

New

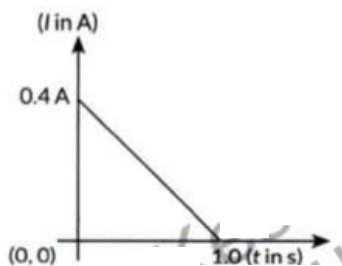
SURE SHOT QUESTIONS 2026

Chapter – 06 (Questions)

Electromagnetic Induction

Questions

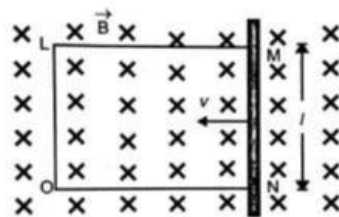
- Starting from the expression for the energy $W = \frac{1}{2}LI^2$, stored in a solenoid of self-inductance L to build up the current I , obtain the expression for the magnetic energy in terms of the magnetic field B , area A and length l of the solenoid having n number of turns per unit length. Hence, show that the energy density is given by $B^2/2\mu_0$
- When conducting loop of resistance $10\ \Omega$ and area $10\ \text{cm}^2$ is removed from an external magnetic field acting normally, the variation of induced current in the loop with time is shown in the figure.



Find the

- Total charge passed through the loop.
 - Change in magnetic flux through the loop.
 - Magnitude of the magnetic field applied.
- Define mutual inductance between a pair of coils. Derive an expression for the mutual inductance of two long coaxial solenoids of same length wound one over the other.
OR
Define the term 'mutual inductance' between the two coils. Obtain the expression for mutual inductance of a pair of long coaxial solenoid each of length l and radii r_1 and r_2 ($r_2 \gg r_1$). Total number of turns in the two solenoid are N_1 and N_2 respectively.
 - (i) Define mutual inductance.
(ii) A pair of adjacent coils has a mutual inductance of $1.5\ \text{H}$. If the current in one coil changes from 0 to $20\ \text{A}$ in $0.5\ \text{s}$, what is the change of flux linkage with the other coil?

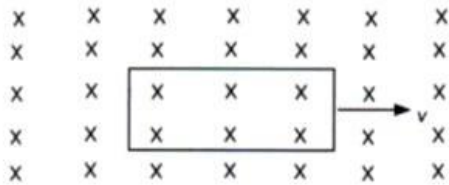
- A 100 -turn coil of radius $1.6\ \text{cm}$ and resistance $5.0\ \Omega$ is co-axial with a solenoid of 250 turns/cm and radius $1.8\ \text{cm}$. The solenoid current drops from $1.5\ \text{A}$ to zero in $25\ \text{ms}$. Calculate the current induced in the coil in this duration. (Take $\pi^2 = 10$)
- (i) State Lenz's law. In a closed circuit, the induced current opposes the change in magnetic flux that produced it as per the law of conservation of energy. Justify.
(ii) A metal rod of length $2\ \text{m}$ is rotated with a frequency $60\ \text{rev/s}$ about an axis passing through its centre and perpendicular to its length. A uniform magnetic field of $2\ \text{T}$ perpendicular to its plane of rotation is switched on in the region. Calculate the e.m.f induced between the (i) centre and the end of the rod.
- A rectangular conductor LMNO is placed in uniform magnetic field of $0.5\ \text{T}$. the field is directed perpendicular to the plane of the conductor. When the arm MN of length of $20\ \text{cm}$ is moved towards left with a velocity of $10\ \text{m s}^{-1}$, calculate the emf induced in the arm. Given the resistance of the arm to be $5\ \Omega$ (assuming that other arms are of negligible resistance) find the value of the current in the arm.



- Define self – inductance of a coil. Obtain the expression for the energy stored in an inductor L connected across a source of emf.
OR
Define the term self – inductance of a solenoid. Obtain the expression for the magnetic energy stored in an inductor of self – inductance L to build up a current I through it.
- The currents flowing in the two coils of self – inductance $L_1 = 16\ \text{mH}$ and $L_2 = 12\ \text{mH}$ are increasing at the same rate. If the power supplied

to the two coils are equal, find the ratio of (i) induced voltages, (ii) the currents and (iii) the energies stored in the two coils at a given instant.

10. A rectangular loop which was initially inside the region of uniform and time – independent magnetic field, is pulled out with constant velocity v as shown in the figure.



- (a) Sketch the variation of magnetic flux, the induced current, and power dissipated as Joule heat as function of time.
 (b) If instead of rectangular loop, circular loop is pulled out; do you expect the same value of induced current? Justify your answer. Sketch the variation of flux in this case with time.

11. State Lenz's law. A metallic rod held horizontally along east-west direction, is allowed to fall under gravity. Will there be an emf induced at its ends? Justify your answer.

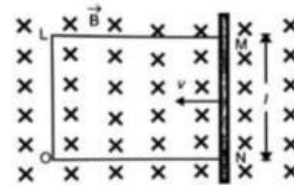
12. (a) Derive an expression for the induced emf developed when a coil of N turns, and area of cross-section A , is rotated at a constant angular speed ω in a uniform magnetic field B .

- (b) A wheel with 100 metallic spokes each 0.5 m long is rotated with a speed of 120 rev/min in a plane normal to the horizontal component of the Earth's magnetic field. If the resultant magnetic field at that place is 4×10^{-4} T and the angle of dip at the place is 30° , find the emf induced between the axle and the rim of the wheel.

13. (a) State the principle of an ac generator and explain its working with the help of a labelled diagram. Obtain the expression for the emf induced in a coil having N turns each of cross-sectional area A , rotating with a constant angular speed ' ω ' in a magnetic field \vec{B} , directed perpendicular to the axis of rotation.

- (b) An aeroplane is flying horizontally from west to east with a velocity of 900 km/hour. Calculate the potential difference between the ends of its wings having a span of 20m. The horizontal component of the Earth's magnetic field is 5×10^{-4} T and the angle of dip is 30° .

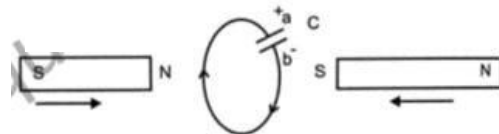
14. A rectangular conductor LMNO is placed in uniform magnetic field of 0.5 T. The field is directed perpendicular to the plane of the conductor. When the arm MN of length of 20 cm is moved towards left with a velocity of 10 ms^{-1} , calculate the emf induced in the arm. Given the resistance of the arm to be 5Ω (assuming that other arms are of negligible resistance) find the value of the current in the arm.



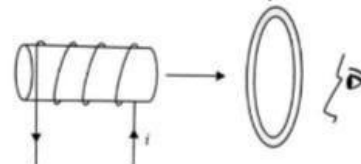
15. Two bar magnets are quickly moved towards a metallic loop connected across a capacitor 'C' as shown in the figure. Predict the polarity of the capacitor.



Soln. In this situation, a will become positive with respect to b, as current induced is in clockwise direction.

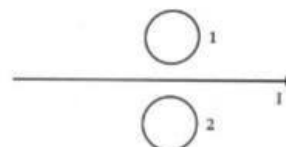


16. Figure shows a current carrying solenoid moving towards a conducting loop. Find the direction of the current induced in the loop.



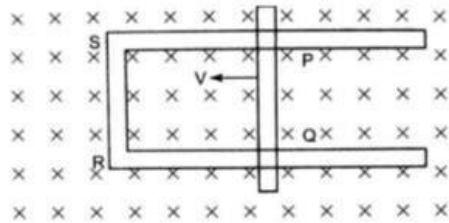
17. What is magnetic flux? Write its SI unit.

18. What is the direction of induced currents in metal rings 1 and 2 when current I in the wire is increasing steadily?



19. Figure shows a rectangular loop conducting PQRS in which the arm PQ is free to move. A uniform magnetic field acts in the direction perpendicular to the plane of the loop. Arm PQ is moved with a velocity v toward the arm RS. Assuming that the arms QR, RS and SP have negligible resistances and the moving arm PQ has the resistance r , obtain the

expression for (i) the current in the loop (ii) the force and (iii) the power required to move the arm PQ



20. A metallic rod of length L is rotated at angular speed normal to a uniform magnetic field B . Derive expressions for the (i) emf induced in the rod (ii) current induced and (iii) heat dissipation, if the resistance of the rod is R .
21. State Lenz's Law. Explain, by giving examples that Lenz's Law is a consequence of conservation of energy
22. A light bulb and a solenoid are connected in series across an ac source of voltage. Explain, how the glow of the light bulb will be affected when an iron rod is inserted in the solenoid.
23. Define self-inductance of a coil. Show that magnetic energy required to build up the current I in a coil of self-inductance L is given by $\frac{1}{2}LI^2$
24. An air-cored solenoid with length 30 cm, area of cross-section 25 cm^2 and number of turns 500, carries a current of 2.5 A. The current is suddenly switched off in a brief time of 10^{-3} s . How much is the average back emf induced across the ends of the open switch in the circuit?

25. Distinguish between self-inductance and mutual inductance.
26. A conductor of length ' l ' is rotated about one of its ends at a constant angular speed ' ω ' in a plane perpendicular to a uniform magnetic field B . Plot graphs to show variations of the emf induced across the ends of the conductor with (i) angular speed ω and (ii) length of the conductor l .
27. Two concentric circular loops of radius 1 cm and 20 cm are placed coaxially.
- Find mutual inductance of the arrangement.
 - If the current passed through the outer loop is changed at a rate of 5 A/ms, find the emf induced in the inner loop. Assume the magnetic field on the inner loop to be uniform.
28. (a) Draw a schematic diagram for an ac generator. Explain its working and obtain the expression for the instantaneous value of the emf in terms of the magnetic field B , number of turns N of the coil of area A rotating with angular frequency ω . Show how an alternating emf is generated by a loop of wire rotating in a magnetic field.
- (b) A circular coil of radius 10 cm and 20 turns is rotated about its vertical diameter with angular speed of 50 rad s^{-1} in a uniform horizontal magnetic field of $3.0 \times 10^{-2} \text{ T}$.
- Calculate the maximum and average emf induced in the coil.
 - If the coil forms a closed loop of resistance 10Ω , calculate the maximum current in the coil and the average power loss due to Joule heating.



SURE SHOT QUESTIONS 2026

Chapter – 06 (Solutions)

Electromagnetic Induction

Solutions

1. Soln. Given:

$$\text{Energy } W = \frac{1}{2} LI^2$$

A solenoid having magnetic field B, area A, & length l and having n numbers of turns per unit length.

Self-inductance of the solenoid is given by:

$$L = \mu_0 n^2 l A$$

$$B = \mu_0 n I$$

$$\therefore W = \frac{1}{2} \mu_0 n^2 l A I^2$$

$$\therefore B^2 = \mu_0^2 n^2 I^2$$

$$V = AL(\text{volume})$$

$$\Rightarrow W = \frac{1}{2\mu_0} \mu_0^2 n^2 l A I^2$$

$$\Rightarrow W = \frac{1}{2\mu_0} B^2 V$$

$$\text{Energy density} = \frac{W}{V} = \frac{B^2}{2\mu_0}$$

2. Ans. (i) We know that, $l = \frac{dq}{dt} \Rightarrow dq = I dt$

$$\therefore q = \int I dt = \text{Area under the } I-t \text{ curve}$$

$$= \frac{1}{2} \times 0.4 \times 1 = 0.2 \text{ C}$$

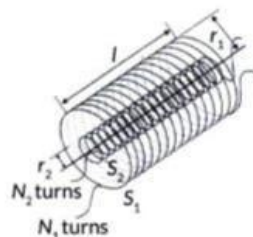
(ii) As we know $|\mathcal{E}| = \frac{d\phi}{dt} \Rightarrow \frac{dq}{dt} \times R = \frac{d\phi}{dt}$

$$\Rightarrow \phi = qR = 0.2 \times 10 = 2 \text{ Wb}$$

(iii) Now, $\phi = B.A = B(10 \times 10^{-4})$

$$\Rightarrow B = \frac{2}{10 \times 10^{-4}} = 2000 \text{ T}$$

3. Ans. Mutual Inductance: The phenomenon according to which an opposing emf is produced as a result of change in current or magnetic flux linked with another coil. Consider two long coaxial solenoids each of length l. Let n_1 be the number of turns per unit length of inner solenoid S_1 of radius r_1 , n_2 be the number of turns per unit length of outer solenoid S_2 of radius r_2 . Let N_1 and N_2 be the total number of turns of solenoids S_1 and S_2 respectively.



When a current i is passed through S_2 , the magnetic flux linked with solenoid S_1 is

$$N_1 \phi_1 = M_{12} i_2 \quad \dots\dots\dots(i)$$

Where M_{12} is called the mutual inductance of solenoid S_1 with respect to solenoid S_2 .

It is also referred as the coefficient of mutual induction.

The magnetic field due to current i in S_2 is

$$B_2 = \mu_0 n_2 i \quad \dots\dots\dots(ii)$$

\therefore The magnetic flux linked with S_1 is

$$N_1 \phi_1 = B_2 (\pi r_1^2) n_1 l = \mu_0 n_1 n_2 \pi r_1^2 l i_2 \quad \dots\dots\dots(iii)$$

Where $n_1 l$ is the total number of turns in solenoid S_1 .

From (i) and (iii), we get

$$M_{12} = \mu_0 n_1 n_2 \pi r_1^2 l \quad \dots\dots\dots(iv)$$

Which is required expression.

Similarly, $M_{21} = \mu_0 n_1 n_2 \pi r_1^2 l \quad \dots\dots\dots(v)$

From (iv) and (v), we get

$$M_{12} = M_{21} = M$$

Hence, coefficient of mutual induction between two coaxial solenoid is

$$M = \mu_0 n_1 n_2 \pi r_1^2 l \text{ or } M = \frac{\mu_0 N_1 N_2 \pi r_1^2}{l}$$

4. Ans. (i) The phenomenon of inducing current in a circuit by changing the current or flux in a neighbouring circuit is called mutual induction. S.I. unit of mutual inductance is henry denoted by H.

(ii) Here, $M = 1.5 \text{ H}$, $\Delta I_1 = 20 \text{ A}$, $\Delta t = 0.5 \text{ s}$, $\Delta \phi = ?$

We know, emf induced in the second coil,

$$\mathcal{E} = - \frac{(\Delta \phi)_2}{\Delta t} = - \frac{M \Delta I_1}{\Delta t}$$

$$\therefore (\Delta\phi)_2 = M\Delta I_1 = 1.5 \times 20 = 30 \text{ Wb}$$

5. Ans. Induced emf is given by,

$$e = -N \frac{d\phi}{dt} = -N \frac{d}{dt} (BA \cos\theta)$$

Magnetic field produced by solenoid, $B = \mu_0 ni$

$$\text{Emf induced in coil } \varepsilon = -N \frac{d\phi}{dt}; iR = -N \frac{d}{dt} (BA)$$

(I is the current induced in coil)

$$\text{Hence, } iR = -N \frac{d}{dt} (\mu_0 niA)$$

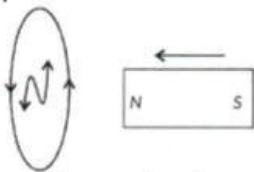
$$i = -\frac{N}{R} \mu_0 nA \frac{di}{dt}$$

Given, $di = 1.5 \text{ A}$ for $dt = 25 \text{ ms}$, $n = 250 \text{ turns/cm}$,
 $A = r(1.8 \times 10^{-2})^2$, $N = 100$ and $R = 5.0 \Omega$;

$$i = (-) \frac{100}{5} \times 4\pi \times 10^{-7} \times \frac{250}{10^{-2}} \times \pi \times (1.8 \times 10^{-2})^2 \times \frac{1.5}{25 \times 10^{-3}}$$

$$|i| = 0.0389 \text{ A}$$

6. Ans. (i) Lenz's law states that the direction of the induced emf and the direction of induced current are such that they oppose the cause which produces them.



When the N pole of a magnet is moved towards a coil, the induced current in the coil flows in anticlockwise direction on the side of magnet, so as to acquire north polarity and oppose the motion of the magnet towards the coil, by applying repulsive force on it.

In order to continue the change in magnetic flux linked with the circuit, some work is to be done or some energy has to be spent against the opposition offered by induced EMF. This energy spent by the external source ultimately appears in the circuit in the form of electrical energy.

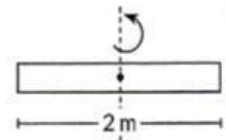
Suppose that the Lenz's law is not valid. Then the induced current flows through the coil in a direction opposite to one dictated by Lenz's law. The resulting force on the magnet makes it move faster and faster, i.e., the magnet gains speed and hence kinetic energy without expanding an equivalent amount of energy. This sets up a perpetual motion machine, violating the law of conservation of energy. Thus Lenz's law is valid and is a consequence of the law of conservation of energy.

(ii) E.m.f. induced between the centre and the end of rod

$$\text{is, } \varepsilon = \frac{B\omega l^2}{2}$$

$$\varepsilon = \frac{2 \times 60 \times (1)^2}{2}$$

$$\varepsilon = 60 \text{ V}$$



7. Soln. Let ON be x at some instant.

The emf induced in the loop = e .

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

$$e = Bl \left(\frac{-dx}{dt} \right)$$

$$= Blv = 0.5 \times 0.2 \times 10$$

$$\left[\because v = \frac{dx}{dt} \right]$$

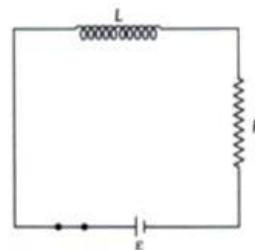
$$= 1 \text{ V}$$

Current in the arm,

$$I = \frac{e}{R} = \frac{1}{5} = 0.2 \text{ A}$$

8. Ans. The phenomena of induced emf in a solenoid due to change in current or magnetic flux linked with the solenoid is called self inductance of the solenoid. The self inductance of a long solenoid, the core of which consists of a magnetic material of permeability μ is given by $L = \mu l_0 n^2 Al$

Where, A is the area of cross-section of the solenoid, l is the length and n is the number of turns per unit length.



Consider the circuit shown here, consisting of a inductor L and a resistor R , connected to a source of emf e . As the connections are made, the current grows in the circuit and the magnetic field increases in the inductor. Part of the work done by the battery during the process is stored in the inductor as magnetic field energy and the rest appears as thermal energy in the resistor. After sufficient time, the current, and hence the magnetic field, becomes constant and further work done by the battery appears completely as thermal energy. If, I be the current in the circuit at time t , we have

$$\text{Self induced emf } \varepsilon = L \frac{dI}{dt}$$

$$dW = \varepsilon I dt$$

$$dW = L \frac{dI}{dt} I dt$$

$$dW = LI dI$$

Work done by source of emf to supply current I for a small time dt .

Now total work done by cell to establish current I_0 in inductor

$$W = \int dW = L \int_0^{I_0} I dI = \frac{1}{2} LI_0^2$$

Total work done is stored as magnetic energy in the solenoid.

9. Ans. (i) Induced voltage $V = L \frac{di}{dt}$

$$\frac{V_1}{V_2} = \frac{L_1}{L_2} \left(\text{as } \frac{di}{dt} \text{ is same} \right)$$

$$\Rightarrow \frac{V_1}{V_2} = \frac{16}{12} = \frac{4}{3}$$

(ii) Power $P = iV$

$$\frac{i_1}{i_2} = \frac{V_2}{V_1} = \frac{3}{4} \text{ (as } P \text{ is same)}$$

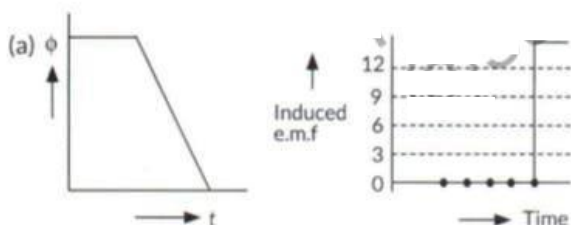
$$\Rightarrow \frac{i_1}{i_2} = \frac{3}{4}$$

(iii) Energy stored $E = \frac{1}{2} Li^2$

$$\frac{E_1}{E_2} = \frac{L_1 i_1^2}{L_2 i_2^2} = \frac{16}{12} \times \frac{9}{16} = \frac{3}{4}$$

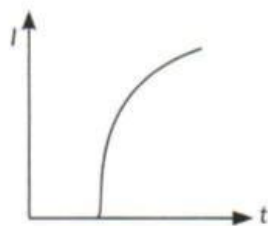
$$\Rightarrow \frac{E_1}{E_2} = \frac{3}{4}$$

10. Ans. (a)

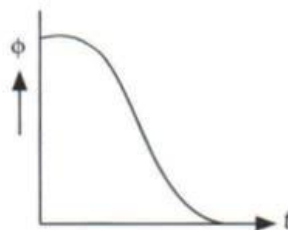


Induced current and power, sketch is same as shown above.

(b) In case of circular coil, rate of change of area of the loop during its passage out of field is not constant, hence induced current varies accordingly.



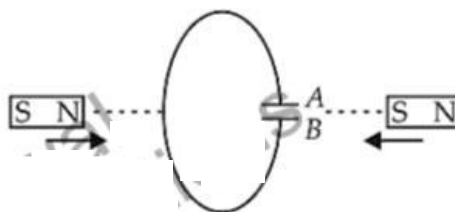
Variation of flux with time (in case of circular loop):



11. Soln. Lenz's law states that the direction of the induced emf and the direction of induced current are such that they oppose the cause which produces them.

The rod held along east west direction will fall in a perpendicular magnetic field B_H present in N-S direction. Hence an emf will be induced in the rod following the relation for the motional emf $\varepsilon = B_H v l$.

Predict the polarity of the capacitor in the situation described below:



Soln. Polarity of plate A will be positive with respect to plate B in the capacitor.

12. Soln. (a) As the armature coil is rotated in the magnetic field, angle θ between the field and normal to the coil changes continuously. Therefore, magnetic flux linked with the coil changes. An e.m.f. is induced in the coil. According to Fleming's right hand rule, current induced in AB is from A to B and it is from C to D in CD in the external circuit current flows from B_2 to B_1 .

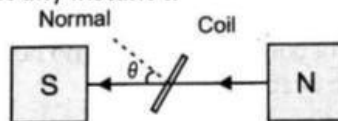
To calculate the magnitude of e.m.f. induced: Suppose,

A → Area of each turn of the coil

N → Number of turns in the coil

B → Strength of magnetic field

θ → Angle which normal to the coil makes with \vec{B} at any instant t .



∴ Magnetic flux linked with the coil in this position.

$$\phi = N(\vec{B} \cdot \vec{A}) = NBA \cos \theta = NBA \cos \omega t \quad \dots\dots(i)$$

Where, ω is angular velocity of the coil

As the coil rotates, angle θ changes. Therefore, magnetic flux ϕ linked with the coil changes and hence, an e.m.f. is induced in the coil. At this instant t , if e is the e.m.f. induced in the coil, then

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

$$= -NAB \frac{d}{dt}(\cos \omega t)$$

$$= -NAB(-\sin \omega t)\omega$$

$$\therefore e = NAB\omega \sin \omega t$$

$$e = \varepsilon_0 \sin \omega t \text{ (Here } \varepsilon_0 = NBA\omega \text{)}$$

(b) We have number spokes (N) = 100

Length of each spoke (L) = 0.5 m

Magnetic field (B) = $0.4 \times 10^{-4} T = 4 \times 10^{-5} T$

Frequency (f) = 120 rpm = 2 rps

Induced e.m.f. between axle and rim is given by

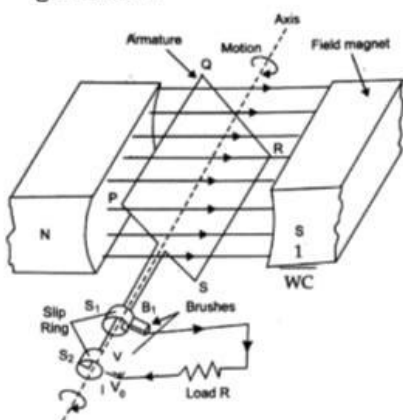
$$e = N \times B \times l^2 \times \pi \times f$$

$$= 100 \times 4 \times 10^{-5} \times (0.5)^2 \times 3.14 \times 2$$

$$= 6.28 \times 10^{-3} V$$

13. Soln. (a) Principle of ac generator: The ac generator is based on the principle of electromagnetic induction. When closed coil is rotated in a uniform field with its axis perpendicular to field, then magnetic flux changes and emf is induced.

Working: When the armature coil rotates, the magnetic flux linked with it changes and produces induced current. If initially, coil PQRS is in vertical position and rotated clockwise, then PQ moves down and SR moves up. By Fleming's right hand rule, induced current flows from Q to P and S to R which is the first half rotation of coil. Brush B_1 is positive terminal and B_2 is negative. In second half rotation, PQ moves up and SR moves down. So induced current reverses and the alternating current is produced in this manner by the generator.



Expression for emf : If number of turns in coil = N, cross-section = A, angular speed of rotation = ω , magnetic field \vec{B} , then to find emf induced, Flux through the coil when its normal makes angle θ with the field,

$$\phi = BA \cos \theta$$

When coil rotates with angular velocity ω and turns through θ in time 't' then $\theta = \omega t$

$$\Rightarrow \phi = BA \cos \omega t$$

When coil rotates, ϕ changes to set in induced emf.

$$\varepsilon = -\frac{d\phi}{dt} = -\frac{d}{dt}(BA \cos \omega t)$$

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

For N turns, total induced emf,

$$\varepsilon = NBA\omega \sin \omega t$$

(b) Given: Velocity (v)

$$= 900 \text{ km/h} = 900 \times \frac{5}{18} \text{ m/s}$$

$$= 250 \text{ m s}^{-1}$$

Wing span (l) = 20 m

Horizontal component of earth's field (B_H) =

$$5 \times 10^{-4} T$$

Angle of dip (δ) = 30°

Potential difference

$$B_v = B_H \tan \delta$$

$$= 5 \times 10^{-4} \times \tan 30^\circ$$

$$= 5 \times 10^{-4} \times \frac{1}{1.732}$$

Emf induced = $B_v l v$

$$= \frac{5 \times 10^{-4}}{1.732} \times 20 \times 250$$

$$= 1.44 \text{ V}$$

14. Soln. Let ON be x at some instant.

The emf induced in the loop = e.

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

$$e = Bl \left(\frac{-dx}{dt} \right)$$

$$= Blv = 0.5 \times 0.2 \times 10$$

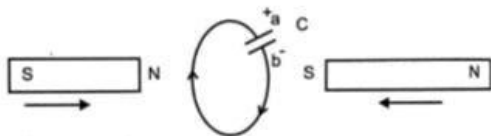
$$\left[\because v = \frac{dx}{dt} \right]$$

$$= 1 \text{ V}$$

Current in the arm,

$$I = \frac{e}{R} = \frac{1}{5} = 0.2 \text{ A}$$

15. Soln. In this situation, a will become positive with respect to b, as current induced is in clockwise direction.



16. Soln. From an observer, the direction of current in the solenoid is anti-clockwise. On displacing it towards the loop, current in the loop will get induced in a direction in order to oppose the approach of solenoid, hence direction of induced current as seen by the observer will be clockwise.

17. Soln. Magnetic flux. *The magnetic flux through any surface placed in a magnetic field is the total number of magnetic lines of force crossing this surface normally.* It is measured as the product of the component of the magnetic field normal to the surface and the surface area.

Magnetic flux is a scalar quantity, denoted by ϕ OR ϕ_B .

SI unit of magnetic flux. The SI unit of magnetic flux is weber (Wb). *One weber is the flux produced when a uniform magnetic field of one tesla acts normally over an area of 1 m^2 .*

$$1 \text{ weber} = 1 \text{ tesla} \times 1 \text{ metre}^2$$

$$\text{Or } 1 \text{ Wb} = 1 \text{ Tm}^2$$

18. Soln. When current is increasing magnetic flux linked with the coils also increases. The magnetic field due to the current element in 2 is into the plane and 1 is out of the plane. Since flux increases, the current induced is such that it opposes the cause due to which it is produced thus the induced emf in the loop 1 is clockwise and in coil 2 is anticlockwise.

19. Soln.

(i) Current in the loop PQRS.

$$I = \frac{\varepsilon}{r}$$

$$\text{Since } \varepsilon = \frac{d\phi}{dt} = Blv \text{ So, } I = \frac{Blv}{r}$$

(ii) The force required to keep the arm PQ in constant motion

$$F = BIl = B \left(\frac{Blv}{r} \right) l = \frac{B^2 l^2 v}{r}$$

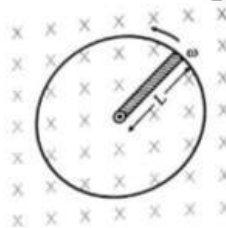
(iii) Power required to move the arm PQ

$$P = |F| |v| = \left(\frac{B^2 l^2 v}{r} \right) |v| = \left(\frac{B^2 l^2 v^2}{r} \right)$$

20. Soln. Suppose the rod completes one revolution in time T. Then change in flux

$$= B \times \text{Area swept} = B \times \pi L^2$$

$$\text{Induced emf} = \frac{\text{Change in flux}}{\text{Time}}$$



$$\text{Or } \varepsilon = \frac{B \times \pi L^2}{T} = B \pi L^2 f \quad \left[\because T = \frac{1}{f} \right]$$

As $f = \frac{\omega}{2\pi}$, therefore

$$\varepsilon = B \pi L^2 \cdot \frac{\omega}{2\pi} = \frac{1}{2} B L^2 \omega.$$

Induced current,

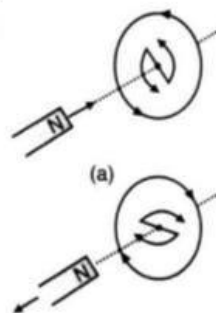
$$I = \frac{\varepsilon}{R} = \frac{1}{2} \frac{B L^2 \omega}{R}$$

Heat dissipation in time t,

$$Q = \frac{\varepsilon^2 t}{R} = \frac{1}{4} \frac{B^2 L^4 \omega^2 t}{R}$$

21. Soln. Lenz's law: The direction of an induced emf always opposes the change in magnetic flux which produces it.

Explanation:



When the north pole of a bar magnet is pushed towards the close coil, the magnetic flux through coil increases and the current is induced in the coil in such a direction that it opposes the increase in flux. This is possible when the induced current in the coil is in the anticlockwise direction. Just the opposite happens when the north pole is moved away from the coil. In either case, it is the work done against the force of magnetic repulsion/attraction that gets 'converted' into the induced emf.

22. Soln. (i) Brightness will decrease when an iron rod is inserted in the solenoid.

(ii) When an iron rod is inserted in the solenoid with a velocity, the iron rod will cut the magnetic field

lines of an inductor, so as per Kirchoof's and Faraday's Laws, cutting of magnetic field will tend to induce a current inside the Inductor which opposes the direction of it's cause. So when the current is being induced by the moving rod, it opposes the current flow of existing current in the circuit, causing the bulb's brightness to go down as there is less current passing through it.

23. Soln. Self-Inductance is the property by which an opposing induced emf is produced in a coil due to a change in current, or magnetic flux, linked with the coil.

OR

Self – inductance of a coil is numerically equal to the flux linked with the coil when the current through the coil is 1 A.

OR

Self – inductance of a coil is equal to the induced emf developed in the coil when the rate of change of current in the coil is one ampere per second.

Energy stored in an inductor:

Consider a source of emf connected to an inductor L. As the current starts growing, the opposing induced emf is given by

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

If the source of emf flows a current i through the inductor for a small time dt , then the amount of work done by the source, is given by

$$\begin{aligned} dW &= |\varepsilon| i dt \\ &= Li \frac{di}{dt} dt \\ &= Lid\dot{i} \end{aligned}$$

Hence the total amount of work done (by the source of emf) when the current increases from its initial value ($i = 0$) to its final value (I) is given by

$$W = \int_0^I Lid\dot{i} = L \int_0^I i di = L \left[\frac{i^2}{2} \right]_0^I = \frac{1}{2} LI^2$$

This work done gets stored in the inductor in the form of energy.

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

24. Soln. $l = 30 \text{ cm} = 0.30 \text{ m}$,

$A = 25 \text{ cm}^2 = 25 \times 10^{-4} \text{ m}^2$, $N = 500$, $dt = 10^{-3} \text{ s}$,
 $dI = 0 - 2.5 = -2.5 \text{ A}$

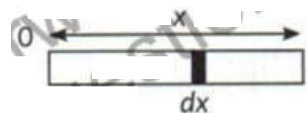
$$\begin{aligned} \text{Back emf} &= -L \frac{dI}{dt} = -\frac{\mu_0 N^2 A}{l} \cdot \frac{dI}{dt} \\ &= -\frac{4\pi \times 10^{-7} \times (500)^2 \times 2.5 \times 10^{-4} \times (-2.5)}{0.30 \times 10^{-3}} \end{aligned}$$

= 6.542 V.

25. Soln.

Self – Inductance	Mutual
1. Self – Inductance is the phenomenon of production of induced emf in a coil when a changing current passes through it.	Mutual induction is the phenomenon of production of induced emf in one coil due to a change of current in the neighboring coil.
2. Self – inductance depends upon the size, shape and the number of turns of the col. Larger the number of turns and area of cross-section, larger is the self – inductance.	The mutual inductance of two coils depends on the number of turns in the two coils, their geometrical shape and their relative separation.

26. Ans. Induced EMF $\varepsilon = (\vec{v} \times \vec{B}) l = vBl$



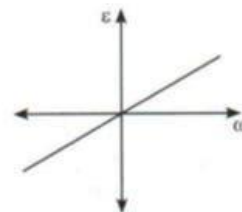
For the element dx , induced EMF,

$$d\varepsilon = Bvdx = B\omega x dx$$

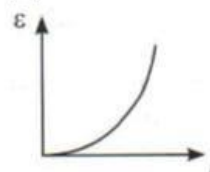
$$\therefore \varepsilon = \int d\varepsilon = \int_0^l B\omega x dx = \frac{B\omega l^2}{2}$$

$$\Rightarrow \varepsilon \propto \omega \text{ and } \varepsilon \propto l^2$$

(i)



(ii)



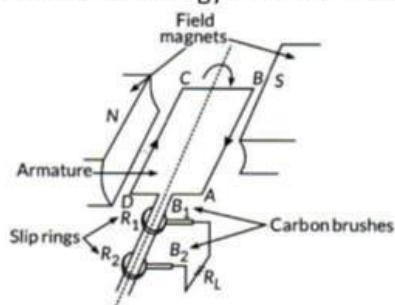
27. Ans. (i) Given $r_1 = 1 \text{ cm} = 1 \times 10^{-2} \text{ m}$ and $r_2 = 20 \text{ cm} = 20 \times 10^{-2} \text{ m}$ Mutual inductance of two concentric

and coplanar coils is given by, $M = \frac{\mu_0 N_1 N_2 \pi r_1^2}{2r_2}$

$$= \frac{4\pi \times 10^{-7} \times 1 \times 1 \times \pi (1 \times 10^{-2})^2}{2(20 \times 10^{-2})} = \pi^2 \times 10^{-10} \text{ H}$$

(ii) The induced emf,

28. Ans. (a) Principle : AC generator is based on the principle of electromagnetic induction. It converts mechanical energy into electrical energy.



It consists of

- (i) Armature coil of large number of turns of copper wire wound over soft iron core. Soft iron core is used to increase magnetic flux.
- (ii) Field magnets used to apply magnetic field, in which armature coil is rotated with its axis perpendicular to field lines.
- (iii) Slip rings used to provide movable contact of armature coil with external circuit containing load.
- (iv) Brushes which are the metallic pieces used to pass on electric current from armature coil to the external circuit containing load.

When armature is rotated in the magnetic field, due to change in orientation of the coil magnetic flux through it changes. Due to change in flux an e.m.f. is induced.

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

$$\varepsilon = NBA\omega \sin \omega t \quad [\because \phi = BA \cos \omega t]$$

$$i = \frac{\varepsilon}{R} = \frac{NBA\omega}{R} \sin \omega t$$

Direction of induced current is given by Fleming's right hand rule.

(b) Radius of coil, $r = 10 \text{ cm} = 0.1 \text{ m}$

$$\text{Area, } A = \pi r^2 = 3.14 \times (0.1)^2 = 0.0314 \text{ m}^2$$

Number of turns, $N = 20$

Angular speed, $\omega = 50 \text{ rads}^{-1}$

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

(i) Maximum induced emf $\varepsilon_{\text{max}} = NAB\omega$

$$= 20 \times 0.0314 \times 3.0 \times 10^{-2} \times 50 = 0.942 \text{ V}$$

Average induced emf,

$$\varepsilon = \frac{\varepsilon_{\text{max}} + \varepsilon_{\text{min}}}{2} = \frac{0.942 + 0}{2} = 0.471 \text{ V}$$

(ii) Given, $R = 10 \Omega$

Maximum current in the coil,

$$I_0 = \frac{\varepsilon_0}{R} = \frac{0.942}{10} = 0.0942 \text{ A}$$

Average current, $I = \frac{\varepsilon}{R} = \frac{0.471}{10} = 0.0471 \text{ A}$

Now average power loss, $P = I^2 R$

$$= (0.0471)^2 \times 10 = 0.022 \text{ W}$$

$$= |\varepsilon| = -M \left| \frac{di}{dt} \right| = \pi^2 \times 10^{-10} \times 5 \times 10^3$$

$$= 4.93 \times 10^{-6} \text{ V} = 4.93 \mu\text{V}$$