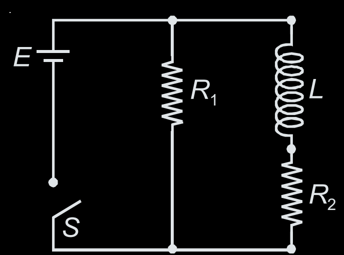
# Chapter 19

# Electromagnetic Induction

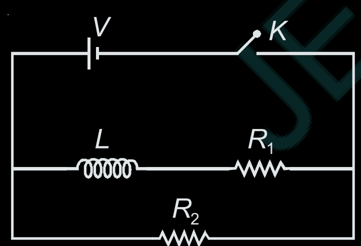
1. An inductor of inductance $L$ = 400 mH and resistors of resistances $R_1$ = 2 Ω and $R_2$ = 2 Ω are connected to a battery of emf 12 V as shown in the figure. The internal resistance of the battery is negligible. The switch $S$ is closed at $t$ = 0. The potential drop across $L$ as a function of time is **[AIEEE-2009]**




(1) $\frac{12}{t}e^{-3t}$ V (2) $6(1 - e^{-t/0.2})$ V

(3) $12e^{-5t}$ V (4) $6e^{-5t}$ V

2. In the circuit shown below, the key $K$ is closed at $t$ = 0. The current through the battery is **[AIEEE-2010]**



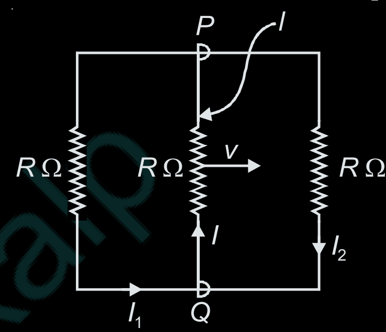

(1) $\frac{V(R_1+R_2)}{R_1R_2}$ at $t$ = 0 and $\frac{V}{R_2}$ at $t = \infty$

(2) $\frac{VR_1R_2}{\sqrt{R_1^2+R_2^2}}$ at $t$ = 0 and $\frac{V}{R_2}$ at $t = \infty$

(3) $\frac{V}{R_2}$ at $t$ = 0 and $\frac{V(R_1+R_2)}{R_1R_2}$ at $t = \infty$

(4) $\frac{V}{R_2}$ at $t$ = 0 and $\frac{VR_1R_2}{\sqrt{R_1^2+R_2^2}}$ at $t = \infty$

3. A rectangular loop has a sliding connector $PQ$ of length $l$ and resistance $R$ Ω and it is moving with a speed $v$ as shown. The set-up is placed in a uniform magnetic field going into the plane of the paper. The three currents $I_1$, $I_2$ and $I$ are **[AIEEE-2010]**




(1) $I_1 = I_2 = \frac{Blv}{6R}, I = \frac{Blv}{3R}$

(2) $I_1 = -I_2 = \frac{Blv}{R}, I = \frac{2Blv}{R}$

(3) $I_1 = I_2 = \frac{Blv}{3R}, I = \frac{2Blv}{3R}$

(4) $I_1 = I_2 = I = \frac{Blv}{R}$

4. A horizontal straight wire 20 m long extending from east to west is falling with a speed of 5.0 m/s, at right angles to the horizontal component of the earth's magnetic field 0.30 × $10^{-4}$ Wb/m$^2$. The instantaneous value of the e.m.f. induced in the wire will be **[AIEEE-2011]**

(1) 1.5 mV

(2) 6.0 mV

(3) 3 mV

(4) 4.5 mV

5. A coil is suspended in a uniform magnetic field, with the plane of the coil parallel to the magnetic lines of force. When a current is passed through the coil it starts oscillating; it is very difficult to stop. But if an aluminium plate is placed near to the coil, it stops. This is due to **[AIEEE-2012]**

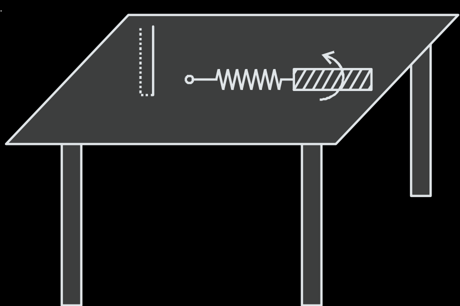
(1) Induction of electrical charge on the plate

(2) Shielding of magnetic lines of force as aluminium is a paramagnetic material

(3) Electromagnetic induction in the aluminium plate giving rise to electromagnetic damping

(4) Development of air current when the plate is placed

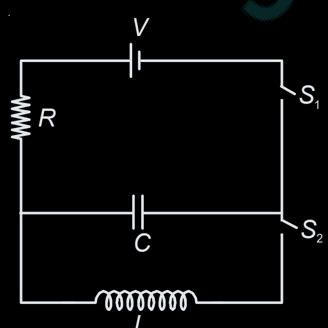
6. A metallic rod of length $l$ is tied to a string of length $2l$ and made to rotate with angular speed $\omega$ on a horizontal table with one end of the string fixed. If there is a vertical magnetic field $B$ in the region, the e.m.f. induced across the ends of the rod is **[JEE (Main)-2013]**



(1) $\frac{2B\omega l^2}{2}$ (2) $\frac{3B\omega l^2}{2}$

(3) $\frac{4B\omega l^2}{2}$ (4) $\frac{5B\omega l^2}{2}$

7. In an LCR circuit as shown below both switches are open initially. Now switch $S_1$ is closed, $S_2$ kept open ($q$ is charge on the capacitor and $\tau$ = RC is Capacitive time constant). Which of the following statement is correct ? **[JEE (Main)-2013]**



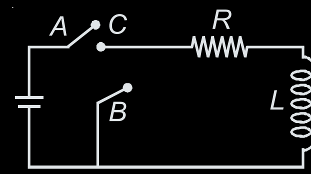

(1) Work done by the battery is half of the energy dissipated in the resistor

(2) At $t = \tau$ , $q = CV/2$

(3) At $t = 2\tau$ , $q = CV(1 - e^{-2})$

(4) At $t = \frac{\tau}{2}$ , $q = CV(1 - e^{-1})$

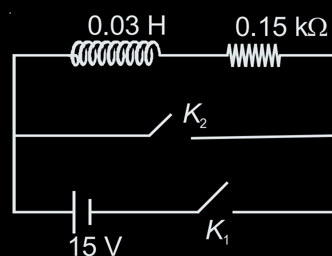
8. In the circuit shown here, the point '$C$' is kept connected to point '$A$' till the current flowing through the circuit becomes constant. Afterward, suddenly, point '$C$' is disconnected from point '$A$' and connected to point '$B$' at time $t$ = 0. Ratio of the voltage across resistance and the inductor at $t = L/R$ will be equal to **[JEE (Main)-2014]**




(1) $\frac{e}{1-e}$ (2) 1

(3) –1 (4) $\frac{1-e}{e}$

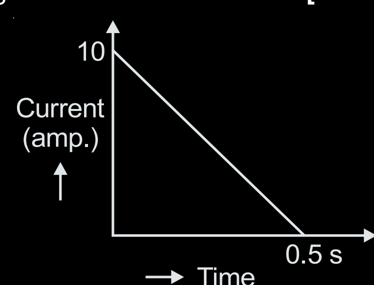
9. An inductor ($L$ = 0.03 H) and a resistor ($R$ = 0.15 k$\Omega$) are connected in series to a battery of 15 V EMF in a circuit shown below. The key $K_1$ has been kept closed for a long time. Then at $t$ = 0, $K_1$ is opened and key $K_2$ is closed simultaneously. At $t$ = 1 ms, the current in the circuit will be ($e^5 \cong 150$) **[JEE (Main)-2015]**




(1) 100 mA (2) 67 mA

(3) 6.7 mA (4) 0.67 mA

10. In a coil of resistance 100 $\Omega$, a current is induced by changing the magnetic flux through it as shown in the figure. The magnitude of change in flux through the coil is **[JEE (Main)-2017]**




(1) 200 Wb

(2) 225 Wb

(3) 250 Wb

(4) 275 Wb

11. A conducting circular loop made of a thin wire, has area $3.5 \times 10^{-3}$ m$^2$ and resistance 10 $\Omega$. It is placed perpendicular to a time dependent magnetic field $B(t) = (0.4T)\sin(50\pi t)$. The field is uniform in space. Then the net charge flowing through the loop during $t = 0$ s and $t = 10$ ms is close to

**[JEE (Main)-2019]**

(1) 7 mC  (2) 0.14 mC
(3) 6 mC  (4) 14 mC

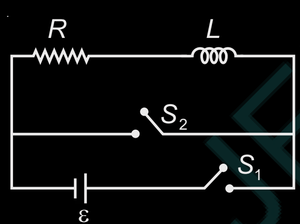
12. A solid metal cube of edge length 2 cm is moving in a positive $y$-direction at a constant speed of 6 m/s. There is a uniform magnetic field of 0.1 T in the positive $z$-direction. The potential difference between the two faces of the cube perpendicular to the $x$-axis, is **[JEE (Main)-2019]**

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

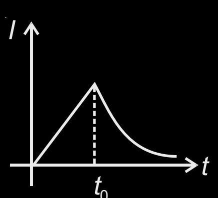
13. The self induced emf of a coil is 25 volts. When the current in it is changed at uniform rate from 10 A to 25 A in 1 s, the change in the energy of the inductance is **[JEE (Main)-2019]**

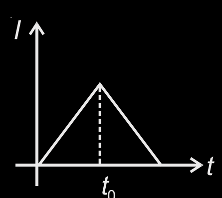
(1) 437.5 J  (2) 740 J
(3) 637.5 J  (4) 540 J

14. 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 behaviour of the current $I$ as a function of time '$t$' is given by **[JEE (Main)-2019]**

(1)



(2)
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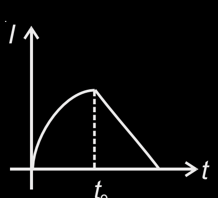
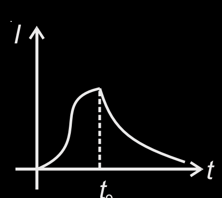



(4)



15. There are two long co-axial solenoids of same length $l$. The inner and outer coils have radii $r_1$ and $r_2$ and number of turns per unit length $n_1$ and $n_2$, respectively. The ratio of mutual inductance to the self inductance of the inner-coil is

**[JEE (Main)-2019]**

(1) $\frac{n_2}{n_1} \cdot \frac{r_2^2}{r_1^2}$  (2) $\frac{n_2}{n_1}$

(3) $\frac{n_2}{n_1} \cdot \frac{r_1}{r_2}$  (4) $\frac{n_1}{n_2}$

16. 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 **[JEE (Main)-2019]**

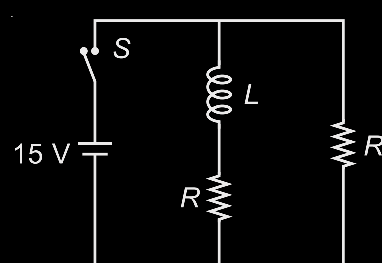
(1) Increases by a factor of 3

(2) Decreases by a factor of $9\sqrt{3}$

(3) Decreases by a factor of 9

(4) Increases by a factor of 27

17. In the figure shown, a circuit contains two identical resistors with resistance $R = 5\ \Omega$ and an inductance with $L = 2$ mH. 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? **[JEE (Main)-2019]**



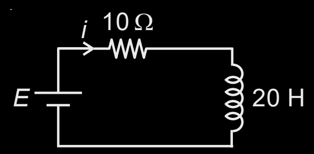

(1) 7.5 A  (2) 3 A
(3) 6 A  (4) 5.5 A

18. Let $l$, $r$, $c$ and $v$ represent inductance, resistance, capacitance and voltage, respectively. The dimension of $\frac{1}{rcv}$ in SI units will be

**[JEE (Main)-2019]**

(1) $[A^{-1}]$  (2) $[LA^{-2}]$
(3) $[LT^2]$  (4) $[LTA]$

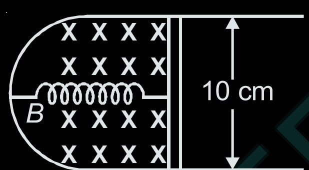
19. A 20 henry inductor coil is connected to a 10 ohm resistance in series as shown in figure. The time at which rate of dissipation of energy (Joule's heat) across resistance is equal to the rate at which magnetic energy is stored in the inductor, is **[JEE (Main)-2019]**




(1) $\frac{2}{\ln 2}$ (2) $2 \ln 2$

(3) $\ln 2$ (4) $\frac{1}{2}\ln 2$

20. 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 oscillations it performs before its amplitude decreases by a factor of $e$ is $N$. If the mass of the strip is 50 grams, its resistance 10 Ω and air drag negligible, $N$ will be close to **[JEE (Main)-2019]**




(1) 1000 (2) 5000

(3) 50000 (4) 10000

21. 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

**[JEE (Main)-2019]**

(1) $1/L$ (2) $L$

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

22. Two coils '$P$' and '$Q$' are separated by some distance. When a current of 3 A flows through coil '$P$', a magnetic flux of $10^{-3}$ Wb passes through $Q$. No current is passed through '$Q$'. When no current passes through '$P$' and a current of 2 A passes through '$Q$', the flux through '$P$' is

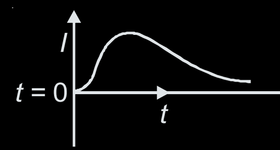
**[JEE (Main)-2019]**

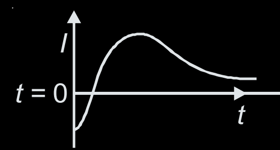
(1) $6.67 \times 10^{-3}$ Wb (2) $6.67 \times 10^{-4}$ Wb

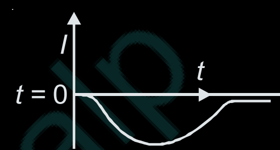
(3) $3.67 \times 10^{-3}$ Wb (4) $3.67 \times 10^{-4}$ Wb

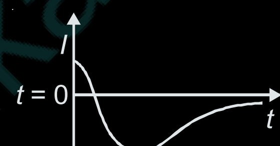
23. A very long solenoid of radius $R$ is carrying current $I(t) = kte^{-\alpha t}$ ($k > 0$), as a function of time ($t \geq 0$). Counter clockwise current is taken to be positive. A circular conducting coil of radius $2R$ is placed in the equatorial plane of the solenoid and concentric with the solenoid.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

**[JEE (Main)-2019]**

(1) 


(2) 


(3) 


(4) 

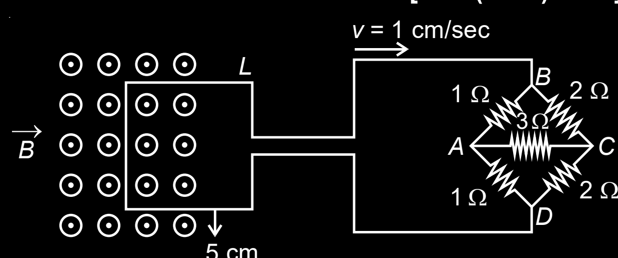

24. A coil of self inductance 10 mH and resistance 0.1 Ω is connected through a switch to a battery of internal resistance 0.9 Ω. After the switch is closed, the time taken for the current to attain 80% of the saturation value is: **[JEE (Main)-2019]**

[Take ln5 = 1.6]

(1) 0.002 s (2) 0.324 s

(3) 0.103 s (4) 0.016 s

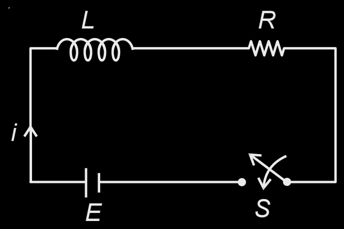
25. The figure shows a square loop $L$ of side 5 cm which is connected to a network of resistances. The whole setup is moving towards right with a constant speed of 1 cm $s^{-1}$. At some instant, a part of $L$ is in a uniform magnetic field of 1 T, perpendicular to the plane of the loop. If the resistance of $L$ is 1.7 Ω, the current in the loop at that instant will be close to: **[JEE (Main)-2019]**




(1) 170 μA (2) 60 μA

(3) 150 μA (4) 115 μA

26. Consider the $LR$ circuit shown in the figure. If the switch $S$ is closed at $t = 0$ then the amount of charge that passes through the battery between $t = 0$ and $t = \frac{L}{R}$ is: **[JEE (Main)-2019]**




(1) $\frac{2.7\,EL}{R^2}$ (2) $\frac{EL}{2.7\,R^2}$

(3) $\frac{7.3\,EL}{R^2}$ (4) $\frac{EL}{7.3\,R^2}$

27. A long solenoid of radius $R$ carries a time ($t$) - dependent current $I(t) = I_0 t(1 - t)$. A ring of radius $2R$ is placed coaxially near its middle. During the time interval $0 \le t \le 1$, the induced current ($I_R$) and the induced EMF ($V_R$) in the ring change as **[JEE (Main)-2020]**

(1) Direction of $I_R$ remains unchanged and $V_R$ is zero at $t = 0.25$

(2) Direction of $I_R$ remains unchanged and $V_R$ is maximum at $t = 0.5$

(3) At $t = 0.5$ direction of $I_R$ reverses and $V_R$ is zero

(4) At $t = 0.25$ direction of $I_R$ reverses and $V_R$ is maximum

28. An emf of 20 V is applied at time $t = 0$ to a circuit containing in series 10 mH inductor and 5 Ω resistor. The ratio of the currents at time $t = \infty$ and at $t = 40$ s is close to **[JEE (Main)-2020]**

(Take $e^2 = 7.389$)

(1) 1.06 (2) 1.15

(3) 1.46 (4) 0.84

29. A planar loop of wire rotates in a uniform magnetic field. Initially, at $t = 0$, the plane of the loop is perpendicular to the magnetic field. If it rotates with a period of 10 s about an axis in its plane then the magnitude of induced emf will be maximum and minimum, respectively at **[JEE (Main)-2020]**

(1) 2.5 s and 7.5 s (2) 5.0 s and 7.5 s

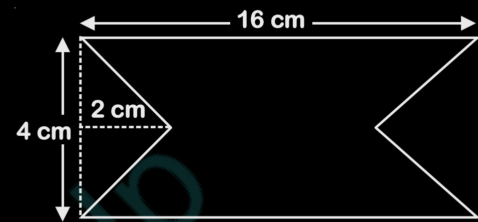
(3) 2.5 s and 5.0 s (4) 5.0 s and 10.0 s

30. The dimension of $\frac{B^2}{2\mu_0}$, where $B$ is magnetic field and $\mu_0$ is the magnetic permeability of vaccum, is **[JEE (Main)-2020]**

(1) $ML^{-1}T^{-2}$ (2) $ML^2T^{-2}$

(3) $ML^2T^{-1}$ (4) $MLT^{-2}$

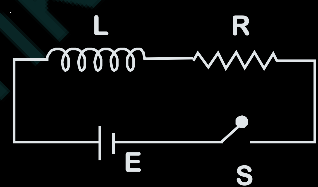
31. At time $t = 0$ magnetic field of 1000 Gauss is passing perpendicularly through the area defined by the closed loop shown in the figure. If the magnetic field reduces linearly to 500 Gauss, in the next 5 s, then induced EMF in the loop is **[JEE (Main)-2020]**




(1) 48 μV (2) 36 μV

(3) 56 μV (4) 28 μV

32.

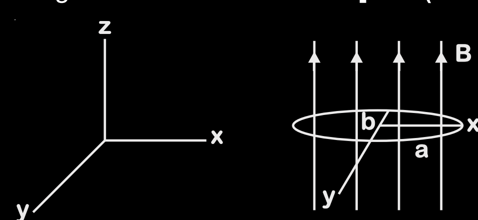



As shown in the figure, a battery of emf $E$ is connected to an inductor $L$ and resistance $R$ in series. The switch is closed at $t = 0$. The total charge that flows from the battery, between $t = 0$ and $t = t_c$ ($t_c$ is the time constant of the circuit) is **[JEE (Main)-2020]**

(1) $\frac{EL}{R^2}$ (2) $\frac{ER}{eL^2}$

(3) $\frac{EL}{R^2}\left(1 - \frac{1}{e}\right)$ (4) $\frac{EL}{eR^2}$

33. An elliptical loop having resistance $R$, of semi major axis $a$, and semi minor axis $b$ is placed in a magnetic field as shown in the figure. If the loop is rotated about the $x$-axis with angular frequency ω, the average power loss in the loop due to Joule heating is **[JEE (Main)-2020]**



(1) $\frac{\pi abB\omega}{R}$ (2) $\frac{\pi^2a^2b^2B^2\omega^2}{2R}$

(3) Zero (4) $\frac{\pi^2a^2b^2B^2\omega^2}{R}$

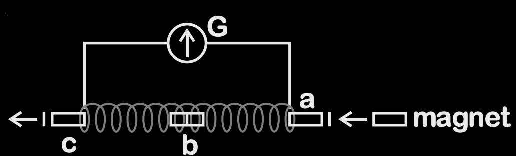
34. A uniform magnetic field $B$ exists in a direction perpendicular to the plane of a square loop made of a metal wire. The wire has a diameter of 4 mm and a total length of 30 cm. The magnetic field changes with time at a steady rate $dB/dt = 0.032$ $Ts^{-1}$. The induced current in the loop is close to (Resistivity of the metal wire is $1.23 \times 10^{-8}$ Ωm)

**[JEE (Main)-2020]**

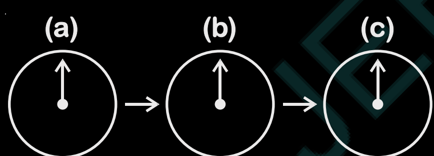
(1) 0.34 A (2) 0.61 A

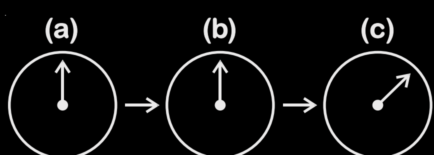
(3) 0.53 A (4) 0.43 A

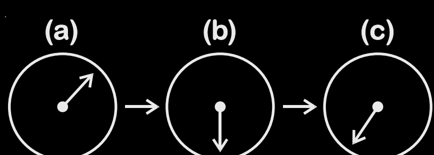
35. A small bar magnet is moved through a coil at constant speed from one end to the other. Which of the following series of observations will be seen on the galvanometer G attached across the coil?

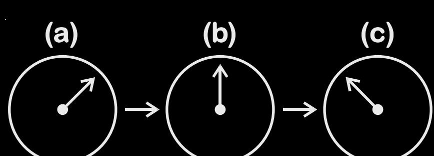



Three positions shown describe : (a) the magnet's entry (b) magnet is completely inside and (c) magnet's exit. **[JEE (Main)-2020]**

(1) 


(2) 


(3) 


(4) 

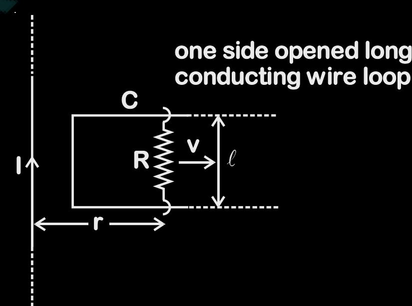

36. A series $L$-$R$ circuit is connected to a battery of emf $V$. If the circuit is switched on at $t = 0$, then the time at which the energy stored in the inductor reaches $\left(\frac{1}{n}\right)$ times of its maximum value, is

**[JEE (Main)-2020]**

(1) $\frac{L}{R}\ln\left(\frac{\sqrt{n}+1}{\sqrt{n}-1}\right)$ (2) $\frac{L}{R}\ln\left(\frac{\sqrt{n}}{\sqrt{n}-1}\right)$

(3) $\frac{L}{R}\ln\left(\frac{\sqrt{n}}{\sqrt{n}+1}\right)$ (4) $\frac{L}{R}\ln\left(\frac{\sqrt{n}-1}{\sqrt{n}}\right)$

37. An infinitely long, straight wire carrying current $I$, one side opened rectangular loop and a conductor $C$ with a sliding connector are located in the same plane, as shown, in the figure. The connector has length $\ell$ and resistance $R$. It slides to the right with a velocity $v$. The resistance of the conductor and the self inductance of the loop are negligible. The induced current in the loop, as a function of separation $r$, between the connector and the straight wire is **[JEE (Main)-2020]**




(1) $\frac{\mu_0}{4\pi}\frac{Iv\ell}{Rr}$ (2) $\frac{\mu_0}{\pi}\frac{Iv\ell}{Rr}$

(3) $\frac{\mu_0}{2\pi}\frac{Iv\ell}{Rr}$ (4) $\frac{2\mu_0}{\pi}\frac{Iv\ell}{Rr}$

38. In a fluorescent lamp choke (a small transformer) 100 V of reverse voltage is produced when the choke current changes uniformly from 0.25 A to 0 in a duration of 0.025 ms. The self inductance of the choke(in mH) is estimated to be _______

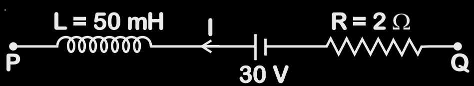
**[JEE (Main)-2020]**

39. A circular coil of radius 10 cm is placed in a uniform magnetic field of $3.0 \times 10^{-5}$ T with its plane perpendicular to the field initially. It is rotated at constant angular speed about an axis along the diameter of coil and perpendicular to magnetic field so that it undergoes half of rotation in 0.2 s. The maximum value of EMF induced (in μV) in the coil will be close to the integer _______.

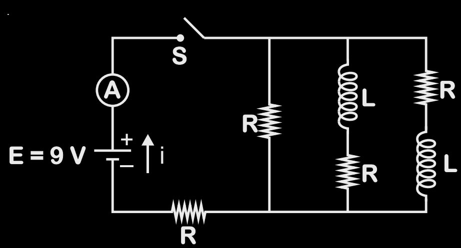
**[JEE (Main)-2020]**

40. Two concentric circular coils, $C_1$ and $C_2$ are placed in the $XY$ plane. $C_1$ has 500 turns, and a radius of 1 cm. $C_2$ has 200 turns and radius of 20 cm. $C_2$ carries a time dependent current $I(t) = (5t^2 - 2t + 3)$ A where $t$ is in s. The emf induced in $C_1$ (in mV), at the instant $t = 1$ s is $\frac{4}{x}$. The value of $x$ is _____ . **[JEE (Main)-2020]**

41. A part of a complete circuit is shown in the figure. At some instant, the value of current $I$ is 1 A and it is decreasing at a rate of $10^2$ A $s^{-1}$. The value of the potential difference $V_P - V_Q$, (in volts) at that instant, is _________. **[JEE (Main)-2020]**



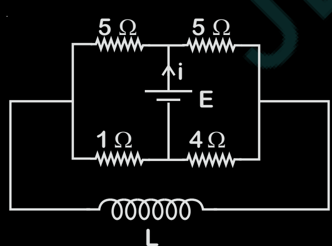

42. Figure shows a circuit that contains four identical resistors with resistance R = 2.0 Ω, two identical inductors with inductance L = 2.0 mH and an ideal battery with emf E = 9 V. The current 'i' just after the switch 'S' is closed will be **[JEE (Main)-2021]**




(1) 3.37 A (2) 3.0 A

(3) 2.25 A (4) 9 A

43. The current (i) at time t = 0 and t = ∞ respectively for the given circuit is : **[JEE (Main)-2021]**




(1) $\frac{5E}{18}, \frac{10E}{33}$

(2) $\frac{18E}{55}, \frac{5E}{18}$

(3) $\frac{5E}{18}, \frac{18E}{55}$

(4) $\frac{10E}{33}, \frac{5E}{18}$

44. A coil of inductance 2 H having negligible resistance is connected to a source of supply whose voltage is given by V = 3t volt. (where t is in second). If the voltage is applied when t = 0, then the energy stored in the coil after 4 s is _________ J. **[JEE (Main)-2021]**

45. An aeroplane, with its wings spread 10 m, is flying at a speed of 180 km/h in a horizontal direction. The total intensity of earth's field at that part is $2.5 \times 10^{-4}$ Wb/m$^2$ and the angle of dip is 60°. The emf induced between the tips of the plane wings will be _________ . **[JEE (Main)-2021]**

(1) 108.25 mV

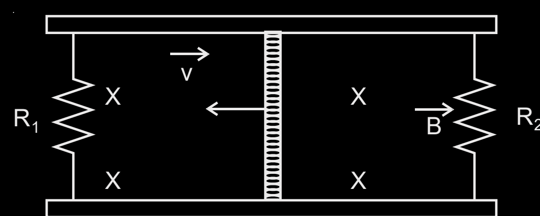
(2) 88.37 mV

(3) 62.50 mV

(4) 54.125 mV

46. A conducting bar of length L is free to slide on two parallel conducting rails as shown in the figure

**[JEE (Main)-2021]**




Two resistors $R_1$ and $R_2$ are connected across the ends of the rails. There is a uniform magnetic field $\vec{B}$ pointing into the page. An external agent pulls the bar to the left at a constant speed v.

The correct statement about the directions of induced currents $I_1$ and $I_2$ flowing through $R_1$ and $R_2$ respectively is:

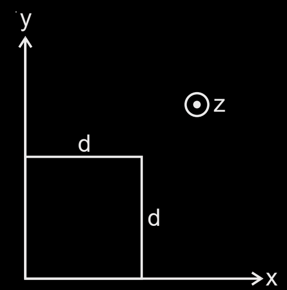
(1) $I_1$ is in clockwise direction and $I_2$ is in anticlockwise direction

(2) $I_1$ is in anticlockwise direction and $I_2$ is in clockwise direction

(3) Both $I_1$ and $I_2$ are in clockwise direction

(4) Both $I_1$ and $I_2$ are in anticlockwise direction

47. The magnetic field in a region is given by $\vec{B} = B_0\left(\frac{x}{a}\right)\hat{k}$. A square loop of side d is placed with its edges along the x and y axes. The loop is moved with a constant velocity $\vec{v} = v_0\hat{i}$. The emf induced in the loop is: **[JEE (Main)-2021]**




(1) $\frac{B_0 v_0 d^2}{2a}$

(2) $\frac{B_0 v_0 d^2}{a}$

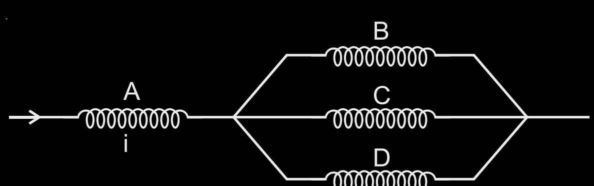
(3) $\frac{B_0 v_0 d}{2a}$

(4) $\frac{B_0 v_0^2 d}{2a}$

48. Four identical long solenoids A, B, C and D are connected to each other as shown in the figure. If the magnetic field at the center of A is 3 T, the field at the centre of C would be:

(Assume that the magnetic field is confined within the volume of respective solenoid).

**[JEE (Main)-2021]**




(1) 12 T

(2) 9 T

(3) 1 T

(4) 6 T

49. The time taken for the magnetic energy to reach 25% of its maximum value, when a solenoid of resistance R, inductance L is connected to a battery, is: **[JEE (Main)-2021]**

(1) $\frac{L}{R}\ln 5$

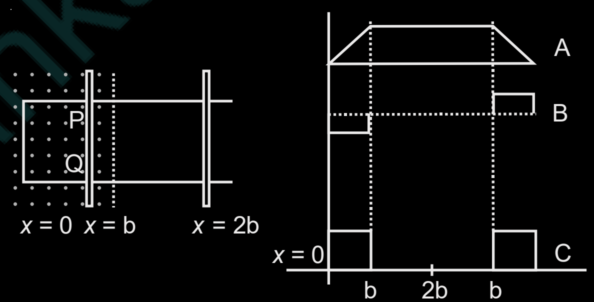
(2) Infinite

(3) $\frac{L}{R}\ln 10$

(4) $\frac{L}{R}\ln 2$

50. The arm PQ of a rectangular conductor is moving from $x = 0$ to $x = 2b$ outwards and then inwards from $x = 2b$ to $x = 0$ as shown in the figure.

A uniform magnetic field perpendicular to the plane is acting from $x = 0$ to $x = b$. Identify the graph showing the variation of different quantities with distance. **[JEE (Main)-2021]**




(1) A-Flux, B-EMF, C-Power dissipated

(2) A-Flux, B-Power dissipated, C-EMF

(3) A-Power dissipated, B-Flux, C-EMF

(4) A-EMF, B-Power dissipated, C-Flux

51. An inductor of 10 mH is connected to a 20 V battery through a resistor of 10 kΩ and a switch. After a long time, when maximum current is set up in the circuit, the current is switched off. The current in the circuit after 1 μs is $\frac{x}{100}$ mA. Then $x$ is equal to ________. (Take $e^{-1} = 0.37$)

**[JEE (Main)-2021]**

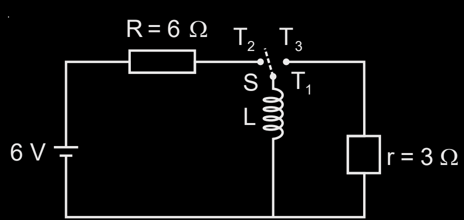
52. A circular conducting coil of radius 1 m is being heated by the change of magnetic field $\vec{B}$ passing perpendicular to the plane in which the coil is laid. The resistance of the coil is 2 μΩ. The magnetic field is slowly switched off such that its magnitude changes in time as **[JEE (Main)-2021]**

$$B = \frac{4}{\pi} \times 10^{-3} T\left(1 - \frac{t}{100}\right)$$

The energy dissipated by the coil before the magnetic field is switched off completely is E = _______mJ.

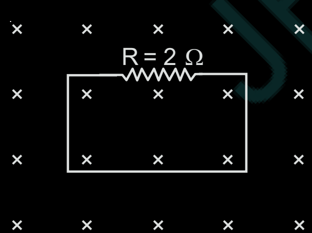
53. Consider an electrical circuit containing a two way switch 'S'. Initially S is open and then $T_1$ is connected to $T_2$. As the current in R = 6 Ω attains a maximum value of steady state level, $T_1$ is disconnected from $T_2$ and immediately connected to $T_3$. Potential drop across r = 3 Ω resistor immediately after $T_1$ is connected to $T_3$ is ________ V. (Round off to the nearest integer)

**[JEE (Main)-2021]**




54. In the given figure the magnetic flux through the loop increases according to the relation $\phi_\beta(t) = 10t^2 + 20t$, where $\phi_\beta$ is in milliwebers and $t$ is in seconds.

The magnitude of current through R = 2 Ω resistor at $t$ = 5 s is _____ mA. **[JEE (Main)-2021]**




55. An inductor coil stores 64 J of magnetic field energy and dissipates energy at the rate of 640 W when a current of 8 A is passed through it. If this coil is joined across an ideal battery, find the time constant of the circuit in seconds.

**[JEE (Main)-2021]**

(1) 0.4

(2) 0.8

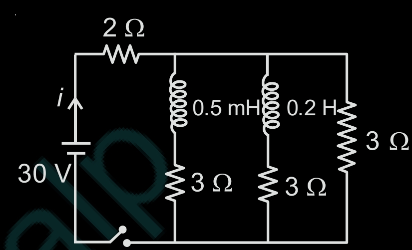
(3) 0.2

(4) 0.125

56. A circular coil of radius 8.0 cm and 20 turns is rotated about its vertical diameter with an angular speed of 50 rads$^{-1}$ in a uniform horizontal magnetic field of 3.0 × $10^{-2}$ T. The maximum emf induced the coil will be ______ × $10^{-2}$ volt (rounded off to the nearest integer). **[JEE (Main)-2021]**

57. For the given circuit the current $i$ through the battery when the key in closed and the steady state has been reached is ______.

**[JEE (Main)-2021]**



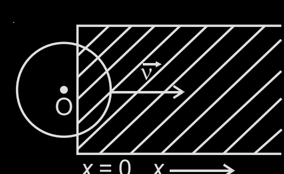

(1) 6 A

(2) 10 A

(3) 0 A

(4) 25 A

58. A constant magnetic field of 1 T is applied in the $x$ > 0 region. A metallic circular ring of radius 1 m is moving with a constant velocity 1 m/s along the $x$-axis. At t = 0 s, the centre O of the ring is at $x$ = –1 m. What will be the value of the induced emf in the ring at t = 1 s? (Assume the velocity of the ring does not change) **[JEE (Main)-2021]**




(1) 2 V

(2) 2π V

(3) 1 V

(4) 0 V

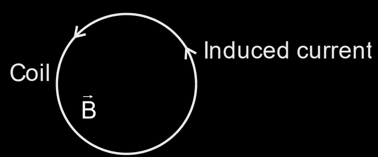
59. A small square loop of side 'a' and one turn is placed inside a larger square loop of side b and one turn (b > >a). The two loops are coplanar with their centres coinciding. If a current is passed in the square loop of side 'b', then the coefficient of mutual inductance between the two loops is:

[JEE (Main)-2021]

(1) $\frac{\mu_0}{4\pi}\frac{8\sqrt{2}}{b}$ (2) $\frac{\mu_0}{4\pi}8\sqrt{2}\frac{a^2}{b}$

(3) $\frac{\mu_0}{4\pi}\frac{8\sqrt{2}}{a}$ (4) $\frac{\mu_0}{4\pi}8\sqrt{2}\frac{b^2}{a}$

60. A coil is placed in a magnetic field $\vec{B}$ as shown below: [JEE (Main)-2021]




A current is induced in the coil because $\vec{B}$ is:

(1) parallel to the plane of coil and increasing with time

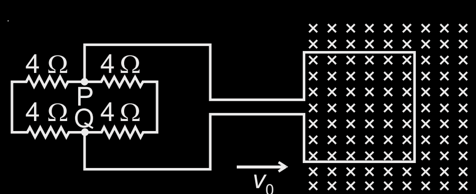
(2) outward and decreasing with time

(3) outward and increasing with time

(4) parallel to the plane of coil and decreasing with time

61. A square loop of side 20 cm and resistance 1 Ω is moved towards right with a constant speed $v_0$. The right arm of the loop is in a uniform magnetic field of 5 T. The field is perpendicular to the plane of the loop and is going into it. The loop is connected to a network of resistors each of value 4 Ω. What should be the value of $v_0$ so that a steady current of 2 mA flows in the loop?

[JEE (Main)-2021]




(1) 1 m/s (2) $10^{-2}$ cm/s

(3) 1 cm/s (4) $10^2$ m/s

62. A circular coil of 1000 turns each with area 1 $m^2$ is rotated about its vertical diameter at the rate of one revolution per second in a uniform horizontal magnetic field of 0.07 T. The maximum voltage generation will be _______ V. [JEE (Main)-2022]

63. The current in a coil of self inductance 2.0 H is increasing according to $I = 2\sin(t^2)$ A. The amount of energy spent during the period when current changes from 0 to 2 A is _______ J. [JEE (Main)-2022]

64. The magnetic flux through a coil perpendicular to its plane is varying according to the relation $\phi = (5t^3 + 4t^2 + 2t - 5)$ Weber. If the resistance of the coil is 5 ohm, then the induced current through the coil at $t$ = 2 s will be, [JEE (Main)-2022]

(1) 15.6 A

(2) 16.6 A

(3) 17.6 A

(4) 18.6 A

65. A 10 Ω, 20 mH coil carrying constant current is connected to a battery of 20 V through a switch. Now after switch is opened current becomes zero in 100 μs. The average e.m.f. induced in the coil is ____V. [JEE (Main)-2022]

66. A metallic rod of length 20 cm is placed in North-South direction and is moved at a constant speed of 20 m/s towards East. The horizontal component of the Earth's magnetic field at that place is $4 \times 10^{-3}$ T and the angle of dip is 45°. The emf induced in the rod is __________mV. [JEE (Main)-2022]

67. A coil is placed in a time varying magnetic field. If the number of turns in the coil were to be halved and the radius of wire doubled, the electrical power dissipated due to the current induced in the coil would be:

(Assume the coil to be short circuited.)

[JEE (Main)-2022]

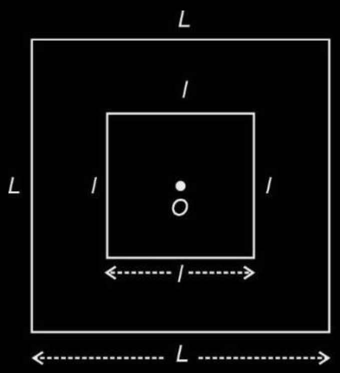
(1) Halved

(2) Quadrupled

(3) The same

(4) Doubled

68. A small square loop of wire of side $l$ is placed inside a large square loop of wire $L(L >> l)$. Both loops are coplanar and their centres coincide at point $O$ as shown in figure. The mutual inductance of the system is **[JEE (Main)-2022]**




(1) $\frac{2\sqrt{2}\,\mu_0 L^2}{\pi l}$

(2) $\frac{\mu_0 l^2}{2\sqrt{2}\,\pi L}$

(3) $\frac{2\sqrt{2}\,\mu_0 l^2}{\pi L}$

(4) $\frac{\mu_0 L^2}{2\sqrt{2}\,\pi l}$

69. When you walk through a metal detector carrying a metal object in your pocket, it raises an alarm. This phenomenon works on: **[JEE (Main)-2022]**

(1) Electromagnetic induction

(2) Resonance in ac circuits

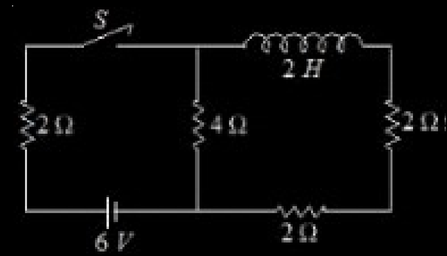
(3) Mutual induction in ac circuits

(4) Interference of electromagnetic waves

70. Magnetic flux (in weber) in a closed circuit of resistance 20 Ω varies with time $t$(s) as $\phi = 8t^2 - 9t + 5$. The magnitude of the induced current at $t$ = 0.25 s will be ______ mA. **[JEE (Main)-2022]**

71. A conducting circular loop is placed in $X$-$Y$ plane in presence of magnetic field $\vec{B} = \left(3t^3\hat{j} + 3t^2\hat{k}\right)$ in SI unit. If the radius of the loop is 1 m, the induced emf in the loop, at time $t$ = 2 s is $n\pi$ V. The value of $n$ is ______. **[JEE (Main)-2022]**

72. For the given circuit the current through battery of 6 $V$ just after closing the switch $S$ will be ______ A. **[JEE (Main)-2022]**




73. A coil of inductance 1 H and resistance 100 Ω is connected to a battery of 6 V. Determine approximately :

(a) The time elapsed before the current acquires half of its steady – state value.

(b) The energy stored in the magnetic field associated with the coil at an instant 15 ms after the circuit is switched on.

(Given ln2 = 0.693, $e^{-3/2}$ = 0.25) **[JEE (Main)-2022]**

(1) $t$ = 10 ms; U = 2 mJ

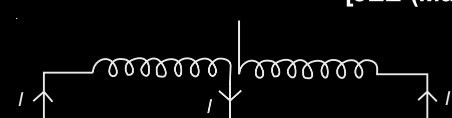
(2) $t$ = 10 ms; U = 1 mJ

(3) $t$ = 7 ms; U = 1 mJ

(4) $t$ = 7 ms; U = 2 mJ

74. In a coil of resistance 8 Ω, the magnetic flux due to an external magnetic field varies with time as $\phi = \frac{2}{3}\left(9 - t^2\right)$. The value of total heat produced in the coil, till the flux becomes zero, will be ______ J. **[JEE (Main)-2022]**

75. Two coils of self inductance $L_1$ and $L_2$ are connected in series combination having mutual inductance of the coils as $M$. The equivalent self inductance of the combination will be: **[JEE (Main)-2022]**




(1) $\frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{M}$

(2) $L_1 + L_2 + M$

(3) $L_1 + L_2 + 2M$

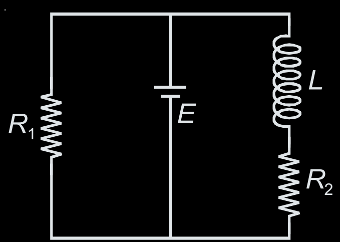
(4) $L_1 + L_2 - 2M$

Chapter 19

# Electromagnetic Induction

1. Answer (3)

Given circuit is




$I$ through inductor as a function of time is

$$I = \frac{E}{R_2}\left\{1 - e^{-t/L/R_2}\right\}$$

$$V_L = L\frac{dI}{dt} = Ee^{-\frac{R_2 t}{L}}$$

$$= 12e^{-5t}$$

2. Answer (3)

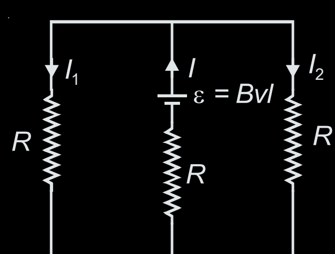
At $t = 0$, no current flows through inductor

So, $I = \dfrac{V}{R_2}$

At $t = \infty$, inductor behaves as a conductor

So, $I = \dfrac{V}{\dfrac{(R_1 R_2)}{(R_1 + R_2)}}$

3. Answer (3)




$$I = \frac{\varepsilon}{R + \frac{R}{2}} = \frac{2\varepsilon}{3R}$$

$$I_1 = \frac{\varepsilon}{3R},\ I_2 = \frac{\varepsilon}{3R}$$

where $\varepsilon = Bvl$

4. Answer (3)

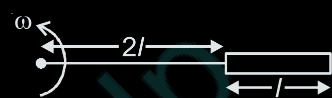
$\varepsilon = Bvl$

$= 0.30 \times 10^{-4} \times 5 \times 20$

$= 3$ mV

5. Answer (2)

6. Answer (4)




$$\varepsilon = \int_{2l}^{3l} B(x\omega)dx = B\omega\left(\frac{x^2}{2}\right)_{2l}^{3l} = \frac{5B\omega l^2}{2}$$

7. Answer (3)

It is a simple $RC$ charging circuit.

$q = CV\,(1 - e^{-t/\tau})$

$\Rightarrow$ $q = CV\,(1 - e^{-2})$, when $t = 2\tau$

8. Answer (3)

Applying Kirchhoff's law in closed loop, $-V_R - V_C = 0$

$\Rightarrow$ $V_R/V_C = -1$

Note : The sense of voltage drop has not been defined. The answer could have been 1.

9. Answer (4)

$$I = I_0 e^{-\frac{t}{\tau}},\ \tau = \frac{L}{R}$$

$$= \frac{15}{150}e^{-\frac{1\times10^{-3}}{1/5\times10^{3}}} = 0.67 \text{ mA}$$

10. Answer (3)

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

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

$$\int d\phi = R\int idt$$

Magnitude of change in flux

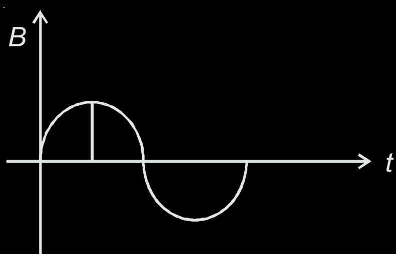
$= R \times$ area under current vs time graph

$= 100 \times \frac{1}{2} \times \frac{1}{2} \times 10$

$= 250$ Wb

11. Answer (2)

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




$$B(t) = 0.4 \sin 50\pi t$$

$$\Rightarrow \frac{2\pi}{T} = 50\pi$$

$$T = \frac{1000}{25}\text{ms} \Rightarrow T = 40 \text{ ms}$$

$$\Delta Q = \frac{0.4 \times 3.5 \times 10^{-3}}{10}$$

$$\Delta Q = 1.4 \times 10^{-4}\,\text{C}$$

12. Answer (1)

$E = vB$

$= 0.6$ V/m

$V = Ed$

$= 0.6 \times 2 \times 10^{-2}$

$= 12$ mV

13. Answer (1)

$$\Delta E = \frac{1}{2}LI_f^2 - \frac{1}{2}LI_{in}^2$$

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

$$\therefore \quad L \times \frac{25 - 10}{1} = 25$$

$$\Rightarrow \quad L = \frac{25}{15} = \frac{5}{3}\text{ H}$$

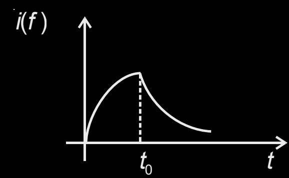
$$\therefore \quad \Delta E = \frac{1}{2} \times \frac{5}{3}(625 - 100)$$

$$\Rightarrow \Delta E = 437.5 \text{ J}$$

14. Answer (3)

$$i(f) = \frac{V}{R}(1 - e^{-\frac{R}{L}t}), \quad t \le t_0$$

$$i(f) = \frac{V}{R}e^{-\frac{R}{L}(t-t_0)}, \quad t > t_0$$




* The closest to appropriate graph is in option 3.

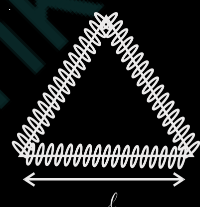
15. Answer (2)

$$M = \mu_0 n_1 n_2 \pi r_1^2 l$$

$$L = \mu_0 n_1^2 \pi r_1^2 l$$

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

16. Answer (1)




$LI = (\mu_0 nI)\, A\, (n.3\ell)$

where $n$ = No. of turns/length

$L \propto \ell$

17. Answer (3)

After long time, the inductor will behave like a wire.

$$I = \frac{15}{R/2} = \frac{30}{5} = 6\text{ A}$$

18. Answer (1)

$$\left[\frac{I}{rcv}\right] = \left[\frac{I}{TV}\right]$$

$[ML^2T^{-2}] = [IA^2]$

$\Rightarrow \quad [I] = [ML^2T^{-2}A^{-2}]$

$$[V] = \frac{ML^2T^{-2}}{AT} = ML^2T^{-3}A^{-1}$$

$$\Rightarrow \quad \left[\frac{I}{rcv}\right] = \frac{ML^2T^{-2}A^{-2}}{T\,ML^2T^{-3}A^{-1}} = [A^{-1}]$$

19. Answer (2)

$P_R = i^2 \times R$

$P_B = V \times i$

$\therefore\ P_L = Vi - i^2R$

$\Rightarrow\ Vi - i^2R = i^2R$

$$\Rightarrow\ i = \frac{V}{2R} \text{ and } i = \frac{V}{R}\cdot\left(1-e^{-t/\tau}\right)$$

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

$$\Rightarrow\ t = \tau\ln(2) = \frac{20}{10}\ln(2) = 2\ln(2)$$

20. Answer (2)

$$F = -kx - ilB = -kx - \frac{Blv}{R}\times lB$$

$$F = -kx - \frac{B^2l^2}{R}\times v$$

So, it is case of damped oscillation.

$$\Rightarrow\ A = A_0 e^{-\frac{bt}{2m}}$$

$$\Rightarrow\ \frac{A_0}{e} = A_0 e^{-\frac{bt}{2m}}$$

$$\Rightarrow\ t = \frac{2m}{\left(\frac{B^2l^2}{R}\right)} = \frac{2\times 50\times 10^{-3}\times 10}{0.01\times 0.01} = 10000\ \text{s}$$

$$\text{Time period, } T = 2\pi\sqrt{\frac{m}{k}} \simeq 2\ \text{s}$$

$$\therefore\ \text{Number, } N = \frac{10000}{2} = 5000$$

21. Answer (1)

$B = \mu_0 ni$

$\phi = \mu_0 ni(nL)\ A$

(Inductance) $L' = \mu_0 n^2 L\ A$ $\left[\eta = \frac{N}{L}\right]$

$$L' = \mu_0 NA\left(\frac{N}{L}\right)$$

$$L' \propto \frac{1}{L}$$

22. Answer (2)

$\phi_Q = Mi$

$\Rightarrow\ 10^{-3} = M(3)$

$\phi_P = M(2)$

$$\therefore\ \frac{10^{-3}}{3} = \frac{\phi_P}{2}$$

$$\phi_P = \frac{20}{3}\times 10^{-4} = 6.67\times 10^{-4}\ \text{Wb}$$

23. Answer (2)

$i = te^{-\alpha t}\cdot k$

$\therefore\ \phi = k_1 i = k_1 te^{-\alpha t}$ $[k_1 = k\pi(2R)^2]$

$$\therefore\ E = -\left(\frac{d\phi}{dt}\right) = -k_1e^{-\alpha t} + k_1\alpha te^{-\alpha t}$$

$$= -k_1e^{-\alpha t}(1-\alpha t)$$

$$\therefore\ \text{Induced current } I = \frac{E}{r} = -k_1e^{-\alpha t}(1-\alpha t)$$

24. Answer (4)

$$I = I_{sat}\left(1-e^{-\frac{Rt}{L}}\right) \quad \text{Here } R = R_L + r = 1\ \Omega$$

$$0.8I_{sat} = I_{sat}\left(1-e^{-\frac{t}{.01}}\right)$$

$$\Rightarrow\ \frac{4}{5} = 1-e^{-100t}$$

$$\Rightarrow\ e^{-100t} = \left(\frac{1}{5}\right)$$

$\Rightarrow\ 100t = \ln 5$

$$\Rightarrow\ t = \frac{1}{100}\ln 5$$

$= 0.016$ sec

25. Answer (1)

$VBl = iR_{eq}$

$$\because\ R_{eq} = \frac{4}{3}\Omega + 1.7 = 3\ \Omega$$

$$i = \frac{(BLV)}{R_{eq}} = \frac{(1)(5\times 10^{-2})\times 10^{-2}}{3}$$

$$= \frac{5}{3}\times 10^{-4}\ \text{A} \simeq 1.7\times 10^{-4}\ \text{A}$$

$= 170\ \mu$A

26. Answer (2)

$$i = \frac{E}{R}\left(1 - e^{-\frac{t}{\tau}}\right), \quad \tau = \frac{L}{R}$$

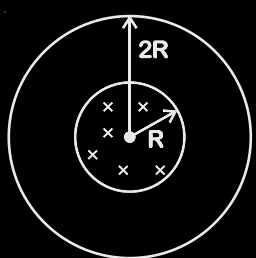
$$\Rightarrow \int dq = \frac{E}{R}\int\left(1 - e^{-\frac{t}{\tau}}\right)dt$$

$$\Rightarrow Q = \frac{E}{R} \times \left[t + e^{-\frac{t}{\tau}} \times \tau\right]_0^t$$

$$= \frac{E}{R} \times \left[\frac{L}{R} + \frac{L}{R} \cdot e^{-1} - \frac{L}{R}\right]$$

$$\Rightarrow Q = \frac{EL}{eR^2} = \frac{EL}{2.7R^2}$$

27. Answer (3)




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

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

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

$$\varepsilon = \mu_0 n \pi R^2 (I_0 - 2I_0 t)$$

$$\Rightarrow \varepsilon = 0 \text{ at } t = \frac{1}{2} \text{ s}$$

28. Answer (1)

$$I = I_0\left(1 - e^{-\frac{tR}{L}}\right)$$

$I_\infty = I\ (t = \infty) = I_0$

$$I_{40} = I(t = 40\ s) = I_0\left(1 - e^{\frac{-40 \times 5}{10 \times 10^{-3}}}\right) = I_0\left(1 - e^{-20,000}\right)$$

$\Rightarrow \dfrac{I_\infty}{I_{40}} = \dfrac{1}{1 - e^{-20,000}}$, which is slightly greater than 1

29. Answer (3)

$\phi(t) = AB \cos \omega t$

$$E = \frac{-d\phi}{dt} = AB\,\omega \sin\omega t = AB\omega \sin\left(\frac{2\pi}{T}.t\right)$$

Induced emf, $|\varepsilon|$ is maximum when $\dfrac{2\pi t}{T} = \dfrac{\pi}{2}, \dfrac{3\pi}{2}$

$\Rightarrow t = \dfrac{T}{4}$ or $\dfrac{3T}{4}$ i.e. 2.5 s or 7.5 s.

For induced emf to be minimum i.e zero

$$\frac{2\pi t}{T} = n\pi \Rightarrow t = n\frac{T}{2},$$

$\Rightarrow$ Induced emf is zero at t = 5 s, 10 s

30. Answer (1)

The quantity $\dfrac{B^2}{2\mu_0}$ is the energy density of magnetic field.

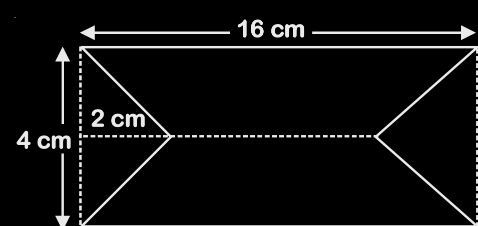
$$\Rightarrow \left[\frac{B^2}{2\mu_0}\right] = \left[\frac{ML^2T^{-2}}{L^3}\right] = ML^{-1}T^{-2}$$

31. Answer (3)

Using Faraday law

$$\text{Induced EMF} = \left|-\frac{d\phi}{dt}\right| = \left|A\frac{dB}{dt}\right|$$

$$\therefore \ \frac{dB}{dt} = \frac{1000 - 500}{5} \times 10^{-4} = 10^{-2} \text{ T/sec}$$




Area = ( 16 × 4 – 2 × Area of triangle) $cm^2$

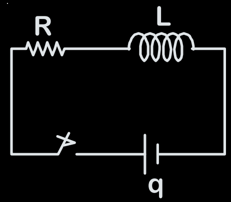
$$= \left(64 - 2 \times \frac{1}{2} \times 2 \times 4\right) cm^2$$

$= 56 \times 10^{-4}\ m^2$

$\therefore\ \varepsilon_{induced} = 56 \times 10^{-6}$ V = 56 $\mu$V

32. Answer (4)

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




$$\because \quad t_C=\frac{L}{R}$$

$$\Rightarrow \int dq=\int\frac{E}{R}(1-e^{-t/t_C})dt$$

$$\Rightarrow q=\frac{E}{R}\left[t+t_Ce^{-t/t_C}\right]_0^{t_C}$$

$$\Rightarrow q=\frac{E}{R}\left[t_C+\frac{t_C}{e}-t_C\right]$$

$$\Rightarrow q=\frac{E}{R}\frac{L}{\mathrm{R}\mathrm{e}}$$

$$\therefore \quad q=\frac{EL}{R^2e}$$

33. Answer (2)

$$\langle P\rangle=\langle\frac{\varepsilon_{\text{ind}}^2}{R}\rangle$$

$$\varepsilon_{\text{ind}}=\frac{-d\phi}{dt}$$

$$\Rightarrow \langle \mathrm{P}\rangle = \langle\frac{A^2B^2\omega^2\sin^2\omega t}{R}\rangle \ (\mathrm{A}=\pi\mathrm{ab})$$

$$=\frac{\pi^2a^2b^2B^2\omega^2}{2R}$$

34. Answer (2)

Area of loop = $\frac{\ell^2}{16}$

$$\varepsilon=-\frac{d\phi}{dt}=\left(\frac{dB}{dt}\right)\frac{\ell^2}{16}$$

$$I=\frac{\left(\frac{dB}{dt}\right)\frac{\ell^2}{16}\times\frac{\pi d^2}{4}}{\rho\ell}$$

I = 0.61 A

35. Answer (4)

Current direction reverses when magnet exits from solenoid and when magnet is completely inside, current is zero.

36. Answer (2)

$$\frac{1}{2}Li^2=\frac{1}{n}\frac{1}{2}Li_0^2$$

$$\Rightarrow \quad i=\frac{i_0}{\sqrt{n}}$$

During growth of current,

$$i=i_0(1-e^{-t/\tau}) \qquad \left(\tau=\frac{L}{R}\right)$$

$$e^{t/\tau}=\frac{\sqrt{n}}{\sqrt{n}-1}$$

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

37. Answer (3)

$\varepsilon = Bv\ell$

$$i=\frac{\varepsilon}{R}$$

$$i=\left(\frac{\mu_0 I}{2\pi r}v\ell\right)\frac{1}{R}$$

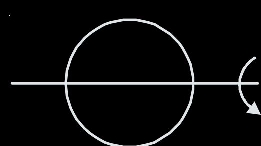
38. Answer (10)

$$E_{\text{ind}}=\frac{\Delta\phi}{\Delta t}$$

$$\Rightarrow \quad 100=\frac{L(0.25-0)}{.025\times10^{-3}}$$

$\Rightarrow$ L = $10^{-2}$ H = 10 mH

39. Answer (15)



$$\omega=\frac{\pi\times10}{2}=5\pi \text{ rad/s}$$

$$\phi=\pi r^2\cdot B\cos\omega t$$

$$\therefore \quad |\epsilon|=\left(\frac{d\phi}{dt}\right)=\pi r^2B\omega\sin\omega t$$

$$\therefore \quad |\epsilon|_{\max}=\pi r^2B\omega$$

$$=\frac{\pi\times1}{100}\times3\times10^{-5}\times5\times\pi$$

Taking $\pi^2\approx10$ we get $(\epsilon_{\max})$ = 15 × $10^{-6}$ volt

40. Answer (05.00)

$I = 5t^2 - 2t + 3$

$$\frac{dI}{dt} = 10t - 2$$

At (t = 1 sec) $\left(\frac{dI}{dt}\right) = 8$ A/s

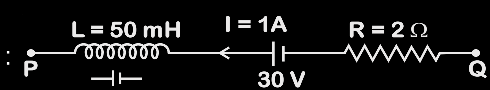
$$\phi = \left(\frac{\mu_0 \times 200 \times I \times 100}{2 \times 20}\right) \times \frac{\pi \times 500}{100 \times 100}$$

$$\therefore \quad e = \left|\frac{d\phi}{dt}\right| = \frac{\mu_0 \times 200 \times 100 \times 500 \times \pi}{2 \times 20 \times 100 \times 100}\left(\frac{dI}{dt}\right)$$

$$\Rightarrow \quad e = \left|\frac{d\phi}{dt}\right| = \left(\frac{8}{10}\right) \text{m volt} = \frac{4}{5} \text{ m volt}$$

x = 5

41. Answer (33.00)

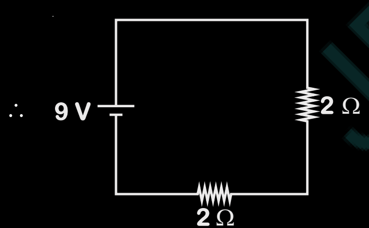



$V_Q - 2 \times 1 + 30 + (50 \times 10^{-3}) \times 10^2 = V_P$

$\Rightarrow V_P - V_Q = 33.0$

42. Answer (3)

At t = 0, inductor behaves as an open switch.




$$\therefore \quad i = \frac{9}{4} = 2.25 \text{ A}$$

43. Answer (1)

$$i(\text{at } t = 0) = \frac{E}{6} + \frac{E}{9} = \frac{5E}{18}$$

$$i(\text{at } t = \infty) = \frac{E}{\frac{5}{2} + \frac{4}{5}} = \frac{10E}{33}$$

44. Answer (144)

$$V - L\frac{di}{dt} = 0$$

$$\int_0^i di = \frac{1}{L}\int_0^t V dt$$

$$i = \frac{3}{4}t^2$$

= 12 A at t = 4 second

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

= 144 J

45. Answer (1)

$\varepsilon_{ind} = (B_V)LV, \quad B_V = B_{Total}\sin 60$

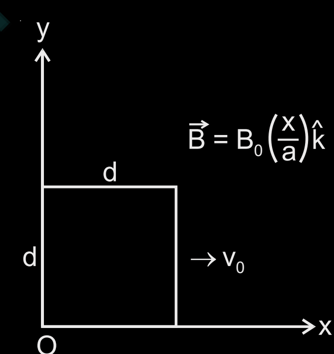
$$= (2.5 \times 10^{-4})(\sin 60) \times 10 \times 180 \times \frac{5}{18}$$

= 108.25 mV

46. Answer (1)

It is based on Lenz Law. $I_1$ is in clockwise direction and $I_2$ is in anticlockwise direction.

47. Answer (2)




$$\therefore \quad \varepsilon = B_0 \times \left(\frac{d}{a}\right) \times d \times v_0 - 0$$

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

48. Answer (3)

As $I_B + I_C + I_D = I_A$

By symmetry $I_B = I_C = I_D$

$\Rightarrow 3LI_C = LI_A$

$\Rightarrow 3\phi_C = \phi_A$

$$\Rightarrow \quad B_C = \frac{B_A}{3} = 1 \text{ T}$$

49. Answer (4)

$$U = \frac{1}{2}LI^2$$

if $\quad U = \frac{U_{max}}{4} \Rightarrow I = \frac{I_{max}}{2}$

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

$$\Rightarrow \frac{1}{2} = 1 - e^{-\frac{Rt}{L}}$$

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

$$\Rightarrow t = \frac{L}{R}\ln 2$$

50. Answer (1)

Flux increases and then becomes constant and finally decreases.

Induced emf changes direction, power dissipation is identical.

51. Answer (74)

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

$$= \frac{20}{10 \times 10^3} \cdot e^{-\frac{10^{-6}}{10^{-6}}}$$

$= 2 \times 10^{-3}\ e^{-1}$

$= 0.74$ mA

52. Answer (80)

$$\phi = B \cdot A = \frac{4 \times 10^{-3}}{\pi} \cdot \left(1 - \frac{t}{100}\right) \cdot \pi \cdot 1^2$$

$$= 4 \times 10^{-3}\left(1 - \frac{t}{100}\right)$$

$$\varepsilon = \left|\frac{d\phi}{dt}\right| = 40 \times 10^{-6}$$

$$i = \frac{\varepsilon}{R} = \frac{40 \times 10^{-6}}{2 \times 10^{-6}} = 20 \text{ A}$$

$$E = i^2 R \cdot t = 20^2 \times 2 \times 10^{-6} \times 100$$

$= 80 \times 10^{-3}$ J

53. Answer (3)

$$i_0 = \frac{\varepsilon}{R} = \frac{6}{6} = 1 \text{ A}$$

As current through inductor will not change instantly

$V_r = i_0 r = 1 \times 3 = 3$ V

54. Answer (60)

$$\varepsilon = \left|\frac{d\phi}{dt}\right| = (20t + 20) \times 10^{-3}$$

$$i = \frac{\varepsilon}{R} = \frac{(20 \times 5 + 20)}{2} \times 10^{-3} = 60 \text{ mA}$$

55. Answer (3)

We know discharging of inductor

$I = I_0\ e^{-t/\tau}$

$$U = \frac{1}{2}LI^2 \Rightarrow 64 = \frac{1}{2}LI^2 \quad \text{...(i)}$$

Rate of loss of energy = $I^2 R$

$640 = I^2R$ ...(ii)

from (i)/(ii)

$$\frac{64}{640} = \frac{\frac{1}{2}LI^2}{I^2R}$$

$$\Rightarrow \frac{1}{10} = \frac{L}{2R} \Rightarrow \frac{L}{R} = 0.2$$

$\Rightarrow \tau = 0.2$

56. Answer (60)

$\varepsilon_{max} = NAB\omega$

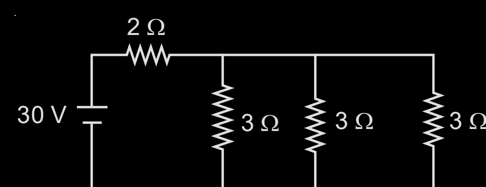
$= 20 \times 3.14 \times (8 \times 10^{-2})^2 \times 3 \times 10^{-2} \times 50$

$= 60.29 \times 10^{-2}$ V

57. Answer (2)

We know in steady state, potential difference across inductor = 0

So equivalent circuit is




Equivalent resistance across cell = 1 + 2 = 3 Ω

So current, $i = \frac{30}{3} = 10$ A

58. Answer (1)

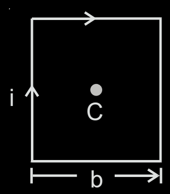
At t = 1 s, centre of ring is on verge of boundary

$\varepsilon = Bvl$

$l = 2R$

$\varepsilon = 1 \times 1 \times 2$

59. Answer (2)




Magnetic field at C, $B = \frac{\mu_0 i}{2\pi b}\sqrt{2} \times 4$

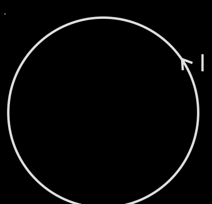
So flux through small loop = $Ba^2$

$$= \frac{4\mu_0\sqrt{2}}{2\pi b}a^2 i$$

$$= \frac{\mu_0 8\sqrt{2}}{4\pi b}a^2 i$$

$$M = \frac{\mu_0}{4\pi}\frac{8\sqrt{2}\,a^2}{b}$$

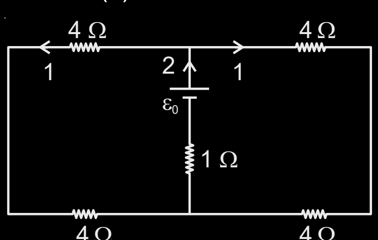
60. Answer (2)




As current is induced in the direction shown,

$\Rightarrow$ B is decreasing and outward

61. Answer (3)




KVL

$+(2 \times 10^{-3}) \times 1 - \varepsilon_0 + 8 \times 10^{-3}$

$= 0$

$\Rightarrow \varepsilon_0 = 10 \times 10^{-3}$ Volts

$= 10^{-2}$ Volts

$Bv_0 l = \varepsilon_0$

$$\Rightarrow v_0 = \frac{\varepsilon_0}{Bl}$$

62. Answer (440)

$V_{max} = NAB\omega$

$= 1000 \times 1 \times 0.07 \times (2\pi \times 1)$

$= 440$ volts

63. Answer (4)

$$U = \frac{1}{2}LI^2 = \frac{1}{2}2 \times 2^2 = 4 \text{ J}$$

64. Answer (1)

$$\text{Emf} = -\frac{d\phi}{dt} = -(15t^2 + 8t + 2)$$

$$\text{So, } i = \frac{|\text{Emf}|}{R} = \frac{(15t^2 + 8t + 2)}{5}$$

at $t = 2$

$i = 15.6$ A

65. Answer (400)

Initial flux through inductor = LI

$$\Rightarrow \phi_i = 20 \times 10^{-3} \times \frac{20}{10}$$

$= 4 \times 10^{-2}$ weber

Final flux = 0

$\Rightarrow$ average emf

$$= \frac{|\phi_i - \phi_f|}{100\ \mu s}$$

$$= \frac{4 \times 10^{-2}}{10^{-4}} = 400 \text{ V}$$

66. Answer (16)

$E = Blv$

$$= 4 \times 10^{-3} \times \frac{20}{100} \times 20 \text{ Volts}$$

$= 16$ mV

67. Answer (4)

As number of turns are halved so length of wire is halved, and radius is doubled, then area will be 4 times the previous one if previous resistance is $R$ then new resistance is $\frac{R}{8}$ and if previous emf is $E$ then new emf will be $\frac{E}{2}$ so

$$P_i = \frac{E^2}{R}$$

$$P_f = \frac{(E/2)^2}{R/8} = \frac{2E^2}{R} = 2P_i$$

As the answer key is changing students can challenge this question.

68. Answer (3)

We know $\phi = Mi$

Let $i$ current be flowing in the larger loop

$$\Rightarrow \quad \phi \simeq \left[4 \times \frac{\mu_0 i}{4\pi(L/2)}[\sin 45^\circ + \sin 45^\circ]\right] \times \text{Area}$$

$$= \frac{2\sqrt{2}\mu_0 i}{\pi L} \times l^2$$

$$\Rightarrow \quad M = \frac{\phi}{i} = \frac{2\sqrt{2}\mu_0 l^2}{\pi L}$$

69. Answer (2)

Metal detector works on the principle of resonance in ac circuits.

70. Answer (250)

$R = 20\ \Omega$

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

$$\varepsilon = \left|-\frac{d\phi}{dt}\right| = |16t - 9| = |16(0.25) - 9| = 5$$

$$i = \frac{\varepsilon}{R} = \frac{5}{20} = 0.25 \text{ A} = \frac{0.25}{10^3} \times 10^3 \text{ A} = 250 \text{ mA}$$

71. Answer (12)

$B_\perp = 3t^2$

$$\frac{dB_\perp}{dt} = 6t = 12 \text{ at } t = 2$$

$$\frac{d\phi_1}{dt} = 12 \times \pi(1)^2 = 12\pi$$

72. Answer (1)

Just after closing the switch, $i = \frac{6}{4+2} = 1 \text{ A}$

73. Answer (3)

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

$$\frac{L}{R} = \frac{1}{100} \text{s} \Rightarrow \frac{L}{R} = 10 \text{ ms} \quad \ldots(2)$$

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

$$\Rightarrow \quad e^{-Rt/L} = \frac{1}{2} \Rightarrow t = \frac{L}{R}\ln 2 = 6.93 \text{ ms}$$

$$U = \frac{1}{2}Li^2 = \frac{1}{2}[1 - e^{-15/10}]^2 \left[\frac{6}{100}\right]^2$$

$$= \frac{1}{2}[1 - 0.25]^2 \times 36 \times 10^{-4}$$

$$= 1 \text{ mJ}$$

74. Answer (2)

$R = 8\ \Omega$

$$\phi = \frac{2}{3}(9 - t^2)$$

At $t = 3$, $\phi = 0$

$$\varepsilon = \left|-\frac{d\phi}{dt}\right| = \frac{4}{3}t$$

$$H = \int_0^3 \frac{V^2}{R} dt = \int_0^3 \frac{1}{8} \times \frac{16}{9} t^2 dt$$

$$= \frac{2}{9} \times \left(\frac{t^3}{3}\right)_0^3 = \frac{2}{9 \times 3} \times 27 = 2 \text{ J}$$

75. Answer (4)

Self inductances are in series but their mutual inductances are linked oppositely so equivalent self inductance

$L = L_1 + L_2 - M - M = L_1 + L_2 - 2M$

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