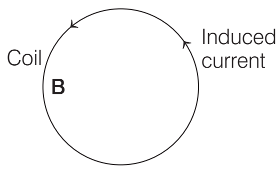
20

Electromagnetic Induction

TOPIC 1
Magnetic Flux, Faraday's and Lenz's Laws

01 A coil is placed in a magnetic field **B** as shown below.



A current is induced in the coil because **B** is **[2021, 31 Aug Shift-II]**

(a) outward and decreasing with time
(b) parallel to the plane of coil and decreasing with time
(c) outward and increasing with time
(d) parallel to the plane of coil and increasing with time

Ans. *(a)*

In the given figure, the magnetic field is outward, means N-pole is formed on outward face and S-pole is formed on inward (back) face.

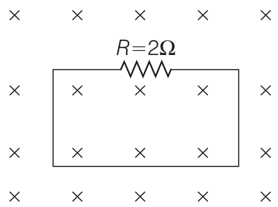
As the induced current is anti-clockwise which is also making N-pole on outward face.

According to the Lenz's law, the induced current always opposes the nature by which it is produced.

Hence, induced current is in the direction, so the strength of N-pole is maintained as it is decreasing.

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

The magnitude of current through $R = 2\Omega$ resistor at $t = 5$ s is ...... mA. **[2021, 20 July Shift-II]**



Ans. *(60)*

As per question, flux through the loop increases according to

$$\phi_0(t) = 10t^2 + 20t \quad \text{...(i)}$$

where, ϕ_0 is in milliwebers and t in seconds.

Differentiate Eq. (i) with respect to t, we get

Induced emf $|\mathbf{E}| = \frac{d\phi}{dt} = (20t + 20)$ mV

Current, $i = \frac{|E|}{R} \Rightarrow i = \frac{20t + 20}{2}$

$\Rightarrow \quad i = (10t + 10)$ mA

$\therefore$ Current, $= (10 \times 5 + 10)$ mA $\quad [\because i\,(t = 5\text{ s})]$

$= (50 + 10)$ mA,

$i = 60$ mA

03 A circular coil of radius 10 cm is placed in a uniform magnetic field of 3.0×10^{-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 0.2s. The maximum value of emf induced (in μV) in the coil will be close to the integer .... **[2020, 2 Sep Shift-I]**

Ans. *(15)*

Flux linked with the coil is

$$\phi = \mathbf{B} \cdot \mathbf{A} = BA\cos\omega t$$

Magnitude of emf induced in coil

$$= \left|\frac{d}{dt}\phi\right| = |BA\omega \sin\omega t|$$

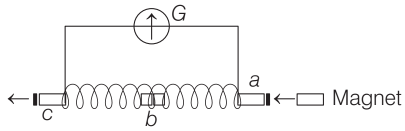
Maximum value of induced emf

$$= BA\omega = \frac{BA2\pi}{T}$$

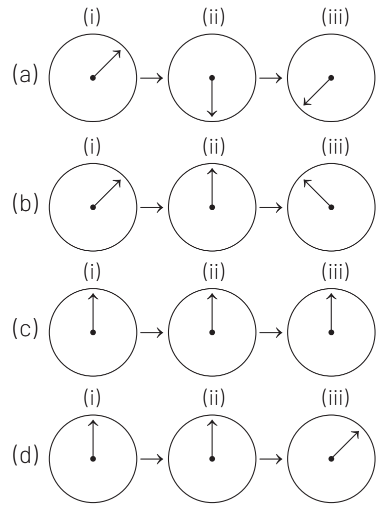
$$= \frac{3 \times 10^{-5} \times \pi \times (0.1)^2 \times 2\pi}{0.4}$$

$$\approx 15 \times 10^{-6} = 15\,\mu\text{V}$$

04 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: (i) the magnet's entery (ii) magnet is completely inside and (iii) magnet's exit. **[2020, 4 Sep Shift-I]**



Ans. ***(b)***

At point (i)

The bar magnet enters into the coil, so the magnetic flux passing through the loops will change. In order to oppose that, an emf gets generated and an induced current starts to flow. So, the pointer of galvanometer will deflect in a particular direction.

(We can not be definite about the direction, as which pole of magnet is being entered into the coil is not given.)

At point (ii)

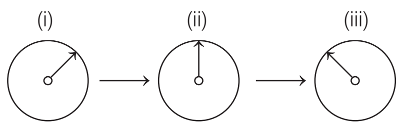
The bar magnet is completely inside the coil, so the flux will not change. No emf will be generated and no current flows. So, the pointer will not deflect towards any side. It will show zero.

At point (iii)

The bar magnet exits from the coil, so again the flux will change in opposite manner to what happened at point (i), so again an opposing emf gets generated and an induced current starts to flow in a direction opposite to that when the magnet was entering.

So in this case, the pointer will deflect in the direction opposite to the case when magnet was entering.

Looking at the options, following cases seems to be possible.



Hence, correct option is (b).

05 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 $dB/dt = 0.032\ \text{Ts}^{-1}$. The induced current in the loop is close to (Take, resistivity of the metal wire $= 1.23 \times 10^{-8}\ \Omega\text{m}$)

[2020, 3 Sep Shift-II]

(a) 0.61 A (b) 0.43 A
(c) 0.53 A (d) 0.34 A

Ans. ***(a)***

Induced emf in square loop,

$$E = A\left(\frac{dB}{dt}\right) = l^2\left(\frac{dB}{dt}\right) = \left(\frac{L}{4}\right)^2\left(\frac{dB}{dt}\right)$$

Here, $L = 30$ cm

$= 30 \times 10^{-2}$ m

$$\frac{dB}{dt} = 0.032\ \text{Ts}^{-1}$$

$\therefore \quad E = 1.8 \times 10^{-4}$ V

$$\text{Induced current} = \frac{E}{R} = \frac{E}{\rho\frac{L}{A}} = \frac{EA}{\rho L}$$

Here, $\rho = 1.23 \times 10^{-8}\ \Omega$-m

$L = 30 \times 10^{-2}$ m

$A = \pi r^2 = \pi(2 \times 10^{-3})^2 = 12.56 \times 10^{-6}\ \text{m}^2$

$$\text{So},\ I = \frac{1.8 \times 10^{-4} \times 1.256 \times 10^{-5}}{1.23 \times 10^{-8} \times 30 \times 10^{-2}} = 0.61\ \text{A}$$

Hence, correct option is (a).

06 Two concentric circular coils C_1 and C_2 are placed in the xy-plane. C_1 has 500 turns and 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 secon(d) The emf induced in C_1 (in mV), at the instant $t = 1$ s is $\frac{4}{x}$.

The value of x is ....

[2020, 5 Sep Shift-I]

Ans. ***(5)***

Given, $I(t) = 5t^2 - 2t + 3$

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

At $t = 1$ s, $\frac{dI}{dt} = 8$ A/s

$$\text{Magnetic flux, } \phi = \left(\frac{\mu_0 I n_2}{2R}\right)(\pi r^2 n_1)$$

$$\text{Induced emf, } e = \left|\frac{d\phi}{dt}\right| = \left(\frac{\mu_0 n_2}{2R}\right)\pi r^2 n_1 \frac{dI}{dt}$$

Given, $n_1 = 200$, $r = 1\ \text{cm} = 10^{-2}$ m, $n_2 = 500$, $R = 20\ \text{cm} = 20 \times 10^{-2}$ m and $\mu_0 = 4\pi \times 10^{-7}$

$$\therefore e = \frac{4\pi \times 10^{-7} \times 200 \times \pi \times 10^{-4} \times 500}{2 \times 20 \times 10^{-2}} \times 8$$

$= 8 \times 10^{-4}$ V $= 0.8$ mV

According to question, $0.8\text{mV} = \frac{4}{x}$

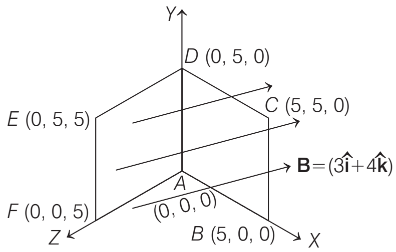
$$\Rightarrow x = \frac{4}{0.8} = 5$$

07 A loop $ABCDEFA$ of straight edges has six corner points $A(0, 0, 0)$, $B(5, 0, 0)$, $C(5, 5, 0)$, $D(0, 5, 0)$, $E(0, 5, 5)$ and $F(0, 0, 5)$. The magnetic field in this region is $\mathbf{B} = (3\hat{\mathbf{i}} + 4\hat{\mathbf{k}})$T. The quantity of flux through the loop $ABCDEFA$ (in Wb) is ....

[2020, 7 Jan Shift-I]

Ans. ***(175)***

If given situation, loop and magnetic field are given as shown in the figure.



Flux through loop $ABCDEFA$ = Flux through part $ABCDA$ + Flux through part $ADEFA$ $= \mathbf{B} \cdot \mathbf{A}_1 + \mathbf{B} \cdot \mathbf{A}_2$

Here, from figure,

$$\mathbf{A}_1 = 25\hat{\mathbf{k}} \text{ and } \mathbf{A}_2 = 25\hat{\mathbf{i}}$$

So, flux associated with complete loop

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

$= 100 + 75 = 175$ Wb

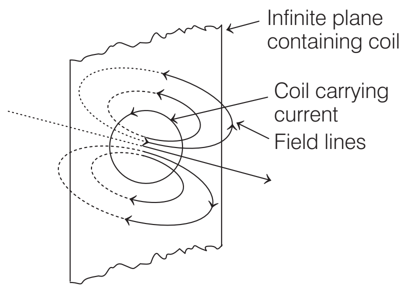
08 Consider a circular coil of wire carrying constant current I, forming a magnetic dipole. The magnetic flux through an infinite plane that contains the circular coil and excluding the circular coil area is given by ϕ_i. The magnetic flux through the area of the circular coil area is given by ϕ_o. Which of the following option is correct ?

[2020, 7 Jan Shift-I]

(a) $\phi_i > \phi_o$ (b) $\phi_i < \phi_o$
(c) $\phi_i = \phi_o$ (d) $\phi_i = -\phi_o$

Ans. ***(d)***

We are given with following situation,



From the diagram of field lines, we can observe that whatever be the number of field lines emitted from coil, all of them goes back into the infinite plane only.

So, magnetic flux emanating from coil is equal and opposite to the flux linked with infinite plane.

So, $\quad \phi_i = -\phi_o$

09 A planar loop of wire rotates in a uniform magnetic fiel(d) Initially at $t=0$, the plane of the loop is perpendicular to the magnetic fiel(d) If it rotates with a period of 10s about an axis in its plane, then the magnitude of induced emf will be maximum and minimum respectively at **[2020, 7 Jan Shift-II]**

(a) 2.5 s and 7.5 s (b) 2.5 s and 5.0 s
(c) 5.0 s and 10.0 s (d) 5.0 s and 7.5 s

Ans. ***(b)***

Induced emf in the wire loop,

$$e = BA\omega \sin\omega t$$

Induced emf is maximum when $\sin\omega t = \pm 1$

$\Rightarrow \quad \omega t = \frac{\pi}{2}$

$\Rightarrow \quad \frac{2\pi}{T}\cdot t = \frac{\pi}{2}$

Here, $\quad T = 10$ s

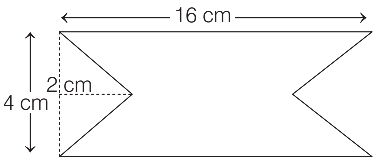
So, $\quad t = \frac{10}{4} = 2.5$ s

and induced emf is minimum when $\sin\omega t = 0$

$\Rightarrow \quad \omega t = \pi$ or $\frac{2\pi}{T}\cdot t = \pi$

$\Rightarrow \quad t = \frac{10}{2} = 5$ s

10 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 **[2020, 8 Jan Shift-I]**



(a) $48\,\mu$V (b) $28\,\mu$V
(c) $56\,\mu$V (d) $36\,\mu$V

Ans. ***(c)***

Induced emf in the loop,

$$E = -\frac{\Delta\phi}{\Delta t} = -\left(\frac{\Delta B}{\Delta t}\right)(A[\because \phi = BA]$$

$$= -\left(\frac{B_2 - B_1}{\Delta t}\right)A \qquad \text{...(i)}$$

Here, $B_2 = 500\text{ G} = 500 \times 10^{-4}$ T,
$B_1 = 1000\text{ G} = 1000 \times 10^{-4}$ T,
$\Delta t = 5$s

$\therefore \quad A$ = area of loop
= Area of rectangle – Area of two triangles

$$= \left(16 \times 4 - 2 \times \frac{1}{2} \times 4 \times 2\right)\text{cm}^2$$

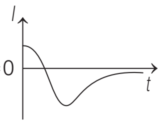
$$= 56 \times 10^{-4}\text{ m}^2$$

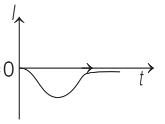
Using Eq. (i), we get

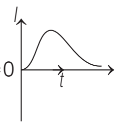
$$E = \frac{(1000 - 500) \times 10^{-4} \times 56 \times 10^{-4}}{5}$$

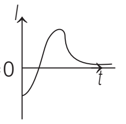
$$= 56 \times 10^{-6}\text{ V} = 56\,\mu\text{V}$$

11 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 solenoi(d) The current induced in the outer coil is correctly depicted, as a function of time, by **[2019, 9 April Shift-II]**

(a) $t=0$


(b) $t=0$


(c) $t=0$


(d) $t=0$


Ans. ***(d)***

Magnetic flux associated with the outer coil is

$$\phi_{\text{outer}} = \mu_0 \pi NR \cdot I$$
$$= \mu_0 N\pi R(kte^{-\alpha t})$$
$$= Cte^{-\alpha t}$$

where,

$$C = \mu_0 N\pi Rk = \text{constant}$$

Induced emf,

$$e = \frac{-d\phi_{\text{outer}}}{dt} = Ce^{-\alpha t} + (-\alpha\, C\, t\, e^{-\alpha t})$$

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

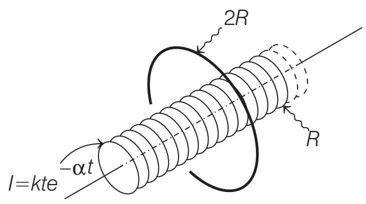
$\therefore$ Induced current, $I = \frac{e}{\text{Resistance}}$

$\Rightarrow \quad$ At $t = 0$, $I = -$ ve

$\therefore$ The correct graph representing this condition is given in option (d).

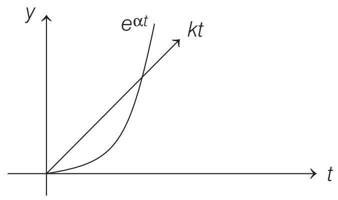
Alternate Solution

Given solenoid is shown below as,



At $\quad t = 0$, current in solenoid
$= I(t=0) = k(0)\, e^{-\alpha \cdot 0} = 0$

Graph of $e^{\alpha t}$ and kt *versus* time can be shown as,



As, $\quad I = \frac{kt}{e^{\alpha t}}$;

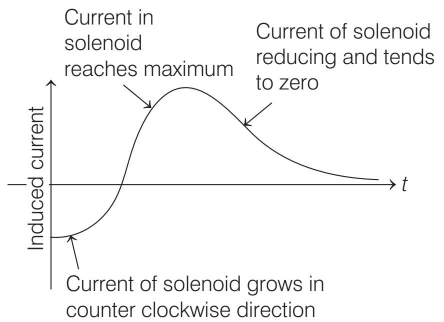
Initially, $\quad kt > e^{\alpha t}$

So, current is increasing in magnitude.

Finally, after a short time $kt < e^{\alpha t}$. So, current is decreasing in magnitude.

But in both cases, it remains positive or counter clockwise. So, current induced is at first anti-clockwise (following Lenz's law) and then it becomes clockwise and finally reduces to zero as $t \longrightarrow \infty$.

So, correct graph of induced current is



12 A conducting circular loop is made of a thin wire has area $3.5 \times 10^{-3}\text{ m}^2$ and resistance 10 Ω. It is placed perpendicular to a time dependent magnetic field $B(t) = (0.4\text{T})\sin(0.5\pi t)$. 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 **[2019, 9 Jan Shift-I]**

(a) 6 mC (b) 21 mC
(c) 7 mC (d) 14 mC

Ans. *(d)*

Since, the magnetic field is dependent on time, so the net charge flowing through the loop will be given as

$$Q = \frac{\text{change in magnetic flux, } \Delta\phi_B}{\text{resistance, } R}$$

As, $\Delta\phi_B = B\,A = BA\cos\theta$

where, A is the surface area of the loop and 'θ' is an angle between B and A.

Here, $\theta = 0 \Rightarrow \Delta\phi_B = BA$

$\therefore$ For the time interval, $t = 0$ ms to $t = 10$ ms,

$$Q = \frac{\Delta\phi_B}{R} = \frac{A}{R}(B_{f \text{ at } 0.01\text{ s}} - B_{i \text{ at } 0 \text{ s}})$$

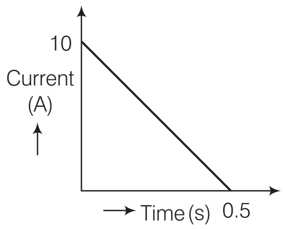
Substituting the given values, we get

$$= \frac{3.5 \times 10^{-3}}{10}[0.4\sin(0.5\pi) - 0.4\sin 0]$$

$$= 3.5 \times 10^{-4}(0.4\sin\pi/2)$$

$$= 1.4 \times 10^{-4}\text{ C} = 14\text{ mC}$$

13 In a coil of resistance 100 Ω, 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]**



(a) 225 Wb (b) 250 Wb
(c) 275 Wb (d) 200 Wb

Ans. *(b)*

Induced constant, $I = \frac{e}{R}$

Here, e = induced emf $= \frac{d\phi}{dt}$

$$I = \frac{I}{R} = \left(\frac{d\phi}{dt}\right)\cdot\frac{1}{R}$$

$$d\phi = IRdt$$

$$\phi = \int IRdt$$

$\therefore$ Here, R is constant

$\therefore$ $\phi = R\int I dt$

$\int I \cdot dt$ = Area under $I - t$ graph

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

$\therefore$ $\phi = R \times 2.5$

$= 100 \times 2.5$

$= 250$ Wb

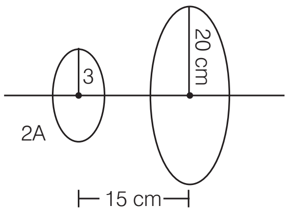
14 A circular loop of radius 0.3 cm lies parallel to a much bigger circular loop of radius 20 cm. The centre of the small loop is on the axis of the bigger loop. The distance between their centres is 15 cm. If a current of 2.0 A flows through the smaller loop, then the flux linked with bigger loop is **[JEE Main 2013]**

(a) 9.2×10^{-11} Wb (b) 6×10^{-11} Wb
(c) 3.3×10^{-11} Wb (d) 6.6×10^{-9} Wb

Ans. *(a)*

The magnetic field due to the bigger circular loop is

$$B = \frac{\mu_0 IR^2}{2(x^2 + R^2)^{3/2}}$$



Given, $I = 2$ A, $R = 20$ cm $= 20 \times 10^{-2}$ m,

$x = 15$ cm

$= 15 \times 10^{-2}$ m

$$B = \frac{\mu_0 \times 2 \times (20 \times 10^{-2})^2}{[(0.2)^2 + (0.15)^2]^{3/2}}$$

Flux linked, $\phi = BA$

where, A is area of small circular loop.

$A = \pi r^2 = \pi \times (0.3 \times 10^{-2})^2$

$$\therefore \phi = \frac{\mu_0 \times 2 \times (20 \times 10^{-2})^2}{2[(0.2)^2 + (0.15)^2]^{3/2}} \times \pi \times (0.3 \times 10^{-2})^2$$

$\phi = 9.2 \times 10^{-11}$ Wb

15 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]**

(a) development of air current when the plate is placed
(b) induction of electrical charge on the plate
(c) shielding of magnetic lines of force as aluminium is a paramagnetic material
(d) electromagnetic induction in the aluminium plate giving rise to electromagnetic damping

Ans. *(d)*

According to Lenz's law, electromagnetic induction takes place in the aluminium plate due to which eddy current is developed which oppose the motion or vibrations of coil.

This causes loss in energy which results in damping of oscillatory motion of the coil.

16 The flux linked with a coil at any instant t is given by $\phi = 10t^2 - 50t + 250$. The induced emf at $t = 3$ s is **[AIEEE 2006]**

(a) −190 V (b) −10 V (c) 10 V (d) 190 V

Ans. *(b)*

$$\phi = 10t^2 - 50t + 250$$

From Faraday's law of electromagnetic induction,

$e = -d\phi/dt$

$\therefore$ $e = -[10 \times 2t - 50]$

$\therefore$ $e|_{t=3\text{s}} = -[10 \times 6 - 50] = -10$ V

17 A coil having n turns and resistance $R\ \Omega$ is connected with a galvanometer of resistance $4R\ \Omega$. This combination is moved for time t seconds from a magnetic field W_1 weber to W_2 weber. The induced current in the circuit is **[AIEEE 2004]**

(a) $\frac{W_2 - W_1}{5Rnt}$ (b) $-\frac{n(W_2 - W_1)}{5Rt}$
(c) $-\frac{(W_2 - W_1)}{Rnt}$ (d) $-\frac{n(W_2 - W_1)}{Rt}$

Ans. *(b)*

The rate of change of flux or emf induced in the coil is $e = -n\frac{d\phi}{dt}$.

$\therefore$ Induced current, $I = \frac{e}{R'} = -\frac{n}{R'}\frac{d\phi}{dt}$ ...(i)

Given, $R' = R + 4R = 5R, d\phi = W_2 - W_1$, $dt = t$

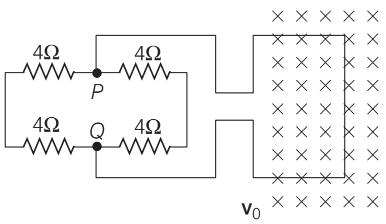
[here, W_1 and W_2 are flux associated with one turn]

Putting the given values in Eq. (i), we get

$$I = -\frac{n}{5R}\frac{(W_2 - W_1)}{t}$$

TOPIC 2
Motional EMF and Eddy Current

18 A square loop of side 20 cm and resistance 1Ω 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 4Ω. What should be the value of $\mathbf{v}_0$, so that a steady current of 2 mA flows in the loop ? **[2021, 1 Sep Shift-II]**



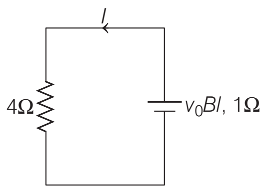
(a) 1 m/s (b) 1 cm/s
(c) 10^2 m/s (d) 10^{-2} cm/s

Ans. *(b)*

According to given circuit diagram, equivalent resistance between point P and Q.

$$R_{PQ} = (4+4) \,||\, (4+4) = \frac{8 \times 8}{8+8} = 4\,\Omega$$

The equivalent circuit can be drawn as,



Equivalent resistance, $R_{eq} = 4 + 1 = 5\,\Omega$

Magnetic field, $B = 5\text{T}$

The side of the square loop, $l = 20$ cm $= 0.20$ m

The steady value of the current, $I = 2$ mA $= 2 \times 10^{-3}$ A

Induced emf, $e = Bv_0l$

Induced current, $I = \dfrac{e}{R_{eq}}$

Substituting the values in the above equation, we get

$$2 \times 10^{-3} = \frac{5 \times v_0 \times 0.2}{5}$$

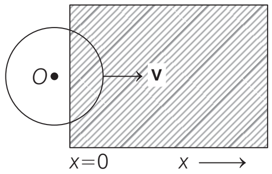
$$\Rightarrow \quad v_0 = 10^{-2}\,\text{m/s} = 1\,\text{cm/s}$$

$\therefore$ The value of $v_0 = 1$ cm/s, so that a steady current of 2 mA flows in the loop.

19 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 of 1 m/s along the X-axis. At $t = 0$ s, the centre of 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.)

[2021, 27 Aug Shift-II]



(a) 1 V (b) 2π V
(c) 2 V (d) 0

Ans. *(c)*

Given, magnetic field, $B = 1\text{T}$

Radius of ring, $R = 1$ m

Velocity of ring, $v = 1$ m/s

Time taken, $t = 1$ s

Let emf be ε.

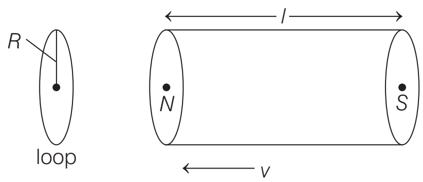
Since, $\varepsilon = Blv \sin\theta$

$\therefore \quad = 1 \times 2R \times 1 \times \sin 90°$

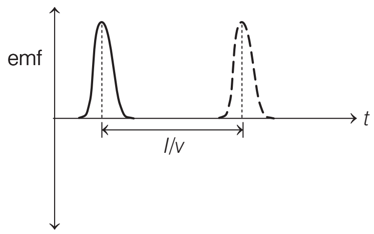
$= 2R = 2\text{V}$

20 A bar magnet is passing through a conducting loop of radius R with velocity v. The radius of the bar magnet is such that it just passes through the loop. The induced emf in the loop can be represented by the approximate curve

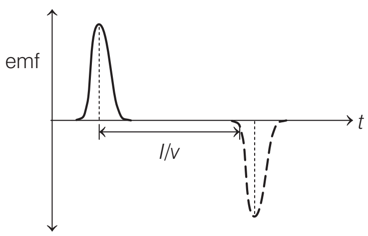
[2021, 26 Aug. Shift-I]



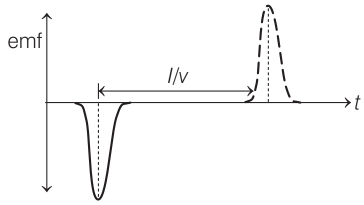
(a)



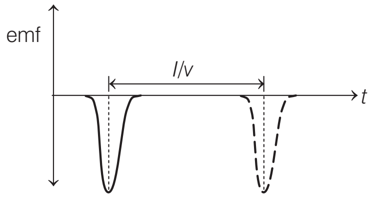
(b)



(c)



(d)



Ans. *(c)*

Given, radius of loop is R and velocity of the bar magnet is v.

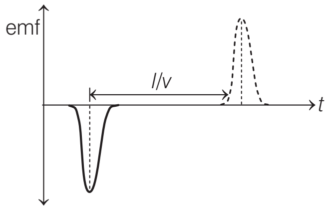
According to Faraday's law of electromagnetic induction, the emf induced in loop is given by

$$e = -\frac{Nd\phi}{dt} \qquad \text{...(i)}$$

As initially the bar magnet is moving towards the coil, so the rate of change of magnetic flux linked with the coil will increase. Thus, initially the emf induced in coil will decrease as per Eq. (i)(due to –ve sign).

When magnet reaches the middle point in the coil, for that moment the emf induced will be equal to zero because in this situation, change in magnetic flux associated with bar magnet becomes zero. Now, after that when magnet moves forward, the magnetic flux again starts changing but the polarity of magnetic flux change will be reversed. So, the emf will now increase in opposite direction.

The graph for change in emf of coil is shown below.



21 A circular coil of radius 8.0 cm and 20 turns is rotated about its vertical diameter with an angular speed of 50 rad s^{-1} in a uniform horizontal magnetic field of 3.0×10^{-2} T. The maximum emf induced in the coil will be ...... $\times 10^{-2}$ V.

(rounded off to the nearest integer.) **[2021, 26 Aug Shift-I]**

Ans. *(60)*

Given, radius of circular coil, $r = 8.0$ cm $= 0.08$ m

Number of turns, $N = 20$

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

Magnetic field, $B = 3.0 \times 10^{-2}$ T

The maximum emf induced in a coil can be expressed as $\varepsilon = \omega NBA$

Here, A is the area of coil.

$$\varepsilon = NB\,\omega(\pi r^2)$$

Substituting the given values, we get

$$\varepsilon = 20 \times 3.0 \times 10^{-2} \times 50 \times \pi \times (0.08)^2$$

$$= 60.3 \times 10^{-2}\,\text{V} \simeq 60 \times 10^{-2}\,\text{V}$$

22 A circular conducting coil of radius 1 m is being heated by the change of magnetic field **B** passing perpendicular to the plane in which the coil is laid. The resistance of the coil is 2 $\mu\Omega$. The magnetic field is slowly switched off such that its magnitude changes in time as

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

The energy dissipated by the coil before the magnetic field is switched off completely is $E = \ldots\ldots$ mJ.

[2021, 25 July Shift-I]

Ans.

(80) Given,

Radius of coil, $r = 1$ m

Resistance of coil, $R = 2\mu\Omega = 2 \times 10^{-6}\,\Omega$

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

As we know that,

Induced emf $(\varepsilon) = -\frac{d\phi}{dt} = -A\frac{dB}{dt}$ $(\because \phi = \mathbf{B} \cdot \mathbf{A})$

where, $\frac{d\phi}{dt}$ = rate of charge of flux

A = area of coil

$\frac{dB}{dt}$ = rate of change of magnetic field strength

$$\Rightarrow \quad \varepsilon = -(\pi r^2)\frac{d}{dt}\left[\frac{4}{\pi} \times 10^{-3}\left(1 - \frac{t}{100}\right)\right]$$

$$= -\pi r^2 \times \frac{4}{\pi} \times 10^{-3} \times \frac{-1}{100}$$

$$= r^2 \times 4 \times 10^{-5} = 1^2 \times 4 \times 10^{-5}$$

$$= 4 \times 10^{-5}\,\text{V}$$

If $B = 0$,

Then, $\frac{4}{\pi} \times 10^{-3}\left(1 - \frac{t}{100}\right) = 0 \Rightarrow t = 100$ s

Since, Energy (E) = Power (P) × Time (t)

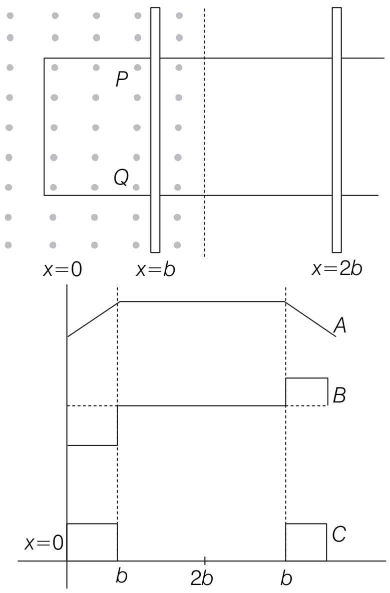
Also, $P = \frac{\varepsilon^2}{R}$

$$\Rightarrow E = \frac{\varepsilon^2}{R} \times t = \frac{(4 \times 10^{-5})^2}{2 \times 10^{-6}} \times 100 = \frac{16 \times 10^2}{2}$$

$$= 8 \times 10^{-2} = 0.08 = 80\text{ mJ}$$

23 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.

[2021, 20 July Shift-I]



(a) A - flux, B - power dissipated, C - emf
(b) A - power dissipated, B - flux, C - emf
(c) A - flux, B - emf, C - power dissipated
(d) A - emf, B - power dissipated, C - flux

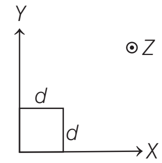
Ans. *(c)*

As the rectangular conductor moves in field area, so flux is increasing up to $x = b$, then flux is generated on return journey from $x = b$ to $x = 0$. The flux is shown by plot A of the graph.

As, emf, $e = -\frac{d\phi}{dt}$, which is shown by curve B.

and power dissipated, $P = VI$ which is shown by curve C.

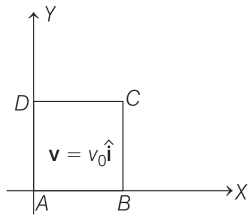
24 The magnetic field in a region is given by $\mathbf{B} = B_0\left(\frac{x}{a}\right)\hat{\mathbf{k}}$. A square loop of side d is placed with its edges along the X and Y-axes. The loop is moved with a constant velocity $\mathbf{v} = v_0\hat{\mathbf{i}}$. The emf induced in the loop is **[2021, 16 March Shift-II]**



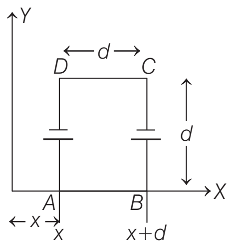
(a) $\frac{B_0 v_0^2 d}{2a}$
(b) $\frac{B_0 v_0 d}{2a}$
(c) $\frac{B_0 v_0 d^2}{a}$
(d) $\frac{B_0 v_0 d^2}{2a}$

Ans. *(c)*

The given situation can be shown as



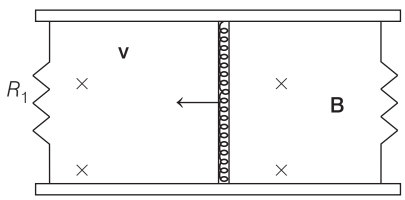
From the above figure, it can be seen that emf induced in side DC and AB will be zero. It is because **v** is parallel to length of conductor along X-axis.



$\therefore$ Net emf induced $= E_{BC} - E_{AD}$

$$= \frac{B_0(x+d)\,v_0 d}{a} - \frac{B_0 x v_0 d}{a} = \frac{B_0 v_0 d^2}{a}$$

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



Two resistors R_1 and R_2 are connected across the ends of the rails. There is a uniform magnetic field **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 **[2021, 16 March Shift-I]**

(a) both I_1 and I_2 are in anti-clockwise direction.

(b) both I_1 and I_2 are in clockwise direction.

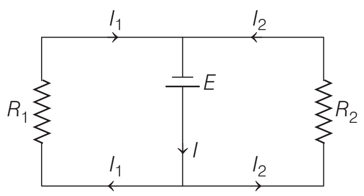
(c) I_1 is in clockwise direction and I_2 is in anti-clockwise direction.

(d) I_1 is in anticlockwise direction and I_2 is in clockwise direction.

Ans. *(c)*

According to Lenz's law, "An induced current flows in a direction in such a way that it always opposes the cause that induced it".

Considering this, it can be concluded that I_1 is in the clockwise direction and I_2 is in the anti-clockwise direction and the effective circuit with the directions of I_1 and I_2 can be shown as follows



26 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 2.5×10^{-4} Wb/m^2 and the angle of dip is 60°. The emf induced between the tips of the plane wings will be **[2021, 26 Feb Shift-II]**

(a) 108.25 mV (b) 54.125 mV
(c) 88.37 mV (d) 62.50 mV

Ans. *(a)*

Given, length of aeroplane wing, $l = 10$ m

Speed of aeroplane,

$$v = 180 \text{ km/h} = 50 \text{ ms}^{-1}$$

Magnetic flux density,

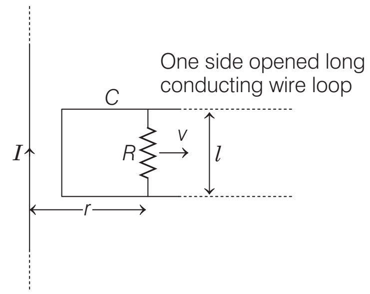
$$B = 2.5 \times 10^{-4} \text{ Wb/m}^2$$

Angle of dip, $\theta = 60°$

The emf induced between the tips of plane wings,

$$\varepsilon = Blv \sin\theta$$
$$= 2.5 \times 10^{-4} \times 10 \times 50 \sin 60°$$
$$= 2.5 \times 5 \times 10^{-2} \times \sqrt{3}/2$$
$$= 6.25 \times 1.732 \times 10^{-2}$$
$$= 108.25 \times 10^{-3}$$
$$= 108.25 \text{ mV}$$

27 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 l 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 **[2020, 5 Sep Shift-II]**



(a) $\frac{\mu_0}{4\pi}\frac{Ivl}{Rr}$ (b) $\frac{\mu_0}{\pi}\frac{Ivl}{Rr}$

(c) $\frac{2\mu_0}{\pi}\frac{Ivl}{Rr}$ (d) $\frac{\mu_0}{2\pi}\frac{Ivl}{Rr}$

Ans. *(d)*

Magnetic field due to wire at a distance r is given by

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

Induced emf, $\varepsilon_{\text{induced}} = Bvl = \frac{\mu_0 I vl}{2\pi r}$

Now, induced current in the loop,

$$I_{\text{induced}} = \frac{\varepsilon_{\text{induced}}}{R} = \frac{\mu_0 I}{2\pi}\frac{vl}{Rr}$$

Hence, correct option is (d).

28 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 **[2019, 10 Jan Shift-I]**

(a) 2 mV (b) 12 mV (c) 6 mV (d) 1 mV

Ans. *(b)*

Potential difference between opposite faces of cube is

$$V = \text{induced emf} = B\,l\,v$$

where,

B = magnetic field = 0.1 T,

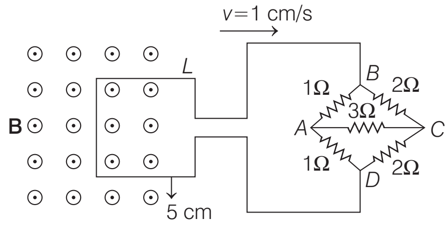
l = distance between opposite faces of cube

= 2 cm = 2×10^{-2} m and

v = speed of cube = 6 ms^{-1}.

Hence, $V = 0.1 \times 2 \times 10^{-2} \times 6 = 12$ mV

29 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 **[2019, 12 April Shift-I]**



(a) 60 μA (b) 170 μA
(c) 150 μA (d) 115 μA

Ans. *(b)*

Induced emf in the conductor of length L moving with velocity of 1 cm/s in the magnetic field of 1T is given by

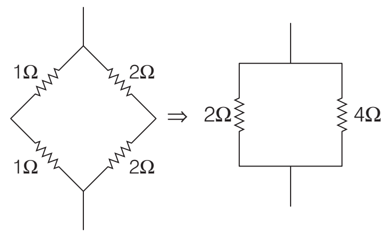
$$V = BLv \quad \text{...(i)}$$

If equivalent resistance of the circuit is R_{eq}, then current in the loop will be

$$i = \frac{V}{R_{eq}} = \frac{BLv}{R_{eq}} \quad \text{...(ii)}$$

Now, given network is a balanced Wheatstone bridge $\left(\frac{P}{Q} = \frac{R}{S}\right)$.

So, equivalent resistance of the Wheatstone bridge is



$$R_W = \frac{2\times4}{2+4} = \frac{8}{6} = \frac{4}{3}\Omega$$

Again, resistance of conductor is $1.7\,\Omega$.

So, effective resistance will be

$$R_{eq} = \frac{4}{3} + 1.7 = \frac{4}{3} + \frac{17}{10},$$

$$R_{eq} = \frac{40+51}{30} = \frac{91}{30} \simeq 3\Omega$$

By putting given values of R_{eq}, B and v in Eq. (ii), we have

$$i = \frac{(1)(5\times10^{-2})\times10^{-2}}{3}$$

[here, $L = 5\times10^{-2}$ m, $v = 1$ cm/s $= 10^{-2}$ m/s]

$$i = \frac{5\times10^{-4}}{3} = 1.67\times10^{-4}\text{ A}$$

$$i = 167\ \mu\text{A} \approx 170\ \mu\text{A}$$

30 A 10 m long horizontal wire extends from North-East to South-West. It is falling with a speed of $5.0\,\text{ms}^{-1}$ at right angles to the horizontal component of the earth's magnetic field of $0.3\times10^{-4}\ \text{Wb/m}^2$. The value of the induced emf in wire is **[2019, 12 Jan Shift-II]**

(a) 1.5×10^{-3} V
(b) 1.1×10^{-3} V
(c) 0.3×10^{-3} V
(d) 2.5×10^{-3} V

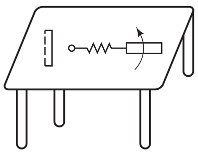
Ans. *(a)*

Wire falls perpendicularly to horizontal component of earth's magnetic field, so induced electromotive force $(\varepsilon) = Blv$

Substituting the given values, we get

$$\varepsilon = 0.3\times10^{-4}\times10\times5 = 1.5\times10^{-3}\text{ V}$$

31 A metallic rod of length l is tied to a string of length $2l$ and made to rotate with angular speed ω on a horizontal table with one end of the string fixe(d) If there is a vertical magnetic field B in the region, the emf induced across the ends of the rod is **[JEE Main 2013]**

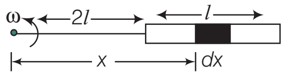


(a) $\frac{2B\omega l^3}{2}$ (b) $\frac{3B\omega l^3}{2}$

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

Ans. *(d)*

$\because$ Induced emf is rate of change of magnetic flux.



32 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 emf induced in the wire will be **[AIEEE 2011]**

(a) 6.0 mV (b) 3 mV
(c) 4.5 mV (d) 1.5 mV

Ans. *(b)*

Induced emf, $e = B_H\, lv$

$= 0.30\times10^{-4}\times20\times5.0$

$= 3$ mV

33 A boat is moving due East in a region where the earth's magnetic field is $5.0\times10^{-5}\text{NA}^{-1}\text{ m}^{-1}$ due North and horizontal. The boat carries a vertical aerial 2m long. If the speed of the boat is 1.50 ms^{-1}, the magnitude of the induced emf in the wire of aerial is **[AIEEE 2011]**

(a) 0.75 mV (b) 0.50 mV
(c) 0.15 mV (d) 1 mV

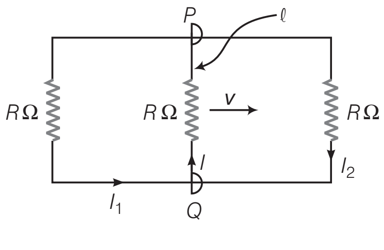
Ans. *(c)*

Induced emf,

$$e = B_H\, lv = 5.0\times10^{-5}\times2\times1.50$$

$$= 0.15\times10^{-3}\text{ V} = 0.15\text{ mV}$$

34 A rectangular loop has a sliding connector PQ of length l and resistance $R\,\Omega$ 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]**



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

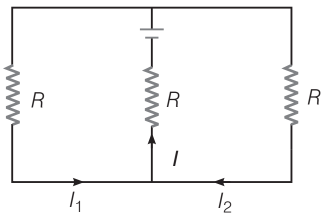
(b) $I_1 = I_2 = \frac{Blv}{3R}, I = \frac{2Blv}{3R}$

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

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

Ans. (*b*)

A moving conductor is equivalent to a battery of emf $= vBl$ [motion emf]



Equivalent circuit, $I = I_1 + I_2$ ...(i)

Applying Kirchhoff's law,

$$I_1R + IR - vBl = 0 \quad ...(ii)$$

$$I_2R + IR - vBl = 0 \quad ...(iii)$$

Adding Eqs. (ii) and (iii), we get

$$I_1R + IR - VBl + I_2R + IR - vBl = 0$$

$\Rightarrow\quad I_1R + I_2R + 2IR - 2vBl = 0$

$\Rightarrow\quad (I_1 + I_2)R + 2IR - 2vBl = 0$

$\Rightarrow\quad 2IR + IR = 2vBl$ [From Eq. (i)]

$\Rightarrow\quad I = \frac{2vBl}{3R}$

Subtracting Eq.(iii) from Eq.(ii), we get

$$I_1R + IR - VBl = 0$$
$$\underset{-}{}I_2R \underset{+}{} \underset{-}{}IR \underset{+}{-} VBl = \underset{-}{}0$$
$$I_1R - I_2R = 0$$

$\Rightarrow\quad R(I_1 - I_2) = 0$

$\Rightarrow\quad I_1 - I_2 = 0$ $[\because R \neq 0]$

$\Rightarrow\quad I_1 = I_2$ ...(iv)

From Eq. (i), we get

$I = 2I_1$ $[\because I_1 = I_2]$

$\Rightarrow\quad 2I_1 = I$

$\Rightarrow\quad I_1 = \frac{I}{2} = \frac{2vBl}{2\times3R} = \frac{vBl}{3R}$

$\therefore\quad I_1 = I_2 = \frac{vBl}{3R}$

35 In a uniform magnetic field of induction B, a wire in the form of semi-circle of radius r rotates about the diameter of the circle with angular frequency ω. If the total resistance of the circuit is R, the mean power generated per period of rotation is **[AIEEE 2004]**

(a) $\dfrac{B\,\pi r^2\omega}{2R}$ (b) $\dfrac{(B\,\pi r^2\omega)^2}{8R}$

(c) $\dfrac{(B\,\pi r\omega)^2}{2R}$ (d) $\dfrac{(B\,\pi r\omega^2)^2}{8R}$

Ans. ***(b)***

The flux associated with coil of area A and magnetic induction B is

$$\phi = BA\cos\theta = \frac{1}{2}B\pi r^2\cos\omega t \quad \left[\because A = \frac{1}{2}\pi r^2\right]$$

$$\therefore\quad e_{\text{induced}} = -\frac{d\phi}{dt} = -\frac{d}{dt}\left(\frac{1}{2}B\pi r^2\cos\omega t\right)$$

$$= \frac{1}{2}B\pi r^2\omega\sin\omega t$$

$$\therefore \text{ Power, } P = \frac{e^2_{\text{induced}}}{R} \quad [\because P = V^2/R]$$

$$= \frac{B^2\pi^2 r^4\omega^2\sin^2\omega t}{4R}$$

Hence, $P_{\text{mean}} = \langle P\rangle$

$$= \frac{B^2\pi^2 r^4\omega^2}{4R}\cdot\frac{1}{2} \quad \left[\because \langle\sin^2\omega t\rangle = \frac{1}{2}\right]$$

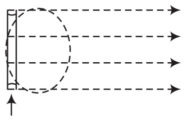
$$= \frac{(B\pi r^2\omega)^2}{8R}$$

36 A metal conductor of length 1 m rotates vertically about one of its ends at angular velocity 5 rad/s. If the horizontal component of earth's magnetic field is 0.2×10^{-4} T, then the emf developed between the two ends of the conductor is **[AIEEE 2004]**

(a) $5\,\mu$V (b) $50\,\mu$V
(c) 5 mV (d) 50 mV

Ans. ***(b)***

The emf induced between ends of conductor



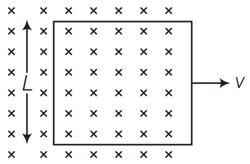
$$e = \frac{1}{2}B\omega L^2 = \frac{1}{2}\times0.2\times10^{-4}\times5\times(1)^2$$

$$= 0.5\times10^{-4}\text{ V}$$

$$= 5\times10^{-5}\text{ V}$$

$$= 50\,\mu\text{V}$$

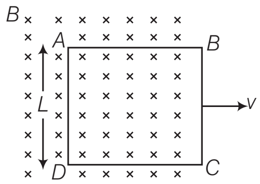
37 A conducting square loop of side L and resistance R moves in its plane with a uniform velocity v perpendicular to one of its sides. A magnetic induction B constant in time and space, pointing perpendicular and into the plane at the loop exists everywhere with half the loop outside the field, as shown in figure. The induced emf is **[AIEEE 2002]**



(a) zero (b) RvB (c) $\dfrac{vBL}{R}$ (d) vBL

Ans. ***(d)***

As the side BC is outside the field, no emf is induced across BC. Since, AB and CD are not cutting any flux, the emf induced across these two sides will also be zero.



The side AD is cutting the flux and emf induced across this side is BvL with corner A at higher potential.

[according to Lorentz force, force on the charges will be towards A and on –ve charges will be towards D].

TOPIC 3

Inductance (Self & Mutual)

38 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 I is passed in the square loop of side b, then the coefficient of mutual inductance between the two loops is **[2021, 31 Aug. Shift-I]**

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

(b) $\dfrac{\mu_0}{4\pi}\dfrac{8\sqrt{2}}{a}$

(c) $\dfrac{\mu_0}{4\pi}8\sqrt{2}\dfrac{b^2}{a}$

(d) $\dfrac{\mu_0}{4\pi}\dfrac{8\sqrt{2}}{b}$

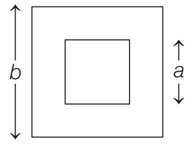
Ans. ***(a)***

Given, side of one square loop $= a$

Side of 2nd square loop $= b$

$b >> a$

Current $= i$



Since, $\phi = Mi$

$$M = \frac{\phi}{i} = \frac{B\cdot A}{i}$$

where, M = mutual inductance,

ϕ = magnetic flux,

B = magnetic field

and A = area.

Mutual inductance by 4 straight conductor,

$$M = \frac{4B\cdot A}{i}$$

$$M = \frac{4\left[\dfrac{\mu_0}{4\pi}\dfrac{i}{b/2}(\sin\pi/4 + \sin\pi/4)\right]a^2}{i}$$

$$\Rightarrow\ M = \frac{4}{i}\left(\frac{\mu_0}{4\pi}\frac{2i}{b}(1/\sqrt{2} + 1/\sqrt{2})\,a^2\right)$$

$$\Rightarrow\ M = 4\left(\frac{\mu_0}{4\pi}\frac{1}{b}\cdot\frac{2\times2}{\sqrt{2}}a^2\right)$$

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

39 An inductor coil stores 64 J of magnetic field energy and dissipates energy at the rate of 640 W when a current of 8A is passed through it. If this coil is joined across an ideal battery, find the time constant of the circuit in seconds. **[2021, 26 Aug. Shift-I]**

a. 0.4 b. 0.8
c. 0.125 d. 0.2

Ans. ***(d)***

Magnetic energy is stored in an inductor, whereas energy is dissipated through resistor.

Given, $U_m = 64$ J

$i = 8$ A and $P = 640$ W

As, magnetic energy, $U_m = \dfrac{1}{2}Li^2$

$$\Rightarrow\quad 64 = \frac{1}{2}\times L\times64$$

$$\Rightarrow\quad L = 2\text{ H}$$

Energy dissipated, $P = i^2R$

$$\Rightarrow\quad 640 = 64\,R \Rightarrow R = 10\,\Omega$$

Time constant of R-L circuit is given by

$$\tau = \frac{L}{R} \Rightarrow \tau = \frac{2}{10} = \frac{1}{5} = 0.2\text{ s}$$

40 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 **[2021, 18 March Shift-II]**

(a) $\frac{L}{R}\ln 5$ (b) infinite

(c) $\frac{L}{R}\ln 2$ (d) $\frac{L}{R}\ln 10$

Ans. ***(c)***

The expression of the magnetic energy stored in the solenoid, $U = LI^2/2$

The maximum value of the magnetic energy stored in the solenoid,

$$U_0 = LI_0^2/2$$

Given, $U = 25\% \times U_0$

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

Therefore, using the formula for the decay current in L-R circuit,

$$I = I_0(1 - e^{-t/\tau}) \Rightarrow \frac{I_0}{2} = I_0(1 - e^{-t/\tau})$$

$$e^{-t/\tau} = 1/2 \Rightarrow t = \tau \ln 2$$

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

41 A coil of inductance 2 H having negligible resistance is connected to a source of supply whose voltage is given by $V = 3t$ V (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. **[2021, 25 Feb Shift-I]**

Ans. ***(144)***

Given, inductance of coil, $L = 2$H

Supply voltage, $V = 3t$ V

Let E be the energy stored in the coil.

Since, emf $V = L \cdot \frac{dI}{dt}$

$$3t = L\frac{dI}{dt} \Rightarrow 3t\,dt = L\,dI$$

On integrating both sides, we get

$$3\frac{t^2}{2} = LI$$

At $t = 4$s,

$$\frac{3}{2} \times 4^2 = LI \Rightarrow \frac{3}{2} \times \frac{16}{L} = I$$

$$\Rightarrow 24/L = I \quad \text{...(i)}$$

As, $E = 1/2\, LI^2$

$\therefore$ $E = 1/2\, L\frac{24^2}{L^2}$ [From Eq. (i)]

$$= \frac{1}{2}\frac{24^2}{L} = \frac{24^2}{2 \times 2} = 144 \text{ J}$$

42 In a fluorescent lamp choke (a small transformer) 100 V of reverse voltage is produced when the choke current changes uniformly from 0.25A to 0 in a duration of 0.025 ms.The self-inductance of the choke (in mH) is estimated to be .... **[2020, 9 Jan Shift-I]**

Ans. ***(10)***

From an inductor (choke),

$$E_{\text{induced}} = L\frac{dI}{dt}$$

$$\Rightarrow L = \frac{E \times \Delta t}{\Delta t}$$

Here, $E = 100$ V, $\Delta I = 0.25$ A

and $\Delta t = 0.025$ ms $= 0.025 \times 10^{-3}$s

So, $L = \frac{100 \times 0.025 \times 10^{-3}}{0.25}$

$$= 100 \times 10^{-4} = 10 \text{ mH}$$

43 The total number of turns and cross-section area in a solenoid is fixe(d) However, its length L is varied by adjusting the separation between windings. The inductance of solenoid will be proportional to **[2019, 9 April Shift-I]**

(a) $1/L$ (b) L^2 (c) L (d) $1/L^2$

Ans. ***(a)***

Self inductance L_{sol} of a solenoid is given by

$$L_{\text{sol}} = \mu_0 n^2 \pi r^2 L$$

(Here, $n = N/L$ and L = length of solenoid)

or $L_{\text{sol}} = \frac{\mu_0 N^2 \pi r^2}{L}$

Clearly, $L_{\text{sol}} \propto \frac{1}{L}$

($\because$ All other parameters are fixed)

Note We can determine expression of L as follows

$$\phi = NBA = L_{\text{sol}}I$$

But for a solenoid, $B = \mu_0 nI$, $A = \pi r^2$

$\therefore$ $L_{\text{sol}}I = \mu_0 nI\pi r^2 N$

or $L_{\text{sol}} = \mu_0 n^2 \pi r^2 L = \mu_0 \frac{N^2}{L}\pi r^2$

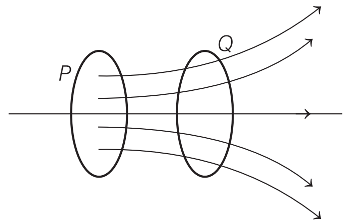
44 Two coils P and Q are separated by some distance. When a current of 3 A flows through coil P, a magnetic flux of 10^{-3} Wb passes through Q. No current is passed through Q. When no current passes through P and a current of 2 A passes through Q, the flux through P is **[2019, 9 April Shift-II]**

(a) 6.67×10^{-3} Wb (b) 6.67×10^{-4} Wb

(c) 3.67×10^{-3} Wb (d) 3.67×10^{-4} Wb

Ans. ***(b)***

As, coefficient of mutual induction is same for both coils



$\therefore$ $M_{PQ} = M_{QP}$

$$\Rightarrow \frac{N_P \phi_{PQ}}{I_Q} = \frac{N_Q \phi_{QP}}{I_P} \quad \text{...(i)}$$

Here, $N_P = N_Q = 1$,

$\phi_{PQ} = ?$, $\phi_{QP} = 10^{-3}$ Wb

$I_Q = 2$A, $I_P = 3$A

Substituting values in Eq (i), we get

$$\phi_{PQ} = \frac{I_Q \cdot \phi_{QP}}{I_P} = \frac{2}{3} \times 10^{-3}$$

$$= 0.667 \times 10^{-3}$$

$$= 6.67 \times 10^{-4} \text{ Wb}$$

45 The self-induced emf of a coil is 25 V. 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 **[2019, 10 Jan Shift-II]**

(a) 437.5 J (b) 740 J

(c) 637.5 J (d) 540 J

Ans. ***(a)***

Energy stored in an inductor of inductance L and current I is given by

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

When current is being changed from I_1 to I_2, change in energy will be

$$\Delta E = E_2 - E_1 = \frac{1}{2}LI_2^2 - \frac{1}{2}LI_1^2 \quad \text{...(i)}$$

As I_1 and I_2 are given, we need to find value of L.

Now, induced emf in a coil is $\varepsilon = L\frac{dI}{dt}$

Here, $\varepsilon = 25$ V,

$dI = I_2 - I_1 = (25 - 10) = 15$ A and $dt = 1$ s

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

Putting values of L, I_1 and I_2 in Eq. (i), we get

$$\Delta E = \frac{1}{2} \times \frac{5}{3} \times [25^2 - 10^2] = \frac{1}{2} \times \frac{5}{3} \times 525$$

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

46 There are two long coaxial 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 **[2019, 11 Jan Shift-I]**

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

(c) $\frac{n_2}{n_1}$ (d) $\frac{n_1}{n_2}$

Ans. ***(c)***

Mutual inductance for a coaxial solenoid of radius r_1 and r_2 and number of turns n_1 and n_2, respectively is given as,

$M = \mu_0 n_1 n_2 \pi r_1^2 l$ (for internal coil of radius r_1)

Self inductance for the internal coil,

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

$$\therefore \quad \frac{M}{L} = \frac{n_1 n_2}{n_1^2} = \frac{n_2}{n_1}$$

47 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 **[2019, 11 Jan Shift-II]**

(a) increases by a factor of 3

(b) decreases by a factor of $9\sqrt{3}$

(c) increases by a factor of 27

(d) decreases by a factor of 9

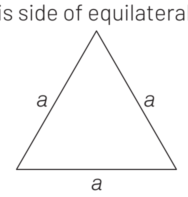
Ans. ***(c)***

Self-inductance of a coil is given by the relation $L = \mu_0 n^2 A \cdot l$

where, n is number of turns per unit length. Shape of the wooden frame is equilateral triangle.

$\therefore$ Area of equilateral triangle, $A = \frac{\sqrt{3}}{4} a^2$

(where, a is side of equilateral triangle)



$\therefore$ Self-inductance,

$$L = \mu_0 n^2 \left[\frac{\sqrt{3}}{4} a^2\right] . l$$

Here, $l = 3a \times N$ (where, N is total turns)

$$\therefore \quad L = \mu_0 n^2 \left[\frac{\sqrt{3}}{4} a^2\right] \times 3aN \text{ or } L \propto a^3$$

When each side of frame is increased by a factor 3 keeping the number of turns per unit length of the frame constant.

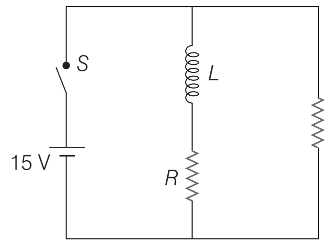
Then, $a' = 3a$

$\therefore \quad L' \propto (a')^3$ or $L' \propto (3a)^3$

or $\quad L' \propto 27a^3$ or $L' = 27L$

So, self-inductance will becomes 27 times.

48 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. **[2019, 12 Jan Shift-I]**

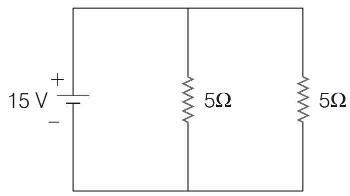


What will be the current through the battery long after the switch is closed?

(a) 6 A (b) 3 A (c) 5.5 A (d) 7.5 A

Ans. ***(a)***

After a sufficiently long time, in steady state, resistance offered by inductor is zero. So, circuit is reduced to



$\therefore$ Current in circuit is

$$I = \frac{E}{R_{eq}} = \frac{15}{\left(\frac{5 \times 5}{5+5}\right)} = \frac{15 \times 2}{5} = 6 \text{ A}$$

49 Two coils are placed close to each other. The mutual inductance of the pair of coils depends upon **[AIEEE 2003]**

(a) the rates at which currents are changing in the two coils

(b) relative position and orientation of the two coils

(c) the materials of the wires of the coils

(d) the currents in the two coils

Ans. ***(b)***

Mutual inductance M between two coils is given two coils is given by $M = \mu_0 n_1 n_2 \pi r_1^2 L$ where, n_1, n_2 are number of turns, r_1 is the radius of, coil and L is the length. From the above formula, it is clear that mutual inductance depends on distance between the coils and geometry $(\pi r^2 = \text{area})$ of two coils.

50 When the current changes from +2 A to –2 A in 0.05 s, an emf of 8 V is induced in a coil. The coefficient of self-induction of the coil is **[AIEEE 2003]**

(a) 0.2 H (b) 0.4 H

(c) 0.8 H (d) 0.1 H

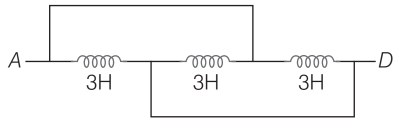
Ans. ***(d)***

$$e = -L \frac{dI}{dt} = -L \frac{(-2-2)}{0.05}$$

$$\Rightarrow \quad 8 = L \frac{(4)}{0.05}$$

$$\therefore \quad L = \frac{8 \times 0.05}{4} = 0.1 \text{ H}$$

51 The inductance between A and D is

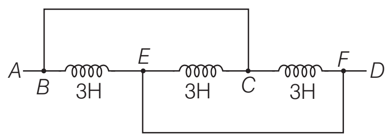


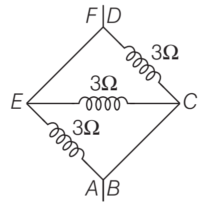
[AIEEE 2002]

(a) 3.66 H (b) 9 H

(c) 0.66 H (d) 1 H

Ans. ***(d)***





Here, inductors are in parallel.

$$\therefore \quad \frac{1}{L} = \frac{1}{3} + \frac{1}{3} + \frac{1}{3}$$

or $\quad L = 1 \text{ H}$