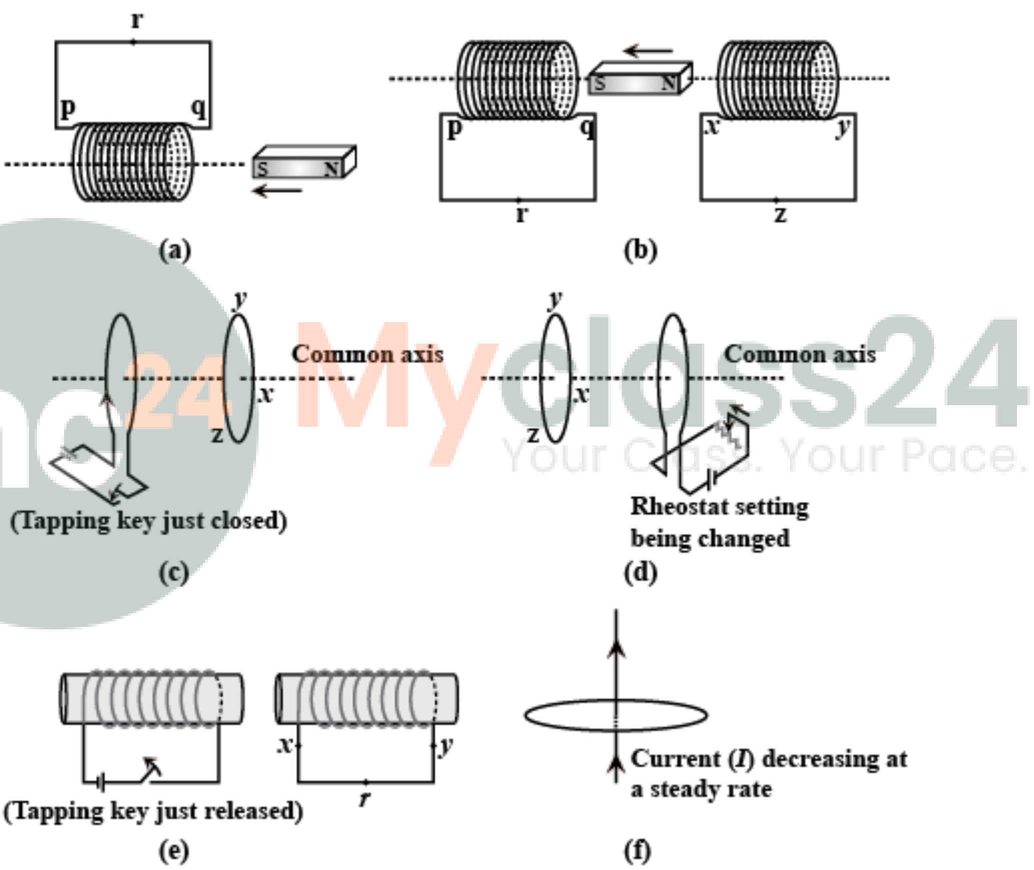
NCERT Solutions for Class-XII Physics

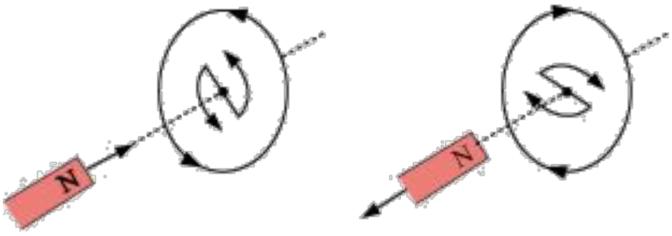
Chapter-6

NCERT Physics Class 12

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



1. 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:

(a) The direction of the induced current is along qrpq.

(b) The direction of the induced current is along prqp.

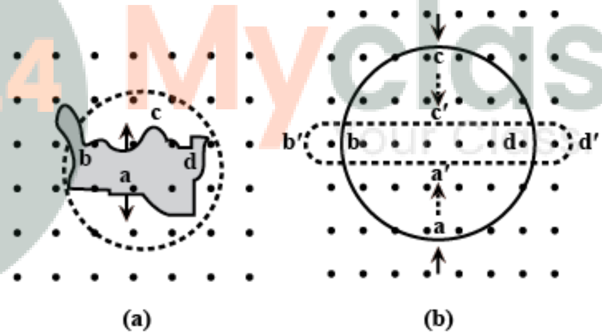
(c) The direction of the induced current is along yzxy.

(d) The direction of the induced current is along zyxz.

(e) The direction of the induced current is along xryx.

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

2. Use Lenz's law to determine the direction of induced current in the situations described by Figure 6.19:

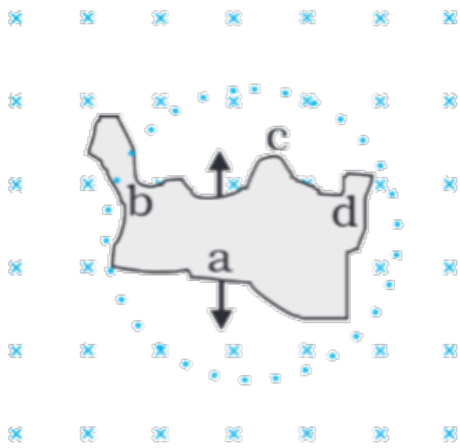


(a) A wire of irregular shape turning into a circular shape;

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

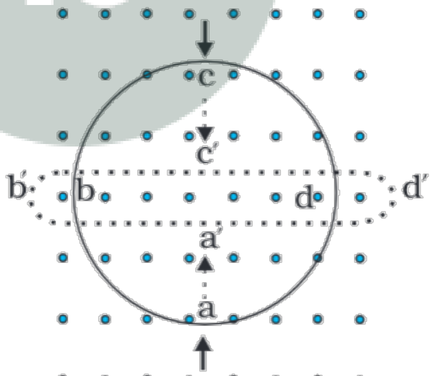
2. According to the Lenz's law: The direction of induced current by change in magnetic field (Faraday's induction) will be such that it opposes the change that caused it.

(a) In the figure given below, the direction of magnetic field is perpendicular into the paper.



(a)

Now, when we change the shape of irregular loop into a circular loop, then the area of the loop will increase. Because, area of circle is considered to be greatest.
Since, area of loop increases, ∴ the magnetic flux will also increase.
Now, the current will be induced in the loop such that the magnetic flux decreases. And, magnetic field will decrease when the area will decrease i.e. the wires should be pulled in the inwards directions, to decrease the net magnetic field.
∴ the current will be along "adcba".
(b) In the figure given below, the direction of magnetic field is perpendicular coming out of the paper.



(b)

Now, when circular loop is transformed into a narrow straight wire, then the area of the loop will decrease. Since, area of loop decreases, ∴ the magnetic flux will also decrease. Now, the current will be induced in the loop such that the net magnetic flux increases in the wire. ∴ the current flow will be along "adcba" which produces the induced magnetic field outwards the paper.

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 to 4.0 A in 0.1 s, what is the induced emf in the loop while the current is changing?

3. 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, $A = 2.0\ cm^2 = 2 \times 10^{-4}\ m^2$
Current carried by the solenoid changes from 2 A to 4 A.
∴ 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 Farday's law as: $e = \frac{d\Phi}{dt}$ ...(i)
Where, Φ = Induced flux through the small loop = BA …(ii)
B = Magnetic field = μ_0 ni …(iii)
μ_0 = Permeability of free space = $4\pi \times 10^{-7}$ H/m
Hence, equation (i) reduces to:

$$e = \frac{d}{dt}(BA)$$

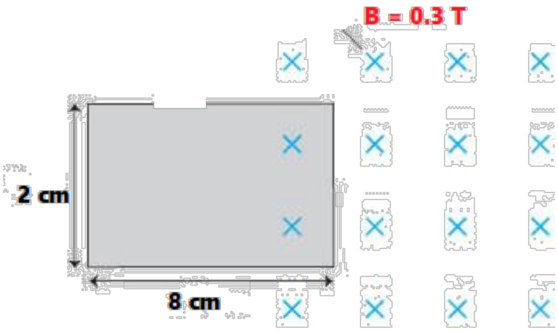
$$= A\mu_0 n \times \left(\frac{di}{dt}\right)$$

$$= 2 \times 10^{-4} \times 4\pi \times 10^{-7} \times 1500 \times \frac{2}{0.1}$$

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

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?

4. Given:
Length of rectangular wire = 8 cm
Breadth of rectangular wire = 2 cm



The area of the rectangular wire can be calculated as follows:
$A = l \times b$
$A = 8\text{ cm} \times 2\text{ cm} = 16\text{ cm}^2$
In m^2, area will be $A = 16 \times 10^{-4}\text{ m}^2$
Magnitude of magnetic field B = 0.3T
Velocity of the loop, $v = 1\text{ cms}^{-1} = 0.01\text{ ms}^{-1}$
(a) The emf developed across the cut can be calculated as follows:
$e = Blv$ … (1)
where B is the magnetic field
l is the length of the loop and,
v is the velocity of the rectangular loop
substituting the values in equation (1), we get,
$e = (0.3\text{ T} \times 0.08\text{ m} \times 0.01\text{ ms}^{-1})$
$e = 2.4 \times 10^{-4}\text{ V}$
Time taken for travelling along the width of the loop can be calculated as follows:
T = distance travelled/velocity with which distance is travelled
T = b (width of the loop)/v (velocity)
$T = 0.02\text{ m}/0.01\text{ ms}^{-1}$
T= 2 seconds
This means that the induced voltage will last for very short direction of 2 seconds.
(b) The emf developed across the cut if the velocity of the loop is 1 cms^{-1} in a direction normal to the shortest side of the loop can be calculated as follows:
$e = Bbv$ … (2)
where B is the magnetic field
b is the width of the loop and,
v is the velocity of the rectangular loop
substituting the values in equation (2), we get,
$e = (0.3\text{ T} \times 0.02\text{ m} \times 0.01\text{ ms}^{-1})$
$e = 0.6 \times 10^{-4}\text{ V}$
Time taken for travelling along the width of the loop can be calculated as follows:
T = distance travelled/velocity with which distance is travelled
T = l (length of the loop)/v
$T = 0.08\text{ m}/0.01\text{ms}^{-1}$
T= 8 seconds
This means that the induced voltage will last for 8 seconds.

5. A 1.0 m long metallic rod is rotated with an angular frequency of 400 rad s^{-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 0.5 T parallel to the axis exists everywhere. Calculate the emf developed between the centre and the ring.

5. Length of the rod, I = 1 m

Angular frequency, ω = 400 rad/s

Magnetic field strength, B = 0.5 T

One end of the rod has zero linear velocity, while the other end has a linear velocity of Iω.

Average linear velocity of the rod, $V = \frac{l\omega + 0}{2} = \frac{l\omega}{2}$

Emf developed between the centre and the ring,

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

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

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

6. A circular coil of radius 8.0 cm and 20 turns is rotated about its vertical diameter with an angular speed of 50 rad s^{-1} in a uniform horizontal magnetic field of magnitude 3.0×10^{-2} T. Obtain the maximum and average emf induced in the coil. If the coil forms a closed loop of resistance 10Ω, calculate the maximum value of current in the coil. Calculate the average power loss due to joule heating. Where does this power come from?

6. Given:

Radius of the circular coil r = 8.0 cm = 0.08 m

No. of turns in the coil, N = 20

Angular frequency ω = 50 rad s^{-1}

Magnitude of magnetic field B = 3.0×10^{-2} T

Resistance of the closed loop = 10 Ω

The area of the coil can be calculated using the formula $A = \pi r^2$

$A = 3.14 \times (0.08 \text{ m})^2$

The maximum induced e.m.f. is calculated as follows:

e = N ω A B

$e = 20 \times 50 \text{ rad s}^{-1} \times 3.14 \times (0.08 \text{ m})^2 \times 3.0 \times 10^{-2}$ T

On calculating we get

e = 0.603 V

Since for a full cycle, the average induced emf will be zero.

The maximum current for the circular coil can be calculated as follows:
$I = e/R$
Substituting the values
$I = 0.603\ V/10\ \Omega$
$I = 0.0603\ A$
The average power loss due to Joule's heating effect in the circular coil will be given by:
$P = (eI)/2$
$P = (0.603\ V \times 0.0603\ A)/2$
On calculating we get
$P = 0.018\ W$
A torque was produced due to current induced in the coil. This torque opposes the rotation of the circular coil. Since a rotor is the external agent in the coil and it should apply the torque so that the coil keeps rotating in the uniform manner. Therefore, the dissipated power comes from the external rotor.

7. A horizontal straight wire 10 m long extending from east to west is falling with a speed of 5.0 ms^{-1}, at right angles to the horizontal component of the earth's magnetic field, 0.30×10^{-4} Wb m^{-2}.
(a) What is the instantaneous value of the emf induced in the wire?
(b) What is the direction of the emf?
(c) Which end of the wire is at the higher electrical potential?

7. Length of the wire, I = 1.0 m
Falling speed of the wire, v = 5.0 m/s
Magnetic field strength, $B = 0.3 \times 10^{-4}$ Wb m^{-2}
(a) Emf induced in the wire, $e = BIv = 0.3 \times 10^{-4} \times 5 \times 10 = 1.5 \times 10^{-3}$ V
(b) Using Fleming's right hand rule, it can be inferred that the direction of the induced emf is from West to East.
(c) The eastern end of the wire is at a higher potential.

8. 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, given an estimate of the self-inductance of the circuit.

8. Given: Initial current $I_1 = 5.0$ A
Final current $I_2 = 0.0$ A
Time = 0.1 seconds
Average e.m.f = 200 V
Change in the current can be calculated as:
$dI = I_1 - I_2 = 5.0A – 0.0A$
$dI = 5$ A
The self-conductance of the circuit is calculated using the formula:

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

$$\text{or } L = \frac{e}{\left(\frac{dI}{dt}\right)}$$

substituting the values, we get

$$\Rightarrow L = \frac{200V \times 0.1\,sec}{5A}$$

$\therefore$ L = 4 Henry

9. 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?

9. Mutual inductance of a pair of coils, μ = 1.5 H

Final current I_2 = 20 A

Change in current, dl = $I_2 - I_1$ = 20 – 0 = 20 A

Time taken for the change, t = 0.5 s

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

Where, dΦ is the change in the flux linkage with the coil.

Emf is related with mutual inductance as:

$$e = \mu\frac{dI}{dt}$$

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

$$\frac{d\Phi}{dt} = \mu\frac{dI}{dt}$$

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

= 30 Wb

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

10. A jet plane is travelling towards west at a speed of 1800 km/h. What is the voltage difference developed between the ends of the wing having a span of 25 m, if the Earth's magnetic field at the location has a magnitude of 5×10^{-4} T and the dip angle is 30°.

10. Given: Speed of the jet plane towards west = 1800 km/h

In m/s, speed of the jet plane towards west = 500 m/s

Length of the span of the jet plane = 25 m

Magnetic field = 5×10^{-4} T

Dip angle = 30°

The vertical component of Earth's magnetic field can be calculated as follows:

$B_v = B \sin\delta$

On substituting the values, we get,

$B_v = 5 \times 10^{-4}$ T × sin 30°
⇒ $B_v = 5 \times 10^{-4}$ T × ½
∴ $B_v = 2.5 \times 10^{-4}$ Tesla
The voltage difference developed between the ends of the jet can be calculated using the formula:
$e = B_v \times l \times v$
On substituting the values, we get
$e = 2.5 \times 10^{-4}$ T × 25m × 500 m/sec
on calculating, we get
e = 3.125 V
∴ the voltage difference developed between the ends of the wings is approximately 3V.