

CHAPTER 6

ELECTROMAGNETIC INDUCTION

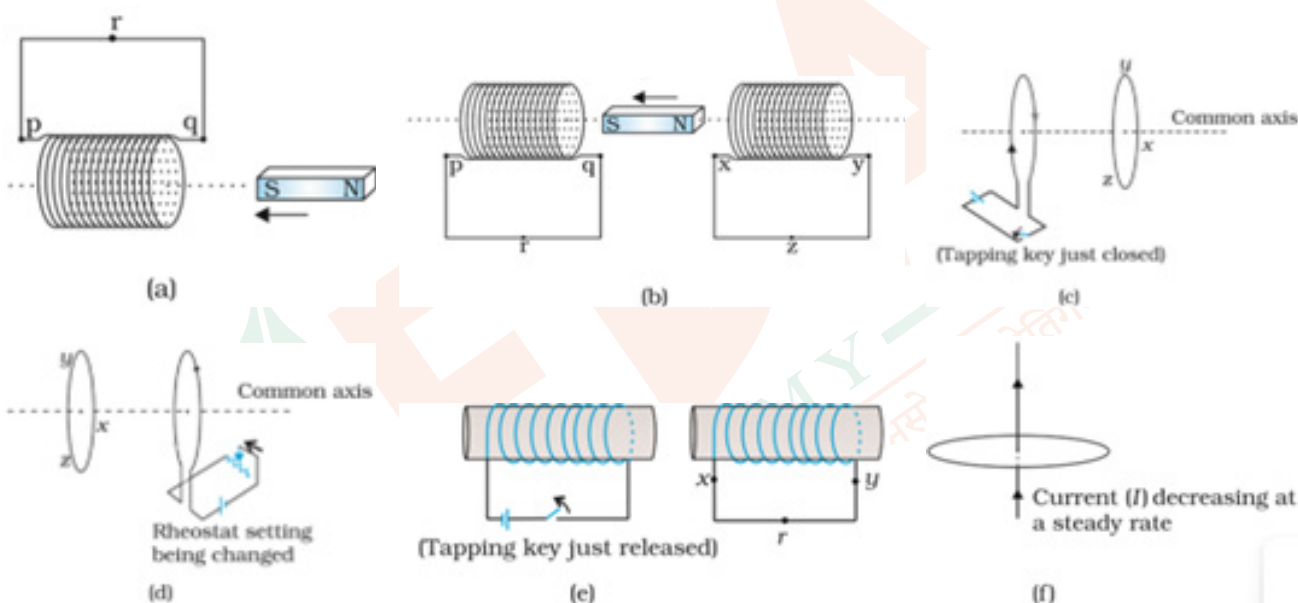
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CLASS 12TH

NCERT EXERCISE AND SOLUTIONS - PHYSICS



6.1 Predict the direction of induced current in the situations described by the following Figs. 6.15(a) to (f).



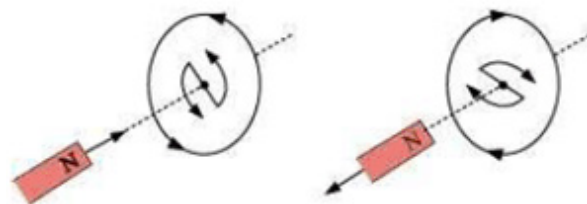
SOLUTION:

We can determine the direction of induced current in a closed loop by Lenz's law.

When the north pole of a magnet is moved towards or away from the closed loop then the direction of closed loop is shown in the figure.

By using Lenz law, the direction of induced current can be predicted as:

- The direction of induced current is along $qrpq$.
- The direction of induced current is along prq and along yzx .
- The direction of induced current is along $yzxy$.
- The direction of induced current is along $zyxz$.
- The direction of induced current is along $xryx$.
- No induced current because the field lines are lying in the plane of the closed loop.

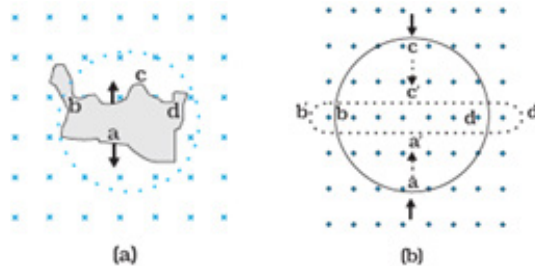


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- 6.2 Use Lenz's law to determine the direction of induced current in the situations described by Fig.:
- A wire of irregular shape turning into a circular shape.
 - A circular loop being deformed into a narrow straight wire.



SOLUTION:

According to Lenz's law, the induced current opposes the change in magnetic flux through the loop.

- As the area of the loop increases over time, the flux through it also increases. Consequently, the induced current generates a magnetic field in the opposite direction to counteract this increase. By applying the right-hand rule, the current flows in a clockwise direction.
- Conversely, when the area of the loop decreases over time, the flux through it reduces. To maintain the flux, the induced current produces a magnetic field in the same direction. According to the right-hand rule, the direction of the current is along the path - adcb.

- 6.3 A long solenoid with 15 turns per cm has a small loop of area 2.0 cm^2 placed inside the solenoid normal to its axis. If the current carried by the solenoid changes steadily from 2.0 A to 4.0 A in 0.1 s , what is the induced emf in the loop while the current is changing?

SOLUTION:

Given – Number of turns/cm (n) = $15/\text{cm} = 1500/\text{m}$, Area (A) = 2 cm^2 ,

Change in current (dI) = $(4 - 2) \text{ A} = 2 \text{ A}$, Time taken (dt) = 0.1 s .

Need to find – Induced emf in the solenoid loop.

By Faraday's law, induced emf in the solenoid is given by,

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

$$\phi = BA = (\mu_0 n I) A \quad (\because B = \mu_0 n I)$$

Now,

$$e = \frac{d(BA)}{dt} = \frac{d(\mu_0 n I A)}{dt}$$

$$e = \mu_0 n A \frac{dI}{dt}$$

$$e = (2 \times 10^{-4}) \times (4\pi \times 10^{-7}) \times (1500) \times \left(\frac{2}{0.1}\right) = 7.54 \times 10^{-6} \text{ V}$$

Therefore, the induced voltage in the loop is $7.54 \times 10^{-6} \text{ V}$.

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- 6.4 A rectangular wire loop of sides 8 cm and 2 cm with a small cut is moving out of a region of uniform magnetic field of magnitude 0.3 T directed normal to the loop. What is the emf developed across the cut if the velocity of the loop is 1 cm/s in a direction normal to the (a) longer side, (b) shorter side of the loop? For how long does the induced voltage last in each case?

SOLUTION:

Given – Length (l) = 8 cm = 0.08 m, Width (b) = 2 cm = 0.02 m, Magnetic field (B) = 0.3 T, Velocity (v) = 1 cm/s = 0.01 m/s.

Need to find – emf developed and time.

Area of rectangular wire loop (A) = $l \times b = (0.08) \times (0.02) = 16 \times 10^{-4} \text{ m}^2$

(a) emf developed across the cut in the direction normal to the longer side is:

$$e = vBl$$

$$e = (0.01) \times (0.3) \times (0.08) = 2.4 \times 10^{-4} \text{ V.}$$

Time taken to travel along the width (d) is:

$$\text{Time}(t) = \frac{\text{Distance travelled (d)}}{\text{Velocity (v)}}$$

$$t = \frac{0.02}{0.01} = 2 \text{ s}$$

Therefore, the induced voltage across the cut in the direction normal to the longer side is $2.4 \times 10^{-4} \text{ V}$ which lasts for 2 s.

(b) emf developed across the cut in the direction normal to the shorter side is:

$$e = vBl$$

$$e = (0.01) \times (0.3) \times (0.02) = 0.6 \times 10^{-4} \text{ V.}$$

Time taken to travel along the length (l) is:

$$\text{Time}(t) = \frac{\text{Distance travelled (l)}}{\text{Velocity (v)}}$$

$$t = \frac{0.08}{0.01} = 8 \text{ s}$$

Therefore, the induced voltage across the cut in the direction normal to the shorter side is $0.6 \times 10^{-4} \text{ V}$ which lasts for 8 s.

- 6.5 A 1.0 m long metallic rod is rotated with an angular frequency of 400 rad/s about an axis normal to the rod passing through its one end. The other end of the rod is in contact with a circular metallic ring. A constant and uniform magnetic field of 0.5 T parallel to the axis exists everywhere. Calculate the emf developed between the centre and the ring.

SOLUTION:

Given – Length of rod (l) = 1 m, Angular frequency (ω) = 400 rad/s, Magnetic field (B) = 0.5 T.

Need to find – emf developed between the centre and the ring.

One end of the rod has zero velocity, and the other end has a linear velocity (v) = $l \omega$



So, Average linear velocity of the rod is,

$$v = \frac{l\omega + 0}{2} = \frac{l\omega}{2}$$

emf developed between the centre and the ring is,

$$e = Blv = Bl \left(\frac{l\omega}{2} \right) = \frac{Bl^2\omega}{2} \quad \left(v = \frac{l\omega}{2} \right)$$

$$e = \frac{0.5 \times (1)^2 \times 400}{2} = 100\text{V}$$

Therefore, the emf developed between the centre and the ring is 100 V.

- 6.6** A horizontal straight wire 10 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, $0.30 \times 10^{-4} \text{ Wb/m}^2$.
- What is the instantaneous value of the emf induced in the wire?
 - What is the direction of the emf?
 - Which end of the wire is at the higher electrical potential?

SOLUTION:

Given – Length of wire (l) = 10 m, Speed (v) = 5 m/s, Earth's magnetic field (B) = $0.30 \times 10^{-4} \text{ Wb/m}^2$.

(a) emf induced in the wire is given by,

$$e = Bvl$$

$$e = 0.3 \times 10^{-4} \times 5 \times 10 = 1.5 \times 10^{-3} \text{ V}$$

(b) Using Fleming's right-hand rule, it can be deduced that the direction of the induced emf is from west to east.

(c) This implies that the eastern end of the wire is at a higher potential.

- 6.7** Current in a circuit falls from 5.0 A to 0.0 A in 0.1 s. If an average emf of 200 V induced, give an estimate of the self-inductance of the circuit.

SOLUTION:

Given – Change in current (di) = $(5 - 0) = 5 \text{ A}$, Time taken (dt) = 0.1 s, Average induced emf (E) = 200 V.

Need to find – Self-inductance (L).

Formula for self-inductance is given by,

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

$$L = \frac{e}{\left(\frac{di}{dt} \right)}$$

$$L = \frac{200}{\frac{5}{0.1}} = 4 \text{ H}$$

Therefore, the self-inductance of the coil is 4 H.



- 6.8 A pair of adjacent coils has a mutual inductance of 1.5 H. If the current in one coil changes from 0 to 20 A in 0.5 s, what is the change of flux linkage with the other coil?

SOLUTION:

Given – Mutual inductance (M) = 1.5 H, Change in current (dI) = (20 – 0) = 20 A,

Time taken (dt) = 0.5 s.

Need to find – Change in flux linkage with another coil.

We know that induced emf is:

$$e = \frac{d\phi}{dt} \dots\dots\dots (i)$$

emf related to mutual inductance is given by,

$$e = M \frac{dI}{dt} \dots\dots\dots (ii)$$

From equation (i) and (ii) we get,

$$\frac{d\phi}{dt} = M \frac{dI}{dt}$$

$$d\phi = 1.5 \times (20)$$

$$d\phi = 30 \text{Wb}$$

Therefore, the change in flux linkage is 30 Wb.

