# 20

# Electromagnetic Induction

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

**01** The magnetic flux linked with a coil (in Wb) is given by the equation $\phi = 5t^2 + 3t + 16$
The magnitude of induced emf in the coil at the fourth second will be **[NEET (Oct.) 2020]**

(a) 33 V (b) 43 V
(c) 108 V (d) 10 V

**Ans.** *(d)*

Magnetic flux linked with coil,

$$\phi = (5t^2 + 3t + 16)\ \text{Wb}$$

Magnitude of induced emf,

$$e = \frac{d\phi}{dt} = \frac{d}{dt}(5t^2 + 3t + 16) = 10t + 3$$

At $t = 3\,\text{s}$,

$$e_3 = 10 \times 3 + 3 = 33\,\text{V}$$

At $t = 4\,\text{s}$

$$e_4 = 10 \times 4 + 3 = 43\,\text{V}$$

$\therefore$ Induced emf in coil at the fourth second is given as

$$e = e_4 - e_3 = 43 - 33 = 10\,\text{V}$$

**02** A coil of 800 turns effective area $0.05\ \text{m}^2$ is kept perpendicular to a magnetic field $5 \times 10^{-5}$ T. When the plane of the coil is rotated by 90º around any of its co-planar axis in 0.1 s, the emf induced in the coil will be **[NEET (National) 2019]**

(a) 0.2 V (b) $2 \times 10^{-3}$ V
(c) 0.02 V (d) 2 V

**Ans.** *(c)*

Given, area of coil, $A = 0.05\,\text{m}^2$
magnetic field, $B = 5 \times 10^{-5}$ T and
number of turns, $N = 800$.
The magnetic flux linked with the coil is

$$\phi = N(\mathbf{B} \cdot \mathbf{A}) = N\,BA\cos\theta \quad \text{... (i)}$$

where, $\theta$ is the angle between **B** and **A**.
The emf induced when coil is rotated from $\theta_1 = 0°$ to $\theta_2 = 90°$ is

$$e = -\frac{\Delta\phi}{\Delta t} = -\frac{\Delta}{\Delta t}(NBA\cos\theta) \ \text{[using Eq. (i)]}$$

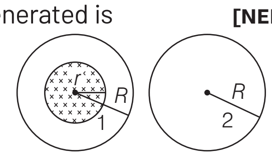
$$= -\frac{NBA}{\Delta t}(\cos\theta_2 - \cos\theta_1) \quad \text{... (ii)}$$

Here, $\Delta t = 0.1\,\text{s}$
Thus, substituting the given values in Eq. (ii), we get

$$e = -\frac{800 \times 5 \times 10^{-5} \times 0.05 \times [\cos 90° - \cos 0°]}{0.1}$$

$$= 2000 \times 10^{-5} = 0.02\,\text{V}$$

**03** A uniform magnetic field is restricted within a region of radius $r$. The magnetic field changes with time at a rate $\frac{d\mathbf{B}}{dt}$. Loop 1 of radius $R > r$ encloses the region $r$ and loop 2 of radius $R$ is outside the region of magnetic field as shown in the figure. Then, the emf generated is **[NEET 2016]**




(a) zero in loop 1 and zero in loop 2
(b) $-\frac{dB}{dt}\pi r^2$ in loop 1 and $-\frac{dB}{dt}\pi r^2$ in loop 2
(c) $-\frac{dB}{dt}\pi R^2$ in loop 1 and zero in loop 2
(d) $-\frac{dB}{dt}\pi r^2$ in loop 1 and zero in loop 2

**Ans.** *(c)*

Induced emf in the region is given by

$$|e| = \frac{d\phi}{dt}$$

where, $\phi = BA = \pi r^2 B$

$$\Rightarrow \quad \frac{d\phi}{dt} = -\pi r^2 \frac{dB}{dt}$$

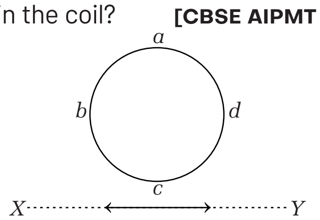
Rate of change of magnetic flux associated with loop 1

$$e_1 = -\frac{d\phi_1}{dt} = -\pi r^2 \frac{dB}{dt}$$

Similarly $e_2$ = emf associated with loop 2

$$= -\frac{d\phi_2}{dt} = 0 \quad [\because \phi_2 = 0]$$

**04** An electron moves on a straight line path $XY$ as shown. The $abcd$ is a coil adjacent in the path of electron. What will be the direction of current, if any induced in the coil? **[CBSE AIPMT 2015]**




(a) *abcd*
(b) *adcb*
(c) The current will reverse its direction as the electron goes past the coil
(d) No current induced

**Ans.** *(d)*

First current develops in direction of *abcd* but when electron moves away then magnetic field inside loop decreases and current changes its direction.

**05** A coil of resistance 400 Ω is placed in a magnetic field. If the magnetic flux $\phi$(Wb) linked with the coil varies with time $t$ (second) as $\phi = 50t^2 + 4$. The current in the coil at $t = 2$ s is **[CBSE AIPMT 2012]**

(a) 0.5 A (b) 0.1 A (c) 2 A (d) 1 A

**Ans.** *(a)*

Induced emf in a coil is given by

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

Given, $\phi = 50t^2 + 4$

and resistance, $R = 400\,\Omega$

So, $E = \left| -\frac{d\phi}{dt} \right|_{t=2} = |100t|_{t=2} = 200$ V

So, current in the coil will be

$$I = \frac{E}{R} = \frac{200}{400} = \frac{1}{2} = 0.5\text{ A}$$

**06** A conducting circular loop is placed in a uniform magnetic field, $B = 0.025$ T with its plane perpendicular to the loop. The radius of the loop is made to shrink at a constant rate of 1 mm $s^{-1}$. The induced emf when the radius is 2 cm, is **[CBSE AIPMT 2010]**

(a) $2\pi\,\mu$V (b) $\pi\,\mu$V (c) $\frac{\pi}{2}\,\mu$V (d) $2\,\mu$V

**Ans.** *(b)*

Magnetic flux $\phi$ linked with magnetic field **B** and area **A** is given by

$$\phi = \mathbf{B} \cdot \mathbf{A} = |\mathbf{B}||\mathbf{A}| \cos\theta$$

Here, $\theta = 0°$

So, $\phi = BA = B\pi r^2$

Now, Induced emf, $|e| = \left| \frac{-d\phi}{dt} \right| = B\pi(2r)\frac{dr}{dt}$

$= 0.025 \times \pi \times 2 \times 2 \times 10^{-2} \times 1 \times 10^{-3} = \pi\mu$V

**07** A rectangular, a square, a circular and an elliptical loop, all in the $xy$-plane, are moving out of a uniform magnetic field with a constant velocity, $\mathbf{v} = v\hat{\mathbf{i}}$. The magnetic field is directed along the negative $z$-axis direction. The induced emf, during the passage of these loops, out of the field region, will not remain constant for **[CBSE AIPMT 2009]**

(a) the rectangular, circular and elliptical loops
(b) the circular and the elliptical loops
(c) only the elliptical loop
(d) any of the four loops

**Ans.** *(b)*

Area coming out per second from the magnetic field is not constant for elliptical and circular loops, so induced emf, during the passage out of these loops, from the field region will not remain constant.

**08** A conducting circular loop is placed in a uniform magnetic field 0.04 T with its plane perpendicular to the magnetic field. The radius of the loop starts shrinking at $2\,\text{mm s}^{-1}$. The induced emf in the loop when the radius is 2 cm is **[CBSE AIPMT 2009]**

(a) $3.2\,\pi\,\mu$V (b) $4.8\,\pi\,\mu$V
(c) $0.8\,\pi\,\mu$V (d) $1.6\,\pi\,\mu$V

**Ans.** *(a)*

Magnetic field, $B = 0.04$ T and rate of change of radius of coil due to shrinkage,

$$\frac{-dr}{dt} = 2\text{ mm s}^{-1}$$

Induced emf,

$$e = \frac{-d\phi}{dt} = -B\frac{dA}{dt} = -B\frac{d(\pi r^2)}{dt}$$

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

Now, if $r = 2$ cm

$$e = -0.04 \times \pi \times 2 \times 2 \times 10^{-2} \times 2 \times 10^{-3}$$
$$= 3.2\,\pi\mu\text{V}$$

**09** A circular disc of radius 0.2 m is placed in a uniform magnetic field of induction $\frac{1}{\pi}$ (Wb/m$^2$) in such a way that its axis makes an angle of 60° with **B.** The magnetic flux linked with the disc is **[CBSE AIPMT 2008]**

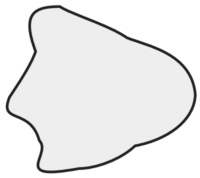
(a) 0.02 Wb (b) 0.06 Wb
(c) 0.08 Wb (d) 0.01 Wb

**Ans.** *(a)*

Magnetic flux $\phi = \mathbf{B} \cdot \mathbf{A}$

$$\phi = BA\cos\theta$$
$$= \frac{1}{\pi} \times \pi(0.2)^2 \cos 60° = 0.02\text{ Wb}$$

**10** As a result of change in the magnetic flux linked to the closed loop shown in the figure, an emf $V$ volt is induced in the loop. The work done (joule) in taking a charge $q$ coulomb once along the loop is **[CBSE AIPMT 2005]**



(a) $qV$ (b) zero
(c) $2qV$ (d) $\frac{qV}{2}$

**Ans.** *(a)*

Work done in moving a charge through potential difference $V$ is given by $W = qV$

**11** The magnetic flux through a circuit of resistance $R$ changes by an amount $\Delta\phi$ in a time $\Delta t$. Then the total quantity of electric charge $q$ that passes any point in the circuit during the time $\Delta t$ is represented by **[CBSE AIPMT 2004]**

(a) $q = \frac{1}{R} \cdot \frac{\Delta\phi}{\Delta t}$ (b) $q = \frac{\Delta\phi}{R}$
(c) $q = \frac{\Delta\phi}{\Delta t}$ (d) $q = R \cdot \frac{\Delta\phi}{\Delta t}$

**Ans.** *(b)*

From Faraday's second law, emf induced in the circuit

$$e = \frac{\Delta\phi}{\Delta t}$$

If $R$ is the resistance of the circuit, then

$$i = \frac{e}{R} = \frac{\Delta\phi}{R\Delta t}$$

Thus, charge passing through the circuit,

$$q = i \times \Delta t$$

$$\Rightarrow \quad q = \frac{\Delta\phi}{R\Delta t} \cdot \Delta t \Rightarrow q = \frac{\Delta\phi}{R}$$

**12** The total charge induced in a conducting loop when it is moved in magnetic field depends on **[CBSE AIPMT 1992]**

(a) the rate of change of magnetic flux
(b) initial magnetic flux
(c) the total change in magnetic flux
(d) final magnetic flux

**Ans.** *(c)*

Total charge induced in a conducting loop is

$$q = \int i\,dt$$

As, $i = \frac{e}{R}$

$$\therefore \quad q = \int \frac{e}{R}\,dt = \frac{1}{R}\int e\,dt$$

Induced emf $e$ is given by

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

$$\therefore \quad q = \frac{1}{R}\int\left(-\frac{d\phi}{dt}\right)dt = \frac{1}{R}\int d\phi$$

Hence, total charge induced in the conducting loop depends upon resistance of loop and change in magnetic flux.

**13** A rectangular coil of 20 turns and area of cross-section 25 sq cm has a resistance of 100 Ω. If a magnetic field which is perpendicular to the plane of coil changes at a rate of 1000 T/s, the current in the coil is **[CBSE AIPMT 1992]**

(a) 1 A (b) 50 A
(c) 0.5 A (d) 5 A

**Ans.** *(c)*

Total number of turns, $N = 20$

Area of coil, $A = 25\,cm^2$

$$= 25 \times 10^{-4}\,m^2$$

Change in magnetic field w.r.t. $t$

$$\frac{dB}{dt} = 1000\,T/s$$

Resistance of coil $R = 100\,\Omega$

$$i = ?$$

$$\text{Induced current, } i = \frac{e}{R} = \frac{NA\frac{dB}{dt}}{R} \quad \left[e = NA\frac{dB}{dt}\right]$$

$$= \frac{20 \times 25 \times 10^{-4} \times 1000}{100}$$

$$= 0.5\,A$$

**14** A magnetic field of $2 \times 10^{-2}$ T acts at right angles to a coil of area 100 $cm^2$, with 50 turns. The average emf induced in the coil is 0.1 V, when it is removed from the field in $t$ second. The value of $t$ is **[CBSE AIPMT 1991]**

(a) 10 s (b) 0.1 s (c) 0.01 s (d) 1 s

**Ans.** *(b)*

Emf induced in the coil due to change in magnetic flux

$$e = -\frac{d\phi}{dt} = -\frac{(\phi_2 - \phi_1)}{dt}$$

When magnetic field is perpendicular to coil

$$\phi_1 = NBA$$

When coil is removed, $\phi_2 = 0$

So, $e = -\frac{(0 - NBA)}{dt}$ or $dt = \frac{NBA}{e}$

Here, $N = 50$, $B = 2 \times 10^{-2}\,T$, $A = 100\,cm^2$

$= 10^{-2}\,m^2$ and $e = 0.1\,V$

$$\therefore \quad dt = \frac{50 \times 2 \times 10^{-2} \times 10^{-2}}{0.1} = 0.1\,s$$

**15** In a region of uniform magnetic induction $B = 10^{-2}$ T, a circular coil of radius 30 cm and resistance $\pi^2$ ohm is rotated about an axis which is perpendicular to the direction of $B$ and which forms a diameter of the coil.
If the coil rotates at 200 rpm the amplitude of the alternating current induced in the coil is **[CBSE AIPMT 1988]**

(a) $4\pi^2$ mA (b) 30 mA
(c) 6 mA (d) 200 mA

**Ans.** *(c)*

When a coil of $N$ number of turns and area $A$ is rotated in external magnetic field **B**, magnetic flux linked with the coil changes and hence an emf is induced in the coil. At this instant $t$, if $e$ is the emf induced in the coil, then

$$e = -\frac{d\phi}{dt} = -\frac{d}{dt}(NBA\cos\omega t)$$

Magnetic flux $\phi = NBA\cos\omega t$

$$\therefore \quad e = -NBA\frac{d}{dt}(\cos\omega t)$$

$$= NBA\,\omega\sin\omega t$$

The induced emf will be maximum, when

$$\sin\omega t = \text{maximum} = 1$$

$$\therefore \quad e_{max} = e_0 = NBA\omega$$

So, alternating emf induced is

$$e = e_0\sin\omega t$$

$$\text{Maximum current } i_0 = \frac{e_0}{R} = \frac{NBA\omega}{R}$$

Given, $N = 1$, $B = 10^{-2}$ T

$$A = \pi(0.3)^2\,m^2,\ R = \pi^2\,\Omega$$

$$f = \frac{200}{60}s^{-1} \quad \text{and} \quad \omega = 2\pi\left(\frac{200}{60}\right)$$

$$\therefore \quad i_0 = \frac{1 \times 10^{-2} \times \pi(0.3)^2 \times 2\pi \times 200}{60 \times \pi^2}$$

# TOPIC 2
## Motional EMF and Eddy Current

**16** A wheel with 20 metallic spokes each 1 m long is rotated with a speed of 120 rpm in a plane perpendicular to a magnetic field of 0.4 G. The induced emf between the axle and rim of the wheel will be (1 G = $10^{-4}$ T) **[NEET (Oct.) 2020]**

(a) $2.51 \times 10^{-4}$ V (b) $2.51 \times 10^{-5}$ V
(c) $4.0 \times 10^{-5}$ V (d) 2.51 V

**Ans.** *(a)*

Given, magnetic field,

$$B = 0.4\,G = 0.4 \times 10^{-4}\,T$$

$$l = 1\,m$$

Frequency, $f = 12\,\text{rpm} = \frac{120}{60}\,\text{rps} = 2\,Hz$

Induced emf between the axle and rim of the wheel is given as

$$e = \frac{1}{2}B\omega l^2 = \frac{1}{2}B(2\pi f)l^2 = \pi B f l^2$$

$$= 3.14 \times 0.4 \times 10^{-4} \times 2 \times 1^2$$

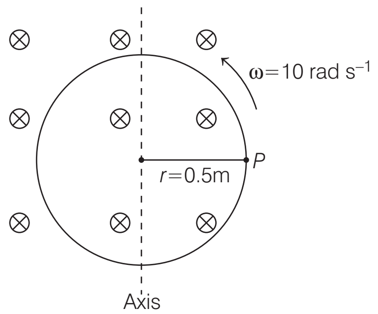
$$= 2.51 \times 10^{-4}\,V$$

**17** A cycle wheel of radius 0.5 m is rotated with constant angular velocity of 10 rad/s in a region of magnetic field of 0.1 T which is perpendicular to the plane of the wheel. The EMF generated between its centre and the rim is **[NEET (Odisha) 2019]**

(a) 0.25 V (b) 0.125 V
(c) 0.5 V (d) zero

**Ans.** *(b)*

When a conducting disc or wheel of radius $r$ rotates with constant angular velocity of $\omega$ about its axis in a uniform magnetic field perpendicular to its plane and parallel to its axis of rotation, then,




Induced emf is given by, $e = \frac{1}{2}B\omega r^2$ ...(i)

Here, $B = 0.1\,T$, $\omega = 10$ rad/s, $r = 0.5$ m

Substituting these values in Eq. (i), we get

$$\therefore \quad e = \frac{1}{2} \times 0.1 \times 10 \times (0.5)^2 = \frac{1}{8}\,V$$

$$= 0.125\,V$$

**18** In which of the following devices, the eddy current effect is not used? **[NEET (National) 2019]**

(a) Magnetic braking in train
(b) Electromagnet
(c) Electric heater
(d) Induction furnace

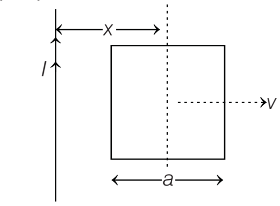
**Ans.** *(c)*

Electric heaters are not based on the eddy current effect. Rather their working is based on Joule's heating effect of current. According to this effect, the passage of an electric current through a resistor produces heat.

However, when a changing magnetic flux is applied to a bulk piece of conducting material, then circulating current is induced in the body of this conductor, which is usually known as eddy currents. This current shows both heating and magnetic effects.

Thus, it is the basic principle behind the working of magnetic braking in train, electromagnet and induction furnace.

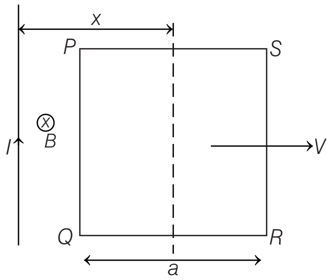
**19** A conducting square frame of side '$a$' and a long straight wire carrying current $I$ are located in the same plane as shown in the figure. The frame moves to the right with a constant velocity '$V$'. The emf induced in the frame will be proportional to **[CBSE AIPMT 2015]**




(a) $\frac{1}{x^2}$ (b) $\frac{1}{(2x-a)^2}$

(c) $\frac{1}{(2x+a)^2}$ (d) $\frac{1}{(2x-a)(2x+a)}$

**Ans.** *(d)*




Potential difference across $PQ$ is

$$V_P - V_Q = B_1(a)v = \frac{\mu_0 I}{2\pi\left(x-\frac{a}{2}\right)}av$$

Potential difference across side $RS$ of frame is

$$V_S - V_R = B_2(a)v = \frac{\mu_0 I}{2\pi\left(x+\frac{a}{2}\right)}av$$

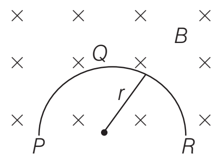
Hence, the net potential difference in the loop will be

$$V_{net} = (V_P - V_Q) - (V_S - V_R) = \frac{\mu_0 iav}{2\pi}\left[\frac{1}{\left(x-\frac{a}{2}\right)} - \frac{1}{\left(x+\frac{a}{2}\right)}\right]$$

$$= \frac{\mu_0 iav}{2\pi}\left(\frac{a}{\left(x-\frac{a}{2}\right)\left(x+\frac{a}{2}\right)}\right)$$

Thus, $V_{net} \propto \frac{1}{(2x-a)(2x+a)}$

**20** A thin semicircular conducting ring ($PQR$) of radius $r$ is falling with its plane vertical in a horizontal magnetic field $B$, as shown in figure. The potential difference developed across the ring when its speed is $v$, is **[CBSE AIPMT 2014]**




(a) zero
(b) $Bv\pi r^2/2$ and P is at higher potential
(c) $\pi rBv$ and R is at higher potential
(d) $2rBv$ and R is at higher potential

**Ans.** *(d)*

**Concept** An induced emf (BLv) called motional emf is produced by moving a conductor instead of varying the magnetic field.

For emf, $e = Bv(L_{eff}) = Bv \times (2r) = 2Bvr$
$[\because L_{eff} = \text{diameter} = 2r]$

$R$ will be at higher potential, we can find it by using right hand rule. The electrons of wire will move towards end $P$ due to electric force and at end $R$ the excess positive change will be left.

**21** A wire loop is rotated in a magnetic field. The frequency of change of direction of the induced emf is **[NEET 2013]**

(a) once per revolution
(b) twice per revolution
(c) four times per revolution
(d) six times per revolution

**Ans.** *(b)*

If a wire loop is rotated in a magnetic field, the frequency of change in the direction of the induced emf is twice per revolution.

**22** A conductor of length 0.4 m is moving with a speed of 7 m/s perpendicular to a magnetic field of intensity 0.9 Wb/m$^2$. The induced emf across the conductor is **[CBSE AIPMT 1995]**

(a) 1.26 V (b) 2.52 V
(c) 5.04 V (d) 25.2 V

**Ans.** *(b)*

Given, length of conductor $(l) = 0.4$ m
speed $(v) = 7$ m/s
Magnetic field $(B) = 0.9$ Wb/m$^2$
Induced emf, $e = Blv \sin\theta$ [$\theta = 90°$ as **B** is $\perp$ **v**]
$= 0.9 \times 0.4 \times 7 \times \sin 90° = 2.52$ V

**23** Eddy currents are produced when **[CBSE AIPMT 1988]**

(a) a metal is kept in varying magnetic field
(b) a metal is kept in steady magnetic field
(c) a circular coil is placed in a magnetic field
(d) current is passed through a circular coil

**Ans.** *(a)*

Eddy currents are the currents induced in the body of a conductor when the amount of magnetic flux linked with the conductor changes.

e.g. when we move a metal plate out of a magnetic field, the relative motion of the field and the conductor again induces a current in the conductor for which conduction electrons move in closed loops forming circular eddy currents in such a way that it opposes the magnetic field that created it as if the electrons are caught in an eddy or whirlpool. It is also called Foucault current.

# TOPIC 3

## Self and Mutual Inductances

**24** Two conducting circular loops of radii $R_1$ and $R_2$ are placed in the same plane with their centres coinciding. If $R_1 >> R_2$, the mutual inductance $M$ between them will be directly proportional to **[NEET 2021]**

(a) $\frac{R_1}{R_2}$ (b) $\frac{R_2}{R_1}$ (c) $\frac{R_1^2}{R_2}$ (d) $\frac{R_2^2}{R_1}$

**Ans.** *(d)*

Since, both conducting circular loops are in same plane and their centres are coinciding.

Hence, magnetic flux, $\phi = Mi$ ...(i)

Here, $M$ is the mutual inductance.

Also, the magnetic flux, $\phi = BA$

Here, $B$ is the magnetic field and $A (= \pi R_2^2)$ is the area of the inner circular loop.

If the current passing through the outer loop is $i$, then the magnetic field,

$$B = \frac{\mu_0 i}{2R_1}$$

Magnetic flux, $\phi = BA$

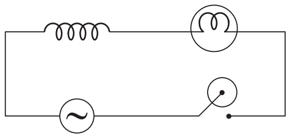
$$\Rightarrow \quad \phi = \frac{\mu_0 i}{2R_1} \pi R_2^2 \quad \text{...(ii)}$$

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

$$M = \frac{\mu_0}{2R_1} \pi R_2^2$$

Thus, the mutual inductance is directly proportional to the $\frac{R_2^2}{R_1}$.

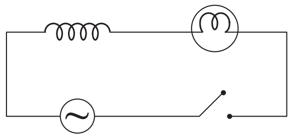
**25** A light bulb and an inductor coil are connected to AC ac source through a key as shown in the figure below. The key is closed and after sometime an iron rod is inserted into the interior of the inductor. The glow of the light bulb **[NEET (Oct.) 2020]**



(a) decreases
(b) remains unchanged
(c) will fluctuate
(d) increases

**Ans.** *(a)*

When an iron rod is inserted into the interior of the inductor, then inductance ($L$) of the coil increases.



Hence, inductive reactance ($X_L = \omega L$) also increases.

$\therefore$ Current in the circuit is given as

$$I = \frac{e}{X_L}$$

Hence, when $X_L$ increases, then current $I$ decreases. Therefore, glow of the light bulb will decrease.

**26** The magnetic potential energy stored in a certain inductor is 25 mJ, when the current in the inductor is 60 mA.

This inductor is of inductance **[NEET 2018]**

(a) 1.389 H
(b) 138.88 H
(c) 0.138 H
(d) 13.89 H

**Ans.** *(d)*

Given, magnetic potential energy stored in an inductor,

$$U = 25 \text{ mJ} = 25 \times 10^{-3} \text{ J}$$

Current in an inductor, $I_0 = 60$ mA $= 60 \times 10^{-3}$ A

As, the expression for energy stored in an inductor is given as

$$U = \frac{1}{2} L I_0^2$$

where, $L$ is the inductance of the inductor.

Substituting the given values in above equation., we get

$$(25 \times 10^{-3}) = \frac{1}{2} \times L \times (60 \times 10^{-3})^2$$

$$\Rightarrow \quad L = \frac{2 \times 25 \times 10^{-3}}{3600 \times 10^{-6}} = \frac{500}{36}$$

or $\quad L = 13.89$ H

**27** A long solenoid of diameter 0.1 m has $2 \times 10^4$ turns per metre. At the centre of the solenoid, a coil of 100 turns and radius 0.01 m is placed with its axis coinciding with the solenoid axis. The current in the solenoid reduces at a constant rate to 0 A from 4 A in 0.05 s. If the resistance of the coil is $10\pi^2\ \Omega$, the total charge flowing through the coil during this time is **[NEET 2017]**

(a) $32\pi\ \mu C$ (b) $16\ \mu C$
(c) $32\ \mu C$ (d) $16\pi\ \mu C$

**Ans.** *(c)*

**Thinking Process** Current induced in the coil is given by

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

$$\Rightarrow \quad \frac{\Delta q}{\Delta t} = \frac{1}{R}\left(\frac{\Delta \phi}{\Delta t}\right)$$

Given, resistance of the solenoid,

$$R = 10\pi^2\ \Omega$$

Radius of second and coil $r = 10^{-2}$

$$\Delta t = 0.05 \text{ s}, \Delta i = 4 - 0 = 4 \text{ A}$$

Charge flowing through the coil is given by

$$\Delta q = \left(\frac{\Delta \phi}{\Delta t}\right)\frac{1}{R}(\Delta t)$$

$$= \mu_0 N_1 N_2 \pi r^2 \left(\frac{\Delta i}{\Delta t}\right)\frac{1}{R}\Delta t$$

$$= 4\pi \times 10^{-7} \times 2 \times 10^4 \times 100 \times \pi \times (10^{-2})^2 \times \left(\frac{4}{0.05}\right) \times \frac{1}{10\pi^2} \times 0.05$$

$$= 32 \times 10^{-6} \text{ C} = 32\ \mu\text{C}$$

**28** A long solenoid has 1000 turns. When a current of 4A flows through it, the magnetic flux linked with each turn of the solenoid is $4 \times 10^{-3}$ Wb. The self-inductance of the solenoid is **[NEET 2016]**

(a) 3 H (b) 2 H
(c) 1 H (d) 4 H

**Ans.** *(c)*

Given, Number of turns of solenoid, $N = 1000$.

Current, $I = 4A$

Magnetic flux, $\phi_B = 4 \times 10^{-3}$ Wb

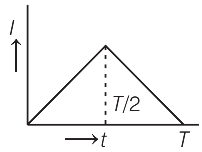
$\because$ Self inductance of solenoid is given by

$$L = \frac{\phi_B . N}{I} \quad \text{...(i)}$$

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

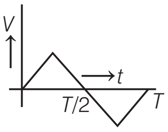
$$L = \frac{4 \times 10^{-3} \times 1000}{4} = 1H$$

**29** The current ($I$) in the inductance is varying with time according to the plot shown in figure. **[CBSE AIPMT 2012]**

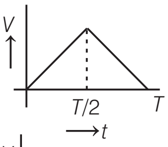



Which one of the following is the correct variation of voltage with time in the coil?

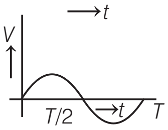
(a)



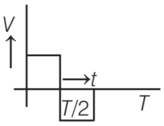

(b)




(c)




(d)




**Ans.** *(d)*

For inductor, as we know induced voltage

for $\quad t = 0$ to $t = T/2$,

$$V = L\frac{dI}{dt} = L\frac{d}{dt}\left(\frac{2I_0 t}{T}\right) = \text{constant}$$

For $\quad t = T/2$ to $t = T$,

$$V = L\frac{dI}{dt} = \left(\frac{-2I_0 t}{T}\right) = -\text{constant}$$

So, answer can be represented with graph (d).

**30** A long solenoid has 500 turns. When a current of 2 A is passed through it, the resulting magnetic flux linked with each turn of the solenoid is $4 \times 10^{-3}$ Wb. The self-inductance of the solenoid is **[CBSE AIPMT 2008]**

(a) 2.5 H (b) 2 H
(c) 1 H (d) 4 H

**Ans.** *(c)*

Net flux through solenoid is,

$$\phi_{net} = N\phi$$

$\therefore \quad \phi_{net} = 500 \times 4 \times 10^{-3} = 2\text{ Wb}$

where, $\phi$ = flux through each turn, and $N$ = total number of turns

Also, $\quad \phi_{net} = Li = 2\text{ Wb}$

Now, $L \times 2 = 2$

$\Rightarrow$ Self-inductance, $L = 1\text{H}$

**31** Two coils of self-inductances 2 mH and 8 mH are placed so close together that the effective flux in one coil is completely linked with the other. The mutual inductance between these coils is **[CBSE AIPMT 2006]**

(a) 10 mH (b) 6 mH
(c) 4 mH (d) 16 mH

**Ans.** *(c)*

When the total flux associated with one coil links with the other i.e. a case of maximum flux linkage, then mutual induction in coil 1 due coil 2 is

$$M_{12} = \frac{N_2\ \phi_{B_2}}{i_1}$$

and mutual induction in coil 2 due to coil 1 is

$$M_{21} = \frac{N_1\ \phi_{B_1}}{i_2}$$

Similarly, self-inductance in coil 1 is

$$L_1 = \frac{N_1\ \phi_{B_1}}{i_1}$$

and self-inductance in coil 2 is

$$L_2 = \frac{N_2\ \phi_{B_2}}{i_2}$$

If all the flux of coil 2 links coil 1 and *vice-versa*, then

$$\phi_{B_2} = \phi_{B_1}$$

Since, $M_{12} = M_{21} = M$, hence we have

$$M_{12}\ M_{21} = M^2$$

$$= \frac{N_1 N_2\ \phi_{B_1}\ \phi_{B_2}}{i_1\ i_2} = L_1 L_2$$

$\therefore M_{max} = \sqrt{L_1 L_2}$

Given, $\ L_1 = 2\text{ mH}, L_2 = 8\text{ mH}$

$\therefore \quad M_{max} = \sqrt{2 \times 8} = \sqrt{16} = 4\text{ mH}$

**32** In an inductor of self-inductance $L$ = 2 mH, current changes with time according to relation $i = t^2 e^{-t}$. At what time emf is zero? **[CBSE AIPMT 2001]**

(a) 4 s (b) 3 s
(c) 2 s (d) 1 s

**Ans.** *(c)*

It is given that emf is zero i.e.,

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

or $\quad L\dfrac{di}{dt} = 0$

or $\quad \dfrac{d}{dt}(t^2 e^{-t}) = 0 \quad (\text{As}, i = t^2 e^{-t})$

or $\ 2t \times e^{-t} + t^2 \times (-1)e^{-t} = 0$

or $\ te^{-t}(2 - t) = 0$ or $t = 2\text{s} \quad (\because te^{-t} \neq 0)$

**33** Two coils have a mutual inductance of 0.005 H. The current changes in the first coil according to equation $i = i_0 \sin\omega t$, $i_0 = 10\text{ A}$ and $\omega = 100\pi$ rad/s. The maximum value of emf in the second coil is **[CBSE AIPMT 1998]**

(a) $2\pi$ (b) $5\pi$
(c) $\pi$ (d) $4\pi$

**Ans.** *(b)*

**Problem Solving Strategy** Differentiate the given equation of current changing in first coil and find out the maximum change in $\dfrac{di}{dt}$.

The given equation of current changing in the first coil is

$$i = i_0 \sin\omega t \qquad \text{...(i)}$$

Differentiating Eq. (i) w.r.t. $t$, we have

$$\frac{di}{dt} = \frac{d}{dt}(i_0 \sin\omega t)$$

or $\quad \dfrac{di}{dt} = i_0\dfrac{d}{dt}(\sin\omega t)$

or $\quad \dfrac{di}{dt} = i_0\ \omega\cos\omega t$

For maximum $\dfrac{di}{dt}$, the value of $\cos\omega t$ should be equal to 1.

So, $\quad \left(\dfrac{di}{dt}\right)_{max} = i_0\ \omega$

The maximum value of emf is given by

$\therefore \quad e_{max} = M\left(\dfrac{di}{dt}\right)_{max} = Mi_0\omega$

As, $\ M = 0.005\text{ H}, i_0 = 10\text{ A}, \omega = 100\pi$ rad/s

$\therefore \quad e_{max} = 0.005 \times 10 \times 100\pi = 5\pi$

**34** A varying current in a coil changes from 10 A to zero in 0.5 s. If the average emf induced in the coil is 220 V, the self-inductance of the coil is **[CBSE AIPMT 1995]**

(a) 5 H (b) 6 H (c) 11 H (d) 12 H

**Ans.** *(c)*

Emf induced in the coil of self-inductance ($L$) is given by

$$e = -\frac{d\phi}{dt} = -\frac{d}{dt}(Li) \quad \text{or} \quad e = -L\frac{di}{dt}$$

$$\left(\frac{di}{dt} = \text{rate of flow of current in coil}\right)$$

As, $di = i_2 - i_1 = 0 - 10 = -10$ A

$dt = 0.5$ s

$e = 220$ V

$\therefore \quad 220 = -L\dfrac{(-10)}{0.5}$

or $\quad L = \dfrac{220}{20} = 11\text{H}$

**35** If $N$ is the number of turns in a coil, the value of self-inductance varies as **[CBSE AIPMT 1993]**

(a) $N^0$ (b) $N$ (c) $N^2$ (d) $N^{-2}$

**Ans.** ***(c)***

Magnetic flux, $\phi = BA$

and magnetic field due to circular coil is

$$B = \frac{\mu_0 Ni}{2R}$$

As self-inductance,

$$L = \frac{N\phi}{i}$$

$$\therefore \quad L = \frac{N}{i}(BA) = \frac{N}{i}\left(\frac{\mu_0 Ni}{2R}\right)A$$

$$= \frac{\mu_0 N^2 A}{2R}$$

$$\therefore \quad L \propto N^2$$

**36** What is the self-inductance of a coil which produces 5 V when the current changes from 3 A to 2 A in one millisecond? **[CBSE AIPMT 1993]**

(a) 5000 H (b) 5 mH
(c) 50 H (d) 5 H

**Ans.** ***(b)***

Emf induced in the coil is given by

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

If coil has self-inductance ($L$) and current $i$, then induced emf is given by

$$e = -\frac{d}{dt}(Li) \quad \text{or} \quad e = -L\frac{di}{dt}$$

$$\therefore \quad L = \frac{|e|}{\frac{di}{dt}}$$

Given, $|e| = 5\,V, di = 3 - 2 = 1\,A$

$$dt = 1\,\text{ms} = 1 \times 10^{-3}\,\text{s}$$

$$\therefore \quad L = \frac{5 \times 10^{-3}}{1} = 5\,\text{mH}$$

**37** A 100 mH coil carries a current of 1 A. Energy stored in its magnetic field is **[CBSE AIPMT 1991]**

(a) 0.5 J (b) 1 A
(c) 0.05 J (d) 0.1 J

**Ans.** ***(c)***

Energy stored in coil is

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

where, $L$ is self-inductance of coil and $i$ is current induced. Here, $L = 100$ mH $= 100 \times 10^{-3}$ H and $i = 1$A

$$\therefore \; E = \frac{1}{2} \times (100 \times 10^{-3}) \times (1)^2 = 0.05\text{ J}$$

**38** If the number of turns per unit length of a coil of solenoid is doubled, the self-inductance of the solenoid will **[CBSE AIPMT 1991]**

(a) remain unchanged
(b) be halved
(c) be doubled
(d) become four times

**Ans.** ***(d)***

A long solenoid is that whose length is very large as compared to its radius of cross-section. If $N$ is total number of turns in the solenoid, $A$ is area of each turn of the solenoid and $l$ is length of solenoid, then self-inductance of solenoid is given by

$$L = \frac{\mu_0 N^2 A}{l} \Rightarrow L = \mu_0 n^2 Al$$

($n$ = number of turns per unit length)

So, $\quad L \propto n^2$

When $n^2$ is doubled, $L$ becomes 4 times.

**39** The current in self-inductance $L = 40$mH is to be increased uniformly from 1 A to 11 A in 4 millisecond. The emf induced in inductor during the process is **[CBSE AIPMT 1990]**

(a) 100 V (b) 0.4 V
(c) 4 V (d) 440 V

**Ans.** ***(b)***

Emf induced in the coil due to change in magnetic flux

$$e = -\frac{d\phi}{dt} = -\frac{(\phi_2 - \phi_1)}{dt}$$

When magnetic field is perpendicular to coil

$$\phi_1 = NBA$$

When coil is removed, $\phi_2 = 0$

So, $\quad e = -\frac{(0 - NBA)}{dt} \quad \text{or} \quad dt = \frac{NBA}{e}$

Here, $N = 50$, $B = 2 \times 10^{-2}$ T, $A = 100\text{ cm}^2$ $= 10^{-2}\text{ m}^2$ and $e = 0.1$V

$$\therefore \quad dt = \frac{50 \times 2 \times 10^{-2} \times 10^{-2}}{0.1} = 0.1\text{ s}$$

**40** An inductor may store energy in **[CBSE AIPMT 1990]**

(a) its electric field
(b) its coils
(c) its magnetic field
(d) Both in electric and magnetic fields

**Ans.** ***(c)***

When the magnetic flux linked with a coil changes, an induced emf acts in the coil which is given by

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

The magnetic flux linked with a coil carrying a current $i$, is proportional to $i$.

or $\quad \phi \propto i \quad \text{or} \quad \phi = Li$

$$\therefore \quad e = -\frac{d\phi}{dt} = -L\frac{di}{dt}$$

The work done in maintaining the current for time $dt$

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

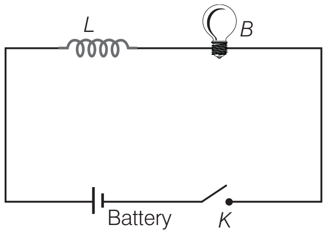
and the total work done while the current $i_0$ is being established

$$W = \int_0^t L\frac{di}{dt}\,i\,dt = \int_0^{i_0} L\,i\,di$$

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

Thus, an inductor may store energy in its magnetic field.

**41** In the circuit of figure, the bulb will become suddenly bright, if **[CBSE AIPMT 1989]**




(a) contact is made or broken
(b) contact is made
(c) contact is broken
(d) None of the above

**Ans.** ***(c)***

When the contact is suddenly broken, self induced current flow in the direction of main current. Therefore, the bulb $B$ will become suddenly bright.

**42** Energy in a current carrying coil is stored in the form of **[CBSE AIPMT 1988]**

(a) electric field
(b) magnetic field
(c) dielectric strength
(d) heat

**Ans.** ***(b)***

Energy stored in a current carrying coil is in the form of magnetic field. Total work done by the external source in building up current from zero to $i_0$ is

$$W = \frac{1}{2}Li_0^2$$

where, $L$ is self-inductance of coil.