cross section of wire used in coil

$P \propto NA_c$

$$\frac{P_2}{P_1} = \frac{\frac{N}{2} \times 4A_c}{NA_c} = 2; \ P_2 = 2P_1$$

31. (A)

$\phi = 5t^3 + 4t^2 + 2t - 5$

$|e| = 15t^2 + 8t + 2 \qquad \left[\because |e| = \frac{d\phi}{dt}\right]$

$R = 5\Omega$

So, $i = \frac{|e|}{R} = \frac{15t^2 + 8t + 2}{5} = 3t^2 + 1.6t + 0.4$

$= 3.2^2 + 1.6 \times 2 + 0.4 = 15.6\,\text{A} \ \ (\because t = 2\,\text{sec})$

32. (C)

(c) $\phi_2 \propto I_1$

$\phi_2 = M_{21} I_1$

$M_{21} = \frac{\phi_2}{I_1} = \frac{B_1 A_2}{I_1}$

Now, $B_1 = \frac{\mu_0 I_1}{4\pi L/2}[\sin 45° + \sin 45°] \times 4$

$= \frac{\mu_0 I_1}{2\pi L} \times \frac{8}{\sqrt{2}} = 2\sqrt{2}\frac{\mu_0 I_1}{\pi L}$

So, $M_{21} = \frac{\frac{2\sqrt{2}\mu_0 I_1}{\pi L}\ell^2}{I_1} = \frac{\mu_0 I_1 \ell^2}{\pi L} \times 2\sqrt{2}$

33. (D)

(d) If current in both inductor is in same direction then

$L_{eq} = L_1 + L_2 + 2M$

and, if current in both inductor is in opposite direction,

then $L_{eq} = L_1 + L_2 - 2M$

34. (B)

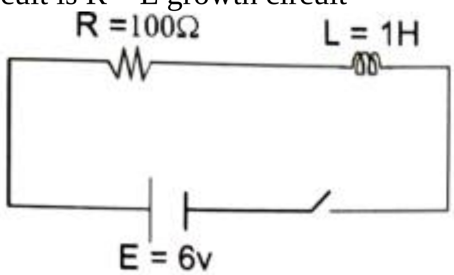
(b) emf induced between the two ends is given by

$$e = \frac{1}{2}B_H\omega l^2 = \frac{1}{2}\times 0.2\times 10^{-4}\times 5\times 1^2$$

$$= 0.1\times 10^{-4}\times 5 = 5\times 10^{-5} = 50\,\mu V$$

35. (C)

Given circuit is R – L growth circuit



$$i = \frac{E}{R}(1-e^{-t/\tau}) = i_0(1-e^{-t/\tau}),\quad \text{when } i = \frac{i_0}{2}$$

$$\Rightarrow\quad \frac{E}{2R} = \frac{E}{R}(1-e^{-t/\tau})$$

Solving we get, $t = \tau\ln 2$

$$\Rightarrow\quad t = \frac{L}{R}\ln 2 = \frac{1}{100}0.693 = 0.00693 = 7\,\text{ms}$$

$$\text{Now, } i(15\,\text{ms}) = \frac{E}{R}\left(1-e^{-\frac{15}{10}}\right) = \frac{E}{R}(1-e^{-3/2})$$

$$\Rightarrow\quad i = \frac{6}{100}\left(1-\frac{1}{4}\right) = \frac{3}{4}\times\frac{6}{100} = \frac{18}{400} = \frac{9}{200}\text{A}$$

$$\text{As, } U = \frac{1}{2}LI^2 = \frac{1}{2}\times 1\times\left(\frac{9}{200}\right)^2 \simeq 10^{-3}\text{J} = 1\text{mJ}$$

36. (10)

(10) Given $dI = 0.25 - 0 = 0.25$ A

$dt = 0.025$ ms

Induced voltage

$E_{ind} = 100$ v

Self-inductance, L = ?

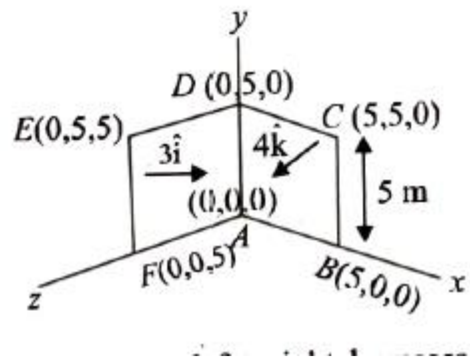
$$\text{Using, } E_{\text{ind}} = \frac{\Delta\phi}{\Delta t}\quad \Rightarrow 100 = \frac{L(0.25-0)}{.025\times 10^{-3}}$$

$\Rightarrow$ L = 0.01 H = 10 mH

37. (175.00)

(175.00)

Flux through the loop ABCDEFA,



$\phi = \vec{B}.\vec{A}$

$= (3\hat{i} + 4\hat{k}).(25\hat{i} + 25\hat{k})$

$\Rightarrow \phi = (3 \times 25) + (4 \times 25)$

$= 175$ weber

38. (60)

(60) Given,

Magnetic field, $B = 3 \times 10^{-2}T$

Angular speed of coil, $\omega = 50$ rad s^{-1}

Number of turns in coil, $n = 20$

Maximum emf, $\varepsilon = N\omega AB$

$$\Rightarrow \varepsilon = 20 \times 50 \times \pi \times (0.08)^2 \times 3 \times 10^2 = 60.28 \times 10^2$$

Rounded off to nearest integer = 60

39. (12)

(12) Given,

Magnetic field, $B = (3t^3\hat{j} + 3t^2\hat{k})$

Magnetic flux, $\phi = \vec{B}.\vec{A}$

$= (3t^3\hat{j} + 3t^2\hat{k}).(\pi(1)^2\hat{k}) = 3t^2\pi$

Induced emf, $\varepsilon = \left|\frac{d\phi}{dt}\right| = \frac{d(3t^2\pi)}{dt} = 6t\pi$

$\therefore \quad \varepsilon_{t=2} = 6 \times 2 \times \pi = 12\pi$

40. (2)

(2) The magnetic flux given by $\phi = \frac{2}{3}(9 - t^2)$

when the flux becomes zero then $\phi = \frac{2}{3}(9 - t^2) = 0$

$t = 3$ sec

The emf will be

$$e = \frac{-d\phi}{dt} = -\frac{2}{3}(0 - 2t) = \frac{4t}{3}$$

Heat produced in 3 sec $= \int_0^t \frac{e^2}{r} dt = \int_0^3 \frac{16t^2}{9 \times 8} dt = 2$ J

41. (250)

(250) We have magnetic flux given as,

$\phi = 8t^2 - 9t + 5$

$$\text{Inuced emf} = -\frac{d\phi}{dt} = -(16t-9)$$

At t = 0.25 s

Emf = $-[(16 \times 0.25) - 9] = 5V$

$$\text{So, Current} = \frac{\text{Emf}}{\text{Resistance}} = \frac{5V}{20\Omega}$$

$$\Rightarrow \frac{1}{4}A = \frac{1000}{4}mA = -250\ mA$$

42. (16)

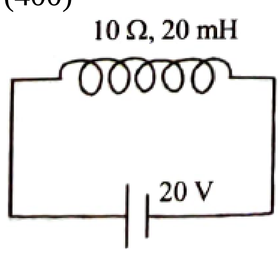
(16) **The moving rod will cut the vertical component of magnetic field perpendicularly.**

So, $e = B_v l V$

$= B_H \times l V \quad [\because Dip = 45° \Rightarrow B_v = B_H]$

$= 4 \times 10^{-3} \times 0.2 \times 20 = 16 \times 10^{-3} V$

43. (400)



$$|e| = \frac{Ldi}{dt} = \frac{L(i_{initial} - 0)}{t} = \frac{LV}{Rt}$$

$$\therefore\ |e| = \frac{20 \times 10^{-3} \times 20}{10 \times 100 \times 10^{-6}} = 400\ V$$

44. (4)

(4) Suppose at any instant, current through inductor is 'I'. Now if in inductor when current change by dI in dt time then, work done by battery is given by

dw = change × P.difference

$$= I\,dt \times L\frac{dI}{dt} = LI\,dI$$

Now, $I = 2\sin(t^2)A$

If $I = 0 \Rightarrow t = 0$

If $I = 2A \Rightarrow 2 = 2\sin(t^2)$

$$\Rightarrow \sin t^2 = \sin \pi/2 \Rightarrow t = \sqrt{\frac{\pi}{2}}.$$

So, amount of total energy spent

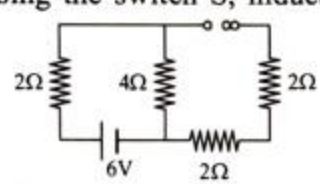
$$U = \int dw = \int LI\,dI = \int 2 \times 2\sin(t^2) \times 4t\cos(t^2)\,dt$$

$$= 8\int_0^{\sqrt{\pi/2}} t\sin(2t^2)\,dt = 8 \times \frac{1}{2} = 4\text{J}$$

45. (1)

(1) Just after closing the switch S, inductor behaves like an open circuit.

$$I = \frac{6}{2+4} = 1\text{ A}$$



46. (10)

(10) In steady state, capacitor is fully charged. Therefore current through it zero.

Charge $q = CV_{100\Omega}$

$$= (1.1 \times 10^{-6})\left(\frac{10}{R+r}R\right) \quad (\because V_{100} = IR_{100})$$

$$= 1.1 \times 10^{-6}\left(\frac{10}{110} \times 100\right) = 10\,\mu\text{C}$$

EMI : SOLUTIONS

Ex I : SINGLE CORRECT MCQs

Q1. ① instantaneous angular speed of the e, $\omega = \alpha t$.

Therefore ~~induce~~ magnetic field at the center of its CM $B = \frac{\mu_0 \{e/(2\pi/\omega)\}}{2R}$

$$\Rightarrow B = \frac{\mu_0}{4\pi}\left(\frac{e\omega}{R}\right)$$

Therefore, magnetic flux thru' the loop

$$\phi_B = B \times \pi r^2 = \frac{\mu_0 e \omega r^2}{4R}$$

$\therefore$ induced emf

$$\mathcal{E} = \left|\frac{d\phi_B}{dt}\right| = \frac{\mu_0 e r^2}{4R}\left(\frac{d\omega}{dt}\right)$$

$$\boxed{\mathcal{E} = \frac{\mu_0 e r^2 \alpha}{4R}} \Rightarrow (B)$$

Q2. ② $R = (R_0 + t) \Rightarrow$ Area $A = \pi R^2 = \pi(R_0+t)^2$

$\Rightarrow$ magnetic flux $\phi_B = BA = B\pi(R_0+t)^2$

$\therefore$ induced e.m.f, $\mathcal{E} = \left|\frac{d\phi_B}{dt}\right| = \frac{d}{dt}\left[B\pi(R_0+t)^2\right]$

$$= B\pi \times 2(R_0+t)$$

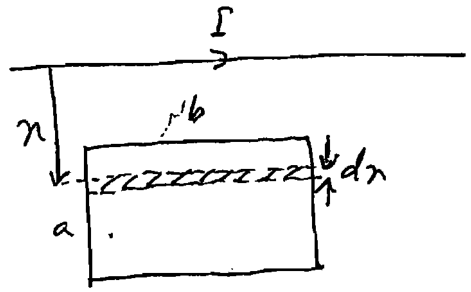
$$\boxed{\mathcal{E} = 2\pi B(R_0+t)}$$

Now, since the ϕ_B (into the plane of the diagram) is increasing, by application of Lenz's law, the induced current should be counter-clockwise

Q3. ✓ (3)

$\mathcal{E} = -\dfrac{d\Phi_B}{dt}$, Now from the given graph, for the interval of time $t=0$ to $t=t_1$, B increases linearly $\Rightarrow \mathcal{E}$ is 'negative' and constant. For time $t=t_1$ to t_2, B is constant $\Rightarrow$ B = 0 and $t=t_2$ to $t=t_3$, B decreases linearly and therefore $\mathcal{E}$ = positive and constant. After $t=t_3$ again $\mathcal{E}$ is zero. (C) ✓

Q4. ✓ (1)



The magnetic flux through a differential strip of thickness 'dx'

$$d\Phi_B = B \times ds = B \times b\,dx = \frac{\mu_0 I b\,dx}{2\pi x}.$$

Therefore the total flux,

$$\Phi_B = \int_{x=d}^{x=(d+a)} \frac{\mu_0 I b}{2\pi x}\,dx = \frac{\mu_0 I b}{2\pi} \ln\left(\frac{d+a}{d}\right)$$

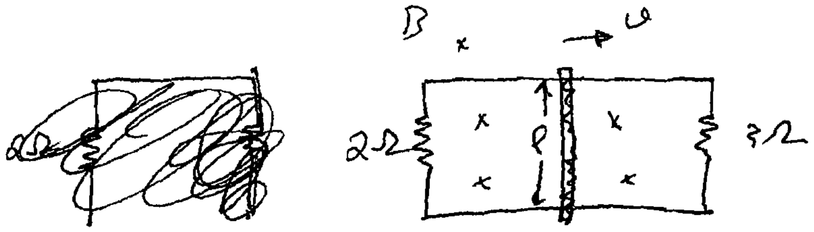
$$\Rightarrow \Phi_B = \frac{\mu_0 b}{2\pi} \ln\left(\frac{d+a}{d}\right) I_0 e^{-t/\tau}$$

$\therefore$ induced voltage $\mathcal{E} = -\dfrac{d\Phi_B}{dt} = -\dfrac{\mu_0 b}{2\pi} \ln\left(\dfrac{d+a}{d}\right) I_0 \dfrac{d}{dt}\left(e^{-t/\tau}\right)$

$$\Rightarrow \mathcal{E} = \frac{\mu_0 b}{2\pi} \frac{I_0}{\tau} \ln\left(\frac{d+a}{d}\right) e^{-t/\tau}$$

$$\Rightarrow \boxed{\mathcal{E} = \frac{\mu_0 b I}{2\pi \tau} \ln\left(\frac{d+a}{d}\right)}$$ (B) ✓

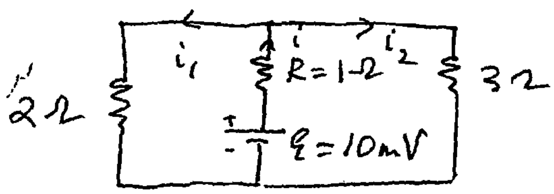
Q5. ✓ (5)



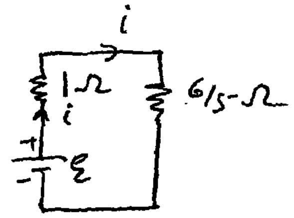
$v = 1\,m/s$
$l = 10\,cm$
$B = 0.1\,T$

The moving connector will act like a voltage source of emf $\mathcal{E} = Blv = 0.1 \times 0.1 \times 1 = 0.01$ Volts and a resistor $R = 1\,\Omega$ in series with it.

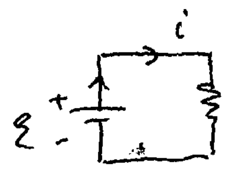
The equivalent circuit is therefore,



$\cong$



$\cong$



$\frac{11}{5} = 2.2\,\Omega = R_{eq}.$

$\therefore \quad i = \frac{\mathcal{E}}{R_{eq}} = \frac{0.01\,V}{2.2\,\Omega} \Rightarrow \boxed{i = \frac{1}{220} \text{ Amp}}$ ✓

(R) ✓

Q6.

(6) $y = ax^2$

$\frac{d^2y}{dt^2} = w \Rightarrow \frac{dy}{dt} = wt \Rightarrow y = \frac{1}{2}wt^2$

$\Rightarrow \frac{1}{2}wt^2 = ax^2$

$\Rightarrow x = \pm\sqrt{\frac{w}{2a}}\,t$

Therefore at any given instant of time $t=t$, the upward velocity of the rod, $v = wt$ and the length of the rod (between the contact points with the parabolic frame) $l = 2\sqrt{\frac{w}{2a}}\cdot t$

$\therefore$ the induced voltage $\mathcal{E} = Blv = B\times 2\sqrt{\frac{w}{2a}}\,t \times wt$

$\Rightarrow \mathcal{E} = \cancel{B\sqrt{w^3}}$

$\Rightarrow \mathcal{E} = Bw\sqrt{\frac{2w}{a}}\,t^2$

$y = \frac{1}{2}wt^2$

$\therefore \mathcal{E} = 2By\sqrt{\frac{2w}{a}}$

(A) ✓

Q7. Cancelled

Area $= 10^{-2}\,m^2$

$B = 0.1$ Tesla $= 0.1\,T$

$R = 0.1\,\Omega$

Final area $= 0.5\times10^{-2}\,m^2 \Rightarrow \Delta A = 0.5\times10^{-2}\,m^2$

time $\Delta t = 0.1$ sec

$\therefore \mathcal{E} = \frac{\Delta\phi_B}{\Delta t} = \frac{B\times\Delta A}{\Delta t} = 0.1\times\frac{0.5\times10^{-2}}{0.1}$

$\mathcal{E} = 0.5\times10^{-2}$ Volts

$\therefore$ average current $i = \frac{\mathcal{E}}{R} = 5\times10^{-2}$ Amp.

(B)

Q8.

(7)

Area : A

Mag. Field : B

Resistance : R

$\theta = 0$ to $\theta = 180°$

$$\therefore \Delta \Phi_B = |\Phi_2 - \Phi_1| = \left| (BA\cos 180° - BA\cos 0) \right|$$

$$\Delta \Phi_B = 2BA$$

$$\therefore \text{Total Charge} \quad \Delta Q = \int i\, dt$$

$$= \int \frac{\mathcal{E}}{R} dt$$

$$= \frac{1}{R} \int \frac{d\Phi_B}{dt} . dt$$

$$\Delta q = \frac{\Delta \Phi_B}{R} = \frac{2BA}{R}$$

(C) ✓

Q9.

(8)

$\mathcal{E} = 0$

The magnetic field lines due to the ~~current carrying~~ current carrying wire along the negative Z-axis do not intersect the square frame (they only 'graze' its surface tangentially). Hence, $\Phi_B = 0$

$$\Rightarrow \mathcal{E} = \frac{d\Phi_B}{dt} = 0$$

(C) ✓

Q10.

(9.)

~~$a_1 < g \Rightarrow$ The falli~~

For fig-I the falling magnet will induce a current in the loop which in turn will create a magnetic field which will "retard" the motion of the magnet, hence $a_1 < g$. ✓

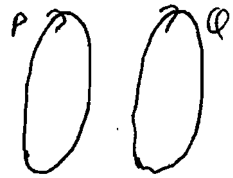
For fig-II the falling loop will experience an induced current due to the magnetic flux through it increasing. This induced current will also interact with magnetic field to produce an 'upward' force on it. Hence $a_2 < g$. ✓

(C) ✓

Q11. (REMOVE)

Cancelled → Repeated in Section II (Q12 has same concept)

Soln:-



If ~~loop~~ P approches Q, the flux through Q will increase, and therefore the induced EMF in Q should oppose this and "reduce" current in it. Invert the statement and same applies to P.

∴ (A) ✓ Cancelled

Q12. Application of Faraday's Law, the current 'I' does not create any flux in the circular coil. $\phi_B = 0 \Rightarrow \frac{d\phi_B}{dt} = 0$
(10) $\Rightarrow$ no induced current.

(D) ✓

Q13. Application of Lenz's law, as the magnet falls, induced current will appear in the metal pipe that 'opposes' the
(11) fall, therefore magnetic force acting on magnet due to the induced current will "oppose" it's motion and ~~thereby~~ increase in magnitude proportionately to velocity after a ~~few~~ time. ~~Hence~~ thereby achieving terminal velocity

∴ (C) ✓

~~Q13~~.

Q14. The flux through the loop is "coming-out" of the
(12) plane, therefore as it increases, induced current should appear clock-wise.

∴ (A) ✓

Q~~15~~. i_2 is constant and from c to d (clockwise)

13 ∴ anti-clockwise ~~current is~~ flux is increasing at a constant rate or clockwise flux is decreasing at a constant rate.

∴ i_1 should be clockwise i.e. positive and decreasing uniformly.

or i_1 -- anti-clockwise (negative) and increasing uniformly.

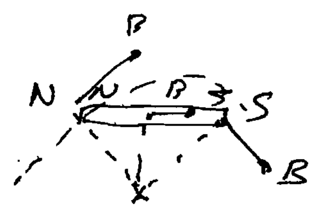
∴ (D) ✓

Q~~16~~ Cancelled REMOVE

↳ Repeated concept as Q13.

↳ Soln.. : the induced current in the copper tube will create a force on the bar magnet that opposes it's motion and increases uniformly with it's speed. Therefore terminal velocity will be achieved after some time.

∴ (B) ✓ Cancelled



Q~~17~~. Torque $= \vec{\tau} = (\vec{M} \times \vec{B})$

14 Now ~~here~~ here $\vec{B}$ and $\vec{M}$ are co-linear so $\tau = 0$

Alternately from the direction of $\vec{B}$ at the N and S poles, the direction of Force and Torque (if any) can be shown to be.

$F \neq 0$ and $\tau = 0$

∴ (D) ✓

Q~~18~~. Cancelled (REMOVE)

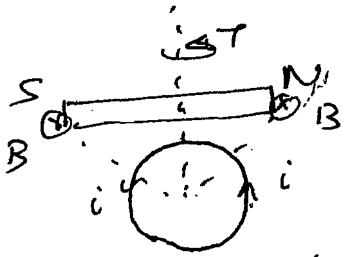
↳ Same concept in Q12

Solution : $\phi_B = 0 \Rightarrow \frac{d\phi_B}{dt} = 0$

$\Rightarrow$ (D) ✓ Cancelled

Q~~19~~. 15

$\therefore$



from the direction of magnetic field, the 'N' pole experiences a force "into" the plane and the 'S' pole a force "coming-out".

$\therefore$ (B) ✓

Q~~20~~. 16

$\mathcal{E} = Blv_0 = \text{Constant}$

$\therefore$ charge in the capacitor $q = C\mathcal{E} = \text{Constant}$

$\therefore \; i = \frac{dq}{dt} = 0$

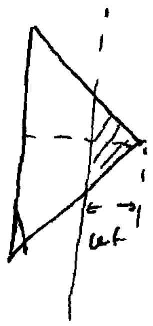
$\therefore$ (C) ✓

Q~~21~~. 17 Apply Lenz's law. Force on 'Q' due to induced current in P should "oppose" change in flux.

$\therefore$ (A) ✓

P.T.O

~~Q22.~~ 18



Area of shaded portion $= \frac{1}{2} \times (\omega t) \times (2\omega t) \propto t^2$

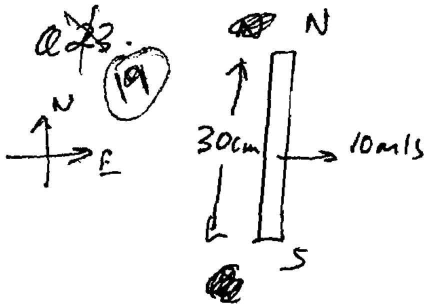
$\therefore$ flux $\phi_B = B \times (\omega t)^2 \Rightarrow \phi_B \propto t^2$

$\therefore \mathcal{E} = \left|\frac{d\phi_B}{dt}\right| \propto t$

$\therefore i = \frac{\mathcal{E}}{R} \propto t$

$\therefore$ (D) ✓

~~Q23.~~ 19



$\otimes B = 4T$

$\mathcal{E} = Bl\upsilon = 4 \times 0.3 \times 10 = 12$ Volts.

and $(\vec{\upsilon} \times \vec{B})$ is upwards $\therefore V_N - V_S = +12V$

$\therefore$ (A) ✓

~~Q24.~~ 20

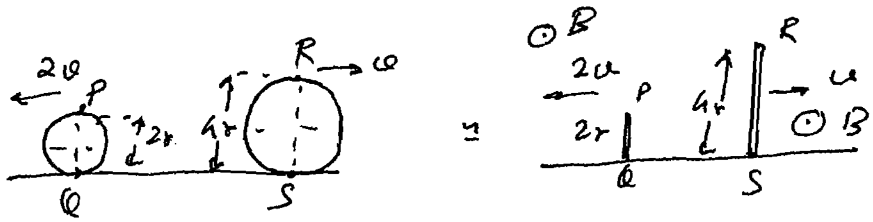
$i = \frac{\mathcal{E}}{R_{eq}} \Rightarrow i = \frac{Bl\upsilon}{3\Omega} \Rightarrow \frac{2 \times 0.1 \times \upsilon}{(3+1)} = 1 \times 10^{-3} \Rightarrow \upsilon = 2 \times 10^{-2}$ m/s

$\Rightarrow$ ~~$\upsilon = 1.5 \times 10^{-2}$ m/s~~ $\Rightarrow \boxed{\upsilon = 2 \text{ cm/s}}$

$= 1.5$

$\therefore$ (C) ✓

Q. ~~26~~ 21:



Now, from motional emf concept,

$$V_P - V_Q = +(B \times 2r \times 2v) = +(4Brv)$$

and $$V_R - V_S = -(B \times 4r \times v) = -(4Brv)$$

$\therefore$ $V_P - V_R = 8Brv$

$\therefore$ (C) ✓

Q ~~26~~. 22

$$\mathcal{E}_y = M\left(\frac{di}{dt}\right)_x \quad \text{and} \quad \mathcal{E}_x = M\left(\frac{di}{dt}\right)_y$$

Now given $\mathcal{E}_y = E$ when $\left(\frac{di}{dt}\right)_x = I$

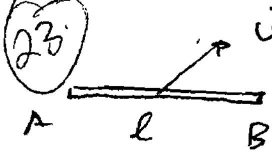
$\therefore$ $M = \left(\frac{E}{I}\right)$

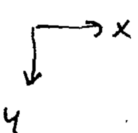
$\therefore$ Flux linkage x $\quad (\phi_B)_x = M I_y \Rightarrow (\phi_B)_x = \left(\frac{E}{I}\right) I_0$

$\therefore$ (B) ✓

Q ~~27~~. 23:

$\vec{v} = v_0(\hat{i} - \hat{j})$, $\vec{B} = B_0(\hat{i} + \hat{j})$





Here the component of $\vec{v}$ $\perp$r to the rod is v_0 and the component of $\vec{B}$ mutually $\perp$r to both these two quantities (~~on~~ plane of motion) is zero.

→ Can be REMOVED : EASY.

~~Q28~~: Cancelled

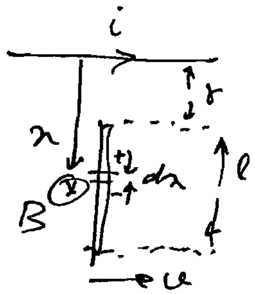
$$B = \frac{\mu_0 I}{2\pi r}$$

$$\therefore \ \mathcal{E} = Blv = \frac{\mu_0 I l}{2\pi r} v$$

∴ (B) Cancelled

~~Q29~~: Cancelled REMOVE → REPEATED from SOLVED EXAMPLE 7

Soln: $B = \frac{\mu_0 i}{2\pi x}$



$$\therefore \ d\mathcal{E} = Bv\,dx = \frac{\mu_0 i v}{2\pi}\frac{dx}{x}$$

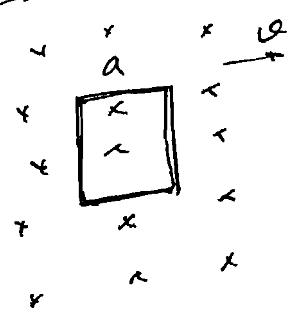
$$\therefore \ \mathcal{E} = \int_{x=r}^{x=r+l} \frac{\mu_0 i v}{2\pi}\frac{dx}{x}$$

$$\Rightarrow \mathcal{E} = \frac{\mu_0 i v}{2\pi}\ln\left(\frac{r+l}{r}\right)$$

∴ (D) Cancelled

→ Can be REMOVED : EASY

~~Q30~~. Cancelled



$W = 0$

as $\phi_B = B \times l^2 = \text{constant}$.

$\therefore \ \mathcal{E} = \frac{d\phi_B}{dt} = 0$

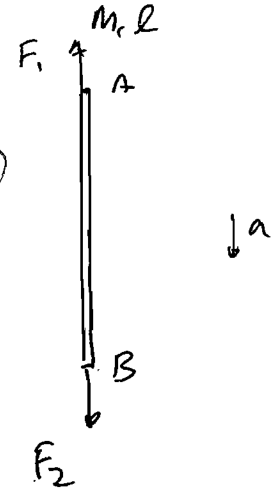
∴ magnetic forces = 0

∴ No external force needed ∴ W = 0

(D) Cancelled

Q3.

24.

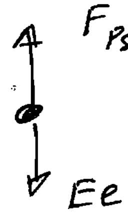


$F_1 \neq F_2 \quad (F_2 > F_1)$

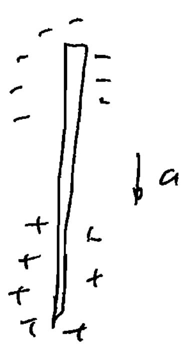
$\therefore \quad a = \left(\frac{F_2 - F_1}{M}\right)$

$\therefore$ for an FBD of a free electron in steady state in the non-inertial frame of the rod.

$F_{Pseudo} = ma = m\left(\frac{F_2 - F_1}{M}\right)$



where E : induced electric field due to 'polarization' of charge.



$\therefore \quad E = \frac{ma}{e} = \frac{m}{e}\left(\frac{F_2 - F_1}{M}\right)$

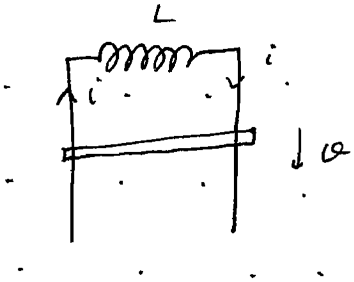
$\therefore$ potential difference btw the end-points of the rod,

$$|\Delta V| = |El| = \left|\frac{m}{e}\left(\frac{F_2 - F_1}{M}\right)l\right|$$

$\therefore$ (A) ✓

PTO

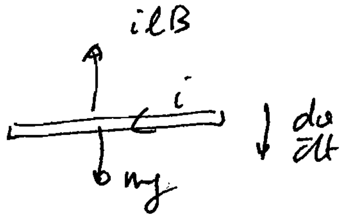
a ~~32~~. 25.



$\varepsilon = Blv$

$\therefore$ from Kirchoff's loop law,

$$Blv - L\frac{di}{dt} = 0 \quad \text{— (I)}$$



Now, from Newton's 2^{nd} law

$$mg - ilB = m\frac{dv}{dt} \quad \text{— (II)}$$

diffⁿ (I) : $\quad Bl\frac{dv}{dt} - L\left(\frac{d^2i}{dt^2}\right) = 0$

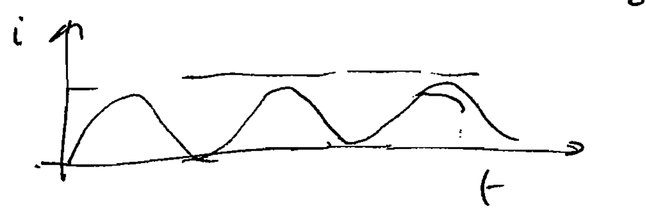
Substitute $\frac{dv}{dt} = \frac{mg - (Bl)i}{m}$ from (II)

$Bl\left[\cancel{mg} - \frac{Bl}{m}i\right] = L\frac{d^2i}{dt^2}$

$$\boxed{\frac{d^2i}{dt^2} = -\left(\frac{B^2l^2}{mL}\right)i + \frac{Blg}{L}}$$

Therefore $i = i_0 \sin\{\omega t + \phi\} + \underbrace{\text{const}}_{= i_0}$..

$\therefore$ i Vs t



$\therefore$ ~~[illegible]~~ $\therefore$ (A) ✓

a ~~32~~. 26. $\quad Q = i^2R = \left(\frac{\varepsilon}{R}\right)^2 R = \frac{\varepsilon^2}{R} = \frac{(Blv)^2}{R}$

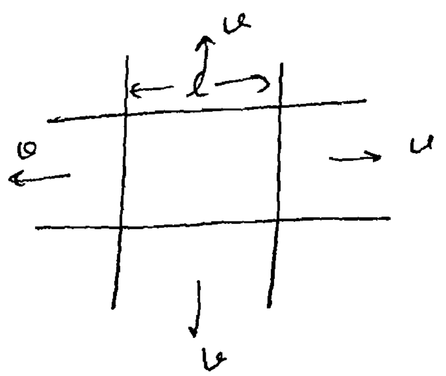
$a = 0 \Rightarrow \quad F - ilB = 0$

$$\Rightarrow F = ilB = \frac{B^2l^2v}{R} = \frac{Q}{v}$$

$\therefore$ (B) ✓

(or use UDM) method.

~~Q34~~ 27.



$l = (a + 2vt)$

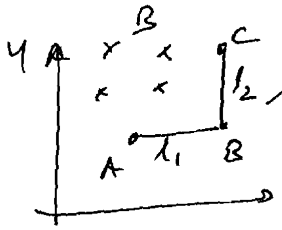
$\therefore \phi_B = Bl^2 = B(a+2vt)^2$

$\Rightarrow \mathcal{E} = \left|\dfrac{d\phi_B}{dt}\right| = 2B(a+2v) \times 2v = 4B(a+2v)v = 4Blv$

$R_{eff} = r \times 4l$

$\therefore i = \dfrac{\mathcal{E}}{R_{eff}} = \dfrac{Bv}{r} \quad \therefore (A)$ ✓

~~Q35~~ 28.



$l_2 \nearrow \vec{v} = v_x\hat{i} + v_y\hat{j}$

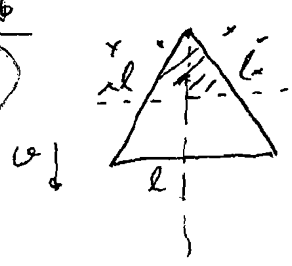
$\mathcal{E}_1 = (V_C - V_B) = Bl_2 v_x$

and $\mathcal{E}_2 = (V_A - V_B) = Bl_1 v_y$

$\therefore (V_A - V_C) = B(l_1 v_y - l_2 v_x)$

$\therefore (C)$ ✓

~~Q36~~ 29.



$\phi_B \propto$ Area of shaded part

and Area $\propto \left(\frac{\sqrt{3}}{2}l - vt\right)^2$

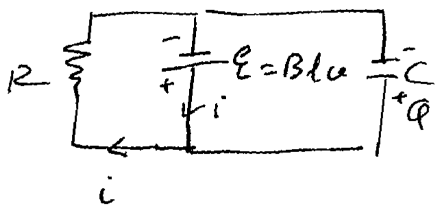
$\therefore \mathcal{E} = \dfrac{d\phi_B}{dt} \propto \left(\frac{\sqrt{3}}{2}l - vt\right)$

$\therefore i = \dfrac{\mathcal{E}}{R} \propto \left(\frac{\sqrt{3}}{2}l - vt\right)$

~~Q3~~

30

$\mathcal{E} = V_E - V_H = Bl\omega$



$Q = C\mathcal{E} = BlC\omega$: constant $\Rightarrow$ current ~~thos~~ through the capacitor $C = 0$

and $i = \dfrac{\mathcal{E}}{R} = \dfrac{Bl\omega}{R}$

$\therefore$ (D) ✓

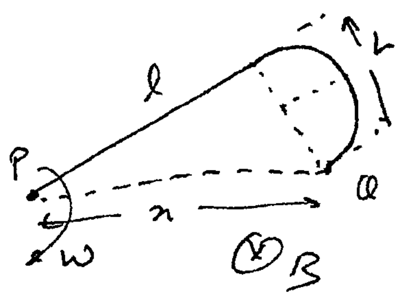
~~Q8~~

31

$\mathcal{E} = V_Q - V_P = \dfrac{B\omega x^2}{2}$

$\Rightarrow \mathcal{E} = \dfrac{B\omega(l^2+L^2)}{2}$

$\therefore$ (C) ✓

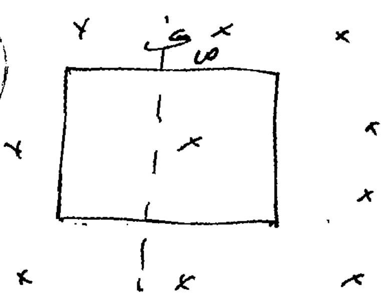


Use superposition as explained in ~~Letter~~ ~~Sol~~ Illustration _____ .

~~Q9~~
Cancelled REMOVE $\longrightarrow$ Same as Q29 in ~~Sol~~ Exercise II .

~~Q10~~

32



$\mathcal{E}_{avg} = \left|\dfrac{\Delta\phi_B}{\Delta t}\right|$: for $90°$ rotation

$|\Delta\phi_B| = (B \times A)$

$\Delta t = \dfrac{\pi}{2\omega}$

$\therefore \mathcal{E}_{avg} = \dfrac{2\omega BA}{\pi}$

Q1

33. Amplitude $\mathcal{E}_0 = NAB\omega$

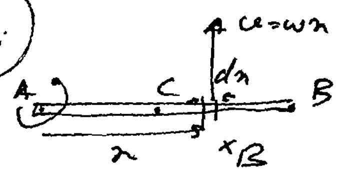
$$= 100\times \pi\times(0.1)^2\times(10\times10^{-3})(100\times 2\pi) = 2\times\pi^2 \approx 20\,V$$

$$\therefore \quad i_0 = \frac{\mathcal{E}_0}{R} = \frac{20}{10} = 2\text{ Amp.} \quad \therefore (B)$$

$10^{2-2-2+2}$

Q2.

34.



$$d\mathcal{E} = Bv\,dx = B\omega x\,dx$$

$$\therefore \quad V_C - V_B = \int_{x=l/2}^{x=l} B\omega x\,dx = \frac{B\omega}{2}\left(l^2 - \frac{l^2}{4}\right)$$

$$\mathcal{E} = \frac{3}{8}B\omega l^2$$

$\therefore$ (D) ✓

Q3.

35. $a = \frac{eE}{m}$

$$\oint E\,dl = \frac{d\phi}{dt} = \pi r^2 \left(\frac{dB}{dt}\right) = \cancel{\text{const}}$$

$\therefore \quad E\times 2\pi r \propto r^2$

$\Rightarrow \quad E \propto \frac{1}{r}$

$\therefore \quad a \propto \frac{1}{r}$

and sense of emf = anti-clock wise

$\therefore \quad a$ = towards right.

(B) ✓

Q44

(36.) $\frac{dB}{dt} = \sqrt{3}\ (T/s)$

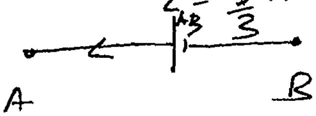
$\mathcal{E} = \left(\frac{dB}{dt}\right) \times \left(\frac{1}{2} \times l \times \frac{\sqrt{3}}{2} l\right)$

$= \sqrt{3} \times \frac{\sqrt{3}}{4} l^2$

$\mathcal{E} = \frac{3}{4} \times 2^2 = 3$ Volt, $\therefore\ \mathcal{E}_{AB} = \mathcal{E}_{AC} = \mathcal{E}_{CB} = \frac{\mathcal{E}}{3} = 1$ Volt

$\therefore$

$\mathcal{E}_{AB} = \frac{3}{3}$ Volt $= 1$ Volt



, $i = \frac{\mathcal{E}}{R_{Total}} = \left(\frac{3}{1+2+2}\right) = 0.6$ Amp

$\therefore\ V_A - V_B = \mathcal{E}_{AB} - iR_{AB} = \cancel{(0.6 \times 1)}$

$= \cancel{3}$

$\Rightarrow\ V_A - V_B = 1 - (0.6 \times 1)$

$= 0.4$ Volt

$\therefore$ (A) ✓

Q45

(37) $i_{min} = \frac{10V}{10\Omega}$ (with S closed at $t = 0$, $L \rightarrow$ open switch)

$i_{min} = 1$ Amp

$i_{max} = \frac{10V}{5\Omega}$ (with S closed @ $t \rightarrow \infty$, $L \rightarrow$ closed switch)

$= 2$ Amp.

$\therefore\ i_{max} - i_{min} = 1$ Amp

(C) ✓

~~Q 46.~~ 38

$$\tau_{charge} = \frac{L}{2R}$$

$$\tau_{Disch} = \frac{L}{3R}$$

$$\therefore \frac{\tau_{charg}}{\tau_{Dis}} = \frac{3}{2}$$

$\therefore$ (B) ✓

~~Q 47.~~ 39

$\mathcal{E} = \mathcal{E}_0 e^{-t/\tau}$ $\mathcal{E}_0$: EMF of battery / source

and and $\mathcal{E} = V_L = \left| -L\frac{di}{dt} \right|$

$i = i_0(1 - e^{-t/\tau})$

$i = \frac{\mathcal{E}_0}{R}(1 - e^{-t/\tau})$

$\therefore i = \frac{\mathcal{E}_0}{R} - \frac{1}{R}\mathcal{E} \Rightarrow \mathcal{E} = \mathcal{E}_0 - iR$

$\therefore$ (A) ✓

~~Q 48.~~ Cancelled → REMOVE Question

$i = (2 + 4t)$ Amps

$L = 2H$

$\therefore U_L = \frac{1}{2}Li^2 = \frac{1}{2} \times 2 \times (2+4t)^2$

$\therefore \frac{dU_L}{dt} = 2(2+4t) \times 4$

$\left(\frac{dU}{dt}\right)_{t=0} = 16$ J/s

PTO

Q49. (40.) $\left|\frac{di}{dt}\right|$ is greater for (1)

$\therefore$ self-induced voltage $V_L = \left|L\frac{di}{dt}\right|$ is greater for (1)

$\therefore$ (A) ✓

Q50. (41.) $\frac{di}{dt} = 4$ Amp/s

@ $t=t$, $i = 2$ Amp, $q = ?$

$$\Rightarrow \mathcal{E} - iR - L\frac{di}{dt} - \frac{q}{C} = 0$$

$$\Rightarrow 4 - (2\times1) - (1\times4) - \frac{q}{C} = 0$$

$$\Rightarrow q = |-2C| \quad , \quad C = 3\mu F$$

$$q = 6\mu C$$

(C) ✓

Q51. cancelled Remove → Repeated ~~concept~~ question (Q25 of Section II

Q52. (42.) $L = 5H$

$\mathcal{E} = 6V$

$R = 10\Omega$

$\tau = \frac{L}{R} = 0.5$ sec.

$V_L = \mathcal{E}e^{-t/\tau}$

$$\therefore (V_L)_{t=\ln\sqrt{2}} = (6V)e^{-\frac{1}{0.5}\ln\sqrt{2}} = (6V)e^{-\ln(2)} = (6V)\,e^{\ln(1/2)}$$

$$= 3 \text{ Volts}$$

$\therefore$ (A) ✓

Q43

A, N, L

$\Phi_B = L i$

$\Rightarrow N \times B \times A = L i$

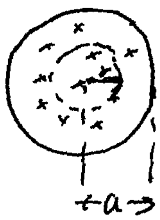
$\Rightarrow$ ~~B~~

$\Rightarrow i = \dfrac{NBA}{L}$

$\therefore$ (A) ✓

Q44

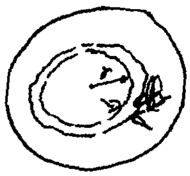
for $r < a$



$B = \dfrac{\mu_0 i (r^2/a^2)}{2\pi r}$

$\Rightarrow B = \dfrac{\mu_0 i r}{2\pi a^2}$

Energy density $u_B = \dfrac{1}{2}\dfrac{B^2}{\mu_0} = \dfrac{(\mu_0 i r / 2\pi a^2)^2}{2\mu_0}$



$= \dfrac{1}{2\mu_0} \times \dfrac{\mu_0^2 i^2 r^2}{4\pi^2 a^4}$

$u_B = \left(\dfrac{\mu_0 r^2}{8\pi^2 a^4}\right) i^2$

Now the energy stored in a differential cylindrical shell of length l, radius r and thickness dr,

$dU = u_B dV = u_B (2\pi r dr l)$

$= \dfrac{\mu_0 r^2 i^2}{8\pi^2 a^4} 2\pi r l dr$

$dU = \dfrac{\mu_0}{4\pi} \dfrac{i^2 l}{a^4} r^3 dr$

$\therefore U = \int_0^a \dfrac{\mu_0}{4\pi} \dfrac{i^2 l}{a^4} r^3 dr = \dfrac{\mu_0}{4\pi} \dfrac{i^2 l}{a^4} \cdot \dfrac{a^4}{4}$

$U = \mu_0 i^2 l$

Therefore energy per unit length:

$$\boxed{\frac{\partial U}{\partial l} = \frac{\mu_0 i^2}{16\pi}}$$

$\therefore$ (B) ✓

Q55.

45. @ $t=0$ (with K closed), $i = \frac{2V}{(10+20)\Omega} = \frac{2}{30}$ Amp

(L → open switch)

@ $t \to \infty$, $i = \frac{2V}{20\Omega} = \frac{1}{10}$ Amp (L → short ckt)

$\therefore$ (A) ✓

Q56. ~~Cancelled~~ (REMOVE)

↳ Repeated ~~ques~~ Concept in Subjectives.

Q57. ~~Cancelled~~ (DISCUSS)

↳ REMOVE

~~Q48.~~
46.

V_{max} (for L) = V_{max} (for C)

$\therefore \quad \frac{Q}{C} = 16$ volts Q : max charge on capacitor

U_{max} (for L) = U_{max} (for C)

$\therefore \quad \frac{Q^2}{2C} = 160\ \mu J$

$\therefore \quad \left(\frac{Q}{C}\right)^2 \times \frac{C}{2} = \frac{Q^2}{2C}$

$\Rightarrow \quad (16)^2 \times \frac{C}{2} = 160 \times 10^{-6}$

$\Rightarrow \quad C = \frac{160 \times 2}{16^2} \times 10^{-6}$ $\frac{5}{4}$

$C = \frac{20}{16}\ \mu C = 1.25 \mu C \quad \therefore$ (D) ✓

~~Q49.~~
Cancelled → REMOVE
→ ~~Soln~~ Soln

$V_L = L\frac{di}{dt} = \mathcal{E}$

$\Rightarrow \int_0^5 di = \frac{\mathcal{E}}{L}\int_0^T dt \quad \Rightarrow T = \frac{5 \times 4}{2} = 10$ sec

$\therefore$ (D)

~~Q50~~
47.

$V = V_0 - \left(\frac{V_0}{T}\right)t$

$\therefore \quad L\frac{di}{dt} = V \Rightarrow \quad di = \frac{V}{L}dt \quad \Rightarrow \int_0^i di = \int_0^t \frac{1}{L}\left\{V_0 - \left(\frac{V_0}{T}\right)t\right\}dt$

$\Rightarrow \quad i = \frac{V_0}{L}\left\{t - \frac{t^2}{2T}\right\}$

∴ ~~total~~ current @ ~~t=T~~

$\cancel{i_T = \frac{V_0}{L}\left\{T - \frac{T}{2}\right\} = \frac{V_0 T}{2L}}$ ~~and @ t=0,~~ $i_0 = \frac{V_0 T}{L}$

∴ [illegible]

and since current ~~is a linear function~~

~~of time. $i_{avg} = \frac{i_0 + i_T}{2} = \frac{V_0 T}{L}\left(\frac{1+1/2}{2}\right)$~~

$$i = \frac{V_0}{L}\left(t - \frac{t^2}{2L}\right)$$

∴ in time $t=0$ to $t=T$, charge flowing through the circuit $\Delta Q = \int i\,dt \Rightarrow \Delta Q = \int_{t=0}^{t=T} \frac{V_0}{L}\left(t - \frac{t^2}{2L}\right) dt$

$$\Rightarrow \Delta Q = \frac{V_0}{L}\left\{\frac{T^2}{2} - \frac{T^3}{6T}\right\}$$

$$\Rightarrow \Delta Q = \frac{V_0 T^2}{2L}\left(\frac{2}{3}\right) = \frac{V_0 T^2}{3L}$$

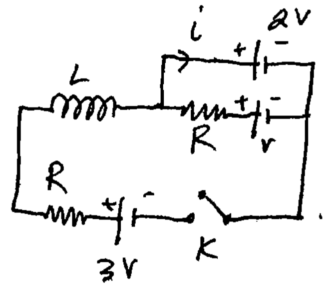
∴ avg current $i_{av} = \frac{\Delta Q}{\Delta t} = \frac{V_0 T^2/3}{T}$

$$\Rightarrow \boxed{i_{avg} = \frac{V_0 T}{3L}}$$ Ans

∴ (B) ✓

Q61

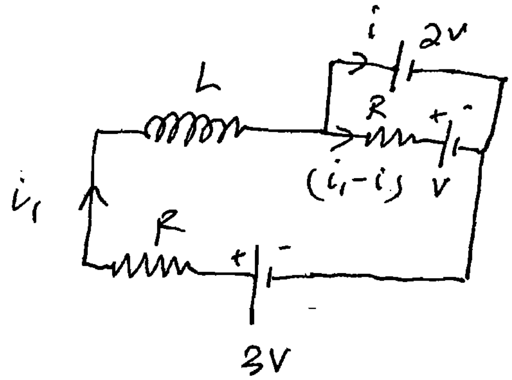
48.



@ $t=0$ (just before the switch

$i = \frac{-V}{R}$ (only the ~~smaller~~ smaller loop operates)

when K is closed @ $t=t$



Let currents and voltages as show.

$$3V - i_1 R - L\frac{di_1}{dt} - R(i_1-i) - V = 0$$

$$\Rightarrow 2V - L\frac{di_1}{dt} - 2Ri_1 + Ri = 0 \quad \text{—(I)}$$

$$-2V + V + R(i_1 - i) = 0$$

$$\Rightarrow R(i_1 - i) = V$$

$$\Rightarrow Ri = Ri_1 - V \quad \text{—(II)}$$

∴ from (I) and (II)

$$2V - L\frac{di_1}{dt} - 2Ri_1 + Ri_1 - V = 0$$

$$\Rightarrow V - L\frac{di_1}{dt} - Ri_1 = 0$$

$$\Rightarrow i_1 = \frac{V}{R}\left(1 - e^{-tR/L}\right)$$

∴ ~~$i = i_1 - \frac{V}{R} = \frac{V}{R}(2 - e^{-tR/L})$~~

Now $i = i_1 - \frac{V}{R}$ (from Eq (II))

∴ $\boxed{i = -\frac{V}{R}e^{-Rt/L}}$ '−' sign showing reverse sense.

∴ (C) ✓

Q62.

49. Heat produced = Potential Energy in the inductor initially (just before switch is toggled from 4 to 7.)

$$= \frac{1}{2} L i_0^2 = \frac{1}{2} L \left(\frac{E}{R_1}\right)^2$$

$\therefore$ (A) ✓

Q63.

50. $\frac{1}{2} L i^2 = 32$ J. for $i = 4$ Amp $\Rightarrow L = \frac{2 \times 32}{16} = 4$ H.

$i^2 R = 320$ watts for $i = 4$ Amp.

~~for i = 4 Amps~~

$$\therefore \quad R = \frac{320}{16} = 20\,\Omega$$

$$\therefore \quad \tau = L/R = 4/20 = 0.2 \text{ sec} \qquad \therefore (A) ✓$$

Q64

57. $V_B - V_A = -(I \times 1\Omega) - 15V - L\left(\frac{dI}{dt}\right)$

$$\Rightarrow V_B - V_A = -(5V) - (15V) - (5 \times 10^{-3} \times (-10^3))$$

$$\Rightarrow V_B - V_A = -20 + 5$$

$$\Rightarrow (V_B - V_A) = -15V$$

$\therefore$ (C) ✓

Q65

52. $i = I e^{-t/\tau}$

$$\Rightarrow \Delta Q = \int i\,dt = \int_0^t I e^{-t/\tau} dt = I\tau(1 - e^{-t/\tau})$$

$$\Delta Q = \frac{IL}{R}(1 - e^{-t/\tau})$$

Now at $t = t_0$, $U = \frac{1}{4} U_0 \Rightarrow i = \frac{1}{2} I \Rightarrow e^{-t/\tau} = \frac{1}{2}$

Q. (53)

$C = 2\mu F$

$V_0 = 12V$

$Q = 24\mu C$

$U_c = \frac{1}{2}CV_0^2 = \frac{1}{2}\frac{Q^2}{C} = 144\mu J$

$L = 0.6mH$

when $V_c = 6V$, $U_c = \frac{1}{2}CV^2 = 36\mu J$

$\therefore \quad U_L = \frac{1}{2}Li^2 = \left(\frac{1}{2}CV_0^2 - \frac{1}{2}CV^2\right) = (144-36)\mu J$

$\Rightarrow \quad \frac{1}{2}Li^2 = 108\mu J$

$\Rightarrow \quad \frac{1}{2} \times 0.6 \times 10^{-3} i^2 = 108 \times 10^{-6}$

$i^2 = \frac{108 \times 10^{-6}}{0.3 \times 10^{-3}} = \frac{\cancel{108}^{36}}{\cancel{3}} \times 10^{-2}$

$\Rightarrow \quad i = 6 \times 10^{-1} = 0.6$ Amp.

$\therefore$ (D) ✓

Q. (54)

$q = q_0 \sin\{\omega t + \phi\}$: LC oscillation ckt.

$\therefore \quad i = -\frac{dq}{dt} = -q_0\omega \cos\{\omega t + \phi\}$

$\therefore \quad |i_{max}| = q_0\omega = \frac{q_0}{\sqrt{LC}}$

$\therefore \quad \frac{di}{dt} = -q_0\omega^2 \sin(\omega t + \phi)$

$\therefore \quad \left|\frac{di}{dt}\right|_{max} = q_0\omega^2 = \frac{q_0}{LC}$

$\therefore$ (A) ✓

Q48. 55

$\frac{1}{2}Li^2 = U \Rightarrow L = \frac{2U}{i^2}$

$Ri^2 = P \Rightarrow R = P/i^2$

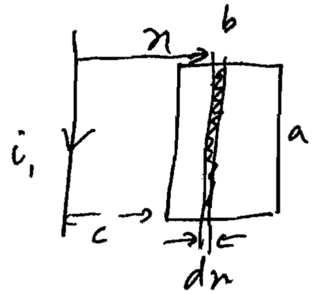
$\therefore \tau = L/R = \frac{2U}{P}$

$\therefore$ (C) ✓

Q49. 56.

$\phi_B = M i_1$

where ϕ_B = flux through the Rectangular loop



$d\phi_B = B\,dS = \frac{\mu_0 i_1}{2\pi x} \cdot a\,dx$

$\therefore \phi_B = \frac{\mu_0 i_1 a}{2\pi} \int_{x=c}^{x=b+c} \frac{dx}{x} \Rightarrow \phi_B = \mu_0$

$\phi_B = \left[\frac{\mu_0 a}{2\pi} \ln\left(1+\frac{b}{c}\right)\right] i_1$

$\therefore \boxed{M = \frac{\mu_0 a}{2\pi} \ln(1+b/c)}$

$\therefore$ (D) ✓

Q70 Cancelled → REMOVE → Repeated Concept.

$\phi_B = 0$ (the current in the long conductor does not produce any flux through the circular ring)

$\therefore$ $\underline{M = 0}$

(D)

EMI : EXERCISE-II

Emil Sch | 22/03/12 | Home | Set (II) | (1)

Multiple option MCQs

Q1. ✓

$$\frac{[\phi_B]}{[R]} = \frac{[B][A]}{[\cancel{E}E/I]}$$

$$\left[\frac{d\phi_B}{dt}\right] = [\mathcal{E}]$$

$$\Rightarrow \frac{1}{[R]}\left[\frac{d\phi_B}{dt}\right] = [i]$$

$$\therefore \frac{[d\phi_B]}{[R]} = [i][dt] = [\text{charge}]$$

(B) ✓

Q2. ✓ Since a clockwise current in I indicates clockwise in ~~@~~ both loops.

$\phi_B = B\times(L^2+l^2)$ for case I

But in case ~~@~~ II, clockwise current in loop abgh indicates anti-clockwise current in fedc

$\therefore \phi_B = B\times(L^2-l^2)$ for case II

(C) ✓

Q3. ✓ Flux 'into' the plane is ~~decreasing~~ decreasing.

~~So~~ Therefore current should be clock-wise in both loops for case I.

(C) ✓

Q4. ✓ ~~Here~~ Again since flux into the plane is decreasing the current in larger loop abgh is clockwise and smaller loop cdef is anti-clockwise

Q5: ✓

for Case I

$$\mathcal{E}_{ind} = \frac{dB}{dt} \times (L^2 + l^2)$$

$$i_{ind} = \frac{1}{R}\frac{dB}{dt}(L^2 + l^2)$$

for Case II

$$\mathcal{E}_{ind} = \frac{dB}{dt}(L^2 - l^2)$$

$$\therefore \; i_{ind} = \frac{1}{R}\frac{dB}{dt}(L^2 - l^2)$$

$$\therefore \; I_2 < I_1$$

(B) ✓

Q6. ✓ There will be an induced EMF of ~~$\frac{dB}{dt} \times \pi a^2$~~) $\left(\frac{dB}{dt} \times \pi a^2\right)$ in each loop where 'a' is the radius and given the field B is diminishing (into the plane), the direction of induced voltages will be clockwise for both loops.

(A), (C), (D) ✓

(Since both are closed loops, assume they operate independently as circuits neglecting the effects of mutual inductance)

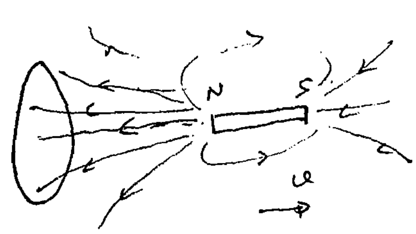
Q7. ✓ The triangle containing CD (larger one) will dominate over the smaller one in deciding the 'sense' or direction of induced current.

Flux 'into' the plane is increasing so the larger △ must have anti-clockwise current (Lenz's Law)

$\therefore$ (A) ✓

Q8 ✓ By application of Lenz's Law, induced voltage, induced current and the resultant magnetic force ~~betw~~ experienced by 'B' when the current in 'A' is changing will all ~~tend~~ tend to 'oppose' the change. Hence when 'i' is increased, the

9. ✓



As the bar magnet is moved away, as seen from the position of the magnet, flux "going into" the circular coil is decreasing and ~~the~~ therefore by application of Lenz's Law there will be an induced "clockwise" current.
(B) ✓

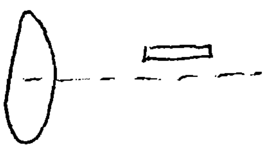
10. ✓ The anti clockwise current observed indicates two possibilities about the magnetic flux through the loop.

(i) If the flux is "into" the loop, it must be increasing. (~~can~~ or north pole faces the ring and moves towards it)

(ii) If the flux is ~~"outwards of~~ "coming out" of the loop, it must be decreasing. (or south pole facing the ring and moving away from it)

(B), (C) ✓

11. ✓ If the magnet is placed "off-axis" as shown, the magnetic field lines ~~are~~ acting on it are both of non-uniform ($\vec{B}$ varies with position) and non-colinear ($\vec{B}$ is slightly "bent" off axis).

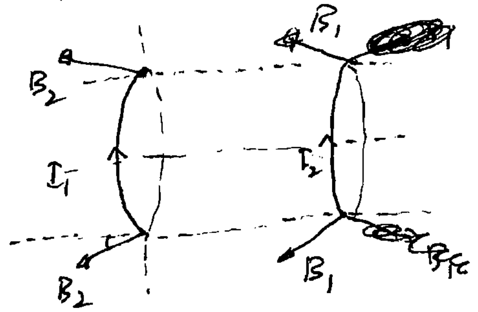


Therefore it experiences both ~~a~~ a net force and a ~~torque~~ torque.

(C) ✓

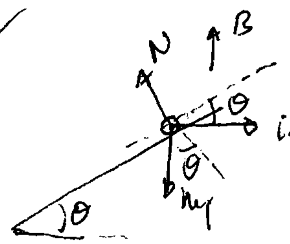
12. ✓ If one of the loops has no current and the other (with a current in it) moves towards it the induced current in the first will be of "opposite" sense by application of Lenz's Law.

'radial' and an 'axial' component. Now, the axial component will not produce any net force on the first loop, however the radial component will produce a net force which will attract the loop if it has current in same direction and oppose it if vice versa.



(B), (D) ✓

13. ✓



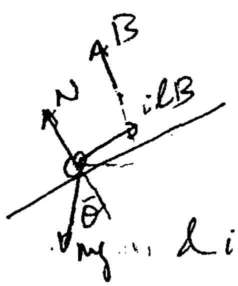
i : into the plane

Equilibrium conditions : $ilB\cos\theta - mg\sin\theta = 0$

$\Rightarrow \boxed{ilB = mg\tan\theta}$

(A), (B) ✓

14 ✓



i: into the plane.

$ilB - mg\sin\theta = 0$

$\Rightarrow \boxed{ilB = mg\sin\theta}$

(B) ✓

15. ✓

$\mathcal{E} = Blv = 4 \times 1 \times 20 = 80$ Volts.

$\therefore \quad q = C\mathcal{E} = 10\mu F \times 80 V = 800 \mu C$

From lenz's law or right hand rule

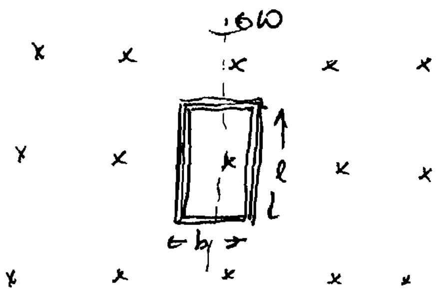
$(V_P - V_Q) = +Blv = +80$ Volts

$\therefore$ Plate A has $+800\mu C$

and B has $-800\mu C$ charge.

(A) ✓

16. ✓



Consider a rectangular coil of N turns of dimensions $(l \times b)$ rotating with angular speed 'ω' in a uniform field B.

By application of Faraday's law

$$\mathcal{E} = -\frac{d\phi_B}{dt} = -\frac{d}{dt}\left(N(l \times b)B(\hat{n}\cdot\hat{k})\right)$$

where $\hat{n}$: area vector's direction

$$\mathcal{E} = NlbB\omega\cos(\omega t)$$

$\therefore$ $\mathcal{E}$ is independent of only 'R'

(D) ✓

17. ✓ The only type of motion that generates a change in flux and therefore an induced emf for a closed conducting loop inside a uniform magnetic field is "rotation".

Therefore (A), (B), (C) and (D)

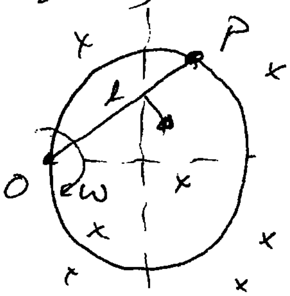
18. ~~For any section~~

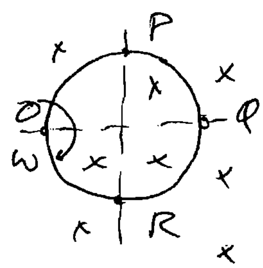
~~For the voltage~~ inc ~~of any~~

18. ✓ For the induced emf across any section of the wire join the end points with a straight line and apply the formula (as shown)

$$\mathcal{E} = \frac{B\omega \ell^2}{2} = V_P - V_O$$

with polarity as per right hand rule.





$$\therefore (V_P - V_O) = +\frac{B\omega (R\sqrt{2})^2}{2}$$

$$(V_R - V_O) = +\frac{B\omega (R\sqrt{2})^2}{2}$$

$$(V_Q - V_O) = \frac{B\omega (2R)^2}{2}$$

$$\therefore (V_Q - V_P) = \frac{B\omega R^2}{2}(4-2) = + B\omega R^2 \text{ etc.}$$

$\therefore$ (B), (D) ✓

19. ✓ Same as above

(C) ✓

20. ✓ For the entire ring the net emf across the closed loop will be zero (Flux is ~~uniform~~ constant $\Phi_B = B\times\pi R^2$)

$\therefore$ (D) ✓

Q21. ✓ $\tau = L/R$ and $i_0 = E/R$ where i_0 = steady state current.

Now, ~~i_0 is greater for ckt (b) than for~~

from the graph, i_0 is same for circuits (b) and (c). Therefore $\frac{V}{R_1} = \frac{V}{R_2} \Rightarrow R_1 = R_2$

~~whereas~~ whereas time constant τ is ~~greater~~ smaller for circuit (b) as compared to (c)

$$\therefore \quad \frac{L_1}{R_1} < \frac{L_2}{R_2} \Rightarrow L_1 < L_2$$

$\therefore$ (B), (D) ✓

Q22. ✓ From the graph of current Vs time it is evident that the steady state current $i_0 = E/R$ remains the same after making the changes whereas the time constant $\tau = (L/R)$ increases.

$\therefore$ (A), (C) ✓

Q23. ✓ The current passing through is constant, therefore for a resistor the voltage $V = iR$ would be constant, for an inductor $V = -L\frac{di}{dt}$ would be zero, and for a capacitor $V = \frac{q}{C}$, $q = i\Delta t$ would increase with time linearly.

$\therefore$ (D) ✓

Q24. ✓ The presence of the iron rod will increase the intensity of the magnetic field inside the solenoid, hence the flux and hence the self-inductance ($\Phi_B = Li$), however it has no effect on the "resistance" of the coil.

Q25: ✓ $[RC] = T$

$[L/R] = T$

$[\sqrt{LC}] = T$

$\therefore$ (A), (B), (C) ✓

Q26. ✓ The back emf @ $t=0$ $= \mathcal{E}$. $\therefore$ the inductor "blocks" current @ $t=0$

$\therefore$ (D) ✓

Q27. ✓ for RC charging ckt $q = C\mathcal{E}(1-e^{-t/RC})$

and $i = \mathcal{E}/R \, e^{-t/RC}$

whereas for LR charging ckt $i = \mathcal{E}/R \, (1-e^{-Rt/L})$

$\therefore$ (B), (D) ✓

~~Q28 (REPLACE QUESTION)~~ ~~For LC oscillations~~ 28. $\cancel{q = q_0 \cos(\omega t),\ i = i_0 \sin(\omega t)}$

$\cancel{\therefore U_c = \frac{1}{2}\frac{q_0^2}{C}\cos^2(\omega t)}$ ~~and~~

$\cancel{U_L = \frac{1}{2} L i_0^2 \sin^2(\omega t)}$

$\cancel{\therefore (B), (D)}$

Q28. ✓ $\tau = L/R$, $U_L = \frac{1}{2} L i^2$

$P_R = i^2 R$

$\therefore \tau = (2 \times U_L)/P_R \Rightarrow$ (A) ✓

Q29. ✓ The inductor initially "blocks" current through 'B_1' but eventually in steady state acts as a short circuit.

$\therefore$ the current through B_1 will be zero initially while the current through $B_2 = \mathcal{E}/R$ (constant)

as the time passes and the circuit goes to steady state, the current through B_1 becomes $i = \mathcal{E}/R$

$\therefore$ (A), ✓

Q30. ✓

$[R] = \frac{[V]}{[I]} = \frac{[J/Q]}{[Q][t]} = Kg\, m^2 sec^{-2} \times (Coulomb)^{-2} \times (sec)^{-1} = \frac{Kg\, m^2 sec^{-2}}{Amp\, sec} \times \frac{1}{Amp}$

$= Kg\, m^2 A^{-2} sec^{-3}$

$[L] = [V] \times \left[\frac{di}{dt}\right]^{-1} = \frac{Kg\, m^2 sec^{-2}}{(Amp\text{-}sec)} \times \frac{sec}{Amp} = Kg\, m^2 A^{-2} s^{-2}$

$[C] = \frac{[V]}{[Q]} = \frac{Kg\, m^2 sec^{-2}}{(Amp\, sec)} \times \frac{1}{(Amp\, sec)} = Kg\, m^2 A^{-2} sec^{-4}$

$[\phi_B] = [B][Area] = \frac{[F]}{[il]} \times [L^2] = \frac{Kg\, m\, sec^{-2}}{Amp\, m} \times m^2 = Kg\, m^2 A^{-1} S^{-2}$

$\therefore$ (A) ✓

Q31 ✓

When the switch 'S' is opened, the magnetic flux through the inductor tends to change at a very rapid rate (since 'i' starts to decay fast) creating a strong back emf.

$\therefore$ (C) ✓

Q32 ✓

The induced "back" emf in the inductor initially tends to block current through the lamp but as the circuit achieves steady state the back emf minimizes and the current through the lamp stabilizes.

$\therefore$ (B) ✓

Q33 ✓ $E_{ind} = -\left(\frac{d\phi_B}{dt}\right)$, now $\left(\frac{\Delta\phi_B}{\Delta t}\right)_A = 0.4$ Wb/sec due to current in 'B' changing.

$(E_{ind}) = -M\left(\frac{di}{dt}\right) \Rightarrow 0.4 = M \times \left(\frac{\Delta i}{\Delta t}\right)$ ...

Moved to ...

~~Q21.~~ ~~(MOVE TO AC Ckts)~~ : Theory Question.

~~(B), (D)~~

EMI Solutions

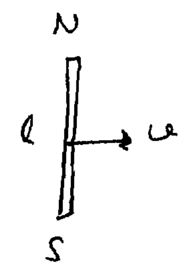
~~Exercise - III~~ EXERCISE IV - SUBJECTIVES

Q1. ✓ $B_H = 3\times10^{-4}$ T

dip = $\tan^{-1}(4/3)$

$l = 0.25$ m

$v = 10$ cm/s



The induced voltage $\mathcal{E} = Blv$ where B: Component of the earth's magnetic field 'perpendicular' to the plane of the rod's motion or B_v, $B_v = B_H \tan\theta = \left(3\times10^{-4}\times\frac{4}{3}\right)$

$$\Rightarrow \mathcal{E} = B_v l v = \underset{(T)}{4\times10^{-4}} \times \underset{(m)}{0.25} \times \underset{(m/s)}{0.1} = 10^{-5}\ \text{Wb/m}^2\text{s}$$

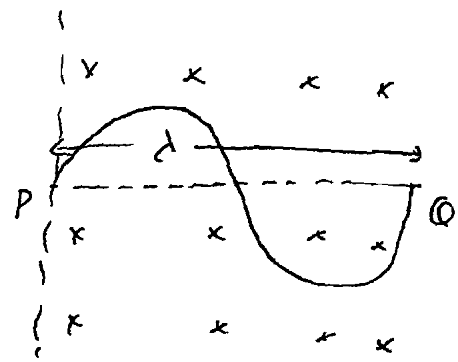
$$\Rightarrow \mathcal{E} = 10\times10^{-6}\ \text{T/s}$$

$$\boxed{\mathcal{E} = 10\,\mu V}$$

Q2. ✓ $\vec{v} = v_x\hat{i} + v_y\hat{j}$

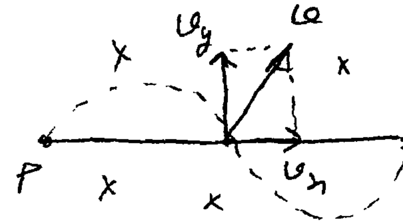
$\vec{B} = -B_0\hat{k}$

induced motional emf $\mathcal{E}$?

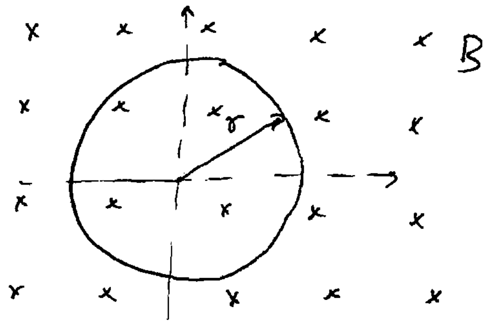


If we were to join the points P and Q with a straight wire (assume no electrical contact at the mid-point of PQ), the resulting closed loop would experience 'zero' induced voltage (flux through it will not change due to the translational motion)

Hence by application of superposition the induced voltage across the Sin-curve shaped conductor is equal (and opposite) ... imaginary straight wire



Q3. ✓



$B = 0.02T$, $r = (r_0 - 0.1t)$

~~$r = r_0 - 0.1t$~~ where 0.1 (mm/s)

t (sec)

r (mm)

$\therefore$ induced emf $\mathcal{E} = \left| -\frac{d\Phi_B}{dt} \right| = B \frac{d}{dt}(\pi r^2)$

$= 2\pi r \frac{dr}{dt} \times B$

$$\boxed{\mathcal{E} = 2\pi r \times (0.1) \times B}$$

~~$\therefore$ when $r = 4mm$~~

~~$\mathcal{E} = 2\pi \times 4 \times 0.1 \times 0.02 \times 10^{-6}$ Volts~~

~~$\Rightarrow \boxed{\mathcal{E} = 16\pi \times 10^{-7}}$ Volts~~

when $r = 4cm$

$\mathcal{E} = 2\pi \times (4 \times 10^{-2}) \times (0.1 \times 10^{-3}) \times 0.02$

$\Rightarrow \mathcal{E} = 16\pi \times 10^{-7}$

$\Rightarrow \mathcal{E} \approx 50 \times 10^{-7}$ Volts

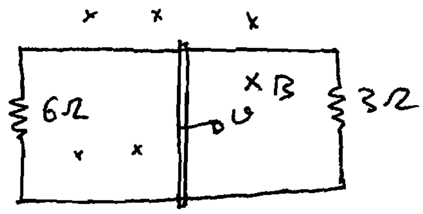
$$\boxed{\mathcal{E} = 5 \ \mu\text{Volts}}$$ ✓

Q4. $\left[\frac{L}{RCV}\right] = \frac{[ML^2T^{-2}A^{-2}]}{[T][ML^2T^{-3}A^{-1}]}$ $\quad [RC] = [\tau] = T$

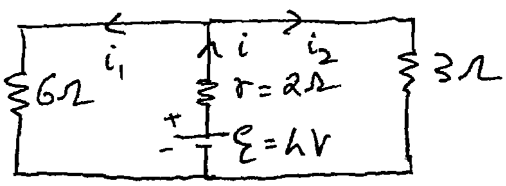
$\Rightarrow \left[\frac{L}{RCV}\right] = M^0L^0T^0A^{-1}$

Q5

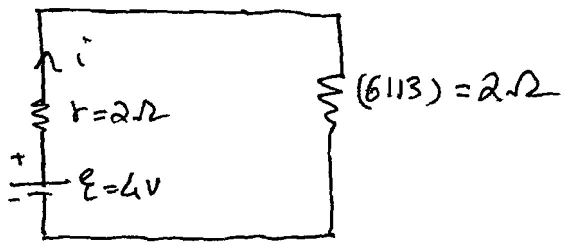
$l = 1.0\,m$
$B = 2.0\,T$
$r = 2\Omega$, $v = 2\,m/s$
$F = ?$



The moving rod will develop an induced ~~volt~~ voltage of $\mathcal{E} = Blv = 2\times1\times2 = 4$ volts.
It can therefore be replaced with a d.c. source of $\mathcal{E} = 4V$ ~~and~~ in series with a 2Ω resistor in the equivalent circuit diagram. (with polarity as per right-hand rule)



which can be further simplified to



Therefore $i = \frac{\mathcal{E}}{R_{eq}} = \frac{4V}{4\Omega} = 1$ Amp.

Now, the magnetic force $F_B = ilB = 1\times1\times2 = 2$ Newtons acting on the moving rod due to the magnetic field acting on the current will have to be balanced with an external force $F = 2N$ to keep the rod in uniform motion
$= 1 \times R$

Q6. The magnetic flux at the center of the two coils due to an instantaneous current 'i' in the outer coil.

$$B = \frac{\mu_0 i}{2b}$$

Since $a \ll b$, the magnetic flux through the smaller one, $\phi_B \simeq B \times \pi a^2 = \frac{\mu_0 i \pi a^2}{2b}$

$\therefore$ induced voltage $\mathcal{E} = \frac{d\phi_B}{dt} = \frac{\mu_0 \pi a^2}{2b}\left(\frac{di}{dt}\right)$

$\therefore$ induced current $i_{ind} = \frac{\mathcal{E}}{R} = \frac{\mu_0 \pi a^2}{2bR}\left(\frac{di}{dt}\right)$

$\therefore$ charge $\Delta Q = \int i_{ind}\, dt = \int \frac{\mu_0 \pi a^2}{2bR}\left(\frac{di}{dt}\right) dt$

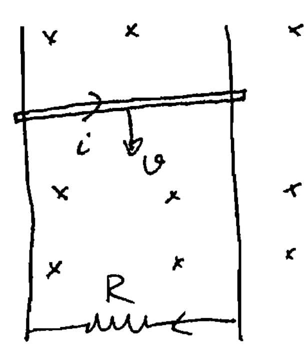
$$= \frac{\mu_0 \pi a^2}{2bR} \int di$$

$$= \frac{\mu_0 \pi a^2 \Delta i}{2bR}$$

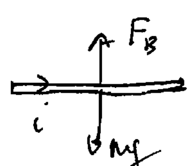
$$\boxed{\Delta Q = \frac{\mu_0 \pi a^2 i}{2bR}}$$

(as current changes from '0' to 'i')

Q7. At some instant $t = t$ when the rod has achieved its terminal velocity 'v', the net force on it should be zero $\Rightarrow$ $F_B = mg \Rightarrow ilB = mg$

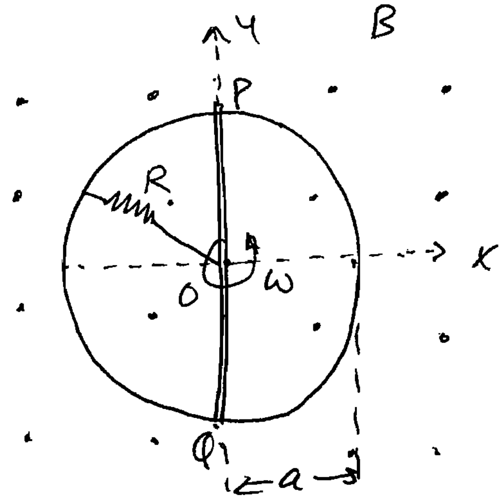


$t = t$, $a = 0$



Now, $i = \frac{\mathcal{E}}{R} = \frac{Blv}{R}$ (motional emf) $\Rightarrow \frac{B^2 l^2 v}{R} = mg \Rightarrow \boxed{v = \frac{mgR}{B^2 l^2}}$

Q8. Q8.



$\vec{B} = 50\hat{k}$ (T)

$\omega = 20$ (rad/s)

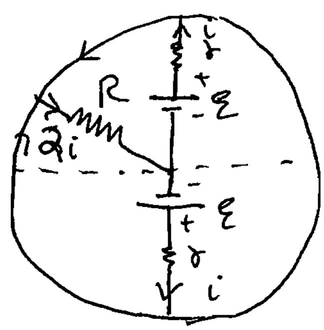
$R = 10\Omega$, $a = 0.1m$

The rotation of the metallic rod attached along the diameter PQ will create motion generated emi such that,

$(V_P - V_O) = +\frac{B\omega a^2}{2}$

and $(V_Q - V_O) = +\frac{B\omega a^2}{2}$

Therefore in an equivalent circuit, two voltage sources $\mathcal{E} = \frac{B\omega a^2}{2} = \frac{50\times 20\times(0.1)^2}{2} = 5$ Volts and two resistors $r = 10\Omega$ can be placed as shown below



$\mathcal{E} - ir - 2iR = 0$

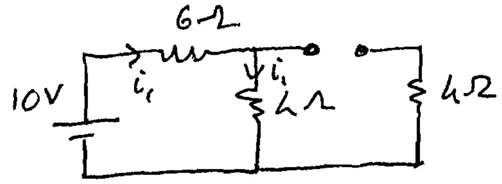
$\Rightarrow i = \frac{\mathcal{E}}{r+2R} = \frac{5}{10+20} = \frac{1}{6}$ Amp

$\therefore$ the current through 'R', $2i = \frac{1}{3}$ Amp $\simeq 0.33$ Amp

Q9.

$i_1 = i(t=0)$

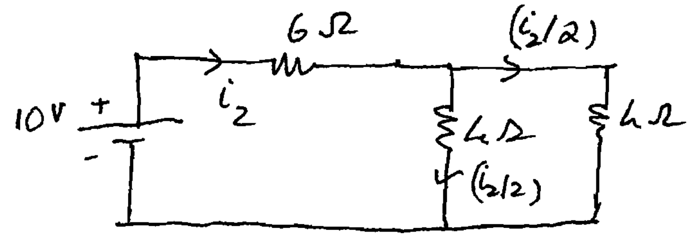
The equivalent circuit at time $t=0$



(inductor acts like an 'open' circuit)

$\Rightarrow \quad i_1 = \frac{10V}{10\Omega} = 1 \text{ Amp}.$

@ $t \to \infty$ (steady state), the inductor will act like a 'short circuit'. Hence the equivalent ckt.



$i_2 = \frac{10V}{8\Omega} = 1.25 \text{ Amp}.$

$\therefore \quad \boxed{i_1 : i_2 = 4:5}$ Ans

Q10

When the switch is closed in position (1) for a long time, the inductor stored potential energy $U = \frac{1}{2} L i^2$

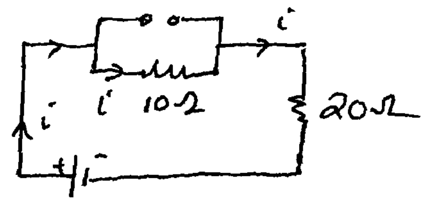
$$\Rightarrow U = \frac{1}{2} L \left(\frac{\varepsilon}{R_1}\right)^2$$

When the switch is moved to position (2) the d.c. source ε disengages and the inductor dissipates its stored potential energy through R_2, therefore heat produced

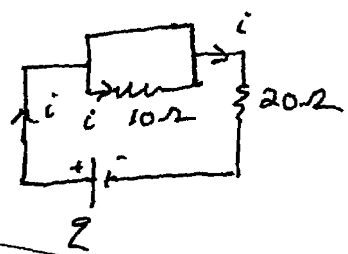
$$\boxed{H = U = \frac{1}{2} \frac{L\varepsilon^2}{R_1^2}}$$

Q11.

At $t=0$, "L" acts as an open-ckt. Therefore from the ~~Equivalent~~ Equivalent ckt diagram $i = \frac{2V}{30\Omega} = 0.067$ Amp.



At steady state, $t \to \infty$, "L" acts as a short-ckt. Therefore from Equivalent ckt diagram $i = \frac{2V}{20\Omega} = 0.1$ Amp.



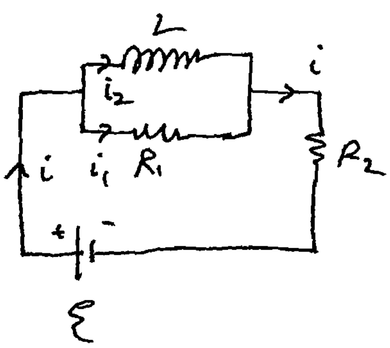
(OPTIONAL)

(To add part about time constant 'τ')

$$\mathcal{E} - L\frac{di_2}{dt} - iR_2 = 0 \quad \text{—— (I)}$$

$$\mathcal{E} - i_1R_1 - iR_2 = 0 \quad \text{—— (II)}$$

$$i = (i_1 + i_2) \quad \text{—— (III)}$$



$\Rightarrow$ $L\frac{di_2}{dt} = i_1R_1$

$\Rightarrow$ $i = \left\{\frac{L}{R_1}\frac{di_2}{dt} + i_2\right\}$ → Substituting in Eq (I)

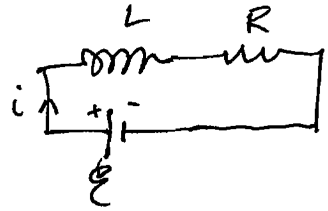
$$\mathcal{E} - L\frac{di_2}{dt} - \left\{\frac{L}{R_1}\frac{di_2}{dt} + i_2\right\}R_2 = 0$$

$$\Rightarrow \mathcal{E} - L\left(1 + \frac{R_2}{R_1}\right)\frac{di_2}{dt} - i_2R_2 = 0$$

$$\Rightarrow \mathcal{E} - L'\left(\frac{di_2}{dt}\right) - R_2 i_2 = 0 \quad \text{—— (IV)}$$

Compare Eq (10) with a standard L-R (charging) circuit's transient equation where

$$i = \frac{\mathcal{E}}{R}\left(1 - e^{-t/\tau}\right)$$



$\tau = L/R$

and $\mathcal{E} - L\dfrac{di}{dt} - Ri = 0$

Since $\tau = L/R$

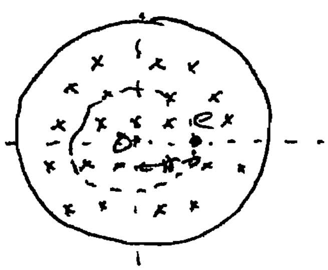
for our given circuit $\tau = L'/R_2 = L\left(1 + \frac{R_2}{R_1}\right)/R_2$

$1.017 \times \left(\frac{30}{200}\right)$

$$\boxed{\tau = L\left(\frac{R_1 + R_2}{R_1 R_2}\right)}$$

$\tau \simeq 1.5$ secs

Q12



$B = kt$

By application of Faraday's Law over closed loop

$$\mathcal{E} = \oint \vec{E}\cdot d\vec{r} = \left|-\frac{d\phi_B}{dt}\right| = \pi r^2 \frac{dB}{dt} =$$

$$\Rightarrow \quad E \times 2\pi r = \pi r^2 \times k$$

$$\Rightarrow \quad \boxed{E = \frac{kr}{2}}$$

E : Non-conservative, non-electrostatic electric field generated due to the time varying magnetic field. B

∴ just after it is released, the acceleration of the e^-, $a = \dfrac{eE}{m}$

$$\Rightarrow \boxed{a = \frac{ekr}{2m}}$$

Ans

Q13.

$i(t) = \frac{\mathcal{E}}{R}(1-e^{-t/\tau})$, $\mathcal{E}/R = 1.5$ Amp

$\tau = L/R = 0.5$ sec

$i(t\to\infty) = \mathcal{E}/R = 1.5A$

$i(t=1) = \frac{\mathcal{E}}{R}(1-e^{-t/\tau}) = 1.5(1-e^{-1/0.5})$

$$\boxed{i_1 = 1.5\left(1-\frac{1}{e^2}\right)}$$

$$\therefore \quad \frac{i_\infty}{i_1} = \frac{1}{\left(1-\frac{1}{e^2}\right)} = \left(\frac{e^2}{e^2-1}\right) \simeq 9/8 \text{ (Approx)}$$

Q14.

$B_0 = 0.08T$

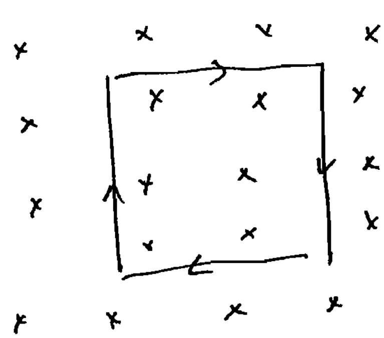
$A = 0.01\,m^2 = (0.1\times0.1)\,m^2$

$-\frac{dB}{dt} = 3.0\times10^{-4}$ T/s $\quad\therefore\quad B = B_0 - kt$

where $k = 3.0\times10^{-4}$

$\therefore$ Magnetic Flux $\Phi_B = BA = (B_0-kt)A$

$\therefore$ induced voltage $\mathcal{E} = -\frac{d\Phi_B}{dt}$



$\mathcal{E} = -\frac{d}{dt}(B_0-kt)A$

$\Rightarrow \mathcal{E} = kA$

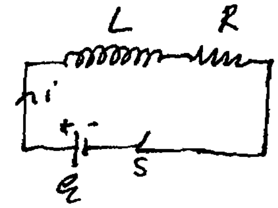
$\Rightarrow \mathcal{E} = 3.0\times10^{-4}\,(T/s)\times 0.01(m^2)$

$\Rightarrow \boxed{\mathcal{E} = 3\times10^{-6}\ (W/s)\ \text{or}\ V} = 3\mu V$

$\Rightarrow$ Orientation of the '$\mathcal{E}$' will be Clock-wise since the Φ_B associated with a field "into" the plane of the diagram is decreasing with time.

Q15.

$$i = \frac{dq}{dt} = \frac{\varepsilon}{R}(1-e^{-t/\tau})$$



$$\Rightarrow \int_0^Q dq = \int_0^\tau \frac{\varepsilon}{R}(1-e^{-t/\tau})\,dt$$

$$\Rightarrow Q = \frac{\varepsilon}{R}\left[\tau - \tau(1-\tfrac{1}{e})\right]$$

$$\Rightarrow \boxed{Q = \frac{\varepsilon}{R}\times\frac{\tau}{e} = \frac{\varepsilon L}{eR^2}}$$

Q16.

$U_i = \frac{1}{2}Li_0^2$ ~~when U = 1/4 · 1/2 Li0^2~~ Energy ~~dissipated~~ through Resistor

Alt method $i = i_0 e^{-t/\tau}$

$H = U_i - U$

$= \frac{3}{4}\cdot\frac{1}{2}Li_0^2$

$\therefore$ @ some time $t=t$, $U = \frac{1}{2}Li_0^2 e^{-2t/\tau}$

$$\text{if } U = \frac{1}{4}U_i \Rightarrow e^{-2t/\tau} = \frac{1}{4}$$

$$\Rightarrow \frac{2t}{\tau} = \ln 4$$

$$\Rightarrow \boxed{t = \tau\ln 2}$$

~~Heat dissipation through resistor~~

$$H = \int i^2 R\,dt = \int_0^\tau i_0^2 e^{-2t/\tau} R\,dt$$

$$= i_0^2 R$$

Therefore, charge flown through the resistor,

$$Q = \int_0^{t=\tau\ln 2} i\,dt = \int_0^{\tau\ln 2}\frac{\varepsilon}{R}(1-e^{-t/\tau})\,dt$$

$$\Rightarrow Q = \frac{\varepsilon}{R}(t - \tau e^{-t/\tau})\Big|^{t=\tau\ln 2} = \frac{\varepsilon}{R}\times\tau(1-e^{-2})$$

Q16.

Initially, the energy stored in the inductor,

$U_i = \frac{1}{2} L i_0^2$,

~~if at time~~

At time $t = t$, $i = i_0 e^{-t/\tau} \Rightarrow U = \frac{1}{2} L i_0^2 e^{-2t/\tau}$

$\Rightarrow$ if $U = \frac{1}{4} U_i \Rightarrow e^{-2t/\tau} = (1/4)$

$\Rightarrow 2t/\tau = \ln 4 \Rightarrow \boxed{t = \tau \ln 2}$

$\Rightarrow \cancel{t = 2\ln 2}$

$\therefore$ the charge flown through the resistor from $t=0$ to $t = \tau \ln 2$ $\quad Q = \int i\,dt = \int_{t=0}^{t=\tau\ln 2} i_0 e^{-t/\tau} dt$

$$= i_0 \left[\frac{e^{-t/\tau}}{-1/\tau} \right]_0^{\tau \ln 2}$$

$$= i_0 \tau \left[1 - e^{-\ln 2} \right]$$

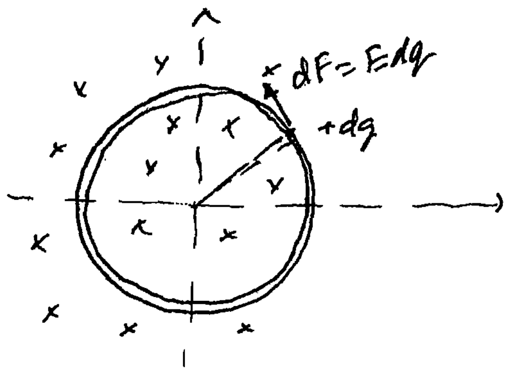
$$\boxed{Q = \frac{i_0 \tau}{2}} \Rightarrow \boxed{Q = \frac{L i_0}{2R}}$$

If $i_0 = \mathcal{E}/R$, & $\tau = L/R$ $\quad \boxed{Q = \frac{\mathcal{E} L}{2R^2}}$

Q17. The magnitude of the Electric Field (of circular geometry) (non-conservative, non-electrostatic) generated at any point on the circumference of the ring due to the time varying field B can be derived from $\oint \vec{E} \cdot \vec{dl} = \left| \frac{d\phi_B}{dt} \right| \Rightarrow E \times 2\pi R = \pi R^2 \times \frac{dB}{dt}$, $B = (0.2t)$

$$\Rightarrow E = \frac{R}{2} \times \frac{dB}{dt} = 0.2 \,(\mathrm{V/m})$$

Now, considering a differential length element of length 'dx' and charge $dq = \lambda dx$ on the



$$d\tau = R\,dF = R\,dq\,E$$

$$\Rightarrow d\tau = R\lambda\,dx \times \frac{R}{2}\left(\frac{dB}{dt}\right)$$

$$\Rightarrow d\tau = \frac{R^2}{2}\lambda\left(\frac{dB}{dt}\right)dx$$

$\Rightarrow$ net torque $\tau = \int d\tau = \frac{R^2\lambda}{2}\left(\frac{dB}{dt}\right)\int_{x=0}^{x=2\pi R} dx$

$$\Rightarrow \tau = \frac{R^2}{2}(\lambda \times 2\pi R)\left(\frac{dB}{dt}\right)$$

$$\Rightarrow \tau = \frac{R^2}{2} \times Q \times \left(\frac{dB}{dt}\right)$$

Therefore, it produces a uniform angular accel' equal to $\alpha = \frac{\tau}{I} = \frac{R^2/2\, Q(dB/dt)}{mR^2} = \frac{Q}{2m}\left(\frac{dB}{dt}\right)$

$\therefore$ angular speed after $t = \Delta t = 10$ sec

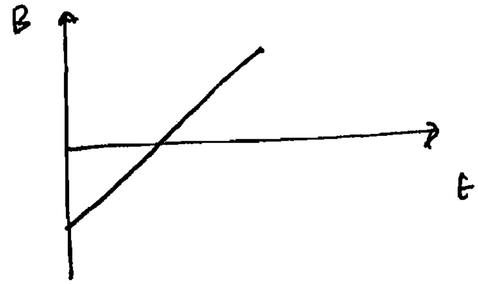
$$\Rightarrow \omega = \alpha\Delta t = \frac{Q}{2m}\left(\frac{dB}{dt}\right)\Delta t$$

$$\omega = \frac{2}{2 \times 50 \times 10^{-3}} \times (0.2) \times 10$$

$$\boxed{\omega = 40 \text{ rad/sec}}$$

Q18.

$B = (kt - c)$; $(0 \le t \le c/k)$



$\mathcal{E} = A\frac{dB}{dt} = (\pi a^2 \times k)$

$i = \frac{\mathcal{E}}{R} = \frac{\pi a^2}{R}k \Rightarrow$ charge $Q = \int i\,dt = \frac{\pi a^2}{R}k\int_{t=0}^{t=c/k} dt$

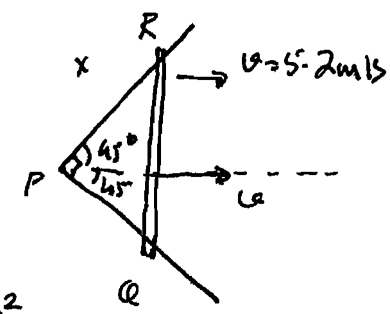
$$\boxed{Q = \frac{c\pi a^2}{R}}$$

Q19.

$B = 0.35\,T$

at $t=0$, $s = (5.2 \times 3)$

$s = 15.6\,m$



$\therefore$ Area of the $\triangle PQR$

Area $= 2 \times \left[\frac{1}{2} \times 15.6 \times 15.6\right] m^2$

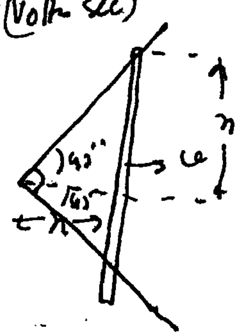
$\therefore \Phi_B = B \times \text{Area} = 0.35 \times (15.6)^2 = 85.18$ (Volt sec)

$\cancel{\mathcal{E} = \left(\frac{d\Phi_B}{dt}\right)}$

At a general time 't'

$x = vt$

$\therefore$ Area $= 2 \times \left(\frac{1}{2} \times x^2\right) = x^2$



$\therefore \Phi_B = B \times x^2$

$\therefore$ induced emf. $\mathcal{E} = \left|\frac{d\Phi_B}{dt}\right| = B \times 2x\frac{dx}{dt}$

$= B \times 2x \times v$

$= 0.35 \times 2 \times 15.6 \times 5.2$

$\mathcal{E} = 56.78$ Volts

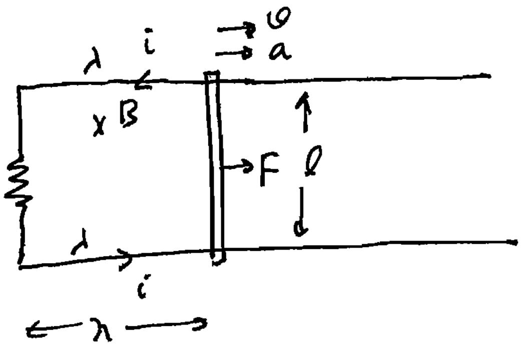
$$\mathcal{E} = 2Bxv \quad , \quad x = vt$$

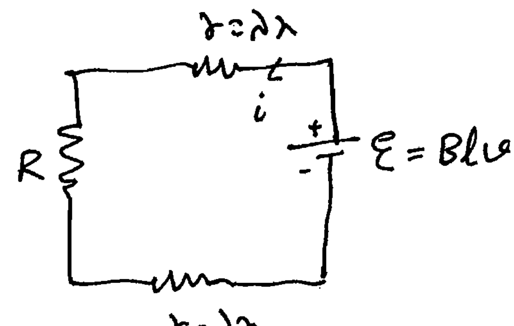
$$\Rightarrow \mathcal{E} = (2Bv^2)t$$

$\therefore$ '$\mathcal{E}$' varies "linearly" w.r.t 'time'

Q.20.

As the rod moves with velocity 'v', and acceleration 'a', the equivalent circuit diagram for any instant $t=t$ when $x=x$ is as shown





now $\mathcal{E} - i(2r+R) = 0$

$$\Rightarrow i = \frac{\mathcal{E}}{(2r+R)}$$

$r = \lambda x$, Since 'i' is constant

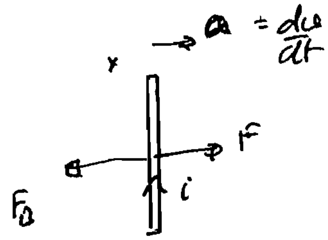
$$\Rightarrow \left(\frac{\mathcal{E}}{2\lambda x + R}\right) = i \Rightarrow \frac{Blv}{2\lambda x + R} = i = \text{Constant} \Rightarrow \boxed{v = \frac{(2\lambda x + R)i}{Bl}}$$

$$\Rightarrow Bl\left(\frac{dx}{dt}\right) = (2\lambda x + R)i$$

To determine the relation between the velocity $v = \frac{dx}{dt}$ and displacement 'x', first integrate the above equation to ~~$\left(Bl\frac{dx}{dt}\right) = (2\lambda x + R)i \times dx$~~ get '$x$' as a function of time.

$$\int_{x=x_0}^{x=x} \frac{dx}{(2\lambda x + R)} = \int_{t=0}^{t=t} \frac{i}{Bl}\,dt$$

$$\Rightarrow \ln(2\lambda x + R) = \frac{i}{Bl}t$$



from the FBD above $\quad F - F_B = m\left(\frac{dv}{dt}\right)$

$$\Rightarrow F = F_B + m\left(\frac{dv}{dt}\right)$$

$$= ilB + m\frac{d}{dt}\left\{\frac{(2\lambda x + R)i}{Bl}\right\}$$

$$= ilB + m \times \frac{2\lambda}{Bl}\left(\frac{dx}{dt}\right)$$

$$= ilB + \frac{2m\lambda v}{Bl}$$

$$= ilB + \frac{2m\lambda i}{Bl}\left\{\frac{(2\lambda x + R)i}{Bl}\right\}$$

$$\Rightarrow \boxed{F = \frac{2m\lambda i^2(2\lambda x + R)}{B^2 l^2} + ilB}$$

Q21. (i) $\vec{B} = (B_0 + 3t)\hat{i}$, $r = 0.1\,m$

For the given loop, the total flux

$$\phi_B = \left(B \times \frac{\pi r^2}{4}\right)$$

(This field will produce flux only through the quadrant (quarter circle)
(This field will produce flux only through the quadrant (quarter circle) as it is "tangential" to the surfaces lying in the Y-Z plane of the other 2 quadrants)

$$\therefore \quad \mathcal{E} = \left|\frac{d\phi_B}{dt}\right| = \frac{\pi r^2}{4} \times \frac{dB}{dt} = \left\{\pi \frac{(0.1)^2}{4} \times 3 \times 10^{-3}\right\} V = 0.024 \times 10^{-3}$$

$$\boxed{\mathcal{E} = 2.4 \times 10^{-5}\ V}$$

(ii) Since the ϕ_B for $\vec{B}$ along the x-axis increases with time, by application of Lenz's Law the induced current in the … " Clock wise " i.e. along cbac, Q.22.

(i) $B = 10\,\mu T$

$l = 3.0\,m$

$F = 10 \times 10^3\,N$

$\therefore\ F = ilB \Rightarrow 10^4 = 10\times10^{-6} \times 3 \times i$

$\therefore\ i = \left(\frac{10^9}{3}\right)$ Amp

$\boxed{i \simeq 3.3\times10^8 \text{ Amp}}$

(ii) Power dissipated $= i^2R$, $R = 1\Omega$

$= (3.3\times10^8)^2 \times 1 \approx 10^{17}$ watts.

(iii) Not realistic

Q.23.

(i) induced voltage $\mathcal{E} = \frac{d\phi_B}{dt} = \left|\frac{1}{2}\times(2m)^2 \times \left(\frac{dB}{dt}\right)\right|$, $B = (0.042 - 0.87t)\,T$

$\therefore\ \mathcal{E} = (2\times0.87) = 1.74$ Volts.

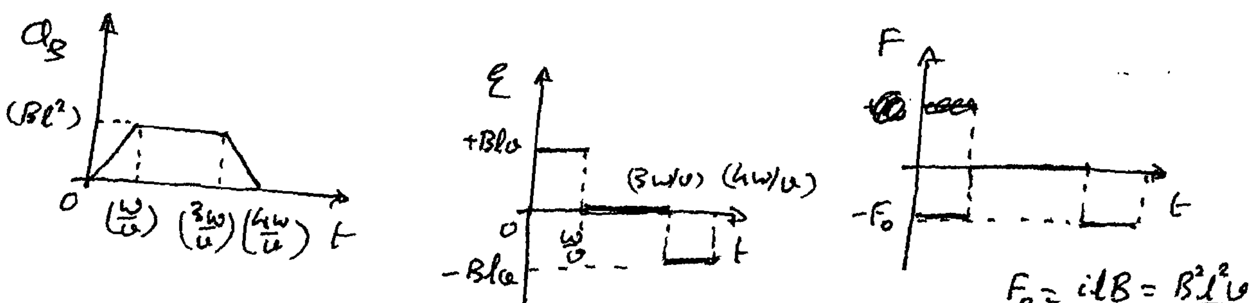
Now, by application of lenz's law, ~~it is~~ it can be shown that the induced voltage will ~~create~~ lead to create an anti-clockwise induced current (same orientation as the battery)

Therefore, net voltage $= 1.74 + 20 = 21.74$ Volts.

(ii) Through the battery (inside it) charge will flow from $-$ve terminal to $+$ve.

~~Out~~ In the circuit it will be anti-clockwise.

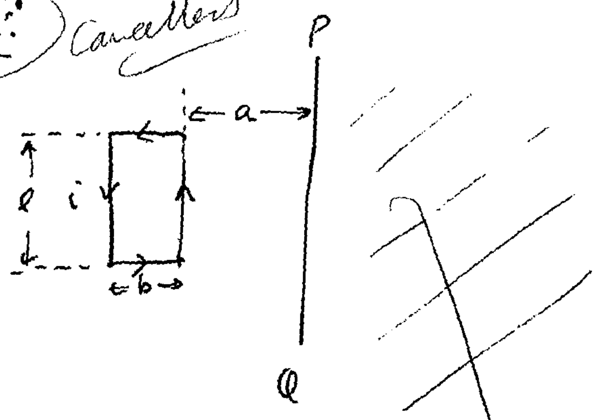
Q24.



$F_0 = ilB = \frac{B^2l^2v}{R}$

$-$ve : force towards

Q25. Cancelled



Flux through loop in shaded region.

Use superposition. Place infinite straight conductor along PQ with current i'. Find the flux due to this through the loop.

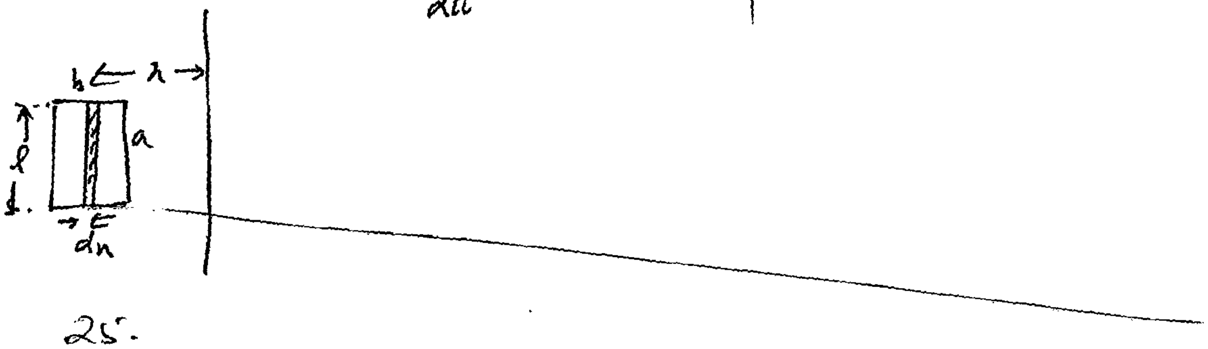
$$\phi = M_{12} i' = M_{21} i = \phi$$

Flux through the loop

↳ Flux through the shaded region.

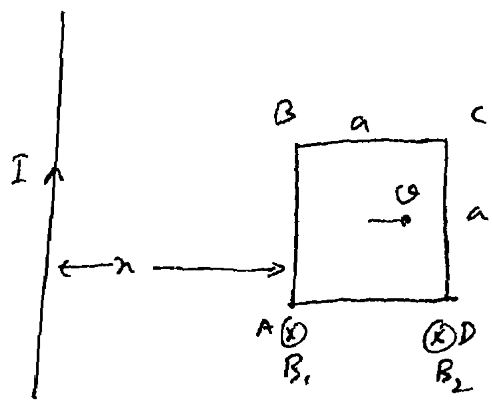
(if $i = i'$)

$$\therefore \quad \phi = \frac{\mu_0 i}{2\pi}$$



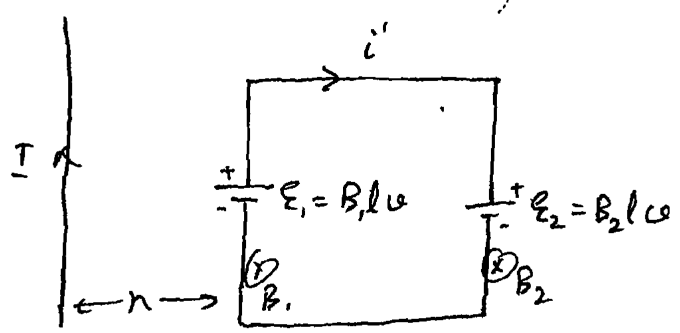
25.

Q.26/



Resistance R
side length a

As the loop moves away there is an induced current flowing (clockwise) through it due to the induced voltage from EMF. The instantaneous equivalent circuit diagram is as shown



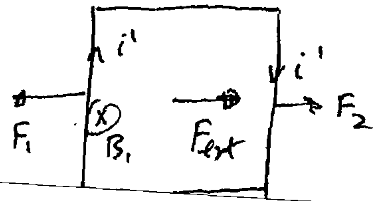
induced current $i' = \left(\frac{\mathcal{E}_1 - \mathcal{E}_2}{R}\right) = \frac{(B_1 - B_2) l v}{R}$

where $B_1 = \frac{\mu_0 I}{2\pi x}$

$$B_2 = \frac{\mu_0 I}{2\pi(x+a)}$$

$$\therefore \quad i' = \frac{\mu_0 I l v}{2\pi R}\left[\frac{1}{x} - \frac{1}{(x+a)}\right], \quad \frac{dx}{dt} = v$$

Therefore magnetic forces ~~[illegible]~~ $F_1 = i' l B_1$ and $F_2 = i' l B_2$ have to be balanced by the external force F_{ext} to keep the loop moving with a uniform velocity 'v'.



$$\Rightarrow \quad F_{ext} = (F_1 - F_2)$$

$$\Rightarrow \quad F_{ext} = i' l (B_1 - B_2)$$

$$\Rightarrow F_{ext} = \frac{\mu_0^2 I^2}{4\pi^2} \frac{l^2 v^2}{R} \left\{ \frac{1}{x} - \frac{1}{(x+a)} \right\}^2$$

$$\therefore \text{ Workdone } \quad W = \int F_{ext}\, dx = \int_{x=a}^{x=2a} \frac{\mu_0^2 I^2 l^2 v^2}{4\pi^2 R} \left\{ \frac{1}{x} - \frac{1}{(x+a)} \right\}^2 dx$$

$$\Rightarrow W = \frac{\mu_0^2 I^2 l^2 v^2}{4\pi^2 R} \int_{x=a}^{x=2a} \left\{ \frac{1}{x^2} + \frac{1}{(x+a)^2} - \frac{2}{x(x+a)} \right\} dx$$

$$\Rightarrow W = \frac{\mu_0^2 I^2 l^2 v^2}{4\pi^2 R} \int_{x=a}^{x=2a} \left\{ \frac{1}{x^2} + \frac{1}{(x+a)^2} - 2\left(\frac{1}{ax} - \frac{1}{a(x+a)} \right) \right\} dx$$

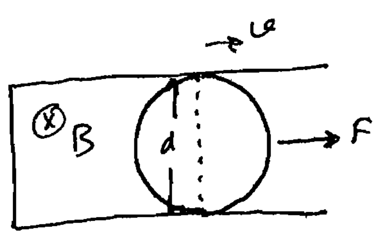
$$\Rightarrow W = \frac{\mu_0^2 I^2 l^2 v^2}{4\pi^2 R} \left[-\frac{1}{x} - \frac{1}{(x+a)} - \frac{2}{a} \ln\left(\frac{x}{a+x}\right) \right]_{x=a}^{x=2a}$$

$$\Rightarrow W = \frac{\mu_0^2 I^2 l^2 v^2}{4\pi^2 R} \left[\frac{1}{2a} + \frac{1}{6a} - \frac{2}{a} \ln(4/3) \right]$$

$$\Rightarrow W = \frac{\mu_0^2 I^2 l^2 v^2}{4\pi^2 R} \left[\frac{2}{3a} - \frac{2}{a} \ln(4/3) \right]$$

$$\Rightarrow \boxed{W = \frac{\mu_0^2 I^2 l^2 v^2}{2\pi^2 R a} \left\{ \frac{1}{3} - \ln(4/3) \right\}}$$

Q 27.



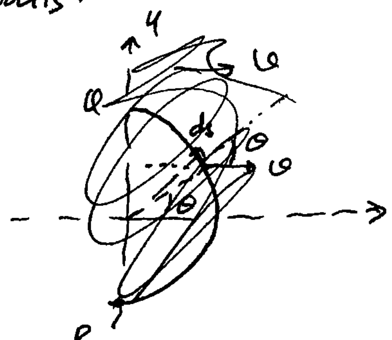
$$F = ilB \qquad l = d, \quad i = \frac{Blv}{R} = \frac{Bdv}{R}, \quad R = \frac{\lambda \times \pi \frac{d}{2}}{2}$$

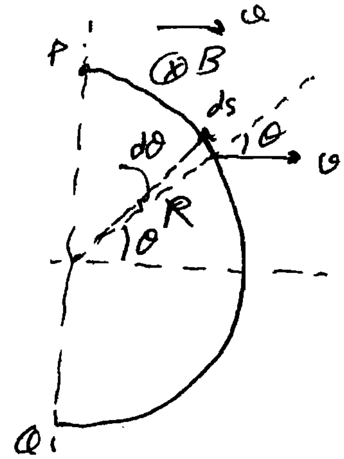
$$\Rightarrow F = \frac{B^2 d^2 v}{R} = \frac{4 B^2 d^2 v}{\pi \lambda d}$$

27 Alternate method

To calculate the induced voltage across the two-semi circular metallic sections between the two contact points on the parallel rails.

The voltage across the diff section of the semi-circle





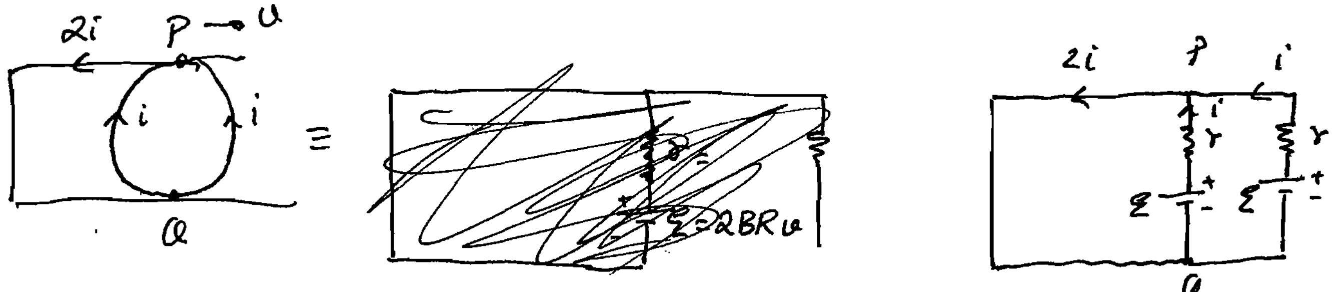
$ds = R\,d\theta,$

$d\mathcal{E} = v\cos\theta\, B\, R\,d\theta$

$\therefore$ net induced voltage $(V_P - V_Q) = \mathcal{E} = \int_{\theta=\theta-\pi/2}^{\theta=\pi/2} vBR\cos\theta\,d\theta$

$$\Rightarrow \boxed{\mathcal{E} = 2vBR}$$

Now, since there are two such semi-circles (part of the ring) in the actual circuit connecting points P and Q, the equivalent ~~ckt diag~~ circuit diagram is as follows.



$r = \lambda\pi r$

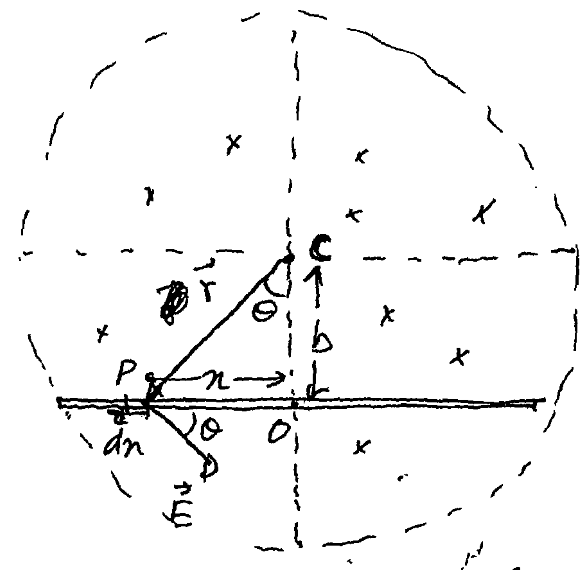
take $r = (d/2)$ $\therefore$ $\mathcal{E} = vBd$, $r = \lambda\dfrac{\pi d}{2}$

Therefore the current through each of the semi-circular branches $i = \mathcal{E}/r = \dfrac{2vB}{\pi\lambda}$

Now each of the branches will experience a magnetic force $F_B = idB = \dfrac{2vB^2d}{\pi\lambda}$

Therefore the external Force needed to balance these $F_{ext} = 2F_B \Rightarrow \boxed{F_{ext} = \dfrac{4vB^2d}{\pi\lambda}}$

Q28.



At any point 'P' on the rod, the distance from 'P' to the mid-point of the rod ~~being~~ 'O' being $PO = x$ and the distance from the cylinder's axis C being $PC = r$ the Electric field $E = \frac{r}{2}\left(\frac{dB}{dt}\right)$ {from app. of Faraday's law and direction perpendicular to $\vec{r}$ as shown. $\oint \vec{E}\cdot d\vec{l} = \frac{d\phi_B}{dt} = \pi r^2 \frac{dB}{dt}$}

Therefore for a diff' section 'dx', induced emf.

$$d\mathcal{E} = |\vec{E}\cdot d\vec{x}| = E\,dx\cos\theta = \frac{r}{2}\left(\frac{dB}{dt}\right)\times dx \times \frac{b}{r} \Rightarrow d\mathcal{E} = \frac{b}{2}\left(\frac{dB}{dt}\right)dx$$

Therefore emf induced $\mathcal{E} = \int_{x=(-l/2)}^{x=(+l/2)} \frac{b}{2}\left(\frac{dB}{dt}\right)dx = \frac{b}{2}\left(\frac{dB}{dt}\right)l$

Since $b = \sqrt{R^2 - \frac{l^2}{4}}$

$$\Rightarrow \boxed{\mathcal{E} = \frac{l}{2}\left(\frac{dB}{dt}\right)\sqrt{R^2 - \frac{l^2}{4}}}$$

PTO

Q29. REMOVED

?

The net EMF $\mathcal{E}$ across closed conducting loop ABCDA will be uniformly distributed over the circumference therefore

$\mathcal{E}_{ABC} = \mathcal{E} \times \left(\frac{\text{length of sector ABC}}{\text{circumference}}\right)$

and $\mathcal{E}_{CDA} = \mathcal{E} \times \left(\frac{\text{length of sector CDA}}{\text{circumference}}\right)$

$\therefore \quad \mathcal{E}_{ABC} + \mathcal{E}_{CDA} = \mathcal{E}$

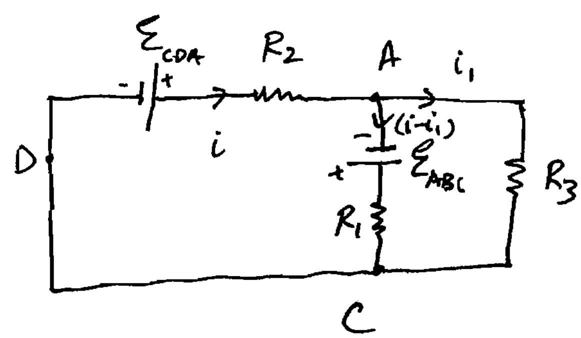
and $\mathcal{E}_{ABC} : \mathcal{E}_{CDA} = (\text{length of sector ABC}) : (\text{sector CDA})$

$\Rightarrow \quad \mathcal{E}_{ABC} : \mathcal{E}_{CDA} = R_1 : R_2 \quad \left(\text{Resistance} = \rho\frac{l}{A}\right)$

$\therefore \quad \mathcal{E}_{ABC} = \left(\frac{R_1}{R_1+R_2}\right)\mathcal{E}$

$\mathcal{E}_{CDA} = \left(\frac{R_2}{R_1+R_2}\right)\mathcal{E}$

$\therefore$ Equivalent ckt diagram



$\Rightarrow \quad i_1 = ?$

$\mathcal{E}_{CDA} - iR_2 - i_1R_3 = 0$

$\mathcal{E}_{ABC} - (i-i_1)R_1 + i_1R_3 = 0$

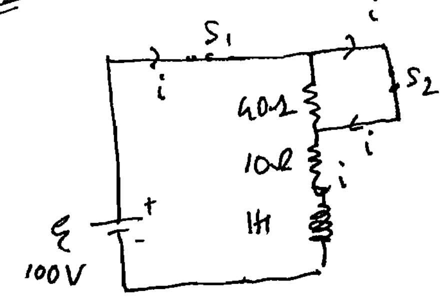
$\Rightarrow \quad \frac{\mathcal{E}_{CDA} - i_1R_3}{R_2} = \frac{\mathcal{E}_{ABC} + i_1R_1 + i_1R_3}{R_1}$

$\Rightarrow \quad i_1 = \frac{(R_1\mathcal{E}_{CDA} - R_2\mathcal{E}_{ABC})}{(R_1R_2 + R_2R_3 + R_1R_3)} = 0$

Question Cancelled

~~Q30~~ for $t=0$ to $t = 0.1 \ln(2)$

Q29.



$R_{eq} = 10\,\Omega$

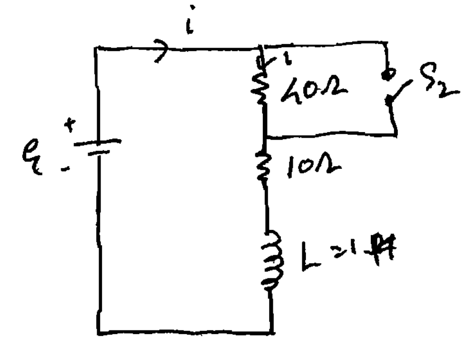
$\therefore \tau = L/R = 1H/10\Omega = 0.1\,sec$

$\therefore \quad i = \frac{\varepsilon}{R}(1-e^{-t/\tau}) = 10(1-e^{-t/0.1sec})$

$\therefore$ @ $t = 0.1 \ln(2)$ sec

$i = 10\left(1-e^{-\ln 2}\right) \Rightarrow i = 5\,Amp$

Now @ $t = 0.1\ln(2)$ the switch S_2 is opened. Therefore at some time $t > 0.1 \ln 2$



$$\varepsilon - iR - L\frac{di}{dt} = 0 \quad \text{where } R = 50\,\Omega, \ L = 1H$$

$$\Rightarrow \int_{i=5\,Amp}^{i=?} \frac{di}{(\varepsilon - iR)} = \int_{t=0.1\ln(2)}^{t=0.2\ln(2)} \frac{dt}{L}$$

$$\Rightarrow -\frac{1}{R}\ln(\varepsilon - iR)\Big|_{5}^{i} = \frac{t}{L}\Big|_{0.1\ln(2)}^{0.2\ln(2)}$$

$$\Rightarrow \ln\left(\frac{\varepsilon - iR}{\ }\right) = -R \times 0.1\ln(2)$$

$$\Rightarrow \cancel{\left(\frac{100-50i}{100-250}\right) = \left(\frac{150}{1}\right)}$$

$$\Rightarrow \left(\frac{\mathcal{E} - iR}{\mathcal{E} - 5R}\right) = e^{-\{R/L \times 0.1 \ln(2)\}}$$

$$\Rightarrow \left(\frac{100 - 50i}{100 - 250}\right) = e^{-\{\frac{50}{1} \times 0.1 \ln(2)\}}$$

$$\Rightarrow \left(\frac{100 - 50i}{-150}\right) = e^{-5\ln(2)}$$

$$\Rightarrow \frac{100 - 50i}{-150} = \left(\frac{1}{2^5}\right) \qquad 2 + \frac{3}{32}$$

$$\Rightarrow i = \frac{\left[100 + \left(\frac{150}{32}\right)\right]}{50} \Rightarrow \boxed{i = 2.09 \text{ Amps}} \quad \text{or } i = \left(2 + \frac{3}{32}\right)$$

$$\boxed{i = \left(\frac{67}{32}\right)} \text{ Amp}$$

Q31. $\longrightarrow$ ~~REMOVE OR REPLACE (Repeated Concept)~~

Q32 $\longrightarrow$ FIGURE MISSING $\longrightarrow$ REMOVE or REPLACE

Q30. For the loop $V - L\frac{di}{dt} = 0$

$$\Rightarrow \frac{di}{dt} = \frac{(2t + 3t^2)}{0.5} \Rightarrow i = 2\{t^2 + t^3\}$$

Now i increases monotonically, therefore

$$\Rightarrow i_{max} = i(t=2) = 2(2^2 + 2^3) = 24 \text{ Amps.}$$

and $U_L = \frac{1}{2}Li^2 = \frac{1}{2} \times 0.5 \times 24^2 = 144$ Joules

Q31.

For the half of the circular loop xy plane, ~~[illegible]~~ area vector $\vec{A_1} = \left(\frac{\pi a^2}{2}\right)\hat{k}$ and for the half bent at an angle of 60° to the horizontal (x-y Plane), $\vec{A_2} = \frac{\pi a^2}{2}\left(-\frac{\sqrt{3}}{2}\hat{i} - \frac{1}{2}\hat{k}\right)$

~~Therefore sing~~ Therefore since the magnetic field is uniform ~~[illegible]~~ in space and given by $\vec{B} = (B_0 t)\hat{k}$, the total flux, $\phi_B = \vec{B}\cdot(\vec{A_1}+\vec{A_2}) = \left(B_0 t \frac{\pi a^2}{2}\right) - \left(B_0 t \frac{\pi a^2}{4}\right)$

$$\Rightarrow \phi_B = \frac{1}{4} B_0 t \pi a^2$$

$$\therefore \text{Emf induced } \boxed{\mathcal{E} = \left|-\frac{d\phi_B}{dt}\right| = \frac{1}{4} B_0 \pi a^2}$$

Now, total resistance of the loop $R = r_0 \times 2\pi a$

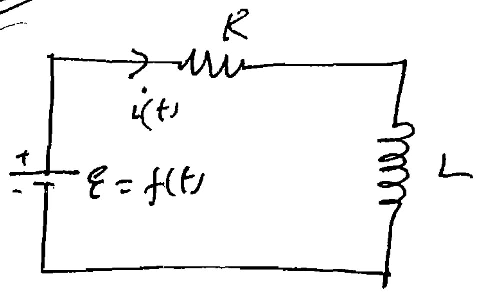
$$\therefore \text{charge flowing through } \Delta Q = i\Delta t$$

$$= \frac{\mathcal{E}}{R}\Delta t$$

$$\Rightarrow \boxed{\Delta Q = \frac{B_0 a t}{8 r_0}}$$

~~directi~~ direction of induced current : RQPSR

Q33. ~~Q32~~



$i = 3+5t$
$R = 4\,\Omega$
$L = 6H$
$\varepsilon = ?$

By application of Kirchoff's loop law,

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

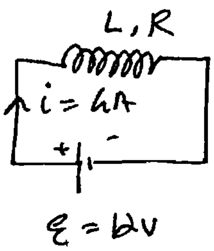
$$\Rightarrow \varepsilon - \{(3+5t)\times 4\} - \{6\times \tfrac{d}{dt}(3+5t)\} = 0$$

$$\Rightarrow \varepsilon - (12+20t) - 30 = 0$$

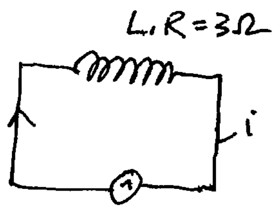
$$\Rightarrow \boxed{\varepsilon = (42+20t)\text{ Volts.}}$$

Q34. ⟶ SHIFT TO AC CIRCUITS ⟶ Q4 AC Ckts Ex3

(a)



$\Rightarrow$ Resistance of the coil $R = \frac{12V}{4Am} = 3\,\Omega$



$V = V_0 \sin(\omega t)$
$V_0 = 12V$
$\omega = 50$ rad/s

$i = i_0 \sin(\omega t + \phi)$

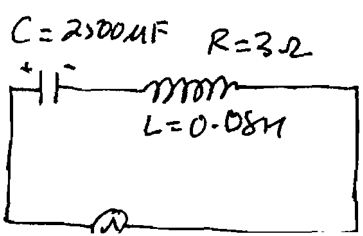
$$i_0 = \frac{V_0}{\sqrt{(\omega L)^2 + R^2}} \Rightarrow 2.4 = \frac{12}{\sqrt{(50L)^2 + 9}}$$

$$\Rightarrow (50L)^2 + 9 = 25$$

$$\Rightarrow 50L = \sqrt{16}$$

$$\Rightarrow L = 4/50 = 0.08\,H$$

(b)



$$\overline{P} = \frac{1}{2} V_0 i_0 \cos\phi$$

$i_0 = \frac{V_0}{Z}$, $Z = \sqrt{(X_c - X_L)^2 + R^2}$

$= \sqrt{\left(\omega L - \frac{1}{\omega C}\right)^2 + R^2}$,

$= \sqrt{(4-8)^2 + 3^2}$

$Z = \sqrt{16+9} = 5$

$\therefore \quad i_0 = \frac{V_0}{Z} = \frac{12}{5} = 2.4$ Amp.

$\cos\phi = \frac{R}{Z} = \frac{3}{5}$

$\therefore \quad \bar{P} = \frac{1}{2} \times 12 \times 2.4 \times \frac{3}{5}$ ~~= 43.2 watts~~

$\boxed{\bar{P} = 8.64 \text{ Watts}}$

$\frac{1}{\omega C} = \frac{1}{50 \times 2500 \times 10^{-6}}$

$= \frac{10^6}{125 \times 10^3}$

$= \frac{1000}{125}$

$= 8$

$12 \times \frac{12}{2} \times \frac{3}{5}$

$\frac{144 \times 3}{10}$

$\frac{432}{10}$ $\frac{1}{2} \times \frac{12^2}{5} \times \frac{3}{5}$

$\frac{144 \times 3}{10 \times 5}$

$\frac{432 \times 2}{100}$

$\frac{16}{25}$

Note:- Question might have assumed $V_{rms} = 12V$ $\therefore$ $i_{rms} = \frac{V_{rms}}{Z} = 2.4$ Amp

$\therefore$ Avg. Power = $\bar{P} = V_{rms} i_{rms} \cos\phi$

$= 12 \times 2.4 \times \frac{3}{5}$

$\Rightarrow \boxed{\bar{P} = 17.28 \text{ Watts}}$

Q3. → (SHIFT TO AC Circuits) → Q5 AC Ckts Ex3

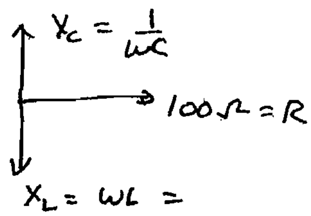
$R = 100\,\Omega$

$V_{rms} = 200$ Volts $\Rightarrow$ $V_0 = 200\sqrt{2}$ Volts.

$\omega = 300$ rad/s

$C = ?$

$L = ?$



when $C = 0$, $\phi = -60°$

$$\Rightarrow \tan 60° = \frac{|X_L|}{R} \Rightarrow \frac{\omega L}{R} = \sqrt{3} \Rightarrow L = \frac{\sqrt{3} \times 100}{300} = 0.57\text{ H}$$

$$\Rightarrow \boxed{L = 0.57\text{ H}}$$

when $L = 0$, $\phi = +60°$

$$\Rightarrow \tan 60° = \frac{X_C}{R} \Rightarrow \frac{(1/\omega C)}{R} = \sqrt{3}$$

$\frac{\sqrt{3}}{9}$ $\frac{1.73}{9}$

$$\Rightarrow C = \frac{1}{\sqrt{3} R\omega} = \frac{1}{\sqrt{3} \times 3 \times 10^4}$$

$$\Rightarrow C = 0.19 \times 10^{-4}$$

$$\Rightarrow \boxed{C \simeq 19\ \mu F}$$

Since $X_C = X_L \Rightarrow$ Resonant Ckt (for the LCR circuit)

$Z = R = 100\,\Omega$

$\phi = 0 \Rightarrow \cos\phi = 1$, $i_{rms} = \frac{200}{100} = 2$ Amp

$$\therefore \bar{P} = V_{rms} i_{rms} = \frac{V_{rms}^2}{Z} = \frac{40000}{100}$$

$$\Rightarrow \boxed{\bar{P} = 400\text{ Watt}}$$

PTO

Q ~~36~~. → move to AC → **Q6 AC Ckts Ex3**

$R = 120\,\Omega$

$2\pi f_0 = 4\times10^5$ rad/sec $\Rightarrow \dfrac{1}{\sqrt{LC}} = 4\times10^5$

$V_R = iR = 60$

$V_L = i\times\omega L = 40$

$\Rightarrow \omega L = \frac{2}{3}\times R = 80$

$\Rightarrow L = \dfrac{80}{4\times10^5} = 2\times10^{-4} \Rightarrow \boxed{L = 2\times10^{-4}\,H}$

$\therefore C = \dfrac{1}{(4\times10^5)^2}\times\dfrac{1}{(2\times10^{-4})} = \cancel{\dfrac{10^{-6}}{32} = 0.125\,\mu F} \quad \cancel{\Rightarrow \boxed{C = 0.125\,\mu F}}$

$\Rightarrow C = \dfrac{10^{-10}\times10^4}{32}$

$\Rightarrow \boxed{C = \frac{1}{32}}\,\mu F$

$RC = 120\times\frac{1}{\cancel{8}\,32}\times10^{-6}$ (30, 3.75)

$LC = \frac{1}{32}\times10^{-6}\times2\times10^{-4}$ (16)

$= \frac{1}{16}\times10^{-10}$

for $\theta = -45°$

$\left(\omega L - \frac{1}{\omega C}\right) = R$

$\Rightarrow \omega^2 LC - \omega RC - 1 = 0$

$\Rightarrow \omega = \dfrac{RC \pm \sqrt{(RC)^2 + 4\times LC}}{2LC} = \cancel{120\times10^{-6}}$

$\Rightarrow \omega = \dfrac{\left(\frac{30}{8}\times10^{-6}\right) \pm \sqrt{\frac{900}{64}\times10^{-12} + \frac{1}{4}\times10^{-10}}}{2\times\frac{1}{16}\times10^{-10}}$

$\Rightarrow \omega = \dfrac{\frac{3}{8}\times10^{-5} \pm \sqrt{\left(\frac{9}{64}+\frac{1}{4}\right)\times10^{-10}}}{\frac{1}{8}\times10^{-10}}$

$\Rightarrow \omega = \left(\frac{3}{8} \pm \sqrt{\frac{25}{64}}\right)\dfrac{\times10^{-5}}{\frac{1}{8}\times10^{-10}} = (3\pm5)\times10^{+5}$

Only One Option Correct

1. (B)

(b) A conducting ring is placed coaxially within a coil and the coil has inductance as well as resistance. The magnetic field at the centre of the coil

$B(t) = \mu_0 n I_1$.

As the current increases, B will also increase with time till it reaches a maximum value (when the current becomes steady).

Induced emf in the ring

$$e = -\frac{d\phi}{dt} = -\frac{d}{dt}(\vec{B}.\vec{A}) = -A\frac{d}{dt}(\mu_0 n I_1)$$

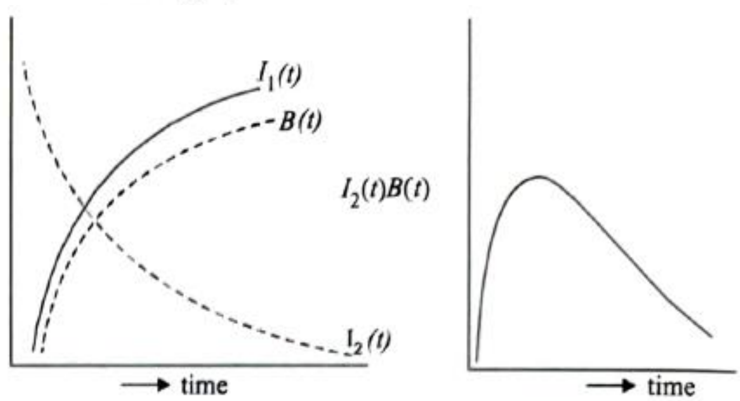
$\therefore$ Induced current in the ring

$$I_2(t) = \frac{|e|}{R} = \frac{\mu_0 n A}{R}\frac{dI_1}{dt}$$

[$\frac{dI_1}{dt}$ decreases with time and hence I_2 also decreases with time.]

Where $I_1 = I_{max}(1 - e^{-t/\tau})$

The relevant graphs are as follows.



Hence as a function of time (t>0) the product $I_2(t)$ B(t) decreases with time.

2. (B)

(b) $\oint \vec{E}.\vec{d\ell} = \frac{d\phi}{dt} = \frac{d}{dt}(\vec{B}.\vec{A}) = \frac{d}{dt}(BA\cos 0°) = A\frac{dB}{dt}$

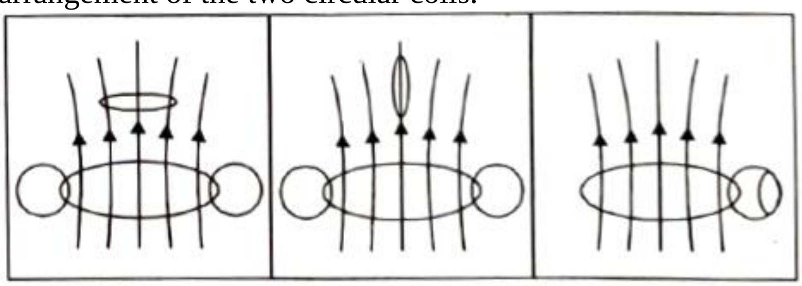
$\Rightarrow \quad E(2\pi r) = \pi a^2 \frac{dB}{dt} \, for \, r \geq a$

$\Rightarrow \quad E = \frac{a^2}{2r}\frac{dB}{dt} \Rightarrow E \propto \frac{1}{r}$

Hence magnitude of the induced electric field at a distance r from centre of circular region decreases as $\frac{1}{r}$.

3. (A)

When current flows in any of the coils, the flux linked with the other coil is maximum when surface area to receive flux is maximum. Clearly the flux linkage is maximum in case (a) due to the spatial arrangement of the two circular coils.



4. (D)

Electric field will be induced, as ABCD moves, in both AD and BC. The metallic square loop moves in its own plane with velocity v in in a uniform magnetic field perpendicular to the plane of the square loop. AD and BC are perpendicular to the velocity as well as perpendicular to field applied.

5. (B)

(b) Power, $P = \frac{E^2}{R} = \frac{\pi r^2}{\rho \ell}\left(\frac{d\phi}{dt}\right)^2 = \frac{\pi r^2}{\rho \ell}\left[\frac{d}{dt}(NBA)^2\right]$

[Here, E = induced emf and $R = \rho\frac{l}{A}$]

or, $P = \frac{\pi r^2}{\rho \ell} N^2 A^2 \left(\frac{dB}{dt}\right)^2 \quad \Rightarrow \quad P \propto \frac{N^2 r^2}{\ell}$

When number of turns quadrupled and the wire radi haved Power $\rho' \propto \frac{(4N)^2 (r/2)^2}{4\ell}$

$\therefore \; \frac{P}{\rho'} = \frac{1}{1} \; \therefore$ Power remains the same.

6. (D)

(d) When switch S is closed, a magnetic field is set-up in the space around P. The field lines threading Q increases in the direction from right to left. According to Lenz's law, I_{Q_1} will flow so as to oppose the cause or chnage and flow in anticlockwise direction as seen by E. Opposite is the case when S is opened. I_{Q_2} will be clockwise.

7. (C)

(c) Polarity of emf will be opposite when the magnet enters and leaves the coil.
Only graph (c) shows these characteristic.

8. (A)

(a) As cylinder is kept parallel to an uniform magnetic field, so no change in magnetic flux and hence induced current will be zero.

9. (B)

Due to motion of magnet above the disc, the plate moves through the magnetic flux, due to which an EMF is generated in the plate and eddy currents are induced. These currents are such that it opposes the relative motion so disc will rotate in the same direction as the direction of magnet's motion. This apparatus is called Arago's disk and the effect was discovered in 1824 by Arago.

10. (B)

(b) In the given question,
Current flowing through the wire, $I = 1\,A$
Speed of the frame, $v = 10\ ms^{-1}$
Side of square loop, $l = 10$ cm
Distance of square frame from current carrying wires $x = 10$ cm.
We have to find, e.m.f induced $e = ?$
According to Biot-Savart's law

$$B = \frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{x^2} = \frac{4\pi\times10^{-7}}{4\pi}\times\frac{1\times10^{-1}}{\left(10^{-1}\right)^2} = 10^{-6}$$

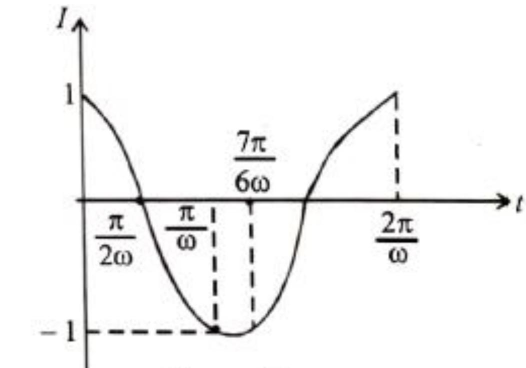
Induced e.m.f. $e = Blv = 10^{-6} \times 10^{-1} \times 10 = 1\ \mu v$

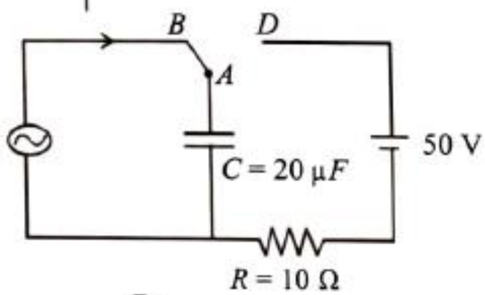
One or More than One Option Correct

1. (C, D)

(c, d) For maximum charge on the capacitor, $\frac{dQ}{dt} = I = 0$

$I = I_0 \cos\omega t = \cos 500\ t$





Till $t = \frac{7\pi}{6\omega}$, the charge will be maximum at $\frac{\pi}{2\omega}$

$$Q' = \int_0^{\pi/2\omega} \cos 500t\ dt = \left[\frac{\sin 500t}{500}\right]_0^{\pi/2\omega}$$

$$= \frac{1}{500}\sin\left(500 \times \frac{\pi}{2 \times 500}\right) = \frac{1}{500}C$$

i.e., $Q_{max} = \frac{1}{500}c = 2 \times 10^{-3}C$

From the graph it is clear that just before $t=\frac{7\pi}{6\omega}$, the current is in anticlockwise direction.
Immediately after A is connected to D.

At $t=\frac{7\pi}{6\omega}$, the charge on the upper plate of capacitor

$$\int_0^{\frac{7\pi}{6\omega}} \cos 500t\, dt = \frac{1}{500}\sin\left(500\times\frac{7\pi}{6\times 500}\right)$$

$$= -\frac{1}{500}\times\frac{1}{2} = -10^{-3}\,C$$

Now applying KVL

$$50+\frac{10^{-3}}{20\times 10^{-6}} - i\times 10 = 0 \;\Rightarrow i = 10\text{ A}$$

The maximum charge on C, $Q = CV = 20\times 10^{-6}\times 50 = 10^{-3}$C
Therefore, the total charge flown from the battery $= 2\times 10^{-3}$ C

2. (A, B)

(a, b) $i=\frac{e}{R}=\frac{BLv}{R}$ – (i) [Counter–clockwise direction while entering, Zero when completely inside and clockwise while exiting]

$F = iLB = \frac{B^2L^2v}{R}$ – (ii) [Toward left while entering and exiting and zero when completely inside]

$$\therefore\quad -mV\frac{dv}{dx}=\frac{B^2L^2v}{R}$$

$$\therefore\quad \int_{v_0}^{v} dV = -\frac{B^2L^2}{mR}\int_0^x dx \Rightarrow V - V_0 = -\frac{B^2L^2}{mR}x$$

$$\therefore \quad V = V_0 - \frac{B^2L^2x}{mR} \quad \text{... (iii)}$$

[V decreases from x = 0 to x = L, remains constant for x = L to x= 3L again decreases from x=3L to x=4L hence graph (a) is correct]

From (i) and (iii)

$$i = \frac{BL}{R}\left[V_0 - \frac{B^2L^2x}{mR}\right]$$

[i decreases from x=0 to x=L i becomes zero from x = L to x = 3Li changes direction and decreases from x = 3L to x = 4L]
Hence graph (b) is correct.

3. (A, D)

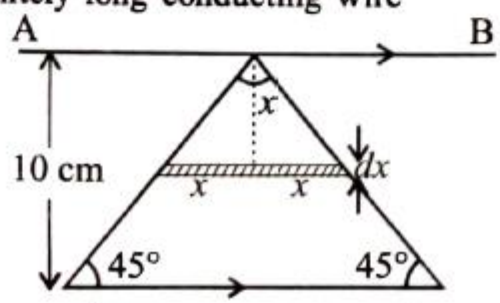
(a, d)

The flux passing through the triangular wire if i current flows through the inifinitely long conducting wire

$$d\phi = \int_0^{0.1} \frac{\mu_0 i}{2\pi x} \times 2\pi dx$$

$$\phi = \frac{\mu_0 i}{10\pi} = Mi$$

$$\therefore M = \frac{\mu_0}{10\pi}$$



$$\left(\frac{dI}{dt} = 10AS^{-1} \text{ given}\right)$$

Induced emf in the wire, $e = M\frac{di}{dt} = \frac{\mu_0}{10\pi} \times 10 = \frac{\mu_0}{\pi} V$

There will be no extra induced emf in the wire because there is no change in the magnetic.
Flux due to rotation of loop.
As the current in the triangular wire is decreasing the induced current in AB is in the same direction as the current in the hypotenuse of the triangular wire. Therefore force will be repulsive.

4. (A, B, C)

(a, b, c) At t = 0 inductors L_1 and L_2 will offer infinite resistance hence current through circuit is zero.
After a long time the current through the resistor is constant I will divide into two parts L_1 and L_2 which are in parallel
$\therefore I_1L_1 = I_2L_2 \qquad [I = I_1 + I_2]$

$$I_1 = \frac{V}{R}\left[\frac{L_2}{L_1 + L}\right]$$

and $$I_2 = \frac{V}{R}\left[\frac{L_1}{L_1 + L_2}\right]$$

Also the ratio of currents through L_1 and L_2 is fixed at all times At t = 0, $I \approx 0$

5. (B, D)

(b, d) The net magnetic flux through the loops at time t
$\phi = B.2A\cos\omega t - BA\cos\omega t = B\ (2A - A)\cos\omega t = BA\cos\omega t$

$$\therefore \left|\frac{d\phi}{dt}\right| = B\omega A\sin\omega t$$

So, $\left|\frac{d\phi}{dt}\right|$ is maximum when $\phi = \omega t = \pi/2$

The emf induced in the smaller loop,

$$\varepsilon_{\text{smaller}} = -\frac{d}{dt}\left(BA\cos\omega t\right) = B\omega A\sin\omega t$$

$\therefore$ Amplitude of maximum net emf induced in both the loops = Amplitude of maxium emf induced in the smaller loop alone.

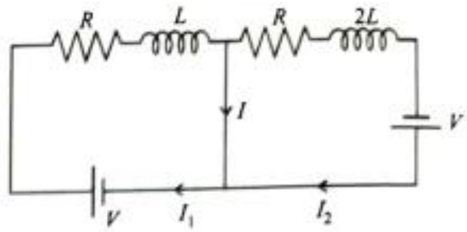
6. (BD)

(b,d) Here $I + I_2 = I_1 \qquad \therefore\ I = I_1 - I_2$

$$\therefore\ I = \frac{V}{R}\left[1 - e^{\frac{-Rt}{2L}}\right] - \frac{V}{R}\left[1 - e^{\frac{-Rt}{L}}\right]$$

$$\Rightarrow I = \frac{V}{R}\left[e^{\frac{-Rt}{L}} - e^{\frac{-Rt}{2L}}\right] \qquad \text{...(i)}$$

For I_{max}, $\frac{dI}{dt} = 0$



$$\therefore \quad \frac{V}{R}\left[\frac{-R}{L}e^{\frac{-Rt}{L}} - \left(\frac{-R}{2L}\right)e^{\frac{-Rt}{2L}}\right] = 0$$

$$\therefore \quad e^{\frac{-Rt}{2L}} = \frac{1}{2} \Rightarrow \left(\frac{R}{2L}\right)t = \ln 2 \qquad \therefore \quad t = \frac{2L}{R}\ln 2$$

This is the time when I is maximum
Putting this value of time in eq.(i)

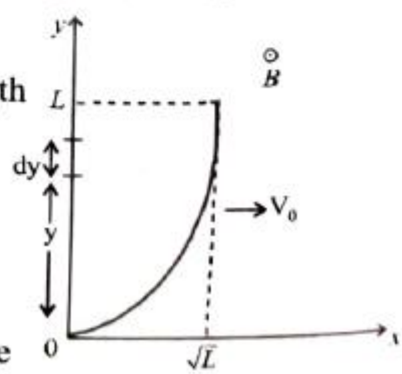
$$\text{Further } I_{max} = \frac{V}{R}\left[e^{\frac{-R}{L}\left(\frac{2L}{R}\ell n 2\right)} - e^{\frac{-R}{2L}\left(\frac{2L}{R}\ell n 2\right)}\right]$$

$$\Rightarrow I_{max} = \frac{V}{R}\left[\frac{1}{4} - \frac{1}{2}\right] = \frac{V}{4R}$$

7. (A, B, D)

(a, b, d) Given: $B = B_0\left[1 + \left(\frac{y}{L}\right)^f\right]\hat{K}\ \vec{V} = V_0\hat{i}$

We now consider a infinite small length of wire dy at a distance y from the origin.



Emf induced across the length dy $|\Delta\phi| = B(dy)V_0$

$$|\Delta\phi| = B_0\left[1 + \left(\frac{y}{L}\right)^B\right]V_0 dy$$

$\therefore$ Induced emf across the

complete projection

$$|\Delta\phi| = B_0V_0\int_0^L\left[1+\left(\frac{y}{L}\right)^{\beta}\right]V_0dy \;= B_0V_0L\left[1+\frac{1}{\beta+1}\right]$$

For $\beta = 0, |\Delta\phi| = 2B_0V_0L$. Clearly, $|\Delta\phi| \propto L$

For $\beta = 2$ $|\Delta\phi| = \frac{4}{3}B_0V_0L$

For a straight wire of length $\sqrt{2}L$ placed along y = x then the value of $|\Delta\phi|$ will remain the same as its projection of y-axis is same L as that of previous.

8. (A, C)

EMF developed across the semi-circular rod,

$$\varepsilon = \int_1^4 \frac{\mu_0 i}{2\pi r}drv = \frac{\mu_0 iv}{2\pi}\ln\frac{b}{a} = \frac{\mu_0 iv}{2\pi}\ln\frac{4}{1} = \frac{\mu_0 iv}{\pi}\ln 2$$

$$\therefore \quad \frac{4\pi\times10^{-7}\times2\times3\times0.7}{\pi} = 24\times7\times10^{-8}$$

$= 1.6 \times 10^{-6}$ V

Therefore maximum current through R,

$$i_{max} = \frac{\varepsilon}{R} = \frac{1.68\times10^{-6}}{1.4} = 1.2\times10^{-6}\text{ A}$$

And maximum charge on capacitor C_0

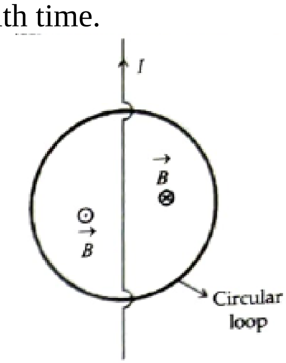
$Q_{max} = C_0E = 5 \times 10^{-6} \times 1.68 \times 10^{-6} = 8.4 \times 10^{-12}$ C

9. (A, C)

If the current is constant, the emf induced in the loop zero.

Emf will be induced in the circular wire loop when flux through it changes with time.

$$e = -\frac{\Delta\phi}{\Delta t}$$



when the current is constant, the flux changing through it will be zero. Also, if the current decreases at steady rate, the emf induced in the loop is zero. When the current is decreasing at a steady rate then the change in the flux (decreasing inwards) on the right half of the wire is equal to the change in flux (decreasing outwards) on the left half of the wire such that $\Delta\phi$ through the circular loop is zero.

Comprehensions Type

1. (B)

$$\int \vec{E}.\vec{dl} = \frac{-d\phi}{dt} = -\frac{d}{dt}(B\pi R^2) = -\pi R^2 \frac{dB}{dt}$$

$$= -\pi R^2 B$$

$\therefore E \times 2\pi R = -\pi R^2 B$

$\therefore E = \frac{-BR}{2}$

2. (B)

(b) Given $M = \gamma L$

$\therefore \quad M = \gamma m\omega R^2$

$\therefore \quad M = \gamma m (\Delta\omega) R^2$ ...(1)

But $\Delta\omega = \frac{Q \times B}{2m}$ ...(2)

From eq. (i) and (ii)

$$\Delta M = -\gamma m \left(\frac{QB}{2m}\right) R^2 = \frac{-\gamma BQR^2}{2}$$

Here –(ve) sign shows that change is opposite to the direction of magnetic field, B.

(b) is the correct option.

Integer / Numerical Answer Type

1. (4)

(4) Time constant, $T = RC$

Impedance $Z = \sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}$

Given $Z = R\sqrt{1.25}$ $\therefore$ $R\sqrt{1.25} = \sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}$

$\therefore RC = \frac{2}{\omega} = \frac{2}{500} \times 1000$ ms $\quad \therefore RC = 4$ ms

2. (8)

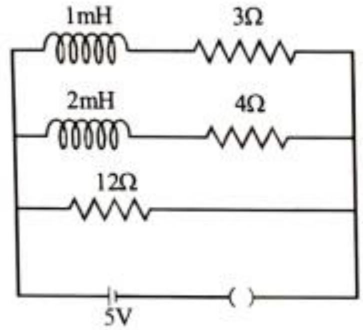
(8) At t = 0 $I_{min} = \frac{5}{12}$

At t = ∞

$$I_{max} = \frac{5}{R_{eq}} = \frac{5}{3/2} = \frac{10}{3}$$

$$\left[\frac{1}{R_{eq}} = \frac{1}{3} + \frac{1}{4} + \frac{1}{12} = \frac{8}{12}\right]$$

$$\therefore \frac{I_{max}}{I_{min}} = \frac{10}{3} \times \frac{12}{5} = 8$$



3. (55.00)

(55.00) Given: Mutual inductance, M = 5mH

$L_1 = 10$ mH, $V_1 = 5$V, $L_2 = 20$ mH & $V_2 = 20$V

$$I_1 = \frac{V_1}{R_1} = \frac{5}{5} = 1A; I_2 = \frac{V_2}{R_2} = \frac{20}{10} = 2A$$

After both the switches are closed simultaneously, the total work done by the batteries against the induced EMF = increase in magnetic energy

$$\therefore W = \Delta U = \frac{1}{2}L_1I_1^2 + \frac{1}{2}L_2I_2^2 + MI_1I_2$$

$$= \frac{1}{2} \times (10 \times 10^{-3})1^2 + \frac{1}{2} \times (20 \times 10^{-3}) \times 2^2$$

$$+ (5 \times 10^{-3}) \times 1 \times 2$$

$$= (5 + 40 + 10) \times 10^{-3}J$$

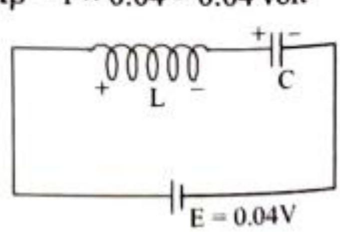
$$\therefore W = 55 \text{ mJ}$$

4. (4)

(4) Induced Emf, $E = \left|\frac{d\phi}{dt}\right| = \frac{d}{dt}(BA) = \frac{Ad}{dt}\left[(B_0 + \beta t)\right]$

$= A\beta = 1 \times 0.04 = 0.04$ volt

So, circuit can be drawn as



By KVL, $E = L\frac{di}{dt} + \frac{q}{c}$

$$\Rightarrow L\frac{di}{dt} = E - \frac{q}{c}$$

$$\Rightarrow \frac{d^2q}{dt^2} = -\frac{1}{LC}(q - CE)$$

Comparing it with equation of SHM, we get

$q = CE + A\sin(\omega t + \phi)$, where $\omega = \frac{1}{\sqrt{LC}}$

So, $i = A\,\omega\cos(\omega t + \phi)$

at $t = 0$, $q = 0$ and $i = 0$

So, $O = CE + A\sin\phi \Rightarrow A\sin\phi = -CE$ ....(i)

$O = \cos\phi \Rightarrow \phi = \frac{\pi}{2}$ ....(ii)

from (i) and (ii), we get

$A = -CE$

So, $i = -CE\,\omega\cos(\omega t + \pi/2)$

$= CE\,\omega\sin\omega t$

Therefore, $i_{max} = CE\,\omega = 10^{-3} \times 0.04 \times \frac{1}{\sqrt{0.1 \times 10^{-3}}} = 4\text{mA}$