

6. Electromagnetic Induction

Answers

Module 1: Faraday's laws of Electromagnetic Induction

A.6.1.1 (D)

$$\phi_1 = B_1 l_1^2, \quad \phi_2 = B_2 l_2^2$$

$$l_2 = 1.5 l_1 = \frac{3l_1}{2}, \quad \text{and} \quad B_2 = 3B_1$$

$$\therefore \phi_2 = 3B_1 \cdot \frac{9}{4} l_1^2 = \frac{27}{4} \phi_1$$

$$\therefore \frac{\phi_2}{\phi_1} = \frac{27}{4}$$

A.6.1.2 (A)

$$\phi_1 = B_1 A, \quad \text{and} \quad \phi_2 = B_1 A \cdot \cos 60^\circ = B_1 A \frac{1}{2} = \frac{\phi_1}{2}$$

$$\begin{aligned} \therefore \Delta\phi &= |\phi_2 - \phi_1| = \frac{\phi_1}{2} \\ \therefore \frac{\Delta\phi}{\phi_1} &= \frac{1}{2} \end{aligned}$$

A.6.1.3 (B)

Change in Flux = $BA - (-BA) = 2BA = \Delta\phi$, Say

induced emf = $\frac{\Delta\phi}{\Delta t}$, where $\Delta t = 1$ sec.

$$= \Delta\phi = 2BA$$

$$\therefore \text{current} = \frac{2BA}{R}$$

A.6.1.4 (C)

Volt = $\frac{\text{weber}}{\text{sec}}$ from Faraday's law

$$\frac{\text{V}}{\text{Wb}} = \frac{1}{\text{sec}}$$

A.6.1.5 (B)

$$\text{unit} = \left(\frac{\text{Tm}^2}{\text{T}} \right)^{\frac{1}{2}} \cdot \frac{1}{\text{s}} = \frac{\text{m}}{\text{s}}$$

A.6.1.6 (D)

$$\text{Change in flux} = \left(B - \frac{B}{2} \right) l^2 \cos \phi = \frac{1}{2} B l^2 \cos \phi$$

$$\text{Magnitude of emf induced} = \frac{1}{2t} B l^2 \cos \phi$$

$$\therefore \text{Corresponding current} = \frac{B l^2 \cos \phi}{2 R t}$$

A.6.1.7 (C)

$$\text{Flux} = \text{Volt. Sec} = \frac{\text{Energy}}{\text{coulomb}} \cdot \text{sec} = \frac{\text{Energy}}{\text{coulomb/sec}} = \frac{\text{Energy}}{\text{ampere}}$$

$$[\text{Energy}] \equiv \text{ML}^2\text{T}^{-2}$$

$$\text{So}[\text{Flux}] = \text{ML}^2\text{T}^{-2}\text{A}^{-1}$$

A.6.1.8 (A)

$$\text{From 6.1.7, } [\text{emf}] = [\text{Flux}]/\text{T} = \text{ML}^2\text{T}^{-3}\text{A}^{-1}$$

A.6.1.9 (A)

$$\text{Motional emf} = Bvl = Bva$$

A.6.1.10 (B)

$$\text{Motional emf} = Bvl = Bvb$$

A.6.1.11 (B)

(i) When velocity is normal to the longer side

$$\text{time} = \frac{\text{Length}}{\text{Velocity}} = \frac{b}{v}$$

(ii) When velocity is normal to the shorter side

$$\text{time} = \frac{a}{v}$$

Module 2 : Lenz's Law and Eddy Currents

A.6.2.1 (A) Clockwise in A and anticlockwise in B according to Lenz's law.

According to the right hand screw rule the magnetic field lines due to the current in the wire will flow through both A and B. In case of A the lines will be flowing out towards the reader from the page. As the current through the wire increases, magnetic flux through the coil A will increase and according to Faraday's law of EMI, a current is induced in the coil and according to Lenz's law this induced current will oppose the increase of flux and therefore induced current will tend to produce a magnetic field in a direction into the page. To do so, the face of the coil towards the reader will have south polarity and hence the direction of induced current in 'A' will be clockwise. Similarly we can see that the direction of induced current in B will be anticlockwise. Hence (A).

A.6.2.2 (D) The magnetic field of the wire lies in the plane of the coil. Therefore, the flux cutting through the coil is zero. Hence no current is induced in the coil. Hence the correct option is (D).

A.6.2.3 (B) When the irregular loop is turned into a circular loop, the area of the loop increases and hence flux passing through the loop also increases.

$$\phi = B A \cos \theta$$

Therefore, according to Faraday's law of EMI a current is induced in the coil and according to Lenz's law, this induced current is induced in such a way that it will oppose the increase of flux. To do so, it will try to decrease magnetic field 'B'. Therefore, induced current will produce a magnetic field just opposite to the given magnetic field, the given magnetic field is outward, so, the magnetic field of induced current will be inward. Hence the face of the coil facing the reader will develop south polarity and it will induce a clockwise current in the coil.

A.6.2.4 (D) For determining the direction of induced current the motion of that arm of the coil which remains inside the magnetic field and perpendicular to the motion of the coil should be taken into consideration.

According to Fleming's right hand rule, current in the coil (1) will be '*adcb*' and in coil (2) will be '*rqps*'.

A.6.2.5 (B) When the metal rod PQ is moved towards the right, then the area of the loop formed by rails, PQ & capacitor increases. So, the flux through the loop also increases.

$$\phi = B A \cos\theta$$

According to Faraday's laws of EMI, current is induced in the loop. This current is induced in such a way that it will oppose the increase of flux and it will do so by causing magnetic field ***B*** to decrease. The given magnetic field '***B***' is in an outward direction, so the induced current will tend to produce a magnetic field in an inward direction, making the face of the loop facing the reader as south and inducing a clockwise current in the loop. Therefore movement of electrons in the loop will be anticlockwise, Hence electrons will leave plate 'F' and reach plate 'E'. Hence plate 'F' acquires negative polarity and plate 'E' acquires positive polarity.

A.6.2.6 (A) When the key in coil 1 is just pressed, current starts growing in coil 1 in an anticlockwise direction, so, according to Lenz's law, current is induced in coil 2 in clockwise direction to oppose the growth of current in coil 1.

When the key in coil 1 is kept pressed, current in coil 1 acquires a steady value, so no flux change takes place in coil 2 and hence no current is induced.

When the key in coil 1 is released, current starts decaying in coil 1 but direction remains anticlockwise. Therefore a current is induced in the same direction i.e. anti-clockwise direction in coil 2 to oppose the decay of current in coil 1.

Hence option (A) is correct.

A.6.2.7 (D) No current is induced in the coil because current can be present only in a closed loop.

A.6.2.8 (B)

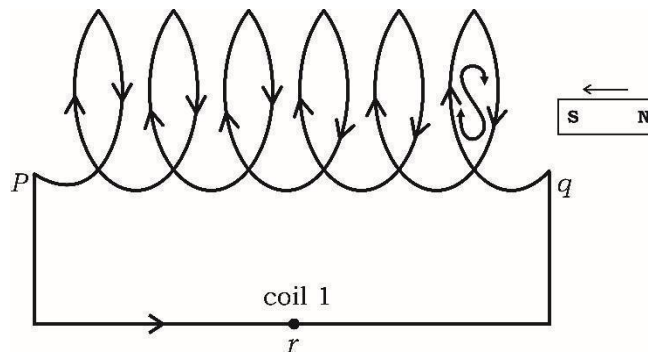


Fig.6.2.1

Direction of current = Prq

When the south pole of the magnet approaches the coil then according to Lenz's law the face of the coil facing the magnet will also behave as a south pole to oppose the motion of the south pole of the bar magnet and current will be induced in a clockwise direction. Hence current in coil 1 will be 'Prq'.

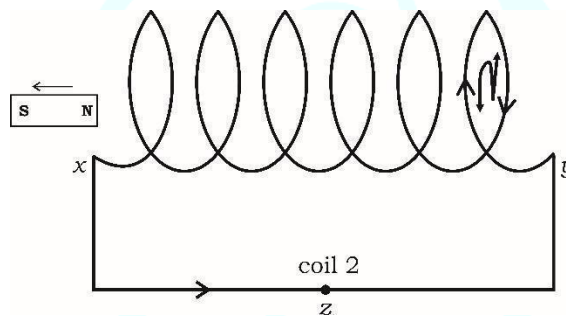


Fig.6.2.2

When north pole of the magnet moves away from coil 2 then according to Lenz's law the face of the coil facing the magnet i.e. left face of the coil will become south pole and because the coil is a magnetic dipole, the right face of the coil will become north and current will be induced in anticlockwise direction. Hence 'yzx'.

A.6.2.9 (D) Microwave oven works on the principle of resonance and uses electromagnetic waves.

A.6.2.10 (C) When a bar magnet falls through pipes (a) and (c) eddy currents are produced because they are made up of metal but no eddy current is induced in pipe (b). Now because eddy currents are induced currents and they oppose the cause of their production, hence acceleration in pipes (a) and (c) will be less than g

(acceleration due to gravity). In pipe 'C' as a cut is provided, so, eddy currents are reduced and are less than the currents in pipe 'a'

Hence, $g_1 < g_3 < g_2$.

A.6.2.11 (D) Oscillation of M_1 When magnet M_1 oscillates near the metal disc, eddy currents are induced in the disc end according to Lenz's law; these currents slow down the oscillations of M_1 , decreasing the frequency and increasing the time period.

Oscillation of M_2 No currents are induced in the wooden disc due to the oscillations of magnet M_2 because the wooden disc is an insulator. Therefore, its time period & frequency will remain the same.

Oscillation of M_3 When magnet M_3 oscillates near the slotted metal disc, eddy currents are induced but the magnitude of the eddy current will be less as compared to the currents induced in case of disc 1. Therefore in this case also the frequency of oscillation will decrease and the time period will increase. But this time period will be less than the time period of magnet M_1 .

Hence $T_2 < T_3 < T_1$ option (D) is correct.

Module 3 : Mutual Inductance and Self-Inductance

A.6.3.1 (C)

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

$$\begin{aligned} \therefore L &\equiv \frac{(\text{emf}) \times \text{time}}{\text{current}} = \frac{\frac{\text{energy}}{\text{charge}} \times \text{time}}{\text{current}} = \frac{\text{energy} \times \text{time}}{\text{current} \times \text{time} \times \text{current}} = \frac{\text{energy}}{(\text{current})^2} \\ &= \frac{ML^2 T^{-2}}{A^2} = ML^2 T^{-2} A^{-2} \end{aligned}$$

A.6.3.2 (D)

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

$$\therefore \text{henry} = \frac{\text{volt sec}}{\text{ampere}}$$

$$\therefore \text{henry} = \text{ohm sec}$$

$$\therefore \frac{\text{henry}}{\text{ohm}} = \text{sec}$$

A.6.3.3 (B)

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

$$\therefore |\varepsilon_{avg}| = L \frac{\Delta i}{\Delta t} \therefore L = \frac{|\varepsilon_{avg}| \Delta t}{\Delta i} = \frac{150 \text{ V} \times 0.02 \text{ s}}{3 \text{ A}} = 1 \text{ H}$$

A.6.3.4 (D)

$$\varepsilon_1 = -M_{12} \frac{dI_2}{dt}$$

$$|\varepsilon_1| = -M_{12} \frac{\Delta I_2}{\Delta t} = 2 \text{ H} \frac{(20 \text{ A} - 10 \text{ A})}{1 \text{ s}}$$

$$= \frac{2 \times 10}{1} \frac{\text{HA}}{\text{s}}$$

$$= 20 \text{ V}$$

A.6.3.5 (A)

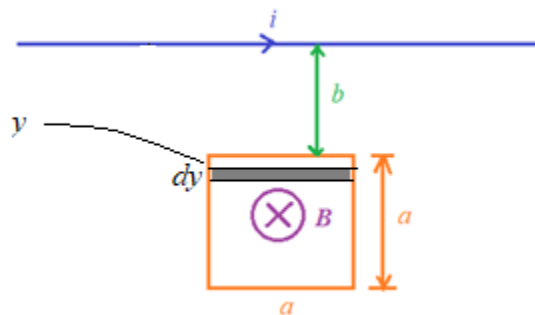


Fig.6.3.1

$$B = \frac{\mu_0 i}{2\pi(b+y)}$$

$$\text{Flux through the elementary strip} = \frac{\mu_0 i a dy}{2\pi(b+y)}$$

∴ Flux through the coil

$$= \frac{\mu_0 i a}{2\pi} \int_0^a \frac{dy}{b+y} = \phi, \text{ say} = \frac{\mu_0 i a}{2\pi} \left| \ln|b+y| \right|_0^a = \frac{\mu_0 i a}{2\pi} \ln \left| \frac{a+b}{b} \right|$$

∴ Mutual inductance

$$= \frac{\mu_0 a}{2\pi} \ln \left| 1 + \frac{b}{a} \right| = \frac{4\pi \times 10^{-7} \text{ Hm}^{-1} \times 0.04 \text{ m}}{2\pi} \ln \left| 1 + \frac{1}{2} \right| = 2 \times 10^{-7} \times 10^{-2} \ln \frac{3}{2} = 2 \ln \frac{3}{2} \times 10^{-9} \text{ H}$$

A.6.3.6 (D)

$$L_{\text{eff}} = L_1 + L_2 = 12 + 3 = 15 \text{ mH}$$

A.6.3.7 (A)

$$L_{\text{eff}} = \frac{L_1 L_2}{L_1 + L_2} = \frac{5 \times 10}{5 + 10} = \frac{50}{15} = \frac{10}{3} = 3.33 \text{ H}$$

A.6.3.8 (D)

$$\phi = NAB \cos \omega t = 50 \times 2 \text{ m}^2 \times 2 \text{ Wm}^{-2} \cos \frac{1200}{60} 2\pi t$$

$$\phi = 200 \cos 40\pi t$$

$$|\epsilon| = \left| \frac{d\phi}{dt} \right| = 4000 \times 2\pi \sin 40\pi t$$

$$|\epsilon| = 8000\pi \sin 40\pi t$$

A.6.3.9 (B)

$$i_{final} = \frac{1V}{1\Omega} = 1$$

Within 1% of the final value means $(1 - 0.01) A = 0.99 A$

∴ From the given eqn.

$$0.99 = 1 - e^{-t}$$

$$\therefore e^{-t} = 1 - 0.99 = 0.01$$

$$\therefore e^t = 100 \text{ or } t = \ln 100 = 2 \ln 10 = 2 \times 2.3 = 4.6 \text{ s}$$

A.6.3.10 (C)

Mass decides rate of change of velocity when force is applied $\left(F = m \frac{dv}{dt}\right)$.

Inductance decides rate of change of current when emf is applied $\left(e = L \frac{di}{dt}\right)$.



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