EMI and AC

SOLUTIONS

EXERCISE - O

1. Ans. (C)
$\phi = B.A = BA\cos\theta$ $(\theta = 90°)$

2. Ans. (A)
According to size law, current in both will decrease.

3. Ans. (D)
Flux will be zero as $\vec{B}$ will be perpendicular to area vector.

4. Ans. (C)
Lenz law.

5. Ans. (C)
Lenz's Law

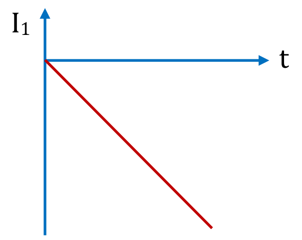
6. Ans. (B)
Len'z Law.

7. Ans. (C)
$E = -\frac{d\phi}{dt} = \frac{dBA}{dt} = \frac{Bd}{dt}\pi(R_0 + t)^2$
$E = 2\pi B\,(R_0 + t)$ Anticlockwise.

8. Ans. (B)
$\phi = B.A$
$E = \frac{d\phi}{dt} = A \times \frac{dB}{dt} = \pi R^2 \frac{dB}{dt} = \frac{\pi \times (0.1)^2}{2} \times 0.1 = 1.57 \times 10^{-3} V$
$i = \frac{\varepsilon}{R} = 3.92 \times 10^{-5} A.$

9. Ans. (B)
(A) Inc dot will induced cross (upper half)
Inc dot will induced cross (lower half)
(B) Inc dot $\rightarrow$ cross (upper half)
Dec dot $\rightarrow$ dot (lower half)
(C) Dec dot $\rightarrow$ dot (upper half)
Inc cross $\rightarrow$ dot (lower half)
Hence $I_A = I_C > I_B$

10. Ans. (D)
Concept - Mutual induction
$\phi_{21} = M_{21} I_1$
$E_{21} = -\frac{d\phi_{21}}{dt} = -M_{21}\frac{dI_1}{dt}$
$I_2 = \left(\frac{e_{21}}{R2}\right) = -\frac{M_{21}}{R_2}\frac{dI_1}{dt}$



According to graph I_2 = constant
$\int dI_1 = \int -\left(\frac{I_2 R_2}{M_{21}}\right) dt$
$I_1 = -$ (constant) $\times\, t$

11. Ans. (A)

Induced EMF is such that it opposes the cause of flux change.

12. Ans. (C)

$\phi = BS = B\pi R^2 = B\pi(R_0 + t)^2$

$$e_{ind} = -\frac{d\phi}{dt} = -2\pi(R_0 + t)B$$

Since flux is increasing e_{in} is anticlockwise

13. Ans. (D)

$V_1 = Bv(4r)$

$V_2 = -B(2v)(2r)$

$V_1 - V_2 = \Delta V = 8Bvr$

14. Ans. (D)

No flux change.

15. Ans. (C)

$\varepsilon_{in} = (\vec{V} \times \vec{B}).\vec{\ell}$

$$\varepsilon = \frac{B\omega(PQ)^2}{2} = \frac{B\omega(L^2+l^2)}{2}$$

$$= \pm(-Bv_x j + Bv_y \hat{\imath}) \quad (\ell_1\hat{\imath} + \ell_2\hat{\jmath})$$

$\varepsilon_{in} = \pm B(\ell_1 V_y - \ell_2 V_a)$

$\varepsilon_{in} \propto \ (\ell_2 V_x - \ell_1 V_y)$

16. Ans. (A)

$$V_p - V_q = B\ell v$$
$$= 4 \times 1 \times 20$$
$$= 80\ V$$

$$q_A = +80 \times 10$$
$$= +800\ \mu C$$
$$q_B = -800\ \mu C$$

17. Ans. (B)

$E = B\ell v$

18. Ans. (A)

$$\Delta E = \frac{1}{2}B\omega\ell^2$$

$V_P > V_Q$

So current from $P \rightarrow Q$

19. Ans. (C)

$m\omega^2 x = eE$

$$\int E dx = \frac{m\omega^2\ell^2}{2e}$$

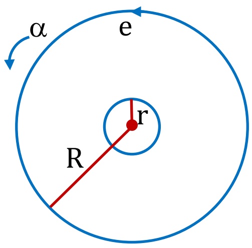
20. Ans. (B)

$B.$ (at centre) $\dfrac{\mu_0}{2R}\left(\dfrac{q\omega}{2\pi}\right)$

$$B = \frac{\mu_0}{4\pi}\ \frac{q\omega}{R}$$

$$\phi = B.\pi r^2;\ \varepsilon_{in} = \frac{d\phi}{dt} = \pi r^2\ \frac{dB}{dt} = \frac{\mu_0}{4\pi}\pi r^2 \frac{q}{R}\frac{d\omega}{dt}$$

$$= \frac{\mu_0 e r^2}{4R}\alpha$$



21. **Ans. (A)**

$\phi = \pi r^2 [\cos \omega t\hat{j} + \sin \omega t\,(-\hat{i})] \cdot [B_y\hat{j} + B_z\hat{k}]$,

$\phi_2 = B_y \pi r^2 \cos \omega t$, $E = \left|\frac{d\phi}{dt}\right| = B_y\, \omega \pi r^2 \sin \omega t$

22. **Ans. (A)**

$$B\left(\frac{B\omega L^2}{2R}\right)\frac{L\times L}{2} = MgL$$

$V = \omega L$

23. **Ans. (A)**

$B(x) = B_0\left(1+\frac{x}{a}\right)$

$\varepsilon_1 = (\varepsilon_{in})_{AB} = B\ell v_0$

$\quad = B_0\left(1+\frac{x}{a}\right) d.v_0$

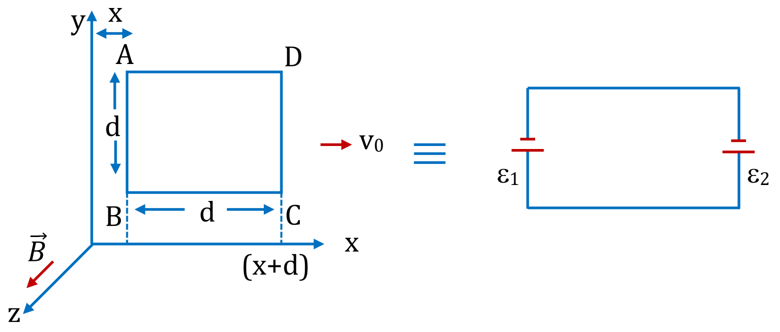
$\quad = B.dv_0\left(1+\frac{x}{a}\right)$

$B(x+d) = B_0\left(1+\frac{x+d}{a}\right)$

$\varepsilon_{net} = \varepsilon_2 - \varepsilon_1$

$\quad = B_0 d v_0\left(\alpha + \frac{\alpha}{d} + \frac{d}{a} - 1\frac{1}{a}\right)$

$\quad = \frac{B_0 d^2 v_0}{a}$



24. **Ans. (C)**

$$\varepsilon = \frac{B\omega (PQ)^2}{2} = \frac{B\omega\left(L^2+l^2\right)}{2}$$

25. **Ans. (C)**

For (A): $V_B - V_A = \frac{1}{2}B\omega\ell^2 \Rightarrow V_A - V_B = -\frac{1}{2}B\omega\ell^2$

For (B) : $V_B - V_A = Bv\ell = B\left(\frac{\omega\ell}{2}\right)\ell = \frac{1}{2}B\omega\ell^2 \Rightarrow V_A - V_B = -\frac{1}{2}B\omega\ell^2$

For (C) : $V_A - V_B = 0$

For (D) : $V_B - V_A = \frac{1}{2}B\omega\ell^2 - \frac{1}{2}B\omega\left(\frac{\ell}{2}\right)^2 = \frac{3}{8}B\omega\ell^2 \Rightarrow V_A - V_B = -\frac{3}{8}B\omega\ell^2$

26. **Ans. (C)**

$$\frac{d\phi}{dt} = \varepsilon = B_v ud$$

$$R_{eq} = R + \frac{\rho d}{ab}$$

$$\Rightarrow \quad I = \frac{\varepsilon}{R_{eq}} = \frac{B_v ud}{R + \frac{\rho d}{ab}}$$

27. Ans. (A)

$$E(2\pi R) = -\frac{d}{dt}[B(\pi r^2)]$$

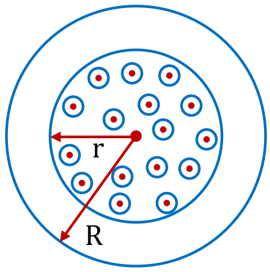
$$\Rightarrow \; E = -\frac{r^2}{2R}\frac{dB}{dt}$$

$$\Rightarrow \; Edt = -\frac{r^2}{2R}dB$$

$$\Rightarrow \; \int qEdt = -\frac{qr^2}{2R}\int_B^0 dB$$

$$\Rightarrow \; mv = \frac{qr^2B}{2R}$$

$$\Rightarrow \; v = \frac{qr^2B}{2mR}$$



28. Ans. (A)

For cylindrical region

$B \, \alpha \, \ell$ for $\ell < R$

$= B \times \lambda \frac{1}{\alpha}$ for $\ell > R$

29. Ans. (A)

$\pi R^2 B_0 = E \times 2\pi r$

$$E = \frac{\pi R^2}{2\pi r}B_0 = \frac{R^2 B_0}{2r}$$

$$a = \frac{qE}{m} = \frac{q}{m}\frac{R^2B_0}{2r} = \frac{qB_0R^2}{2mr}$$

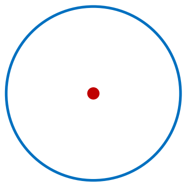
30. Ans. (A)

$B = Kt^2$

$$\int \vec{E}\cdot\vec{dl} = \frac{d\phi}{dt} = \frac{AdB}{dt}$$

$$\Rightarrow \; E\cdot 2\pi r = \pi r^2 \cdot 2Kt$$

$$\Rightarrow \; E = Krt$$



Ring starts moving when torque due to electric field becomes greater than torque due to limiting friction

$QEr = \mu Mgr$

$\Rightarrow \; Q.\,Krt\,.\,r = \mu Mg\,r$

$$\Rightarrow \; t = \frac{\mu Mg}{QKr}$$

31. Ans. (D)

Induced electric field in non conservative in nature. Therefore work done by this field is path dependent.

32. Ans. (A)

$$\oint \vec{E}\,.\,\vec{d\ell} = \frac{d}{dt}\vec{B}.\vec{A}$$

$$\Rightarrow \; E\,.2\pi r = \pi r^2\frac{d}{dt}Kt$$

$$\Rightarrow \; E = \frac{rK}{2}$$

$$\Rightarrow \; a = \frac{eE}{m} = \frac{erK}{2m}$$

Directed along tangent to the circle of radius r, whose centre lies on the axis of cylinder.

33. Ans. (A)

$$E = A\frac{dB}{dt}$$

$$10 = \frac{1}{100} \times \frac{20}{\Delta t}$$

$\Delta t = 20 \times 10^{-3}$ sec = 20 ms

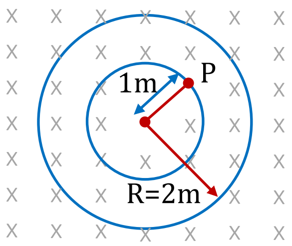
34. Ans. (C)

Magnetic field lines and induced electric field lines always from closed loop.

35. Ans. (A)

$\phi = B\pi r^2 = (16 - 4t^2)\pi r^2$

$$e_{ind} = -\frac{d\phi}{dt} = 8\pi r^2 t$$



$$e_{ind} = \int E \cdot d\ell$$

$$8\pi r^2 t = E 2\pi r$$

$$\Rightarrow \quad E = \frac{8rt}{2} = 4rt$$

At $t = 2$ sec

$E = 8$ Volt/m

36. Ans. (C)

$$y = \frac{1}{2} L i^2$$

$$\frac{di}{dt} = \frac{2}{2} Li \frac{di}{dt}$$

$= 2 \times 2 \times 4$

$= 16 J/s.$

37. Ans. (A)

$$e = -L\frac{di}{dt}$$

$$\frac{di}{dt} = \text{Slope}$$

$|\text{Slope}|_1 > |\text{Slope}|_2$

$e_1 > e_2$

38. Ans. (A)

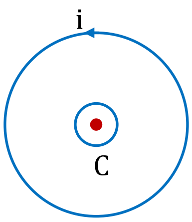
$B = v_0 n_i$

$= \left(v_0 \frac{N}{L} i\right)$

$$\phi_T = B.AN = Li \Rightarrow i = \frac{BAN}{L}$$

39. Ans. (B)

$$B_C = \frac{\mu_0 i}{2R}$$



$$\phi = \frac{\mu_0 i}{2R} \pi r^2$$

$$M = \frac{\mu_0 \pi r^2}{2R}$$

40. Ans. (D)

No flux linked, $M = 0$.

41. Ans. (B)

Mutual inductance, $M = \dfrac{\phi_N}{I_M} = \dfrac{\phi_M}{I_N}$

$$\Rightarrow \phi_M = \left(\frac{I_N}{I_M}\right)\phi_N = \frac{3}{2} \times 1.8 \times 10^{-3}$$

$$= 2.7 \times 10^{-3}\ Wb$$

42. Ans. (C)

For figure (A)

$L_{eq} = L + 2L + 2M$

$$= 3L + 2\frac{1}{\sqrt{2}}\sqrt{L.2L}$$

$= 5L = L$

For Figure (B)

$L_{eq} = L + 2L - 2M$

$$= 3L - 2\frac{1}{\sqrt{2}}\sqrt{L.2L}$$

$\Delta L = 4L$

43. Ans. (B)

$$\varepsilon = \frac{d\phi}{dt} = M\frac{di}{dt}$$

$$\Rightarrow \frac{4}{10} = 2\frac{\Delta i}{10}$$

$\Rightarrow \Delta i = 2A$

44. Ans. (A)

$\phi = at(T - t) = aTt - at^2$

$$e_{ind} = -\frac{d\phi}{dt}$$

$e_{ind} = -a(T - 2t)$

$$i_{ind} = \frac{e_{ind}}{R} = \frac{(2at - aT)}{R}$$

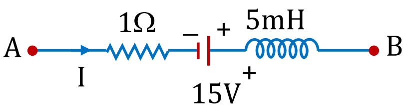
$$H = \int_0^T i^2 R dt = \int_0^T \frac{(2at - aT)^2}{R} dt$$

$$= \frac{\int_0^T (4a^2t^2 + a^2T^2 - 4a^2Tt)dt}{R} = \frac{1}{R}\left(\frac{4a^2T^3}{3} + a^2T^3 - \frac{4a^2T^3}{2}\right)$$

$$H = \frac{a^2T^3}{3R}$$

45. Ans. (B)

$$\frac{di}{dt} = -10^3 A/S$$



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

$$V_A - 5 \times 1 + 15 - 5 \times 10^{-3}(-10^3) = V_B$$

$$V_B - V_A = 15V$$

46. **Ans. (A)**

In L-R circuit,

$$V_L = V_0 e^{-Rt/s} \quad \text{...(i)}$$

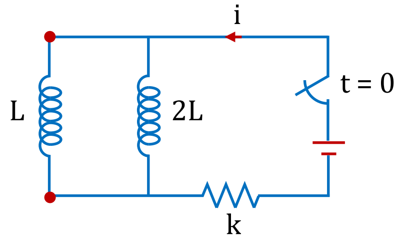
$$i = i_0\left(1 - e^{-Rt/s}\right)$$

47. **Ans. (B)**

Inductor opposes the introduction change of current due to which induced emf in generated in inductor.

48. **Ans. (A)**

At $t \to \infty$



$$i = i_0 = \left(\frac{V}{R}\right)$$

$R_{eq} = R$

$$L_{eq} = \frac{2L\times L}{3L} = \frac{2L}{3}$$

$$i(t) = i_0\left(i - e^{-\frac{Rt}{L_{eq}}}\right)$$

$$= \frac{V}{R}\left(1 - e^{-\frac{3Rt}{2L}}\right)$$

$$V_L(t) = V - iR$$

$$\Rightarrow \frac{Ldi}{dt} = V - v\left(1 - e^{-\frac{3Rt}{2L}}\right)$$

$$i\frac{Ldi}{dt} = Ve^{\frac{-3Rt}{2L}}$$

$$\int_o^i Ldi = \int_o^t ve^{\frac{-3Rt}{2L}}\,dt$$

$$Li = \frac{2LV}{-3R}\left|e^{\frac{-3Rt}{2L}}\right|_0^t$$

$$i = \frac{2V}{3R}\left[1 - e^{-3Rt/2L}\right]$$

49. **Ans. (A)**

At $t = 0$ inductor is open circuit

$$i = \frac{V}{30} = \frac{2}{30} = \frac{1}{15}A$$

$t \to \infty$ inductor is short circuited

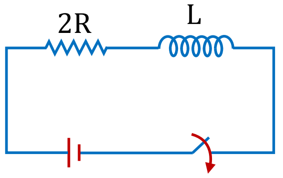
$$i = \frac{2}{20} = \frac{1}{10}A$$

50. **Ans. (A)**

$$\tau = \frac{L}{R} = \frac{2\times\frac{1}{2}Li^2}{i^2R} = \frac{L}{R}$$

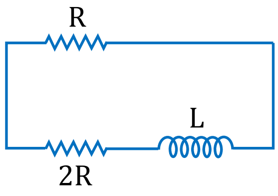
51. **Ans. (B)**

Build up circuit



$\tau_B = L/2R$

Decay



$\tau_D = L/3R$

Ratio = 3 : 2

52. **Ans. (A)**

When $x \to y$

$$i = \frac{E}{R_1}$$

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

53. **Ans. (B)**

Energy of inductor is = $\frac{1}{4}th$ (initial value)

$\Rightarrow$ Current $i = \frac{I}{2}$

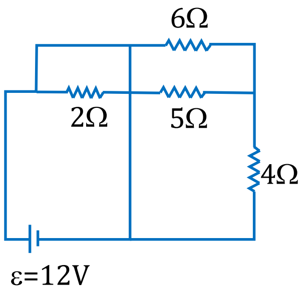
$$Q = \frac{\Delta\phi}{R} = \frac{L\left(I - \frac{I}{2}\right)}{R}$$

54. **Ans. (C)**

$$U = \frac{1}{2}Li^2, P = i^2R, \tau = \frac{L}{R}$$

55. **Ans. (A)**

Initially all capacitor behave like close circuit and all induction behave like open circuit



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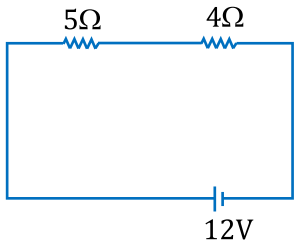


$$i = \frac{12}{9} = \frac{4}{3}$$

56. Ans. (A)

$$\frac{Q^2}{2C} = 640\ \mu J \qquad ...(1)$$

$$\frac{Q}{C} = 16\ V \qquad ...(2)$$

From (1) and (2)

$$\frac{Q}{2} = \frac{640\times10^{-6}}{16}$$

$\Rightarrow\ Q = 80 \times 10^{-6}\ C$

$\therefore\ C = \frac{Q}{16} = \frac{80}{16}\ \mu F = 5\ \mu F$

57. Ans. (A)

Let $q = q_0 \sin \omega t$

$$I = \frac{dq}{dt} = q_0 \omega \cos \omega t$$

$$\frac{dI}{dt} = \frac{d^2q}{dt^2} = -q_0\omega^2 \sin \omega t$$

$\frac{dI}{dt}$ maximum at $\sin \omega t = -1$

$$\left(\frac{dI}{dt}\right)_{\max} = q_0\omega^2$$

$$\omega = \frac{1}{\sqrt{LC}}$$

58. Ans. (B)

When the total energy stored in 300 μF goes into 1200 μF capacitor its voltage is maximum.

$$\frac{V_0}{\sqrt{3}}$$

$V = 50$

59. Ans. (D)

Total energy = Initial energy on capacitor = $\frac{1}{2}$ CV^2, Magnetic field energy = $\frac{1}{2}LI^2$

$\therefore\ \frac{1}{2}\ LI^2 = \frac{1}{3}\times\frac{1}{2}\ CV^2$

$\Rightarrow\ I = \sqrt{\frac{CV^2}{3L}} = \sqrt{\frac{6\times10^{-6}\times6\times6}{3\times2.0\times10^{-3}}}$ = 0.6 A

60. Ans. (D)

Net current through ammeter = zero.

61. Ans. (A)

$i_3 = i_1 + i_2$

$= 5\left(\frac{3}{5}\sin\omega t + \frac{4}{5}\cos\omega t\right)$

$= 5\ (\sin \omega t . \cos 53° + \cos \omega t . \sin 53°)$

$= 5\sin(\omega t + 53°)$

62. Ans. (D)

$$\langle V\rangle = \frac{\int_0^{T/2} V dt}{\int_0^{T/2} dt} = \frac{\text{Area under } V-t \text{ curve}}{\frac{T}{2}}$$

$= \frac{V_0}{2}$

$$V_{rms} = \sqrt{\frac{2\int_0^{T/4} V^2 dt}{\int_0^{T/2} dt}} = \sqrt{\frac{4\int_0^{T/4}\left(\frac{4V_0}{T} - t\right)^2 dt}{T}}$$

$= \frac{V_0}{\sqrt{3}}$

63. Ans. (D)

$e = 10\left[\sin\left(\omega t + \frac{\pi}{6}\right)\right]$

$i = 5\sin\left(\omega t + \frac{\pi}{4}\right)$

$\Delta\phi = \frac{\pi}{4} - \frac{\pi}{6} = \frac{3\pi - 2\pi}{12} = \frac{\pi}{12}$

64. Ans. (B)

$i_0 = \frac{V_0}{X_C} = 300\sqrt{2} \times 100 \times 10^{-6}$

$= 30\sqrt{2}\ mA$

$i_{rms} = \frac{i_0}{\sqrt{2}}$

$i_{rms} = 30\ mA$

65. Ans. (A)

$\omega L = 90 \times 10^{-3} \times 2\pi \times 1000 = 180\,\pi$

$$\frac{1}{\omega C} = \frac{1}{0.5 \times 10^{-6} \times 2\pi \times 1000} = \frac{1000}{\pi}$$

$\Rightarrow$ Circuit is inductive $V_L > V_R$

$\Rightarrow$ Voltage leads the current

$$\tan\phi = \frac{\omega L - \frac{1}{\omega C}}{R} = \frac{80\pi}{R}$$

$$R = \frac{80\pi}{\sqrt{3}}$$

At resonance,

$$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{90\times10^{-3}\times0.5\times10^{-6}}}$$

$$= \frac{1}{\sqrt{45\times10^{-9}}} = \frac{10^5}{15\times\sqrt{2}} = \frac{\sqrt{2}}{3} \times 10^4$$

66. Ans. (B)

$$V_1 = V_L + V_C = 120V$$

$$V_{net} = \frac{200\sqrt{2}}{\sqrt{2}} = 200V$$

$$V_L^2 + V_R^2 = V_{net}^2$$

$$\Rightarrow\ 120^2 + V_R^2 = 200^2$$

$$V_R^2 = 40000 - 14400$$

$$V_R = \sqrt{25600}$$

$$V_R = 160$$

$$i = \frac{V_R}{R} = \frac{160}{40} = 4A$$

67. Ans. (A)

$$V_{eq} = \sqrt{V_0^2 + \left(\frac{V_0}{2}\right)^2}$$

$$R_{eq} = \sqrt{(\omega L)^2 + R^2}$$

68. Ans. (D)

$$\cos\phi = \frac{R}{Z}$$

$$\text{Ratio} = \frac{Z_1}{Z_2} = \frac{\sqrt{(3R)^2 + R^2}}{\sqrt{(2R)^2 + R^2}} = \sqrt{2}$$

69. Ans. (A)

$$z = 100\left(=\frac{v}{I}\right) \cos\phi = \frac{R}{z} = \frac{100}{\sqrt{(100)^2+\left(\frac{1}{\omega C}\right)^2}}$$

$$z = R\ (\Rightarrow x_L = x_C) = \frac{1}{\sqrt{2}}$$

70. Ans. (D)

Current in circuit :

$$I = \frac{V}{X} = \frac{250}{(75-25)} = \frac{250}{50} = 5A$$

$\therefore\ V_L = I\,X_L = 5 \times 25 = 125V$

and $V_C = I\,X_C = 5 \times 75 = 375V$

voltage on capacitor is more than that of supply voltage because the phase difference between V_L and V_C is 180° (i.e. out of phase).

71. Ans. (A)

$Q = \frac{\omega_0}{2Y}$ highest $Q \Rightarrow$ lowest Ys

72. Ans. (C)

$$\tan\phi = \omega L - \frac{1}{\omega C}\left(\frac{X_L - X_C}{R}\right)$$

When $\frac{\omega}{\omega_0} = 1$ i.e. $\omega = \frac{1}{\sqrt{LC}} = \omega_0$

$\tan\phi = O$ as in plot

As R increases $\tan\phi$ decreases for a given ω.

(i) belong to smaller R. compared to (2) and (3) curves.

Hence, (a) – (1)

(b) – (2)

(c) – (3)

73. Ans. (D)

$$\frac{f_{\max}}{\Delta f_{\text{half of max power}}} = \text{Quality factor}$$

74. Ans. (B)

$$I_{rms} = \sqrt{\frac{\int_0^t i^2 dt}{\int_0^t dt}}$$

i^2 is maximum for III and equal for I and II and minimum for IV

So, $I_3 > I_1 = I_2 > I_4$

75. Ans. (C)

$\cos\phi = \frac{R}{z} = \frac{1}{\sqrt{2}} \quad \Rightarrow \left|\omega L - \frac{1}{\omega C}\right| = R$

$\left|100 \times .1 - \frac{1}{100C}\right| = 10$

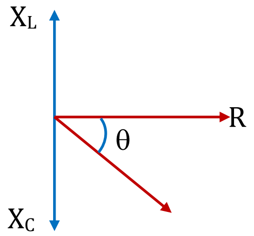
$\frac{1}{100C} = 20 \qquad C = 500\ \mu F$

76. Ans. (B)

$\tan\theta_1 = \frac{X_L}{R}$; $\tan\theta_2 = \frac{X_C}{R}$

$\tan\theta = \frac{X_C - X_L}{R}$

$\tan\theta = \frac{X_C}{R} - \frac{X_L}{R} = \tan\theta_2 - \tan\theta_1$



77. Ans. (C)

$<P> = i_{rms} V_{rms} \cos(\Delta\phi)$

$= \frac{2}{\sqrt{2}} . \frac{200\sqrt{2}}{\sqrt{2}} . \cos(45° - 15°)$

$= 100\sqrt{6}$ Watt

78. Ans. (B)

$\frac{i_p}{i_s} = \frac{N_s}{N_p} \quad \Rightarrow \quad i_p = \frac{1}{8} \times 25 = \frac{25}{8} A$

$P_{in} = i_p V_p \quad \Rightarrow \quad 10 \times 10^3 = \frac{25}{8} \times V$

$V = \frac{10^4 \times 8}{25}$

79. Ans. (A)

$A = \frac{F_0 / m}{\sqrt{\omega^2 - r^2}}$

80. Ans. (D)

$T' = \frac{2\pi}{\omega'}$

$\omega' = \sqrt{\omega_0^2 - y^2}$

$\omega' < \omega_0 \Rightarrow T' > T_0$ and constant

81. Ans. (D)

Amplitude of pendulum will vary as

$A = A_0 e^{-\delta t}$, δ = damping constant

$$E = \frac{1}{2}kA^2 = \frac{1}{2}kA_0 e^{-2\delta t}$$

$$E = E_0 e^{-2\delta t}$$

At $t = 0$, $E_0 = 45\,J$

At $t = 15\,s$, $E = 15\,J$

So $15 = 45e^{-2\delta\times 15} \Rightarrow \delta = \frac{1}{30}\ell n3$

82. Ans. (A)

Damping force, $F = -b\frac{dx}{dt}$

$$= -bx_0\left[\omega_0 e^{-\omega_0 t} - \omega_0(1+\omega_0 t)e^{-\omega_0 t}\right]$$

$$= bx_0\omega_0^2 t e^{-\omega_0 t}$$

F is maximum when

$$\frac{dF}{dt} = 0$$

$$\Rightarrow\ bx_0\omega_0^2\left[e^{-\omega_0 t} - \omega_0 t e^{-\omega_0 t}\right] = 0$$

$$t = \frac{1}{\omega_0} = \frac{1}{100}\sec = 0.01s$$

83. Ans. (B)

$$\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{25\times10^{-3}\times12\times10^{-6}}}$$

$$= 1.825\times10^3\ rad$$

$$\lambda = \frac{I^2}{2L} = \frac{60}{2\times25}\times10^3 = 1.2\times10^3$$

$$\omega' = \sqrt{\omega_0^2 - y^2} = \sqrt{\left(1.825\times10^3\right)^2 - \left(1.2\times10^3\right)^2} = 1.4\times10^3$$

84. Ans. (A)

Charge decays exponentially means oscillation is overdamped:

$$\gamma \ge \omega_0 \Rightarrow \frac{R}{2L} \ge \frac{1}{\sqrt{LC}}$$

$$R \ge 2\sqrt{\frac{L}{C}}$$

$$R \ge 100\sqrt{2}\Omega$$

85. Ans. (D)

$\omega_1 = \sqrt{\omega_0 - 2\gamma^2}$ Maximum amplitude

$\omega_2 = \omega_0$ for power maximum

$^* \omega_2 > \omega_1$

86. Ans. (C)

$$\omega = \sqrt{\frac{k}{m}}\sqrt{1 - \frac{r^2}{4mk}} \qquad \frac{r^2}{mk} = \frac{8}{100}$$

$$\omega = \sqrt{\frac{k}{m}}\sqrt{1 - \frac{8}{4mk}} = \sqrt{0.98\frac{k}{m}}$$

For undamped

$$T_1 = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{k}}$$

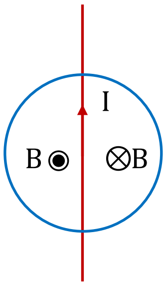
For damped

$$T_2 = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{0.98k}}$$

Change = $\frac{T_2 - T_1}{T_1} \times 100 = \frac{\sqrt{\frac{1}{0.98}} - 1}{1} \times 100 \approx 1\%$ increases

87. Ans. (AC)

Since flux of wire on the loop is zero therefore emf will not be induced.



88. Ans. (ABCD)

Let velocity of wire at time t is v, then

$\varepsilon = Bv\ell$

$q = C\varepsilon,\ i = \frac{dq}{dt} = CB\ell\frac{dv}{dt}$

$F_m = i\ell B$

$F - F_m = ma$

89. Ans. (AC)

At $t = 0$, Inductor behaves as open circuit.

So $A_1 = A_3 = \frac{50}{100+50} = \frac{1}{3}$ and $A_2 = 0$

$$V_1 = 100\left(\frac{1}{3}\right)$$

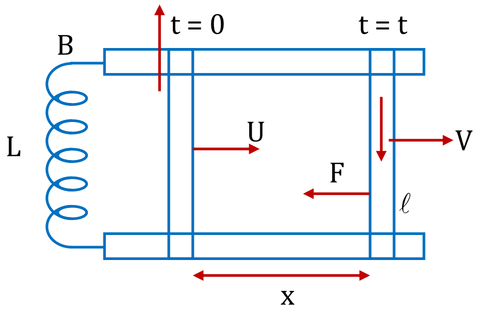
$$V_2 = V_4 = 50\left(\frac{1}{3}\right)$$

90. Ans. (AB)

At an instant at $t = t$ sec

Initially $J = mu$ (U = initial velocity)

$$U = \frac{J}{M}$$



Motional EMF = $BV\ell$ ...(i)

Induced EMF in inductor = $L\frac{di}{dt}$ ...(ii)

$$BV\ell = L\frac{di}{dt}$$

$$\int_0^i L.di = B\ell\int_0^t V.di$$

$$Li = B\ell x \quad \text{...(iii)}$$

Force on rod = $iB\ell$

By NLM

$$-iB\ell = ma$$

$$-\frac{B^2\ell^2 x}{L} = ma$$

$$a = -\frac{B^2\ell^2 x}{mL}(SHM)$$

$$\omega = \frac{B\ell}{\sqrt{mL}}$$

We know in SHM

$$U = \frac{J}{m} = \omega A \Rightarrow A = \frac{J}{mw}$$

$$v = \omega\sqrt{A^2 - x^2}$$

$$\frac{\omega A}{2} = \omega\sqrt{A^2 - x^2}$$

$$\frac{A^2}{4} = A^2 - x^2$$

$$x^2 = \frac{3A^2}{4}$$

$$x = \pm\frac{\sqrt{3}}{2}A$$

$$x = \pm\frac{\sqrt{3}}{2}\times\frac{J}{m\omega}$$

$$x=\pm\frac{\sqrt{3}}{2}\times\frac{J}{m}\times\frac{\sqrt{mL}}{b\ell}$$

$$x=\pm\sqrt{\frac{3J^2L}{4B^2\ell^2m}}$$

From equation (iii)

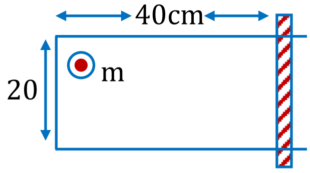
$$i=\frac{B\ell x}{L}$$

$$i=\sqrt{\frac{3}{4}\frac{J^2}{Lm}}$$

91. Ans. (ABC)

At $t = 0$

Resistance of $ckt = \left(\frac{40+40+20}{100}\right)m\times 1r/m$



$R = 1r$

$$\phi=\vec{B}.\vec{A}=(2t)\left(\frac{40\times20}{100\times100}\right)=\frac{16t}{100}$$

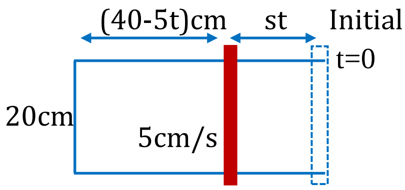
$$|\varepsilon|=\frac{\partial\phi}{\partial t}=\frac{16}{100}=0.16V,\quad \text{So, current } I=\frac{|\varepsilon|}{R}=0.16A$$

$\therefore$ $B = 2t$ (outer)

According to lenz low, induced emf will be opposite to it.

$\Rightarrow$ clockwise sense current.

(B) At $t = t$



$$\phi=\vec{B}.\vec{A}=(2t)\left(\frac{20\times(40-5t)}{100\times100}\right)$$

$$\phi=\frac{40t-5t^2}{250}$$

$$|\varepsilon|=\frac{\partial\phi}{\partial t}=\frac{40-10t}{250}$$

At $t = 2$, $|\varepsilon|=\frac{40-20}{250}=0.08v$

(C) At $t = 2$

$$R=\left(\frac{20+30+30}{100}\right)m\times1\Omega/m=0.8\Omega$$

$\varepsilon=0.08V$, $B = 2t = 4$, $\ell = 20\ cm = 0.2\ m$

$$i=\frac{\varepsilon}{R}=\frac{0.08}{0.8}=0.1A$$

For constant velocity

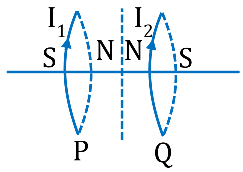
$F = iB\ell = (0.1)\ (4)\ (0.2)$

$F = 0.08\ N$

92. Ans. (BD)

(B) When Q is brought towards P, north and south poles, will be induced at P as shown in the figure which is as a result of current in P is opposite direction as current in Q.

(D) Not due to induction effect but because of magnetic force between them, if the currents are in opposite direction in the loops, the loops will repel each other.



93. Ans. (AD)

$u = v \cot\theta$

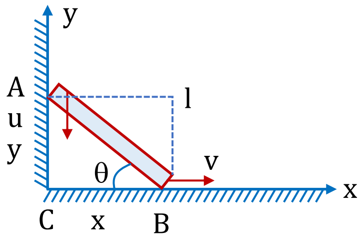
$\omega = \dfrac{v}{\ell \sin\theta} = \dfrac{2v}{\sqrt{3}\ell}$

Consider an imaginary conducting loop ABC.

e.m.f. in this loop = motional e.m.f. in the rod

$= -\dfrac{B}{2}\dfrac{d(xy)}{dt} = -\dfrac{B}{2}[yv - xu]\left[\because \dfrac{dy}{dt} = -u\right]$

$= \dfrac{B\ell v \cos 2\theta}{2 \sin\theta}$



94. Ans. (AB)

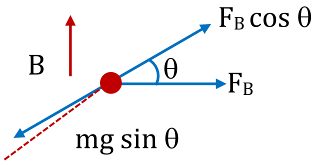
Current must flow from E to F

In equilibrium

$F_B \cos\theta = mg \sin\theta$

$i\ell B = mg \dfrac{\sin\theta}{\cos\theta}$

$i\ell B = mg \tan\theta$



95. Ans. (BC)

By using $e = \dfrac{1}{2}Bl^2\omega$

For part AO ; $e_{OA} = e_o - e_A = \dfrac{1}{2}Bl^2\omega$

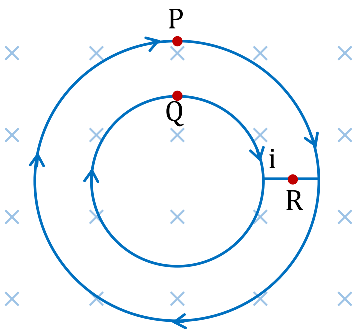
For part OC ; $e_{OC} = e_o - e_C = \dfrac{1}{2}B(3l)^2\omega = \dfrac{9}{2}B\omega\ell^2$

$\therefore \quad e_A - e_C = 4Bl^2\omega$

96. Ans. (ACD)

Since inside flux is decreasing.

$\Rightarrow$ To increase flux (lenz law) current in loops must be clockwise.



Current cannot flow in a single wire connecting two independent loop. Minimum two wires are required.

97. **Ans. (AB)**

Conceptual

98. **Ans. (ABD)**

$$emf = \varepsilon = \frac{d\phi}{dt} = \frac{d}{dt}(B.A) = \pi R^2 \frac{dB}{dt}$$

$$\varepsilon = \int E.dr = \pi R^2 \frac{dB}{dt} \left\{ \frac{dB}{dt} is - ve \right\}$$

For wooden ring $E_w(2R) = \pi R^2 \frac{dB}{dt}$

$$\Rightarrow E_w = \frac{1}{2}\left(\pi R \frac{dB}{dt}\right)$$

For copper ring $E_C = \frac{1}{3}\left(\pi R \frac{dB}{dt}\right)$

$E_w > E_C$

Resistance of wooden ring = ∞

Current induced in wooden ring = $\frac{\varepsilon}{R} = 0$

Electric field which is induced on wooden ring will be in tangential direction, so there will be torque acting on charge Q on the same ring i.e. the ring will rotate.

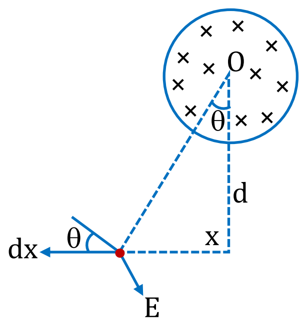
99. **Ans. (ABCD)**

$$\int \vec{E}.\vec{dl} = A.\frac{dB}{dt}$$

$$E.2\pi\sqrt{x^2+d^2} = \pi R^2 k, \text{ where } \left(\frac{dB}{dt} = k\right)$$

$$E = \frac{R^2 k}{2\sqrt{x^2+d^2}} ; W = \int_0^\infty q\vec{E}.\vec{dx}$$

$$= \int_0^\infty qE\cos\theta.dx = \int_0^\infty \frac{qR^2 k}{2\sqrt{x^2+d^2}} \frac{d}{\sqrt{d^2+x^2}} dx = \frac{qR^2 k\pi}{4}$$



100. **Ans. (ACD)**

From faraday's law $V \propto L$

Rate of change of current is constant $\left(v = -L\frac{\partial i}{\partial t}\right)$

$$\therefore \frac{V_2}{V_1} = \frac{L_2}{L_1} = \frac{2}{8} = \frac{1}{4}$$

Power delivers to the two coils is same i.e.,

$$v_1 i_1 = v_2 i_2 \Rightarrow \frac{i_1}{i_2} = \frac{v_2}{v_1} = \frac{1}{4}$$

Energy stores $W = \frac{1}{2}Li^2$

$$\frac{W_2}{W_1} = \left(\frac{L_2}{L_1}\right)\left(\frac{i_2}{i_1}\right)^2 = \left(\frac{1}{4}\right)(4)^2 = 4$$

101. Ans. (AC)

For given situation $\dfrac{q}{C}+L\dfrac{di}{dt}=0$

$\Rightarrow \dfrac{d^2q}{dt^2}+\dfrac{q}{LC}=0 \quad \Rightarrow \dfrac{d^2q}{dt^2}+\omega^2 q=0$

$\Rightarrow$ $q = q_0 \cos \omega t$ and $i = -q_0\omega \sin \omega t$

According to given conditions $\dfrac{q^2}{2C}=\dfrac{1}{2}Li^2$

$\Rightarrow \dfrac{q_0^2\cos^2\omega t}{2C}=\dfrac{1}{2}Lq_0^2\omega^2\sin^2\omega t$

$\Rightarrow$ $\cot^2\omega t = \sin^2\omega t$

$\Rightarrow$ $\omega t = \dfrac{\pi}{4},\dfrac{3\pi}{4},\dfrac{5\pi}{4},\dfrac{7\pi}{4}$ ....

$\Rightarrow t=\dfrac{\pi\sqrt{LC}}{4},\dfrac{3\pi\sqrt{LC}}{4},\dfrac{5\pi\sqrt{LC}}{4},\dfrac{7\pi\sqrt{LC}}{4}$ .....

102. Ans. (AD)

Conceptual

103. Ans. (BC)

$L = 100 \times 10^{-3}\ H$

$C = 10 \times 10^{-6}\ F$

$R = 100\ \Omega$

$V = 5 \sin 500\ t$

$\omega = 500$

$X_L = \omega L \qquad X_C = \dfrac{1}{\omega C}$

$=500\times100\times10^{-3} = 50\ \Omega \qquad X_C=\dfrac{1}{500\times10\times10^{-6}}=200\Omega$

When turns is doubled

$L\propto n^2$

$\Rightarrow X_L$ becomes 4 times

$C=\dfrac{Ak\varepsilon_0}{d}$

When $k = 4$

C becomes 4 times

$\Rightarrow$ X_C becomes $\dfrac{1}{4}^{th}$ *times*

104. Ans. (ACD)

$V_R^2+V_L^2=100^2$

$|V_C-V_L|=120$

$130^2=V_R^2+(V_C-V_L)^2$

$\because \quad V_C>V_L$ so circuit is capacitive.

105. Ans. (CD)

$e = e_1 + e_2 = 200\sin\left(\omega t + \frac{\pi}{2}\right)$

$e_0 = 200\, volt$

$V_5 = \frac{200}{\sqrt{2}} = 100\sqrt{2}$

$z = \sqrt{(500)^2 + (500)^2} = 500\sqrt{2}$

$i_{rms} = \frac{100\sqrt{2}}{500\sqrt{2}} = \frac{1}{5}$

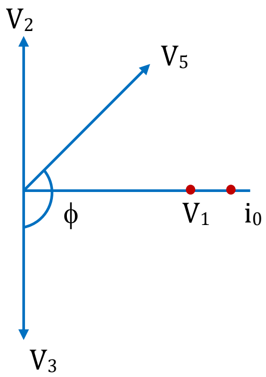
$V_1 = 500 \times \frac{1}{5} = 100\, volt$

$V_2 = 900 \times \frac{1}{5} = 180\, volt$

$V_3 = 400 \times \frac{1}{5} = 80\, volt$

$V_4 = V_2 - V_3 = 100\, volt$

$\Rightarrow \phi = \frac{\pi}{2} + \tan^{-1}\left(\frac{9}{5}\right)$



106. Ans. (ACD)

$X_L = X_C$

$2\pi f.L = \frac{1}{2\pi fC}$

$2\pi f.\frac{2}{\pi} = \frac{10^6}{2\pi f.\frac{8}{\pi}}$

$f^2 = \frac{10^6}{4 \times 16}$

$f = \frac{10^3}{8} = \frac{1000}{8} = 125\, Hz$

$V_L = I\, X_L = 2 \times 2\pi \times \frac{1000}{8} \times \frac{2}{\pi} = 1000\, V$

107. Ans. (BC)

Magnetic flux through the smaller loop due to current in the bigger loop

$= \left(\frac{\mu_0 I}{2\pi d} - \frac{\mu_0 I}{2\pi(2d)}\right)\ell^2 = \frac{\mu_0 I \ell^2}{4\pi d}$

So mutual inductance = $\frac{\mu_0 \ell^2}{4\pi d}$

$\therefore$ So emf induced in the bigger loop = $\frac{d}{dt}\left[\frac{\mu_0 \ell^2}{4\pi d} kt\right] = \frac{\mu_0 \ell^2 k}{4\pi d}$

108. Ans. (BD)

$\varepsilon = \pi R^2 \sin^2\theta\alpha$

So current $di = \dfrac{\varepsilon}{dr} = \dfrac{1}{2\rho} dR^2 \alpha \sin\theta d\theta$

So $\quad \int d\mu = \int_0^{\pi} \dfrac{\pi dR^4 \alpha \sin^3\theta d\theta}{2\rho} = \dfrac{2\pi}{3\rho} dR^4\alpha$

109. Ans. (ABD)

Loop equation gives

$$L\frac{di}{di} + iR = \frac{\mu_0 N a^2 \omega}{2\ell} i$$

So, $\quad \dfrac{di}{dt} = \dfrac{1}{L}\left(\dfrac{\mu_0 N a^2\omega}{2\ell} - R\right) i$

So to grow current always, $\dfrac{\mu_0 N a^2 \omega}{2\ell} - R > 0$

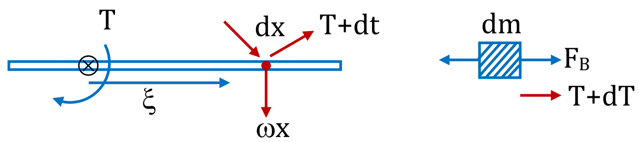
$\Rightarrow \quad \omega > \dfrac{2\ell R}{\mu_0 N a^2}$

110. Ans. (C)

$$T - F_B - (T + dT) = dm\omega^2 x \;\; - F_B - dT = dm\omega^2 x$$

$$\int_{\ell/2}^{x} \lambda dx.\omega x B - \int_O^T dT = \int_{\ell/2}^{x} \frac{m}{\ell}\omega^2 x \; dx$$

$$-\frac{\lambda\omega B}{2}\left(x^2 - \frac{\ell^2}{4}\right) - T = \frac{M\omega^2}{2\ell}\left(x^2 - \frac{\ell^2}{4}\right)$$



$$T = -\frac{\lambda\omega B}{2}\left(x^2 - \frac{\ell^2}{4}\right) - \frac{m\omega^2}{2\ell}\left(x^2 - \frac{\ell^2}{4}\right)$$

$$T = -\left(\frac{\lambda\omega B}{2} + \frac{m\omega^2}{2\ell}\right)a^2 + \frac{\lambda\ell^2\omega B}{8} + \frac{m\omega^2\ell}{8}$$

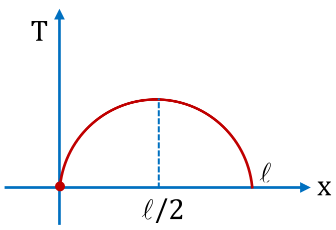
It is an equation of parabola concave in downward direction.

111. Ans. (B)

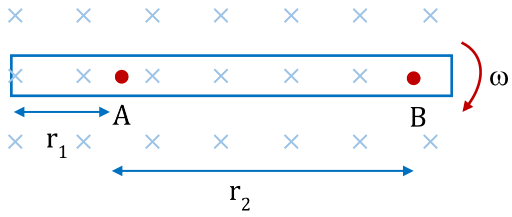
$T_{(x=0)} = \dfrac{\ell^3 \; \omega B}{8} + \dfrac{m\omega^2\ell}{8}$,

$T_{(\alpha=\ell/4)} = \dfrac{3}{32}(B\omega\ell^3 + m\omega^2\ell)$

$\dfrac{T_{(x=o)}}{T_{(x=\ell/4)}} = \dfrac{4}{3}$



112. Ans. (D)

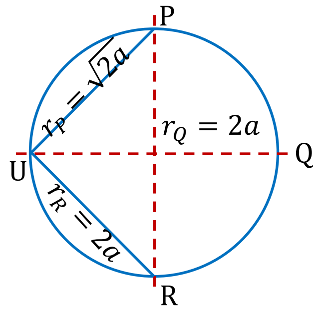


$V_B - V_A = \frac{1}{2}B\omega\left(r_2^{2-},r_1^2\right)$

(A) $V_P - V_0 = \frac{1}{2}\left(r_p^2 - r_u^2\right) > U_2$ ...(1)

$V_R - V_0 = \frac{1}{2}B\omega\left(r_R^2 - r_0^2\right)$

$V_R - V_0 = \frac{1}{2}B\omega\left(\left(\sqrt{2}a\right)^2 - O^2\right) > 0$ ...(2)



(B) from (1) and (2)

(C) From (1), $V_0 < V_P$, $V_Q \neq V_P$

(D) $V_Q - V_P = \frac{1}{2}B\omega\left(r_Q^2 - r_P^2\right) = \frac{1}{2}B\omega\left((2a)^2 - \left(\sqrt{2}a\right)^2\right)$

$v_Q - v_p = \frac{1}{2}B\omega\left(2a^2\right) = V_P - V_0$

113. Ans. (C)

(A) $V_P - V_0 = \frac{1}{2}B\omega(2a^2) = B\omega a^2$

(B) $V_P - V_Q = \frac{1}{2}B\omega\left(r_P^2 - r_Q^2\right) = -B\omega a^2$

(C) $V_Q - V_0 = \frac{1}{2}B\omega\left(r_Q^2 - r_0^2\right) = 2B\omega a^2$

(D) $V_P - V_R = \frac{1}{2}B\omega\left(r_P^2 - r_R^2\right) = 0$

114. Ans. (D)

$V_Q - V_P = V_Q - V_R = V_1$

$V_P - V_0 = V_R - V_0 = V_2$

No current flows in the circuit.

115. Ans. (A)

$$R_{eq} = \frac{R}{2}\Big\|\frac{R}{2} = \frac{R}{4} = \frac{6}{4} = 1.5\Omega$$

$$L_{eq} = \frac{L}{2}\Big\|\frac{L}{2} = \frac{L}{4} = \frac{1.8\times10^{-4}}{4} = 4.5\times10^{-5}H$$

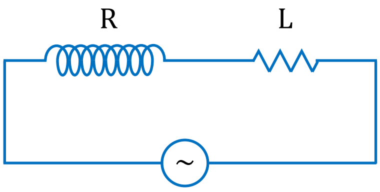
116. Ans. (C)

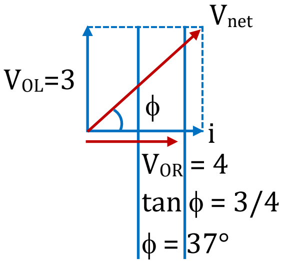
$$\tau = \frac{L/4}{R/4} = \frac{L}{R} = \frac{1.8\times10^{-4}}{6} = 3\times10^{-5}s = 30\mu s$$

117. Ans. (B)

Steady state current, $I = \frac{E}{R/4} = \frac{12}{1.5} = 8A$

118. Ans. (A)





$$V_R = V_{0_R} \sin\omega t$$

$$V_L = V_{0_R} \sin\left(\omega t + \frac{4}{2}\right) \quad \text{when } V_R = 2$$

$$\frac{V_R}{V_L} = \frac{V_{OR}}{V_{OL}}(\tan\omega t) \qquad \Rightarrow V_{OR}\sin\omega t = 2 \qquad \sin\omega t = \frac{2}{4} = \frac{1}{2} \text{ or } \omega t = 30^\circ$$

$$\frac{V_R}{V_L} = \frac{4}{3}\times\frac{1}{\sqrt{3}} \qquad \Rightarrow V_L\left(\frac{2\times3\times\sqrt{3}}{42}\right) = 3\cos\theta$$

119. Ans. (B)

$V_{net} = V_L + V_R$

$= 3 \cos 30° + 2$

$= \left(\dfrac{3\sqrt{3}+4}{2}\right)V$

120. Ans. (A)

Since $V_L = -L\dfrac{di}{dt}$

If $\dfrac{di}{dt}$ is decreasing then V_L is increases.

and $V_{source} = \sqrt{V_R^2 + V_L^2}$

So, V_{source} also increases

EXERCISE – S

1. Ans. 6.5 V

$$B = \frac{\mu_0 NI}{\ell}$$

(Inside the solenoid away from the ends)

$$\phi = \frac{\mu_0 NI}{\ell}A$$

Total flux linkage = $N\phi$ = $\dfrac{\mu_0 N^2 A}{\ell}I$

(Ignoring end variations in B)

$$|\varepsilon| = \frac{d}{dt}(N\phi)$$

$$|\varepsilon|_{av} = \frac{\text{Total change in flux}}{\text{total time}}$$

$$|\varepsilon|_{av} = \frac{4\pi\times10^{-7}\times25\times10^{-4}}{0.3\times10^{-3}}\times(500)^2\times2.5 = 6.5V$$

2. **Ans.** 0.75 T

$$Q = \int_{t_t}^{t_f} Idt = \frac{1}{R}\int_{t_t}^{t_f}\varepsilon dt = -\frac{N}{R}\int_{\phi_i}^{\phi_r} d\phi = \frac{N}{R}(\phi_i - \phi_f)$$

For $N = 25$, $R = 0.50\ \Omega$, $Q = 7.5 \times 10^{-3}C$

$\phi_f = 0$, $A = 2.0 \times 10^{-4}\ m^2$, $\phi_i = 1.5 \times 10^{-4}\ Wb$

$b = \frac{\phi_i}{A} = 0.75\ T$

3. **Ans.** 2

$$q = \frac{\Delta\phi}{R}$$

$\Rightarrow$ $\Delta\phi = qR$ = Area of i-t graph × R

$= \frac{1}{2}(4)(0.1) \times 10 = 0.2 \times 10 = 2$ Weber

4. **Ans.** 32

$\varepsilon = (\vec{v} \times \vec{B}).\vec{\ell}_{eff}$

$\varepsilon = [2\hat{\imath} \times (3\hat{\jmath} + 4\hat{k})].[3\hat{\imath} + 4\hat{\jmath}]$

$|\varepsilon| = 32$ volt

5. **Ans.** $\lambda V_y B_0$

$E = [B\ell v]$

6. **Ans.** 2

$R_{eq} = 4$, $F = \frac{B^2\ell^2 v}{R} = 2N$

7. **Ans.** 4

$e = B\ell v$

$$v = \frac{dx}{dt} = -2 \times 120\pi \sin 120\pi t$$

$$\varepsilon = -\frac{1.2}{\pi} \times 1.5 \times \frac{2}{100} \times 120\pi \sin\left(120\pi \times \frac{1}{80}\right)$$

$$= \frac{240\pi}{100\pi} \times 1.8 = 4.32V$$

≈ 4 volts

8. **Ans.** $1.7 \times 10^{-5}\ V$

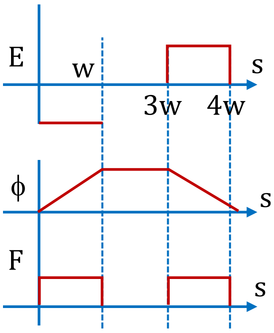
$e = -\frac{d\phi}{dt} = \frac{-d}{dt}(MI)$

$e = -I\frac{d}{dt}\left[\frac{\mu_0 a}{2\pi} log_e\left(\frac{a}{r}+1\right)\right]$

$e = \frac{\mu_0 I a^2}{2\pi} \times \frac{1}{r(r+a)} \times V$

$e = 1.7\times10^{-5} V$

9. **Ans.**



Initially while intering flux increase and then constant and then reduces to zero while coming out.

10. **Ans.** 5

$$\Delta q = \frac{Bab}{R} = 7{,}5.10^{-4}$$

$\phi_i = Bab$

$\phi_f = 0$

$$\therefore \quad \Delta q = \frac{\phi_i - \phi_f + L\int_0^0 d\ell}{R} = \frac{\phi_i - \phi_f}{R}$$

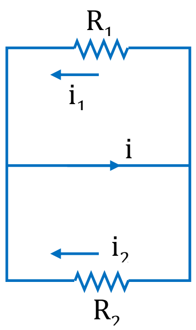
11. **Ans.** (a) zero, (b) $vB(bc)$, positive at c, (c) zero (d) $vB(bc)$, positive at a

Motional emf = BLV

12. **Ans.** $V = 1\ ms^{-1}$, $R_1 = 0.5\ \Omega$, $R_2 = 0.30\ \Omega$

At terminal velocity, $F_{net} = 0$

$$BiL = mg \Rightarrow i = \frac{mg}{BL} = \frac{10}{3}A$$



$i_1 + i_2 = i$ ...(i)

$i_1^2 R_1 = 0.76$ ...(ii)

$i_2^2 R_2 = 1.2$ ...(iii)

$$\frac{V^2}{R_1} = 0.76, \frac{V^2}{R_2} = 1.2 \Rightarrow \frac{R_1}{R_2} = \frac{1.2}{0.76} = \frac{30}{19}$$

$$i_1 = i\left(\frac{R_2}{R_1+R_2}\right) = \frac{10}{3}\left[\frac{1}{\frac{30}{19}+1}\right] \approx 1.3A$$

$$i_2 = i\left(\frac{R_1}{R_1+R_2}\right) = 2A$$

$R_1 = 0.45\Omega$

$R_2 = 0.3\Omega$

$$i_2 = \frac{B\ell V}{R_2} \Rightarrow U = \frac{i_2 R_2}{BL} = \frac{2\times0.3}{0.6\times1} = 1m/s$$

Terminal velocity = 1 m/s

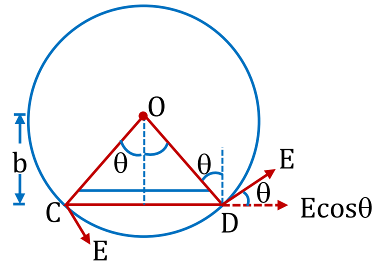
13. **Ans.** $\left(\frac{1}{2}\frac{dB}{dt}\sqrt{R^2-\frac{l^2}{4}}\right)$

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

Let E be induced electric filed due to time-changing magnetic flux.

$$E \times 2\pi R = \frac{d\phi}{dt} = (\pi R^2)\frac{dB}{dt}$$

Potential difference = $\int_{-\frac{l}{2}}^{l/2} -Edl$



$$E = \frac{R}{2}\frac{dB}{dt}$$

$$\Delta V = \frac{R}{2}\frac{dB}{dt}\cos\theta\left[\frac{l}{2}-\left(\frac{-l}{2}\right)\right] = \frac{R}{2}\frac{dB}{dt}\cos\theta \times l$$

$$\Delta V = \frac{R}{2}\times\frac{dB}{dt}\times\frac{b}{R}\times l = \frac{1}{2}\times\frac{dB}{dt}\times\sqrt{R^2-\left(\frac{l}{2}\right)^2}$$

Direction will be from D to C as per Lenz's law.

14. **Ans.** $\left(\frac{\mu_0 i a^2\pi}{2Rb}\right)$

$\varepsilon = \frac{d\phi}{dt}$

$iR = \frac{d\phi}{dt}$

$\frac{dq}{dt}R = \frac{d\phi}{dt}$

$dq = \frac{d\phi}{R}$

$\phi_1 = 0$

$\phi_2 = B \times A = \left(\frac{\mu_0 i}{2b}\right)\pi a^2$

$\phi_2 = \frac{\mu_0 i\pi a^2}{2b}$

$d\phi = \phi_2 - \phi_1 = \frac{\mu_0 i\pi a^2}{2b}$

$dq = \frac{\mu_0 i\pi a^2}{2Rb}$

15. **Ans.** 4.6

$i = \frac{V}{R}(1-e^{-Rt/L})$

$i = \frac{2}{200}[1-e^{-Rt/L}]$

Energy stored in magnetic field,

$$E = \frac{1}{2}Li^2$$

$$\frac{dE}{dt} = Li\frac{di}{dt}$$

$$= 2\left[\frac{2}{200}(1-e^{-Rt/L})\right]\times\left[\frac{2}{200}\times\frac{200}{2}e^{-Rt/L}\right]$$

$$= 4.6\ mW$$

16. **Ans.** 10

$$\phi = BA\cos\theta = \frac{\mu_0 I}{2\pi}\frac{\pi R^2}{8R^3}\times\frac{\pi r^2}{2}\times\cos 53^\circ = \frac{3\mu_0\pi r^2}{160R}$$

$$\therefore \quad M = \frac{\phi}{I} = \frac{3}{160}\frac{\mu_0\pi r^2}{R}$$

17. **Ans.** 7

Magnetic field at a distance x along axis of a circular coil is given by $B(x) = \dfrac{\mu_0 iR^2}{2(R^2+x^2)^{3/2}}$

Flux linked with N coils of square loop inclined at θ = 45° with vertical is given by

$$\phi(x) = \left[\frac{\mu_0 iR^2}{2(R^2+x^2)^{3/2}}\right]N(a^2)(\cos 45^\circ)$$

As $P = Mi$ So $M = \dfrac{\mu_0 R^2(2)}{2\left[R^2+(\sqrt{3}R)^2\right]^{3/2}}\left(\dfrac{a^2}{\sqrt{2}}\right) = \dfrac{\mu_0 a^2}{2^{7/2}R}$ thus $p = 7$

18. **Ans.** 2

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

$$di = \frac{V_L}{L}.dt$$

$$L(i_f - i_0) = \text{areaunder}(V_L - t)\text{graph}$$

$$4(i_f - i_0) = \frac{1}{2}\times 8\times 2$$

$$i_f = 2A$$

19. **Ans.** 80

According to question, $V_L = 2V_R$

So $IX_L = 2IR$

$\Rightarrow$ $\omega L = 2R$

Frequency $f = \dfrac{\omega}{2\pi} = \dfrac{2R}{2\pi L} = \dfrac{8000}{2\pi} = 1273.88\ /s$

20. **Ans.** 5

$$\frac{1}{2} = \frac{R}{\sqrt{R^2+X_C{}^2}}$$

$$\frac{\sqrt{3}}{2} = \frac{R+10}{\sqrt{(R+10)^2+X_C^2}}$$

Solving these two equations

$R = 5\Omega$

21. **Ans.** $\frac{20}{\pi^2} \cong 2H$

For power factor to be unity

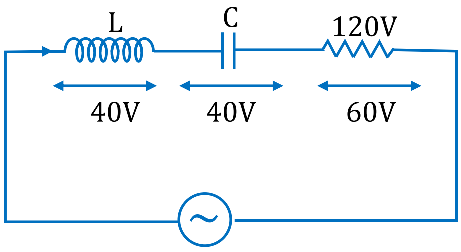
$X_L = X_C$ (Resonance)

$$\omega L = \frac{1}{\omega C}$$

$$L = \frac{1}{\omega^2 C} = \frac{1}{(2\pi \times 50)^2 \times 5 \times 10^{-6}}$$

$$= \frac{20}{\pi^2} \approx 2H.$$

22. **Ans.** 0.2 mH, $\frac{1}{32}$ μF, 8×10^5 rad/s



$W_R = 4 \times 10^5$ rad/sec

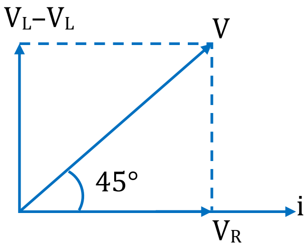
$\because$ The circuit is in resonance

$\therefore$ $V_{\text{rms}} = V_R = 60\ V$

$$i_{rms} = \frac{V_{rms}}{R} = \frac{60}{120} = \frac{1}{2} A$$

So, $40 = i_{\text{rms}} X_L$ and $40 = i_{\text{rms}} X_C$

$\Rightarrow wL = 80$	$\Rightarrow \frac{1}{wc} = 80$
$\Rightarrow L = \frac{80}{4 \times 10^5}$	$\Rightarrow C = \frac{1}{80 \times 4 \times 10^5}$
$\Rightarrow L = 0.2mH$	$\Rightarrow \boxed{C = \frac{1}{32} \mu f}$



If the current lags the voltage by 45° then

$$\tan 45° = \frac{V_L - V_C}{V_R}$$

$$1 = \frac{V_L - V_C}{R} \Rightarrow X_L - X_C = R$$

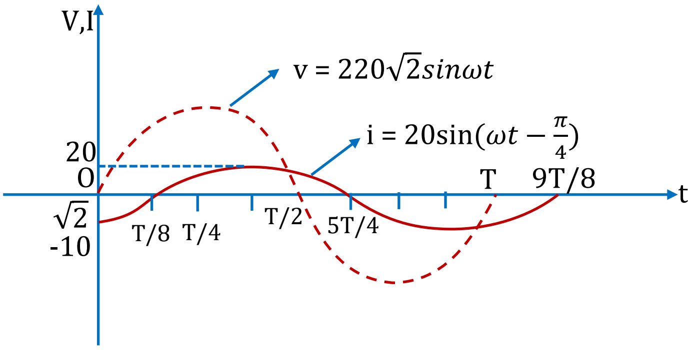
$$\Rightarrow \quad wL - \frac{1}{wL} = R$$

Putting the values of L, C and R we get

$w = 8 \times 10^5$ rad/sec.

23. **Ans.** 20 A, $\pi/4$,

$\therefore$ Steady state current $i = 20\sin\,\pi\left(100t - \frac{1}{4}\right)$



24. **Ans.** 4

$1.25\,R^2 = R^2 + \left(\frac{1}{\omega c}\right)^2$

$0.25\,R^2 = \left(\frac{1}{\omega c}\right)^2$; $0.5\,R = \frac{1}{500\times C}$; $C = \frac{1}{250R}$; $RC = \frac{1}{250}$ sec

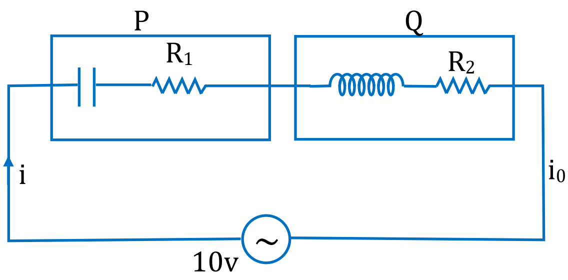
τ = 4 millisecond; τ = 4

25. **Ans.** 77Ω, 97.6Ω, 7.7 V, 9.76 V

For i to become maximum, the circuit must be in resonance so angular frequency of the source will be

$$w = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{4.9\times10^{-3}\times1\times10^{-6}}}$$

$$\Rightarrow\ w = \frac{1}{7}\times10^{5}\,rad/\sec.$$



So the impedance of P and Q,

$$\Rightarrow\ Z_P = \sqrt{X_C^2 + R_1^2}$$

$$= \sqrt{\left(\frac{1}{\omega c}\right)^2 + R_1^2}$$

$$= \sqrt{\left(\frac{1}{\frac{1}{7}\times10^{5}\times10^{-6}}\right)^2 + (32)^2}$$

$$\boxed{z_p \simeq 77\Omega}$$

and $z_Q = \sqrt{X_L^2 + R_2^2}$

$$= \sqrt{(\omega L)^2 + R_2^2}$$

$$= \sqrt{\left(\frac{1}{7}\times10^{5}\times4.9\times10^{-3}\right) + (68)^2}$$

and $z_Q = \sqrt{X_L^2 + R_2^2}$

$= \sqrt{(\omega L)^2 + R_2^2}$

$= \sqrt{\left(\frac{1}{7} \times 10^5 \times 4.9 \times 10^{-3}\right) + (68)^2}$

Voltage across P and Q

$V_p = i\ z_p$	$V_Q i\, z_Q$
$= \frac{V}{R_1 + R_2} z_P$	$= \frac{V}{R_1 + R_2} z_Q$
$= \frac{10}{100} 77$	$\boxed{V_Q = 9.76V}$

$V_P = 7.7\ V$

26. **Ans.** $\frac{F_0 A\omega}{2} \sin\phi$

$P_{av} = < F.V > V = A\omega(\omega t - \phi)$

$P_{av} = < (F_0 \cos \ \omega t_0) A\omega \sin(\omega t - \phi) >$

$= < F_0 A\omega \cos\omega\, t(\sin\omega\, t\, cos\, \phi - cos\ \ \omega t \sin\phi) >$

$= -F_0 A\omega \left(-\frac{\sin\phi}{2}\right) = \frac{F_0 A\omega}{2} \sin\phi$

EXERCISE - JEE (Main) PYQ

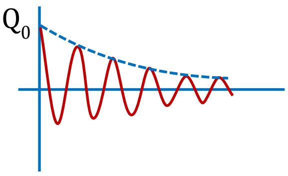
1. **Ans. (1)**

$V_R + V_L = 0$

$\frac{V_R}{V_L} = -1$

2. **Ans. (3)**

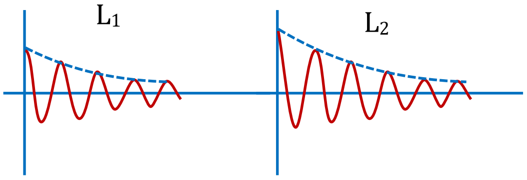
As damping is happening, amplitude of charge would vary as



The oscillations decay exponentially and will be proportional to $e^{-\gamma t}$ where γ depends inversely on L.

So as inductance increases decay becomes slower

$\therefore$ For



3. **Ans. (1)**

$I = 10A$

$V = 80v$

$R = 8\Omega$

$$10 = \frac{220}{\sqrt{8^2 + X_L^2}}$$

$X_L^2 + 64 = 484$

$$X_L = \sqrt{420}$$

$$2\pi \times 50L = \sqrt{420}$$

$$L = \frac{\sqrt{420}}{100\pi}$$

$$\boxed{L = 0.065\ H}$$

4. **Ans. (1)**

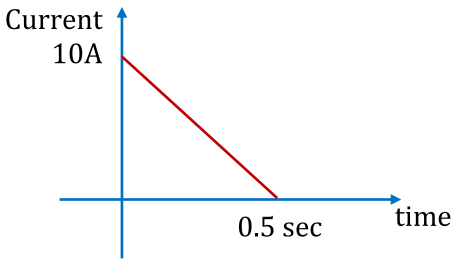
$$q = \frac{\Delta\phi}{R}$$

$\Delta\phi$ = change in flux

$$q = \int I dt$$

= Area of current-time graph

$$= \frac{1}{2}\times 10\times 0.5 = 2.5 \text{ coloumb}$$



$$q = \frac{\Delta\phi}{R}$$

$\Delta\phi = 2.5 \times 100 = 250\ wb$

5. **Ans. (4)**

$$\text{Quality factor} = \frac{\omega_0 L}{R}$$

6. **Ans. (4)**

$$\eta = \frac{P_{out}}{P_{in}} = \frac{V_S I_S}{V_P I_P}$$

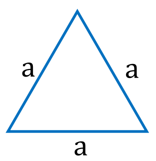
$$\Rightarrow \quad 0.9 = \frac{23\times I_S}{230\times 5}$$

$$\Rightarrow \quad I_S = 45A$$

7. **Ans. (2)**

Number of turns of the coil per unit length of the frame is constant i.e.

$$n = \frac{N}{3a} = \text{constant} \Rightarrow N \propto a$$



Self inductance = $\mu_0 n^2 A \ell$

$= \mu_0 n^2 A\ (3a \times n)$

$\Rightarrow$ Self inductance $\propto a$

So, if $a' = 3a$ then self inductance will become 3 times.

8. Ans. (2)

$$T_0 = 2\pi\sqrt{\frac{m}{k}}$$

$$= \frac{2\pi}{\sqrt{10}}$$

$$A = A_0 e^{-t/\gamma}$$

$\therefore$ For $A = \frac{A_0}{e}, t = \gamma$

$$t = \gamma = \frac{2m}{b} = \frac{2m}{\frac{B^2\ell^2}{R}} = 10^4 s$$

$\therefore$ No. of oscillation $\frac{t}{T_0} = \frac{10^4}{2\pi/\sqrt{10}} \approx 5000$.

9. Ans. (2)

$A = A_0 e^{-0.1t} = \frac{A_0}{2}$

$\ln 2 = 0.1t$

$t = 10 \ln 2 = 6.93 \approx 7$ sec.

10. Ans. (3)

$f = 750\ Hz$, $V_{rms} = 20V$

$R = 100\ W$, $L = 0.1803\ H$

$C = 10\ mF$, $S = 2\ J/°C$

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2 + (\omega L - 1/\omega C)^2}$$

$$= \sqrt{R^2 + \left(2\pi f L - \frac{1}{2\pi f C}\right)^2}$$

Putting values

$|Z| = 834\Omega$

In AC power $P = V_{rms}\, i_{rms} \cos\phi$

We know that $\cos\phi = \frac{R}{|Z|}$ and $i_{rms} = \frac{V_{rms}}{|Z|}$

So, $P = \frac{V_{rms}^2 R}{(|Z|)^2} = \left(\frac{20}{834}\right)^2 \times 100 = 0.0575\ J/s$

$H = Pt = S\Delta\theta$

$$t = \frac{2(10)}{0.0575} = 348 \text{ sec}$$

11. Ans. (3)

$$U_{max} = \frac{1}{2}LI^2_{max}$$

$$i = I_{max}\left(1-e^{-Rt/L}\right)$$

For U to be $\frac{U_{max}}{n}$; i has to be $\frac{I_{max}}{\sqrt{n}}$

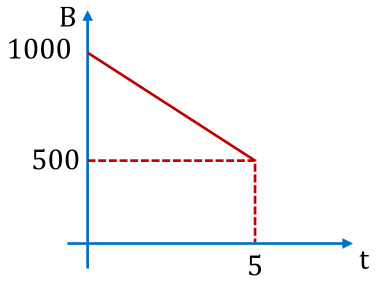
$$\frac{I_{max}}{\sqrt{n}} = I_{max}\,(1-e^{-Rt/L})$$

$$\Rightarrow \quad e^{-Rt/L} = 1-\frac{1}{\sqrt{n}} = \frac{\sqrt{n}-1}{\sqrt{n}}$$

$$\Rightarrow \quad -\frac{Rt}{L} = \ln\left(\frac{\sqrt{n}-1}{\sqrt{n}}\right)$$

$$\Rightarrow \quad t = \frac{L}{R}\ln\left(\frac{\sqrt{n}}{\sqrt{n}-1}\right)$$

12. Ans. (3)



$$\frac{dB}{dt} = 100$$

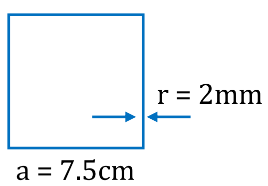
A = 16 ×4 – 4 × 2 = 56 cm^2

$$\varepsilon = \frac{dB}{dt}A = 100\times10^{-4}\times56\times10^{-4}$$

13. Ans. (1)

$$q_i = \frac{d(Ba^2)}{dt} = a^2\frac{dB}{dt}$$

$$i = \frac{q}{R} = \frac{a^2 dB/dt}{\frac{\rho l}{\pi r^2}} = \frac{a^2 dB/dt}{\frac{\rho(30)}{\pi r^2}}$$



14. Ans. (2)

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

$d\phi = \frac{\mu_0 i}{2\pi r} \ell dr$

$\Rightarrow \quad \frac{d\phi}{dt} = \frac{\mu_0 i \ell}{2\pi r} \cdot \frac{dr}{dt}$

$\Rightarrow \quad e = \frac{\mu_0}{2\pi} \cdot \frac{iv\ell}{r}$

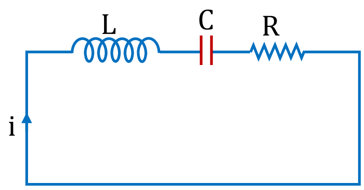
$i = \frac{e}{R} = \frac{\mu_0}{2\pi} \cdot \frac{iv\ell}{Rr}$

15. Ans. (1)

By kVL

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

$$L\frac{d^2q}{dt^2} + \frac{1}{C}q + R\frac{dq}{dt} = 0$$



For damped oscillator

Net force = $-kx - bv = ma$

$$\frac{md^2x}{dt^2} + kx + \frac{bdx}{dt} = 0$$

By comparing; Equivalence is

$$L \to m \,;\ C \to \frac{1}{k} \,;\ R \to b$$

16. Ans. (4)

$U = \frac{1}{2}Li^2 = 64 \quad \Rightarrow \quad L = 2$

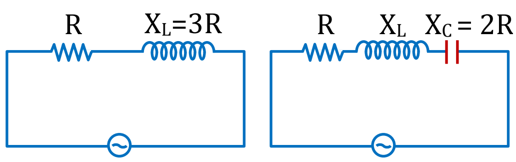
$i^2R = 640$

$R = \frac{640}{(8)^2} = 10$

$\tau = \frac{L}{R} = \frac{1}{5} = 0.2$

17. Ans. (1)

$\cos\phi = \frac{R}{\sqrt{R^2 + 3R^2}} = \frac{1}{\sqrt{10}}$, $\cos\phi' = \frac{R}{\sqrt{R^2 + R^2}} = \frac{1}{\sqrt{2}}$



$\frac{\cos\phi'}{\cos\phi} = \frac{\sqrt{10}}{\sqrt{2}} = \frac{\sqrt{5}}{1}$

$\therefore \quad x = 1$

18. Ans. (3)

if $R = 0$, $P = 0$

19. Ans. (1)

Considering sinusoidal *AC*.

Phase at maximum value $=\frac{\pi}{2}$

Phase at rms value = $\frac{3\pi}{4}$

Thus phase change $=\frac{3\pi}{4}-\frac{\pi}{2}=\frac{\pi}{4}$

Now $\omega = 2\pi f$

$= 2\pi \times 50$

$= 100\,\pi$

Time taken $t = \frac{\theta}{\omega}=\frac{\pi/4}{100\pi}=\frac{1}{400}s$

$t = 2.5 \times 10^{-3} = 2.5\ ms$

20. Ans. (242)

$f=50Hz$

$X_L=2\pi fL$

$=2\pi(50)(200\times10^{-3})$

$=\ 20\pi\Omega$

$i_0=\frac{V_0}{X_L}\Rightarrow\frac{V_{rms}\sqrt{2}}{X_L}$

$=\frac{(220)\sqrt{2}}{20\pi}=\frac{11\sqrt{2}}{\pi}$

$\boxed{i_o=\frac{\sqrt{242}}{\pi}}$

21. Ans. (44)

$N = 600, A = 70 \times 10^{-4}\ m^2, B = 0.4T$

$\omega=\frac{500\times2\pi}{60}=\frac{100\pi}{6}rad/s$

$E= NAB\omega \sin\omega t$ $\qquad$ ωt is angle b/w $\vec{A}\,\&\,\vec{B}$

$= 600 \times 70 \times 10^{-4} \times 0.4 \times \frac{100\pi}{6}\times\frac{1}{2}$

$= 44\ V$

22. Ans. (9)

Maximum energy stored in capacitor is same as maximum energy stored in inductor.

$$\frac{1}{2}Li_{\max}^2=\frac{1}{2}\frac{Q_{\max}^2}{C}$$

$$i_{\max}=\sqrt{\frac{1}{LC}}Q_{\max}$$

$$=\frac{2.7\times10^{-6}}{\sqrt{75\times10^{-3}\times1.2\times10^{-6}}}=9mA$$

23. Ans. (40)

To maximize the average rate at which energy supplied i.e. power will be maximum.

So in *LCR* circuit power will be maximum at the condition of resonance and in resonance condition

$X_L = X_C$

24. Ans. (4)

Quality factor = $\frac{X_L}{R} = \frac{\omega L}{R}$

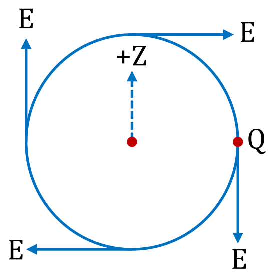
$$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{1\times 6.25\times 10^{-6}}} = \frac{10^3}{2.5} = 400/\sec$$

Q-factor = $\frac{400\times 1}{100} = 4$

EXERCISE - JEE (Advanced) PYQ

1. Ans. (B)

Induce electric field = $\frac{R}{2}\frac{dB}{dt} = \frac{BR}{2}$



Torque on charge = $\frac{QBR^2}{2}(-\hat{k})$

By $\vec{\tau} = \frac{d\vec{L}}{dt} \Rightarrow \int d\vec{L} = \int_0^1 \vec{\tau}dt$

$$\Delta\vec{L} = \frac{QBR^2}{2}(-\hat{k})$$

Change in magnetic dipole moment = $\gamma\Delta\vec{L}$

$$= \frac{\gamma QBR^2}{2}(-\hat{k})$$

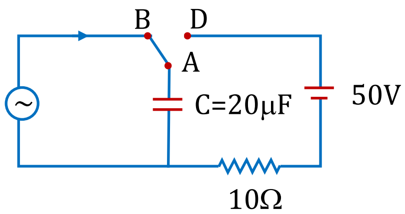
2. Ans. (B)

Magnitude of induced electric field = $\frac{R}{2}\frac{dB}{dt}$ = $\frac{BR}{2}$

3. Ans. (CD)

Current $I = I_0 \cos(\omega t)$

$$\frac{dq}{dt} = I_0\cos(\omega t)$$



$\Rightarrow \quad q = \frac{I_0}{\omega}\sin(\omega t)$

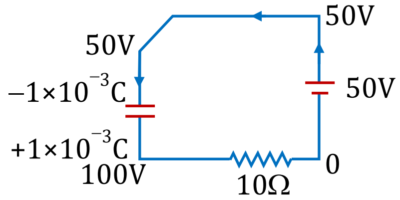
$\Rightarrow \quad q = \frac{1}{500}\sin(\omega t)$

$\Rightarrow \quad q = (2\times 10^{-3})\sin(\omega t)$

So, maximum charge = 2×10^{-3} *C* $\left[\text{Immediately before, } t = \frac{7\pi}{6\omega}\right]$

Current in left part just before, $t = \frac{7\pi}{6\omega}$

$$I = I_0 \cos\left(\omega \times \frac{7\pi}{6\omega}\right) = -\frac{I_0\sqrt{3}}{2}$$



Since current is negative hence current will be anticlockwise.

Immediately after, $t = \frac{7\pi}{6\omega}$

$$q = (2\times10^{-3})\sin\left(\omega\times\frac{7\pi}{6\omega}\right)$$

$= -1 \times 10^{-3}\ C$

Current in 10 Ω resistance,

$$I = \frac{100}{10} = 10A$$

At steady state, potential difference of capacitor is same as of battery,

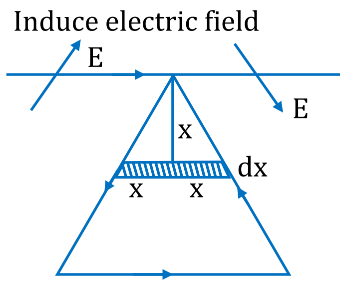
So, final charge is

$Q_f = C\varepsilon = (20\ \mu F)\ (50\ V) = +\ 1 \times 10^{-3}\ C$

Change in charge $= +10^{-3} - (-10^{-3}) = 2 \times 10^{-3}\ C$

4. **Ans. (BD)**

by direction of induced electric field, current in wire is in same direction of current along the hypotenuse.



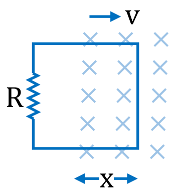
Flux through triangle if wire have current, $i = \int_0^{0.1}\left(\frac{\mu_0 i}{2\pi x}\right)(2x dx) = \frac{\mu_0 i}{10\pi}$

$\Rightarrow$ Mutual inductance $= \frac{\mu_0}{10\pi}$

Induced emf in wire $= \frac{\mu_0}{10\pi}\frac{di}{dt} = \frac{\mu_0}{10\pi}\times10 = \frac{\mu_0}{\pi}$

5. **Ans. (CD)**

When loop was entering ($x < L$)



$\phi = BLx$

$e = -\frac{d\phi}{dt} = -BL\frac{dx}{dt}$

$|e| = BLV$

$i = \frac{e}{R} = \frac{BLV}{R}(ACW)$

$F = ilB$ (Left direction) $= \frac{B^2L^2V}{R}$ (in left direction)

$\Rightarrow$ $a = \frac{F}{m} = -\frac{B^2L^2V}{mR}$ $\left(a = V\frac{dV}{dx}\right)$

$$V\frac{dV}{dx} = -\frac{B^2L^2V}{mR} \Rightarrow \int_{V_0}^{V} dV = -\frac{B^2L^2}{mR}\int_0^x dx$$

$\Rightarrow$ $V = V_0 - \frac{B^2L^2}{mR}x$ (straight line of negative slope for $x < L$)

$I = \frac{BL}{R}V \Rightarrow$ (I vs x will also be straight line of negative slope for $x < L$)

$L \le x \le 3L$

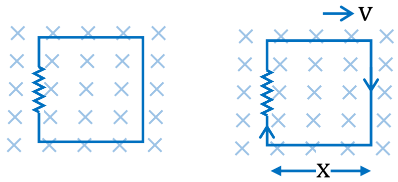
$\frac{d\phi}{dt} = 0$

$e = 0$ $i = 0$

$F = 0$

$x > 4L$

$e = BLv$



Force also will be in left direction.

$i = \frac{BLV}{R}$ (clockwise) $a = -\frac{B^2L^2V}{mR} = V\frac{dV}{dx}$

$F = \frac{B^2L^2V}{R}$ $\quad \int_L^x -\frac{B^2L^2}{mR}dx = \int_{V_i}^{V_f} dV$

$\Rightarrow \quad -\frac{B^2L^2}{mR}(x-L) = Vf - Vi$

$V_f = V_i - \frac{B^2L^2}{mR}(x-L)$ (straight line of negative slope)

$I = \frac{BLV}{R} \rightarrow$ (Clockwise) (straight line of negative slope)

6. Ans. (8)

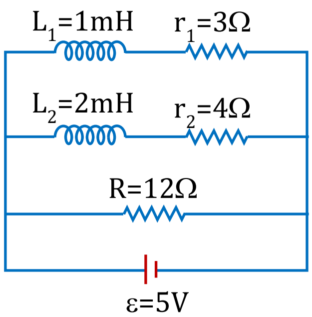
$I_{\min} = \frac{\varepsilon}{R} = \frac{5}{12}A$ (Initially at $t = 0$)

$I_{\max} = \frac{\varepsilon}{R_{eq}} = \varepsilon\left(\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{R}\right)$ (Finally in steady state)

$= 5\left(\frac{1}{3} + \frac{1}{4} + \frac{1}{12}\right)$

$= \frac{10}{3}A$

$\frac{I_{\max}}{I_{\min}} = 8$



7. Ans. (AB)

(A) $\tan\phi = \frac{\omega L - \frac{1}{\omega C}}{R} = 0$

$\omega = \omega_0 = \frac{1}{\sqrt{LC}}$

$\omega_0 = 10^6\ rad/s$

(B) $i_0 = \frac{V_0}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}}$

$\omega \simeq 0, i_0 \simeq 0$

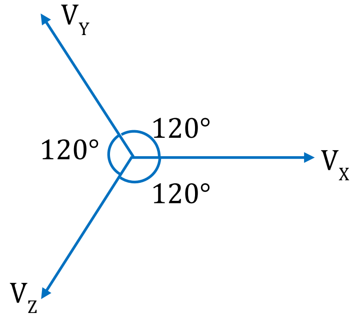
For $\omega >> \omega_0$, circuit behaves as inductor.

8. Ans. (CD)

Potential difference between X and $Y = V_X - V_Y$

Potential difference between Y and $Z = V_Y - V_Z$

Phasor of the voltages :



$\therefore \quad V_X - V_Y = \sqrt{3}V_0$

$$V_{XY}^{rms} = \frac{\sqrt{3}V_0}{\sqrt{2}}$$

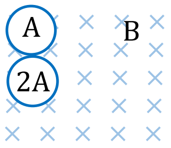
Similarly, $V_{YZ}^{rms} = \frac{\sqrt{3}V_0}{\sqrt{2}}$

Also, difference is independent of choice of two terminals.

9. Ans. (AD)

$f = |B||A|\cos\theta$

$= BA\cos(\omega t)$



$\varepsilon = -\frac{d\phi}{dt} = BA\omega\sin(\omega t)$

so, ε and $\frac{d\phi}{dt} \propto \sin(\omega t)$

so, maximum when, $\omega t = \theta = \frac{\pi}{2}$.

Net emf will be difference of emfs in both loops because their polarities are opposite.

$$\varepsilon_{Net} = \varepsilon_{2A} - \varepsilon_A = B(2A)\omega\sin\omega t - B(A)\omega\sin(\omega t)$$

$$= B(2A - A)\omega\sin\omega t = BA\omega\sin\omega t$$

10. Ans. (ABC)

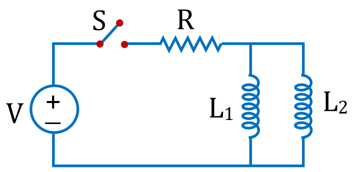
Since inductors are connected in parallel

$$V_{L_1} = V_{L_2}$$

$$L_1\frac{dI_1}{dt} = L_2\frac{dI_2}{dt}$$

$$L_1 I_1 = L_2 I_2$$

$$\frac{I_1}{I_2} = \frac{L_2}{L_1}$$



Current through resistor at any time t is given by

$$I = V/R\,(1 - e^{-\frac{RT}{L}}), \text{ where } L = \frac{L_1 L_2}{L_1 + L_2}$$

After long time $I = \frac{V}{R}$

$I_1 + I_2 = I$ ...(i)

$L_1 I_1 = L_2 I_2$ ...(ii)

From (i) & (ii) we get

$$I_1 = \frac{V}{R}\frac{L_2}{L_1 + L_2}, \quad I_2 = \frac{V}{R}\frac{L_1}{L_1 + L_2}$$

(D) value of current is zero at $t = 0$

Value of current is V/R at $t = \infty$

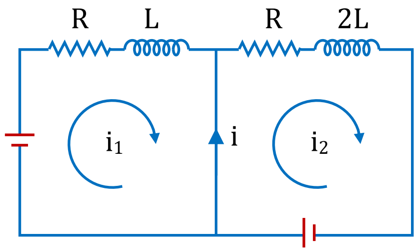
Hence option (D) is incorrect.

11. Ans. (BD)

$i_{max} = (i_2 - i_1)_{max}$

$\Delta i = (i_2 - i_1) = \frac{V}{R}\left[1-e^{-\left(\frac{R}{2L}\right)t}\right]-\frac{V}{R}\left[1-e^{\left(-\frac{R}{L}\right)t}\right]$

$\Rightarrow \quad \frac{V}{R}\left[e^{-\left(\frac{R}{L}\right)t}-e^{-\left(\frac{R}{2L}\right)t}\right]$



For, $(\Delta i)_{max} = \frac{d(\Delta i)}{dt}=0$

$\Rightarrow \quad \frac{V}{R}\left[-\frac{R}{L}e^{-\left(\frac{R}{L}\right)t}-\left(-\frac{R}{2L}\right)e^{-\left(\frac{R}{2L}\right)t}\right]=0$

$e^{-\left(\frac{R}{L}\right)t}=\frac{1}{2}e^{-\left(\frac{R}{2L}\right)t}$

$e^{-\left(\frac{R}{2L}\right)t}=\frac{1}{2}$

$\left(\frac{R}{2L}\right)t=\ell n2$

$t=\frac{2L}{R}\ell n2 \rightarrow$ time when i is maximum.

$i_{\max}=\frac{V}{R}\left[e^{-\frac{R}{L}\left(\frac{2L}{R}\ell n2\right)}-e^{-\left(\frac{R}{2L}\right)\left(\frac{2L}{R}\ell n2\right)}\right]$

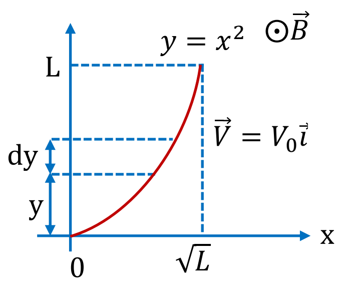
$|i_{\max}|=\frac{V}{R}\left|\left[\frac{1}{4}-\frac{1}{2}\right]\right|=\frac{1}{4}\frac{V}{R}$

12. Ans. (ABD)

$y = x^2$

$B=B_0\left[1+\left(\frac{y}{L}\right)^{\beta}\right]\hat{k}$

$\int d\phi=\int_0^L V_0B_0\left(1+\frac{y^{\beta}}{L^{\beta}}\right)\cdot dy$



$\Delta\phi=V_0B_0\left[L+\frac{L^{\beta+1}}{(\beta+1)L^{\beta}}\right]$

$\Delta\phi=V_0B_0\left[L+\frac{L}{\beta+1}\right]$

$\because \quad |\Delta\phi|=B_0V_0\left(1+\frac{1}{\beta+1}\right)\cdot L$

$|\Delta\phi| \propto L$

$\therefore$ Option 'B' is also correct

If, $\beta = 0$

$\Delta\phi = V_0B_0\,[\,L + L]$

$\Delta\phi = 2V_0B_0L$

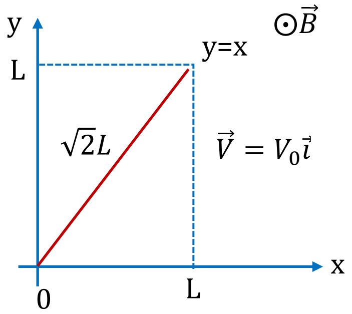
$\Rightarrow$ Option (C) is incorrect

If $b = 2$

$\Delta\phi = V_0B_0\left[L+\frac{L}{3}\right]$

$\Delta\phi = \frac{4}{3}V_0B_0L$ option (D) is correct

$\Delta\phi$ will be same if the wire is replaced by the straight wire of length $\sqrt{2}L$ and $y = x$



$\because$ range of y remains same

$\therefore$ Option 1 is correct.

13. Ans. (0.63)

Since velocity of PQ is constant. So *emf* developed across it remains constant.

$\varepsilon = Blv$, where ℓ = length of wire PQ

Current at any time t is given by

$$i = \frac{\varepsilon}{R}\left(1-e^{-\frac{Rt}{L}}\right)$$

$$i = \frac{B\ell v}{R}(1-e^{-\frac{Rt}{L}})$$

$$= 1\times\left(\frac{10}{100}\right)\times\left(\frac{1}{100}\right)\times\frac{1}{1}\left(1-e^{\frac{-1\times10^{-3}}{1\times10^{-3}}}\right)$$

$$= \frac{1}{1000}\times(1-e^{-1}) = \frac{1}{1000}\times(1-0.37)$$

$i = 0.63 \times 10^{-3}\,A \Rightarrow x = 0.63$

14. Ans. (B)

When the magnet is moved, it creates a state where the plate moves through the magnetic flux, due to which an electromotive force is generated in the plate and eddy currents are induced. These currents are such that it opposes the relative motion $\Rightarrow$ disc will rotate in the direction of rotation of magnet.

Note : This apparatus is called Arago's disk.

Answer is (B).

15. Ans. (B)

Torque experienced by circular loop = $\vec{M}\times\vec{B}$

where, $\vec{M}$ is magnetic moment

$\vec{B}$ is magnetic field

$\therefore$ $\tau = i\pi R^2NB_0$ [at the instant shown $q = \pi/2$]

$\therefore$ $\vec{\tau}dt = d\vec{L} = i\pi R^2NB_0\,dt = Q\pi R^2N\,B_0$ [$idt = Q$]

Answer is (B).

16. Ans. (55)

Mutual inductance is producing flux in same direction as self inductance.

$\therefore \quad U = \frac{1}{2}L_1 I_1^2 + \frac{1}{2}L_2 I_2^2 + MI_1 I_2$

$\Rightarrow \quad U = \frac{1}{2}\times(10\times10^{-3})1^2 + \frac{1}{2}\times(20\times10^{-3})\times2^2 + (5\times10^{-3})\times1\times2$

$= 55\ mJ$

17. Ans. (AC)

EMF developed across the emf of semi-circular rod

$= \int_1^4 \frac{\mu_0 i}{2\pi r} v dr = \frac{\mu_0 iv}{2\pi}\ell n4 = \frac{\mu_0 iv}{\pi}\ell n2$

Form given value,

$E = \frac{4\pi\times10^{-7}\times2\times3\times0.7}{\pi} = 24\times7\times10^{-8}$

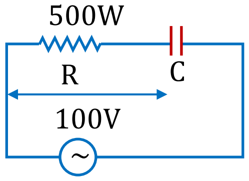
$i_{\max} = \frac{E}{R} = \frac{24\times7\times10^{-8}}{1.4} = 1.2\times10^{-6} A$

$Q_{max} = C_0 E = 24\times7\times10^{-8}\times5\times10^{-6} = 8.4\times10^{-12} C$

18. Ans. (100.00)

19. Ans. (60.00)

Solution for Question No. 18 and 19



$\sqrt{V_C^2 + V_R^2} = \varepsilon_{rms}$

$\Rightarrow \quad V_C^2 + 100^2 = 200^2$

$V_C = 100\sqrt{3}V \qquad ...(i)$

$\tan\phi = \frac{V_C}{V_R} = \frac{100\sqrt{3}}{100}$

$\therefore \quad \phi = 60° \qquad ...(ii)$

$P = I_{rms}\varepsilon_{rms}\cos\phi = \frac{\varepsilon_{rms}^2}{z}\frac{1}{2}$

$500 = \frac{(200)^2}{z}\frac{1}{2}$

$\therefore \quad z = 40\Omega \qquad ...(iii)$

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

$\therefore \quad R = 20$

and $\quad x_C = \sqrt{z^2 - R^2} = \sqrt{40^2 - 20^2} = 20\sqrt{3}\Omega$

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

$\therefore \quad C = 100$

20. Ans. (A)

21. Ans. (C)

Solution for Question No. 20 and 21

$$\phi = Li = \frac{\mu_0 m}{2\pi r^3} \times \pi a^2$$

$$\Rightarrow \quad i = \frac{\mu_0 m \pi a^2}{2\pi r^3 L}$$

$$\Rightarrow \quad i \propto \frac{m}{r^3}$$

$$m' = \pi a^2 i = \frac{\mu_0 m \pi^2 a^4}{2\pi r^3 L}$$

$$F = \frac{k m_1 m_2}{r^4}$$

$$F = \frac{k m^2 \pi^2 a^4}{2\pi r^7 L}$$

$$W = \int F dr \propto \int \frac{m^2 dr}{r^7}$$

22. Ans. (B)

$V = 45 \sin \omega t$, $L = 50\ mH$

$$\omega_0 = 10^5 rad/s = \frac{1}{\sqrt{LC}} \Rightarrow C = \frac{1}{L\omega_0^2} = \frac{1}{5 \times 10^{-2} \times 10^{10}}$$

$$= 2 \times 10^{-9}\ F$$

$$I_0 = \frac{45}{R}$$

$\omega = 8 \times 10^4\ rad/s = 0.8\ \omega_0$

$$I = 0.05 I_0 = \frac{I_0}{20} \Rightarrow Z = 20R$$

$$X_L = 8 \times 10^4 \times 5 \times 10^{-2} \Omega = 4 k\Omega$$

$$X_C = \frac{1}{8 \times 10^4 \times 2 \times 10^{-9}} = \frac{1}{16} \times 10^5 \Omega = \frac{25}{4} k\Omega$$

$$Z^2 = R^2 + (X_C - X_L)^2$$

$$400R^2 = R^2 + \left(\frac{9}{4} k\Omega\right)^2$$

$$R = \frac{\frac{9}{4} k\Omega}{\sqrt{399}} \approx \frac{9}{80} k\Omega = \frac{900}{8} \Omega$$

$$I_0 = \frac{V_0}{R} = \frac{45 \times 8}{900} = \frac{8}{20} A \approx 0.4A = 400mA$$

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{8}{900}\sqrt{\frac{5 \times 10^{-2}}{2 \times 10^{-9}}} = \frac{8}{900}\sqrt{25 \times 10^6}$$

$$Q = \frac{8}{900} \times 5000 = 44.4$$

$$Q = \frac{\omega_0}{\Delta\omega} \Rightarrow \Delta\omega = \frac{\omega_0}{Q} = \frac{10^5}{44.4} = 2250.0$$

$$P_{max} = I_0^2 R = \frac{45^2}{R^2} \times R = \frac{45^2}{R} = \frac{45^2}{900} \times 8 = 18.4W$$

23. **Ans. (D)**

From force equation

$$mg - Bi\ell = \frac{mdv}{dt}$$

$$mg - \frac{BBi\ell}{R} \times \ell = \frac{mdv}{dt}$$

$$\frac{mgR}{B^2\ell^2} - v = \frac{mR}{B^2\ell^2}\frac{dv}{dt}$$

$$\frac{B^2\ell^2}{mR}\int_{t=0}^{t} dt = \int_0^v \frac{dv}{\left(\frac{mgR}{B^2\ell^2} - v\right)}$$

Now, $\frac{mgR}{B^2\ell^2} = \frac{20\times10^{-3}\times10\times10}{16\times\frac{1}{16}} = 2$

and $\frac{B^2\ell^2}{mR} = \frac{16\times\frac{1}{16}}{20\times10^{-3}\times10} = \frac{1}{0.2} = 5$

$\therefore$ $5t = [-\ell n(2-v)]_0^v$

$-5t = \ell n\left[\frac{2-v}{v}\right]$

$\therefore$ $v = 2\,(1 - e^{-5t})$

At $t = 0.2$ sec $\quad v = 2\,(1 - e^{-5\times0.2})$

$v = 2\,(1 - 0.4)$

$v = 1.2\ m/s$

(P) Now at $t = 0.2$ sec

The magnitude of the induced emf $= E = Bv\ell$

$$= 4 \times 1.2 \times \frac{1}{4} = 1.2 Volt$$

(Q) At $t = 0.2$ sec, the magnitude of magnetic force $= BI\ell \sin\theta$

$$= B \times \frac{B\ell v}{R} \times \ell \times \sin 90°$$

$$= \frac{4\times4\times\frac{1}{4}\times1.3\times\frac{1}{4}}{10} = 0.12 \text{ Newton}$$

(R) At $t = 0.2$ sec, the power dissipated as heat

$$P = i^2R = \frac{v^2}{R} = \frac{1.2\times1.2}{10}$$

$P = 0.144$ watt

(S) Magnitude of terminal velocity

At terminal velocity, the net force become zero

$\therefore$ $mg = Bi\ell$

$$mg = B \times \frac{B\ell v_t}{R} \times \ell$$

$$\therefore\ v_T = \frac{mgR}{B^2\ell^2} = \frac{20\times10^{-3}\times10\times10}{16\times\frac{1}{16}}$$

$v_T = 2\ m/s$

Hence, Answer is (D)

JEE (Main) Practice Paper

SECTION–A

1. **Ans. (1)**

If 'i' is increased than flux through coil 'B' also increases. Than according to Lenz' law induced current in coil 'B' is such that it opposes the initial changing magnetic field Hence repulsion occurs.

2. **Ans. (4)**

Flux = $\phi = B.A = BA\cos\theta$

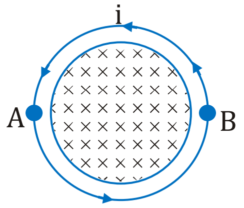
Time period = $T = \dfrac{2\pi}{\omega}$

When coil Rotate through 90°, $\phi = 0$

Average induced EMF = $\varepsilon = \dfrac{\Delta\phi}{\Delta t} = \dfrac{BA}{T/4} = \dfrac{2\omega BA}{\pi}$

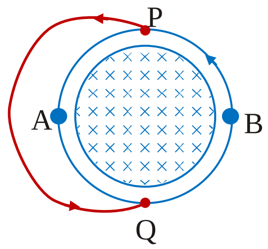
3. **Ans. (1)**

As B increases than according to Lenz law current (i) induced as shown in fig.



Now P & Q short circuited

Current choose Low resistance path so Balb A goes out & Balb B gets brighter.



4. **Ans. (4)**

$Q_2 = \dfrac{(2\omega_1)L}{R}$ (as frequency is doubled) = $2Q$, where $Q_1 = \dfrac{L\omega_1}{R} \Rightarrow Q$ is doubled

$I_1 = \dfrac{V}{\sqrt{(L\omega_1)^2 + R^2}} \simeq \dfrac{V}{L\omega_1}$ (as $L\omega >> R$ for high Q coils) Similarly, $I_2 \simeq \dfrac{V}{L(2\omega_1)} \Rightarrow I_2 = \dfrac{I_1}{2}$

$P_2 = I_2R^2 = \left(\dfrac{I_1}{2}\right)R^2 = \dfrac{I_2R^2}{4} = \dfrac{P_1}{4} \Rightarrow P$ decreases 4 times.

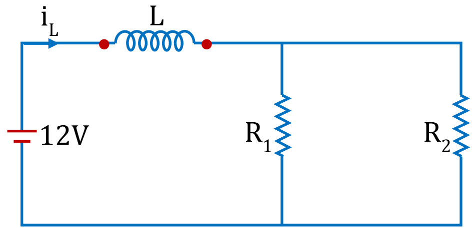
5. **Ans. (4)**

$E - \dfrac{Ldi}{dt} = 0$

$t = \dfrac{Li}{E}$

6. Ans. (4)

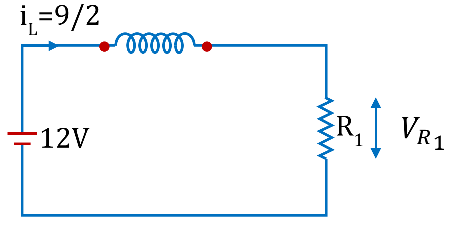
When switch was is closed



$$i_L = \frac{12}{R_1 || R_2}$$

$$= \frac{12 \times 12}{32} = \frac{9}{2} A$$

Just after switch is opened we know current in inductor does not change instantaneously.



Voltage across R_1 is $V_{R_i} = \frac{9}{2}\ R_1 = 18$ volt.

So voltage across inductor = 6 volt & B is at higher potential.

7. Ans. (1)

Field and flux will be outside in ring. So, a clockwise current will be induced as per Lenz law.

8. Ans. (4)

When DC applied

$100 = 1\ (R) \quad \Rightarrow \quad R = 100\ \Omega$

When AC applied

$100 = 0.5\ (Z) \quad \Rightarrow \quad Z = 200\ \Omega$

$z = \sqrt{R^2 + x_L^2} \quad \Rightarrow \quad 200 = \sqrt{100^2 + x_L^2}$

$X_L = \sqrt{200^2 - 100^2}$

$\Rightarrow \quad X_L = 100\sqrt{3}\Omega$

$L\omega = 100\sqrt{3}\ \Omega$

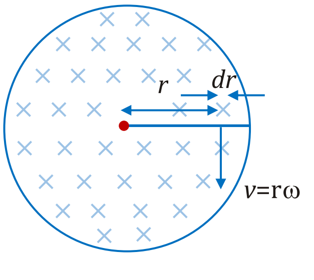
$\Rightarrow \quad L = \frac{100\sqrt{3}}{100\pi} = \frac{\sqrt{3}}{\pi} = 0.55H$

9. Ans. (4)

$\varepsilon = \left(\vec{v} \times \vec{B}\right) \cdot d\vec{\ell}$

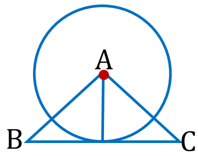
$\varepsilon = \int_{L/2}^{L} r\omega B dr$

$= \frac{3B\omega L^2}{8}$



10. Ans. (4)

$$\int_{AB}\vec{E}.\vec{d\ell}+\int_{BC}\vec{E}.\vec{d\ell}+\int_{CA}\vec{E}d\ell=\frac{\pi R^2}{4}\alpha$$



$$0 + \Delta\varepsilon + 0 = \frac{\pi R^2\alpha}{4}$$

11. Ans. (2)

Induced current (i) is in anticlockwise direction.

So e^- moves tangentially right (clockwise).

12. Ans. (2)

For ring to be in equilibrium,

$$\mu mgr \geq Q\,\frac{\pi r^2 R}{2\pi r}.r$$

13. Ans. (4)

$$|\varepsilon| = N\frac{d\phi}{dt}$$

$$\phi = BA\cos\theta = BA\cos\omega t$$

$$|\varepsilon| = NBA\omega \sin \omega t$$

Hence, it does not depends on Resistance of coil.

14. Ans. (2)

Theoretical.

15. Ans. (2)

If $\vec{B}$ is in $\hat{\imath}$ direction then flux changes is yz plane

Therefore, $E = \left|\frac{d\phi}{dt}\right| = \frac{\pi R^2}{4}\times\frac{dB}{dt} = 2.36\times10^{-5}V$

Used Lenz law from C to B.

16. Ans. (2)

Rate of loss of mechanical energy $\propto \frac{b}{m}$

Hence $\left(\frac{b}{m}\right)_{\min imum}$ $\Rightarrow$ Smallest lost of mechanical energy

17. Ans. (4)

Refer class notes.

18. Ans. (1)

At Resonance $X_L = X_C$ $\quad\{X_L = L\omega, X_C = \frac{1}{C\omega}\}$

When $\omega\downarrow X_L\downarrow X_C\uparrow$

So nature of circuit will be capacitive.

19. **Ans. (1)**

$$I_{rms}=\sqrt{<\left(I_0+I_1\sin\omega t\right)^2>}=\sqrt{<\left(I_0^2+2I_0I_1\sin\omega t+I_1^2\sin^2\omega t\right)>} = \sqrt{I_0^{\,2}+0.5I_1^{\,2}}$$

(Here '< >' represent mean)

Average value of sin ωt = 0 and $\sin^2 \omega t$ = 0.5.

20. **Ans. (1)**

It is oscillating LCR AC circuit

$$L\frac{di}{dt}+\frac{q}{C}+iR=\frac{B\pi a^2\omega}{2}\ \sin\omega t$$

$$i_{rms}=\frac{i_{\max}}{\sqrt{2}}=\frac{E_{\max}}{\sqrt{2}R}=\frac{B\pi a^2\omega}{2\sqrt{2}R}$$

$$=\frac{B\pi a^2}{2R\sqrt{2LC}}$$

maximum energy stored in cap.

$$=\frac{q_{\max}^2}{2C}=\frac{C^2V_{\max}^2}{2}=\frac{1}{2}CV_{\max}^2$$

$$=\frac{1}{2}C\left(I_{rms}X_c\right)^2=\frac{B^2\pi^2a^4}{8R^2C}$$

maximum power by extennal agent

$$P = I_{rms}\, V_{rms}$$

$$=\frac{B^2\pi^2a^4}{8LCR}$$

SECTION–B

1. **Ans. (2)**

$$|\varepsilon|=\left(\vec{v}\times\vec{B}\right).d\vec{\ell}\ \text{-}$$

$$= \left[\left(2\hat{i}+3\hat{j}+\hat{k}\right)\times\left(\hat{i}+2\hat{j}\right)\right].\left(2\hat{k}\right)$$

= 2 volt.

2. **Ans. (16)**

$$P=\frac{\left(\frac{B\omega r^2}{2}\right)^2}{R}=\frac{\left(\frac{20\times2\times2^2\times10^{-4}}{2}\right)^2}{4}=16\ \mu\ W$$

3. Ans. (2)

$E = \frac{d\phi}{dt} = BA\omega N \sin\omega t$

$E_{max} = BA\omega N = 20V$

$I = E/R = 2A$

4. Ans. (6)

At half power frequencies,

$$Z = R\sqrt{2} \Rightarrow |X_L - X_C| = R$$

$$\left(\omega L - \frac{1}{\omega C}\right)^2 = R^2 \Rightarrow \omega^2 L^2 + \frac{1}{\omega^2 C^2} - \frac{2L}{C} = R^2$$

$$\omega^4 L^2 C^2 - \omega^2\left(\frac{2L}{C} + R^2\right)C^2 + 1 = 0$$

The product of roots is $\omega_1^2\omega_2^2 = \frac{1}{L^2C^2} = \omega_1\omega_2 = \frac{1}{LC} = \omega_0^2$

$\Rightarrow \quad \omega_0 = \sqrt{\omega_1\omega_2} = 60\ rad/s \Rightarrow \omega_0/10 = 6$

5. Ans. (3)

Time constant $= \frac{L}{R} = \frac{1}{2}$

So, EMF will be half at $t = \frac{1}{2}\ell n2$

$E \Rightarrow \frac{6}{2} = 3V$

6. Ans. (125)

At $t = 0$, $\quad L = \infty\ \Omega$, $\quad i_1 = 1A$

At $t = \infty$, $\quad L = 0\Omega$, $\quad i_2 = 1.25\ A$

7. Ans. (400)

$\tan 60° = \frac{x_L}{R} \quad \& \quad \tan 60° = \frac{x_C}{R}$

$x_L = 100\sqrt{3} \quad \Rightarrow \quad X_C = 100\sqrt{3}$

$Z = \sqrt{R^2 + (X_L - X_C)^2} = 100\Omega$

Power = $V_{RMS}.\ I_{RMS} \cos\theta$

$= (200)\left(\frac{200}{100}\right)\times 1$

$= 400$ watt

8. Ans. (5)

$$e = \frac{d\phi}{dt} = \frac{d}{dt}(\pi r^2 B) = 2\pi r B\frac{dr}{dt}$$

$$\Rightarrow \quad r = \frac{e}{\left(2\pi B\dfrac{dr}{dt}\right)}$$

$$\Rightarrow \quad r = \frac{10^{-6}}{2\pi\times10^{-3}\times10^{-2}} = \frac{5}{\pi}\,cm$$

9. Ans. (6)

$$V_L^2 + R_R^2 = 150^2 \Rightarrow V_L^2 = 150^2 - 120^2 \Rightarrow V_L = 90V$$

Also $\quad V_C^2 + V_R^2 = 130^2 \Rightarrow V_C = 50V$

$$V = \sqrt{V_R^2 + (V_L - V_C)^2} = \sqrt{120^2 + 40^2} = 40\sqrt{10} = x$$

Power factor $\cos\phi = \frac{R}{Z} = \frac{V_R}{V} = \frac{120}{40\sqrt{10}} = \frac{3}{\sqrt{10}} = y$

10. Ans. (10)

Suppose the left of the loop has co-ordinate x

dx = displacement of loop in time dt

dA = area of the element of width $dx = Ldx$

$d\phi$ = flux associated with dA = $\vec{B}.d\vec{A} = BL\,dx$

ϕ = flux through the loop = $\int_x^{x+L}(\alpha x)Ldx$

$$= \frac{\alpha L}{2}\left[(x+L)^2 - x^2\right] = \frac{\alpha L(2x+L)(L)}{2}$$

ε = induced *emf* = $\left|-\frac{d\phi}{dt}\right| = \alpha L^2 V = (0.2)(0.2)^2(10)$ = $80 \times 10^{-3}\ V$ ..... (i)

As the square moves, the flux increases and so the induced current must produce a field that is out of the page in the interior of the square *i.e.* induced current should flow in anticlockwise direction inside the square.

i = induced current = $\frac{80\times10^{-2}}{80\times10^{-2}} = 1A$

JEE (Advanced) Practice Paper

1. Ans. (A)

As field in inarts increasing therefore B induce will be outwards therefore induce current will be form B to A and from D to C.

Therefore B to A and D to C.

2. Ans. (D)

For L–R circuit

$$\cos\theta = \left(\frac{R_1}{R_1^2 + X_L^2}\right) = 0.6$$

For C–R circuit

$$\cos\theta_2 = \left(\frac{R_2}{R_2^2 + X_C^2}\right) = 0.5$$

Now when L,C,R of two circuits are joined

$$\cos\theta = \left(\frac{R_1 + R_2}{\sqrt{(R_1 + R_2)^2 + (X_L - X_L)^2}}\right)$$

$\cos\theta = 1$ (given)

$\therefore$ $X_C = X_L = X$

$$\tan\theta_1 = \left(\frac{X_L}{R_1}\right)$$

$$\tan\theta_2 = \left(\frac{X_L}{R_2}\right)$$

$$\frac{\tan\theta_1}{\tan\theta_2} = \frac{X_L}{R_1}\frac{R_L}{X_C} = \left(\frac{R_2}{R_1}\right)$$

$$\tan\theta_1 = \frac{4}{3}$$

$$\tan\theta_2 = \sqrt{3}$$

$\therefore$ $$\frac{R_1}{R_2} = \frac{3\sqrt{3}}{4}$$

3. Ans. (A)

The direction of induced electric field is circular and hence potential drop across wire OA and OB is zero. Hence all induced *emf* will be in the wire AB.

$$e = -A\frac{dB}{dt} = -\left(-\frac{\pi \times 1^2}{6} \times \frac{6}{\pi} \times 2\cos 2t\right) = 2\cos 2t$$

$\therefore$ $e_{max} = 2$ volt

4. Ans. (C)

$$i_1 = \frac{V_0}{Z_1} \quad ; \quad i_2 = \frac{V_0}{Z_2}$$

We have, $Z = \sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}$, thus $\omega\uparrow, Z\downarrow \Rightarrow i$ increases

5. **Ans. (C)**

Here $\dfrac{1}{\sqrt{LC}} = \dfrac{1}{\sqrt{5\times10^{-3}\times50\times10^{-6}}} = 2000 rad/s$

$\Rightarrow$ $\omega = \dfrac{1}{\sqrt{LC}}$ so, resonance condition

$\Rightarrow$ $I = \dfrac{V}{R} = \dfrac{20/\sqrt{2}}{6+4} = \sqrt{2} = 1.4A$

$\Rightarrow$ Reading of ammeter = 1.4A.

$\Rightarrow$ Reading of voltmeter = $4\sqrt{2}$ V = 5.6 V

6. **Ans. (ABCD)**

For (A) Expression of voltage of time 't': $V = V_m \sin(\omega t + \phi)$

At $t = 0$: $100 = 200 \sin\phi \Rightarrow \phi = \dfrac{\pi}{6}$ rad; current lags voltage by $\dfrac{\pi}{6}$ rad

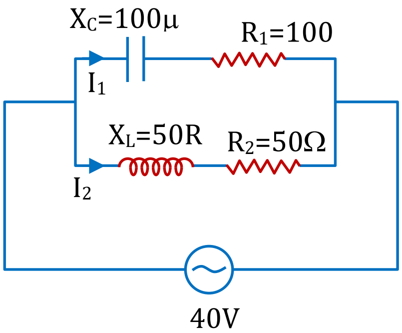
For (B) $R = Z\cos\phi = \dfrac{200V}{400mA}\cos\dfrac{\pi}{6} = 250\sqrt{3}\Omega$

For (C) $X = Z\sin\phi = 250\Omega$

For (D) $P_{av} = \dfrac{V_m I_m}{2}\cos\phi = 20\sqrt{3}\ W$

7. **Ans. (ABC)**

$I_1 = \dfrac{V_{rms}}{z_1} = \dfrac{40}{100\sqrt{2}} = \dfrac{\sqrt{2}}{5}$ A at 45° leading



$I_2 = \dfrac{V_{rms}}{z_2} = \dfrac{40}{50\sqrt{2}} = \dfrac{2\sqrt{2}}{5}$ A at 45° lagging

So, I_1 is 90° ahead of I_2

$I_{res} = \sqrt{I_1^2 + I_2^2} = \dfrac{2}{\sqrt{10}} A$

$V_{R_1} = I_1 R_1 = \dfrac{\sqrt{2}}{5}\times100 = 20\sqrt{2}V$

$V_{R_2} = I_2 R_2 = \dfrac{2\sqrt{2}}{5}\times50 = 20\sqrt{2}V$

8. Ans. (B)

$$\tan\phi_L = \frac{X_L}{R} \quad ; \quad \tan\phi_C = \frac{X_C}{R}$$

$$\tan\phi_L = \omega\sqrt{LC} \quad ; \quad \tan\phi_C = \frac{1}{\omega\sqrt{LC}} \qquad \left[\because R = \sqrt{\frac{L}{C}}\right]$$

We know that

$$\tan(A+B) = \frac{\tan A + \tan B}{1 - \tan A \tan B}$$

Here, $$\tan(\phi_L + \phi_C) = \frac{\tan\phi_L + \tan\phi_C}{1 - \tan\phi_L \tan\phi_C} = \infty$$

$\Rightarrow \quad \phi_L + \phi_C = 90°$

So, $$I = \sqrt{I_L^2 + I_C^2}$$

$$I^2 = \frac{V_{rms}^2}{R^2 + \omega^2 L^2} + \frac{V_{rms}^2}{R^2 + \frac{1}{\omega^2 C^2}}$$

$$I^2 = \frac{V_{rms}^2}{\frac{L}{C} + \omega^2 L^2} + \frac{V_{rms}^2}{\frac{L}{C} + \frac{1}{\omega^2 C^2}}$$

$$= \frac{V_{rms}^2 C}{L}\left(\frac{1}{1+\omega^2 LC} + \frac{1}{1 + \frac{1}{\omega^2 LC}}\right)$$

$$= \frac{V_{rms}^2}{R^2}$$

So, $$I = \frac{V_{rms}}{R}$$

and Impedance of circuit is independent of ω.

9. Ans. (AC)

I_2 is in phase with voltage of source; I_1 leads the voltage by $\frac{\pi}{2}$

I is the resultant of I_1 and I_2.

10. Ans. (B)

For unity power factor, box must contain inductor.

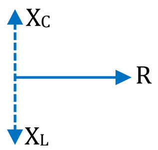
11. **Ans. (A)**

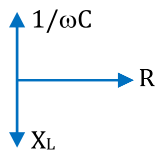
$$\frac{R}{Z}=\frac{1}{\sqrt{2}}\Rightarrow Z=\sqrt{2}R$$

Also, $R=X_L=X_C$

So, $Z=\dfrac{\sqrt{2}}{\omega C}$

12. **Ans. (A)**





$Z=\sqrt{X_L^2+R^2}\ =\ R\sqrt{2}\quad X_L=X_C=1/\omega C$

So, $X_L=X_C=R$ So, the circuit is in resonance.

So, $Z=\sqrt{2}\cdot\dfrac{1}{\omega C}$

13. **Ans. (16)**

$\vec{A}=4\hat{k}$ for x-y plane

$\phi=\vec{B}.\vec{A}=\ B_0(2\hat{i}+3\hat{j}+4\hat{k}).4\hat{k}=16\ B_0$

14. **Ans. (8)**

KCL of junction :

$i_1+i_2-i_L+i_C=0$

$i_C=i_L-(i_1+i_2)$

$\dfrac{dq}{dt}=i_L-(i_1+i_2)$

$C\left(\dfrac{dV_C}{dt}\right)=i_L-(i_1+i_2)$

$2(-6e^{-2t})=i_L-(10e^{-2t}+4)$

$i_L=-\ 2e^{-2t}+4$

$V_L=\ -L\dfrac{di}{dt}=-4\left[4e^{-2t}+0\right]=-16e^{-2t}$

$a=-16,\ b=2$

$\left|\dfrac{a}{b}\right|=8$

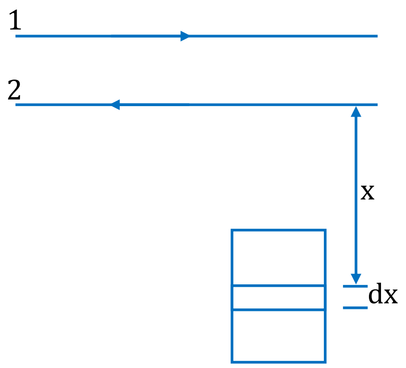
15. Ans. (0.05)

$$\Delta t = \frac{2Q}{\omega}\ell n\eta = 0.05\,\text{sec}$$

16. Ans. (2)

$$d\phi = \int_d^{2d}\left(\frac{\mu_0 i}{2\pi x}d\right)dx - \int_{2d}^{3d}\left(\frac{\mu_0 i}{2\pi x}d\right)dx = \frac{\mu_0 id}{2\pi}\left\{\ell n2 - \ell n\left(\frac{3}{2}\right)\right\}$$

$$\phi = \frac{\mu_0 id}{2\pi}\ell n\left(\frac{4}{3}\right)$$



$$\varepsilon = -\frac{d\phi}{dt} = -\frac{\mu_0 d}{2\pi}\ell n\left(\frac{4}{3}\right)\frac{dI}{dt}$$

17. Ans. (6)

Apply KVL, $E - IR - L\frac{dI}{dt} - \frac{q}{C} = 0$