EMI & AC

1. A series AC circuit containing an inductor (20 mH), a capacitor (120 μF) and a resistor (60Ω) is driven by an AC source of 24V/50Hz. The energy dissipated in the circuit in 60 s is :

(1) 2.26×10^3 J (2) 3.39×10^3 J
(3) 5.65×10^2 J (4) 5.17×10^2 J

2. A power transmission line feeds input power at 2300 V to a step down transformer with its primary windings having 4000 turns. The output power is delivered at 230 V bv the transformer. If the current in the primary of the transformer is 5A and its efficiency is 90%, the output current would be :

(1) 25 A (2) 50 A
(3) 35 A (4) 45 A

3. The self induced emf of a coil is 25 volts. When the current in it is changed at uniform rate from 10 A to 25 A in 1s, the change in the energy of the inductance is :

(1) 437.5 J (2) 637.5 J
(3) 740 J (4) 540 J

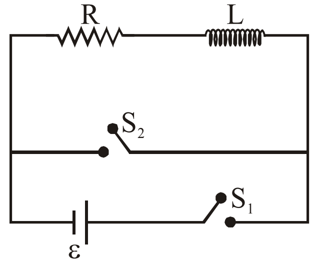
4. A solid metal cube of edge length 2 cm is moving in a positive y direction at a constant speed of 6 m/s. There is a uniform magnetic field of 0.1 T in the positive z-direction. The potential difference between the two faces of the cube perpendicular to the x-axis, is :

(1) 6 mV (2) 1 mV (3) 12 mV (4) 2 mV

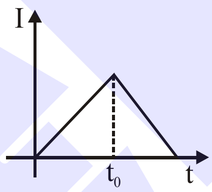
5. A copper wire is wound on a wooden frame, whose shape is that of an equilateral triangle. If the linear dimension of each side of the frame is increased by a factor of 3, keeping the number of turns of the coil per unit length of the frame the same, then the self inductance of the coil :

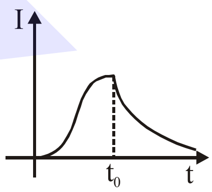
(1) Decreases by a factor of $9\sqrt{3}$
(2) Increases by a factor of 3
(3) Decreases by a factor of 9
(4) Increases by a factor of 27

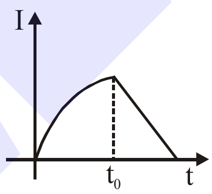
6. In the circuit shown,

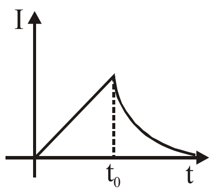


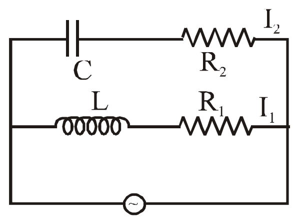
the switch S_1 is closed at time t = 0 and the switch S_2 is kept open. At some later time (t_0), the switch S_1 is opened and S_2 is closed. The behavious of the current I as a function of time 't' is given by :

(1) 

(2) 

(3) 

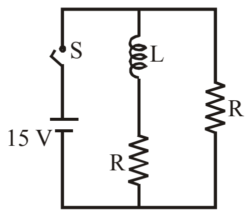
(4) 

7. 

In the above circuit, $C = \frac{\sqrt{3}}{2}\mu F$, $R_2 = 20\Omega$, $L = \frac{\sqrt{3}}{10}$ H and $R_1 = 10\Omega$. Current in L-R_1 path is I_1 and in C-R_2 path it is I_2. The voltage of A.C source is given by $V = 200\sqrt{2}\sin(100t)$ volts. The phase difference between I_1 and I_2 is :

(1) 30° (2) 0° (3) 90° (4) 60°

8. In the figure shown, a circuit contains two identical resistors with resistance $R = 5\Omega$ and an inductance with $L = 2mH$. An ideal battery of 15 V is connected in the circuit. What will be the current through the battery long after the switch is closed?



(1) 6A (2) 7.5A (3) 5.5A (4) 3A

9. A circuit connected to an ac source of emf $e = e_0\sin(100t)$ with t in seconds, gives a phase difference of $\frac{\pi}{4}$ between the emf e and current i. Which of the following circuits will exhibit this ?

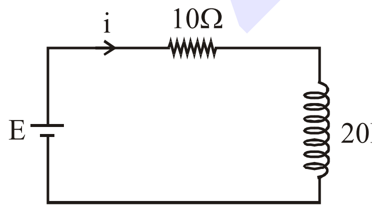
(1) RC circuit with R = 1 kΩ and C = 1μF

(2) RL circuit with R = 1kΩ and L = 1mH

(3) RL circuit with R = 1 kΩ and L = 10 mH

(4) RC circuit with R = 1kΩ and C = 10 μF

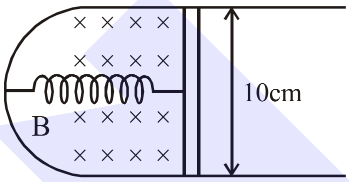
10. A 20 Henry inductor coil is connected to a 10 ohm resistance in series as shown in figure. The time at which rate of dissipation of energy (joule's heat) across resistance is equal to the rate at which magnetic energy is stored in the inductor is :



(1) $\frac{2}{\ell n2}$ (2) $\ell n2$

(3) $2\ell n2$ (4) $\frac{1}{2}\ell n2$

11. A thin strip 10 cm long is on a U shaped wire of negligible resistance and it is connected to a spring of spring constant 0.5 Nm^{-1} (see figure). The assembly is kept in a uniform magnetic field of 0.1 T. If the strip is pulled from its equilibrium position and released, the number of oscillation it performs before its amplitude decreases by a factor of e is N. If the mass of the strip is 50 grams, its resistance 10Ω and air drag negligible, N will be close to :



(1) 50000 (2) 5000

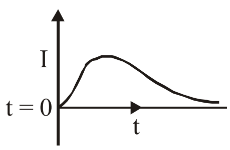
(3) 10000 (4) 1000

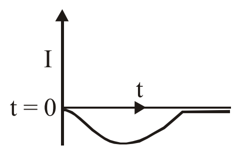
12. An alternating voltage v(t) = 220 sin 100 πt volt is applied to a purely resistance load of 50 Ω. The time taken for the current to rise from half of the peak value to the peak value is :

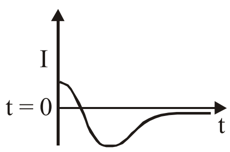
(1) 2.2 ms (2) 5 ms

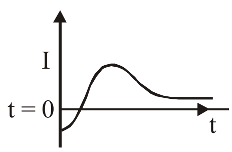
(3) 3.3 ms (4) 7.2 ms

13. A very long solenoid of radius R is carrying current $I(t) = kte^{-\alpha t}(k > 0)$, as a function of time $(t \geq 0)$. counter clockwise current is taken to be positive. A circular conducting coil of radius 2R is placed in the equatorial plane of the solenoid and concentric with the solenoid. The current induced in the outer coil is correctly depicted, as a function of time, by :-

(1) 

(2) 

(3) 

(4) 

14. The total number of turns and cross-section area in a solenoid is fixed. However, its length L is varied by adjusting the separation between windings. The inductance of solenoid will be proportional to :

(1) $1/L^2$ (2) $1/L$ (3) L (4) L^2

15. A coil of self inductance 10 mH and resistance 0.1 Ω is connected through a switch to a battery of internal resistance 0.9 Ω. After the switch is closed, the time taken for the current to attain 80% of the saturation value is : (Take $\ln 5 = 1.6$)

(1) 0.103 s (2) 0.016 s
(3) 0.002 s (4) 0.324 s

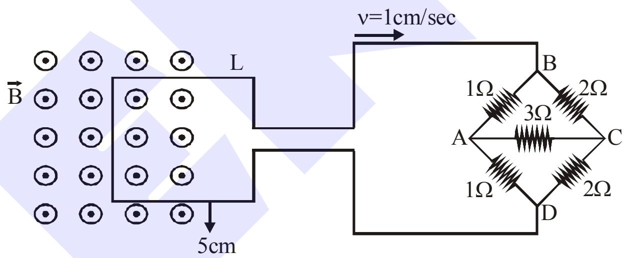
16. A transformer consisting of 300 turns in the primary and 150 turns in the secondary gives output power of 2.2 kW. If the current in the secondary coil is 10A, then the input voltage and current in the primary coil are :

(1) 220 V and 10A (2) 440 V and 5A
(3) 440 V and 20 A (4) 220 V and 20 A

17. The displacement of a damped harmonic oscillator is given by
$x(t) = e^{-0.1t}\cos(10\pi t + \phi)$. Here t is in seconds. The time taken for its amplitude of vibration to drop to half of its initial value is close to :

(1) 13 s (2) 7 s (3) 27 s (4) 4 s

18. The figure shows a square loop L of side 5 cm which is connected to a network of resistances. The whole setup is moving towards right with a constant speed of 1 cms^{-1}. At some instant, a part of L is in a uniform magnetic field of 1T, perpendicular to the plane of the loop. If the resistance of L is 1.7 Ω, the current in the loop at that instant will be close to :



(1) 115 μA (2) 170 μA
(3) 60 μA (4) 150 μA

SOLUTION

1. Ans. (4)

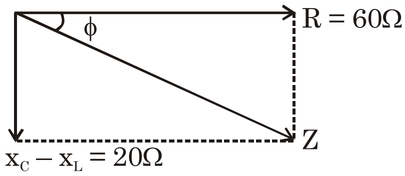
$R = 60\Omega \quad f = 50\text{Hz},\ \omega = 2\pi f = 100\ \pi$

$x_C = \frac{1}{\omega C} = \frac{1}{100\pi \times 120 \times 10^{-6}}$

$x_C = 26.52\ \Omega$

$x_L = \omega L = 100\pi \times 20 \times 10^{-3} = 2\pi\Omega$

$x_C - x_L = 20.24 \approx 20$



$z = \sqrt{R^2 + (x_C - x_L)^2}$

$z = 20\sqrt{10}\Omega$

$\cos\phi = \frac{R}{z} = \frac{3}{\sqrt{10}}$

$P_{avg} = VI\cos\phi,\ I = \frac{V}{z}$

$= \frac{V^2}{z}\cos\phi$

$= 8.64$ watt

$Q = P.t = 8.64 \times 60 = 5.18 \times 10^2$

2. Ans. (4)

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

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

$\Rightarrow I_S = 45A$

3. Ans. (1)

$L\frac{di}{dt} = 25$

$L \times \frac{15}{1} = 25$

$L = \frac{5}{3}H$

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

4. Ans. (3)

Potential difference between two faces perpendicular to x-axis will be

$\ell.(\vec{V} \times \vec{B}) = 12mV$

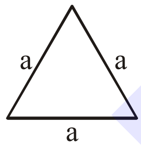
5. Ans. (2)

Total length L will remain constant

$L = (3a)\ N \qquad$ (N = total turns)

and length of winding = (d) N

(d = diameter of wire)



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

$= \mu_0 n^2 \left(\frac{\sqrt{3}a^2}{4}\right) dN$

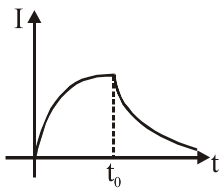
$\propto a^2\ N \propto a$

So self inductance will become 3 times

6. Correct Ans. (2)

According to JEE-Mains Ans. key (1 or 3 or 4)

From time $t = 0$ to $t = t_0$, growth of current takes place and after that decay of current takes place.

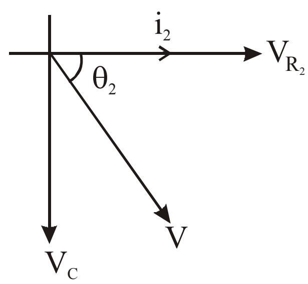


most appropriate is (2)

7. Ans. (3)

According to JEE-Mains Ans. key (Bonus)

For L-C circuit :

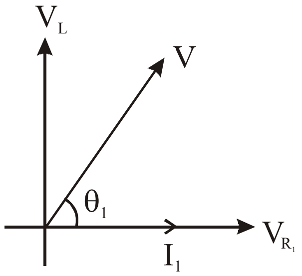


$\tan\theta_2 = \frac{x_C}{R_2} = \frac{10^3}{\sqrt{3}}$

θ_2 is close to 90°

For L–R circuit :

$x_L = \omega L = 100 \times \frac{\sqrt{3}}{10} = 10\sqrt{3}$



$R_1 = 10$

$\tan\theta_1 = \frac{x_e}{R}$

$\tan\theta_1 = \sqrt{3}$

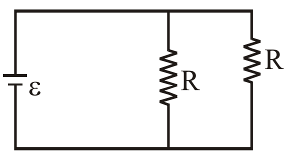
$\theta_1 = 60$

So phase difference comes out 90 + 60 = 150.

Therefore Ans. is Bonus

8. Ans. (1)

Ideal inductor will behave like zero resistance long time after switch is closed



$I = \frac{2\varepsilon}{R} = \frac{2 \times 15}{5} = 6A$

9. Ans. (4)

Sol. Given phase difference = $\frac{\pi}{4}$

and ω = 100 rad/s

⇒ Reactance (X) = Resistance (R)

now by checking options

Option (1)

$R = 1000\ \Omega$ and $X_C = \frac{1}{10^{-6} \times 100} = 10^4\,\Omega$

Option (2)

$R = 10^3\ \Omega$ and $X_L = 10^{-3} \times 100 = 10^{-1}\Omega$

Option (3)

$R = 10^3\ \Omega$ and $X_L = 10 \times 10^{-3} \times 100 = 1\Omega$

Option (4)

$R = 10^3\ \Omega$ and $X_C = \frac{1}{10 \times 10^{-6} \times 100} = 10^3\,\Omega$

Clear option (4) matches the given condition

10. Ans. (3)

Sol. $LIdI = I^2R$

$$L \times \frac{E}{10}\left(-e^{-t/2}\right) \times \frac{-1}{2} = \frac{E}{10}\left(1 - e^{-t/2}\right) \times 10$$

$e^{-t/2} = 1 - e^{-t/2}$

$t = 2\ell n2$

11. Ans. (2)

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

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

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

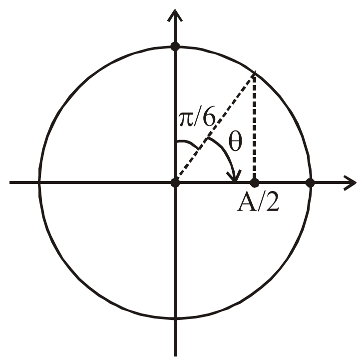
$\therefore$ for $A = \frac{A_0}{e}$, $t = \gamma$

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

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

12. Ans. (3)

Sol.



V(t) = 220 sin(100πt) volt

time taken,

$$t = \frac{\theta}{\omega} = \frac{\frac{\pi}{3}}{100\pi} = \frac{1}{300}\,\text{sec}$$

= 3.3 ms

13. Official Ans. by NTA (2)

Final Ans. by NTA (4)

Sol. $\phi_{outer} = (\mu_0 nKte^{-\alpha t})4\pi R^2$

$$\varepsilon = \frac{-d\phi}{dt} = -Ce^{-\alpha t}[1-\alpha t]$$

$$i_{induced} = \frac{-Ce^{-\alpha t}\ [1-at]}{(Resistance)}$$

At $t=0$ $i_{induced} = -ve.$

14. Ans. (2)

Sol. $\phi = NBA = LI$

$N\mu_0 nI\pi R^2 = LI$

$$N\mu_0 \frac{N}{\ell} I\pi R^2 = LI$$

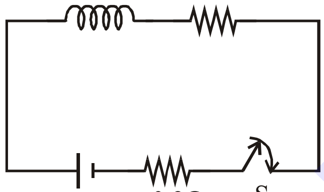
N & R constant

self inductance (L) $\propto \frac{1}{\ell} \propto \frac{1}{\text{length}}$

Option (2)

15. Ans. (2)

Sol.



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

$$\frac{80}{100} i_0 = i_0(1-e^{-t/\tau})$$

$0.8 = 1 - e^{-t/\tau}$

$$e^{-t/\tau} = 0.2 = \frac{1}{5}$$

$$-\frac{t}{\tau} = \ln\left(\frac{1}{5}\right)$$

$$-\frac{t}{\tau} = -\ln(5)$$

$t = \tau.\ln(5)$

$$= \frac{L}{R_{eq}}.\ln(5)$$

$$= \frac{10\times10^{-3}}{(0.1+0.9)} \times 1.6$$

$t = 1.6 \times 10^{-2}$

$t = 0.016$ s

16. Ans. (2)

Sol. Given $N_P = 300$, $N_s = 150$, $P_0 = 2200W$

$I_s = 10A$

$P_0 = V_0 I_0 \Rightarrow 2200 = V_0 \times 10 \Rightarrow V_0 = 220V$

$$\because \frac{V_i}{V_0} = \frac{N_p}{N_s} \Rightarrow V_i = 2\times220 = 440V$$

Also $P_0 = V_i I_i$

$$\Rightarrow I_i = \frac{2200}{440} = 5A$$

17. Ans. (2)

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

$\ell n2 = 0.1t$

$t = 10\ \ell n2 = 6.93 \approx 7$ sec

18. Ans. (2)

Sol. Since it is a balanced wheatstone bridge, its

equivalent resistance $= \frac{4}{3}\Omega$

$\varepsilon = B\ell v = 5 \times 10^{-4}$ V

So total resistance

$$R = \frac{4}{3} + 1.7 \approx 3\Omega$$

$$\therefore i = \frac{\varepsilon}{R} \approx 166\mu A \approx 170\mu A$$