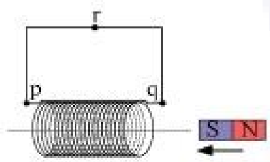
Class XII : Physics
Chapter 6 : Electromagnetic Induction

Questions and Solutions | Exercises - NCERT Books

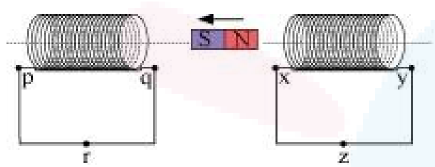
Question 1:

Predict the direction of induced current in the situations described by the following Figs. 6.18(a) to (f).

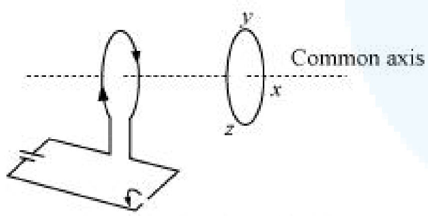
(a)



(b)

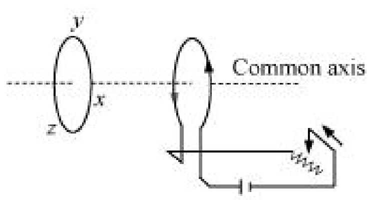


(c)



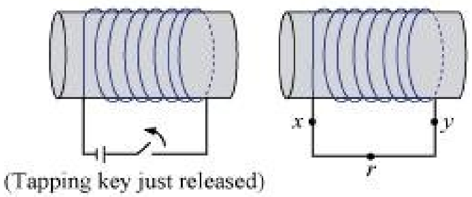
(Tapping key just closed)

(d)

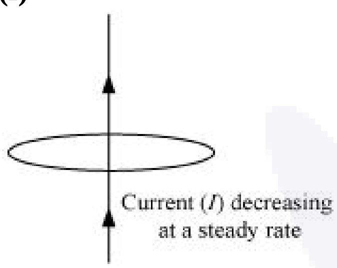


(Rheostat setting
being changed)

(e)

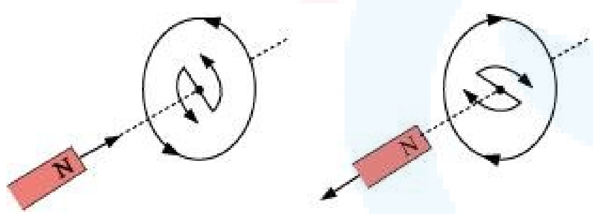


(f)



Answer

The direction of the induced current in a closed loop is given by Lenz's law. The given pairs of figures show the direction of the induced current when the North pole of a bar magnet is moved towards and away from a closed loop respectively.



Using Lenz's rule, the direction of the induced current in the given situations can be predicted as follows:

The direction of the induced current is along **qrpq**.

The direction of the induced current is along **prqp**.

The direction of the induced current is along ***yzxy***.

The direction of the induced current is along ***zyxz***.

The direction of the induced current is along ***xryx***.

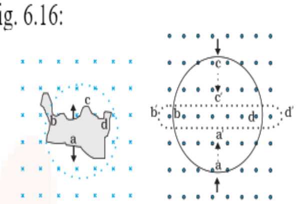
No current is induced since the field lines are lying in the plane of the closed loop.

Question 6.2:

Use Lenz's law to determine the direction of induced current in the situations described by Fig. 6.16:

(a) A wire of irregular shape turning into a circular shape;

(b) A circular loop being deformed into a narrow straight wire.



(a) (b)

Answer 6.2:

(a) As the loop changes from irregular to circular shape, its area increases.

(a)

(b) Hence, the magnetic flux linked with it increases. According to Lenz's law, the induced current should produce magnetic flux in the opposite direction of original flux. For this induced current should flow in the anti-clock wise direction. It means the direction of current will be along adcba.

(b) As the circular loop is being deformed into a narrow straight wire, its area decreases. The magnetic field linked with it also decreases. By Lenz's law, the induced current should produce a flux in the direction of original flux. For this, the induced current should flow in the anti-clock wise direction. It means the direction of current will be along a'd'c'b'.

Question 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?

Answer

Number of turns on the solenoid = 15 turns/cm = 1500 turns/m

Number of turns per unit length, $n = 1500$ turns

The solenoid has a small loop of area, $A = 2.0\ \text{cm}^2 = 2 \times 10^{-4}\ \text{m}^2$

Current carried by the solenoid changes from 2 A to 4 A.

$\therefore$ Change in current in the solenoid, $di = 4 - 2 = 2$ A

Change in time, $dt = 0.1$ s

Induced *emf* in the solenoid is given by Faraday's law as:

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

Where,

ϕ = Induced flux through the small loop

$= BA$ ... (*ii*)

B = Magnetic field

$= \mu_0 n i \qquad \ldots (iii)$

μ_0 = Permeability of free space

$= 4\pi \times 10^{-7}$ H/m

Hence, equation (*i*) reduces to:

$$e = \frac{d}{dt}(BA)$$
$$= A\mu_0 n \times \left(\frac{di}{dt}\right)$$
$$= 2 \times 10^{-4} \times 4\pi \times 10^{-7} \times 1500 \times \frac{2}{0.1}$$
$$= 7.54 \times 10^{-6}\ \text{V}$$

Hence, the induced voltage in the loop is 7.54×10^{-6} V.

Question 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^{-1} 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?

Answer

Length of the rectangular wire, l = 8 cm = 0.08 m

Width of the rectangular wire, b = 2 cm = 0.02 m

Hence, area of the rectangular loop,

$A = lb$

$= 0.08 \times 0.02$

$= 16 \times 10^{-4}\ m^2$

Magnetic field strength, B = 0.3 T

Velocity of the loop, v = 1 cm/s = 0.01 m/s

Emf developed in the loop is given as:

$e = Blv$

$= 0.3 \times 0.08 \times 0.01 = 2.4 \times 10^{-4}$ V

$$\text{Time taken to travel along the width, } t = \frac{\text{Distance travelled}}{\text{Velocity}} = \frac{b}{v}$$

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

Hence, the induced voltage is 2.4×10^{-4} V which lasts for 2 s.

Emf developed, $e = Bbv$

$= 0.3 \times 0.02 \times 0.01 = 0.6 \times 10^{-4}$ V

Time taken to travel along the length, $t = \frac{\text{Distance traveled}}{\text{Velocity}} = \frac{l}{v}$

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

Hence, the induced voltage is 0.6×10^{-4} V which lasts for 8 s.

Question 5:

A 1.0 m long metallic rod is rotated with an angular frequency of 400 $rads^{-1}$ 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 0.5T parallel to the axis exist everywhere. Calculate the emf developed between the centre and the ring.

Answer

l = 1.0 cm ω = 400 rad/s

B = 0.5T

$$\varepsilon = -\frac{d\Phi}{dt} = \frac{d}{dt}\left(B.\frac{\pi r^2\theta}{2\pi}\right) = B\left(\frac{1}{2}r^2\omega\right)$$

= 100V

Question 6:

A horizontal straight wire 10 m long extending from east to west is falling with a speed of 5.0 m s^{-1}, at right angles to the horizontal component of the earth's magnetic field, 0.30 × 10^{-4} 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?

Answer

Length of the wire, l = 10 m

Falling speed of the wire, v = 5.0 m/s

Magnetic field strength, $B = 0.3 \times 10^{-4}$ Wb m^{-2}

Emf induced in the wire,

$e = Blv$

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

Using Fleming's right hand rule, it can be inferred that the direction of the induced emf is from West to East.

The eastern end of the wire is at a higher potential.

Question 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.

Answer

Initial current, $I_1 = 5.0$ A

Final current, $I_2 = 0.0$ A

Change in current, $dI = I_1 - I_2 = 5$ A

Time taken for the change, $t = 0.1$ s

Average emf, $e = 200$ V

For self-inductance (L) of the coil, we have the relation for average emf as:

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

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

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

Hence, the self induction of the coil is 4 H.

Question 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?

Answer

Mutual inductance of a pair of coils, $\mu = 1.5$ H

Initial current, $I_1 = 0$ A

Final current $I_2 = 20$ A

Change in current, $dI = I_2 - I_1 = 20 - 0 = 20\text{ A}$

Time taken for the change, $t = 0.5$ s

Induced emf, $e = \frac{d\phi}{dt}$ ... (1)

Where $d\phi$ is the change in the flux linkage with the coil.

Emf is related with mutual inductance as:

$$e = \mu \frac{dI}{dt} \quad \ldots (2)$$

Equating equations (1) and (2), we get

$$\frac{d\phi}{dt} = \mu \frac{dI}{dt}$$
$$d\phi = 1.5 \times (20)$$
$$= 30\text{ Wb}$$

Hence, the change in the flux linkage is 30 Wb.