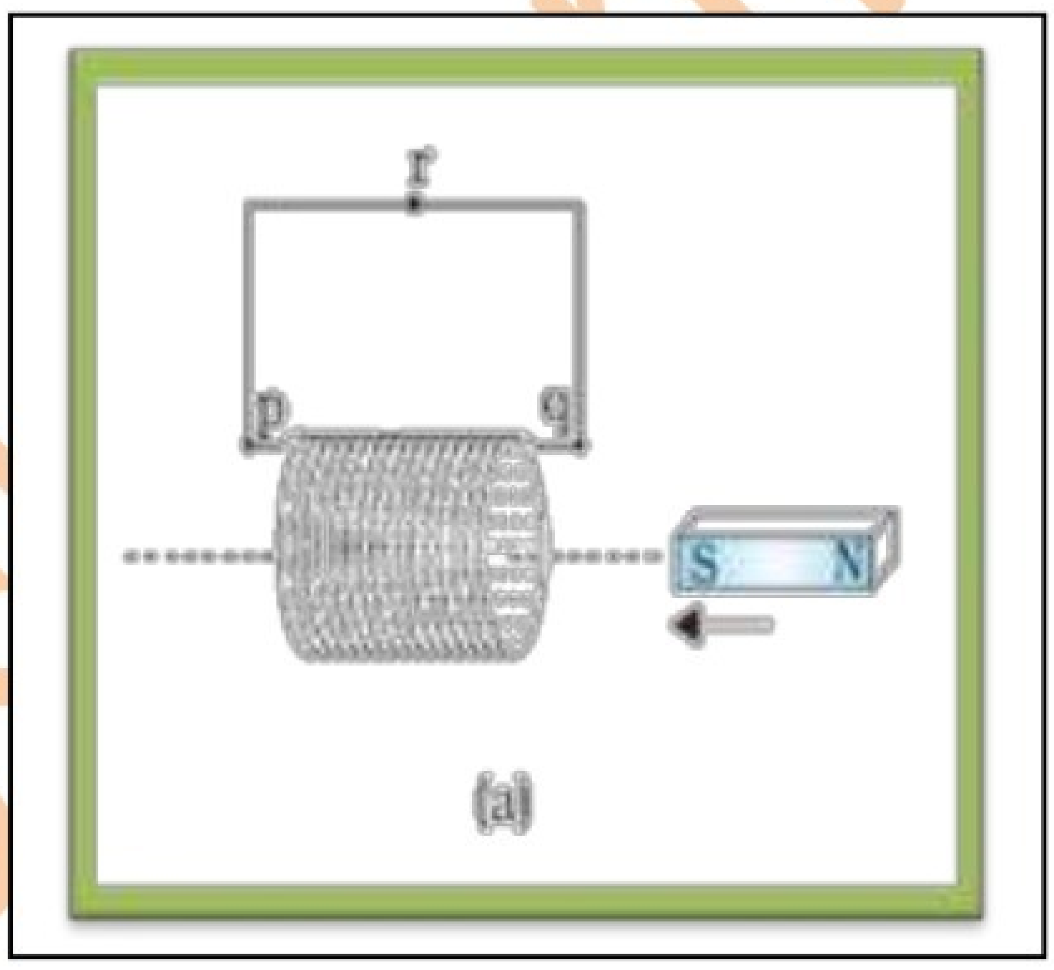
Chapter.6
Electromagnetic induction
Class – XII
Subject – Physics

6.1. **Predict the direction of induced current in the situations described by the following Figs.**

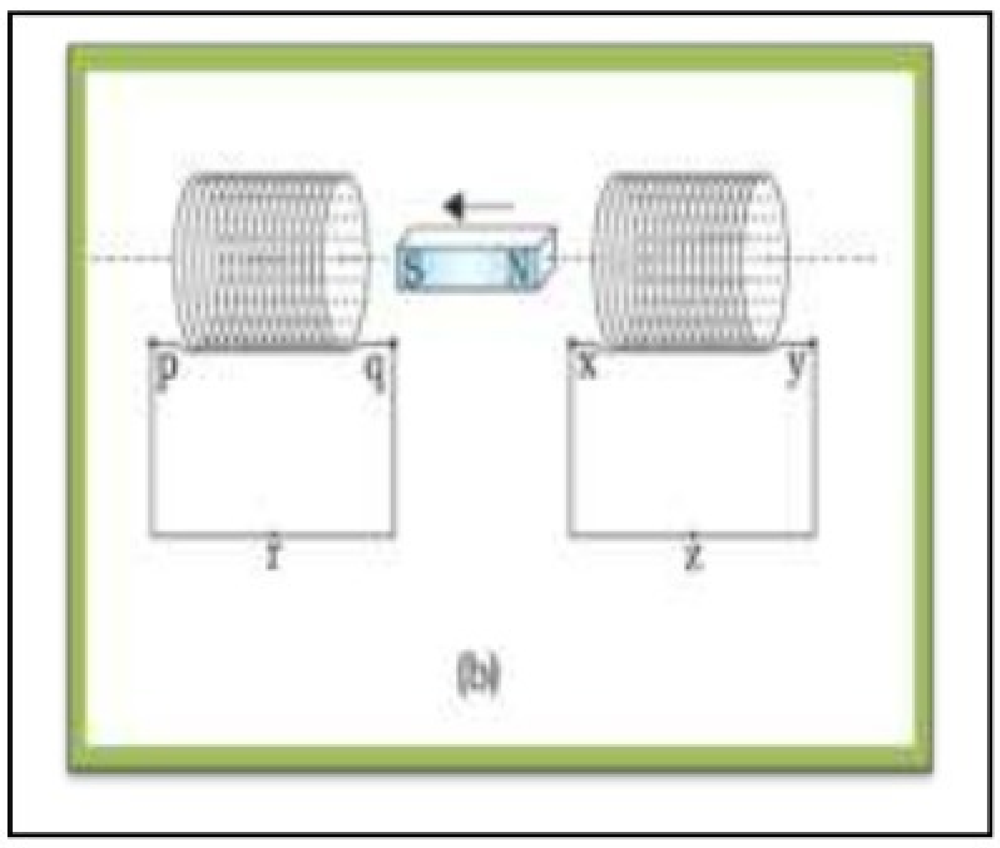
a)



Sol.

Direction: qrpq

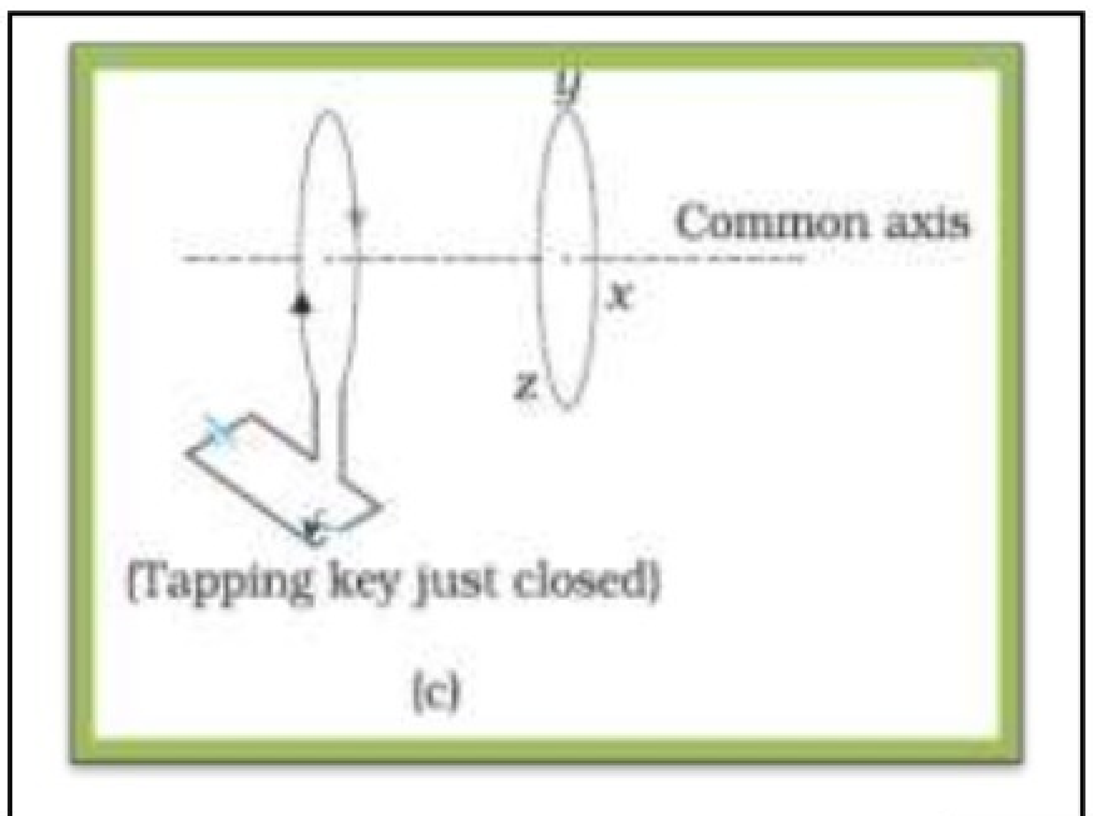
b)



Sol.

Direction: prqp; yzxy

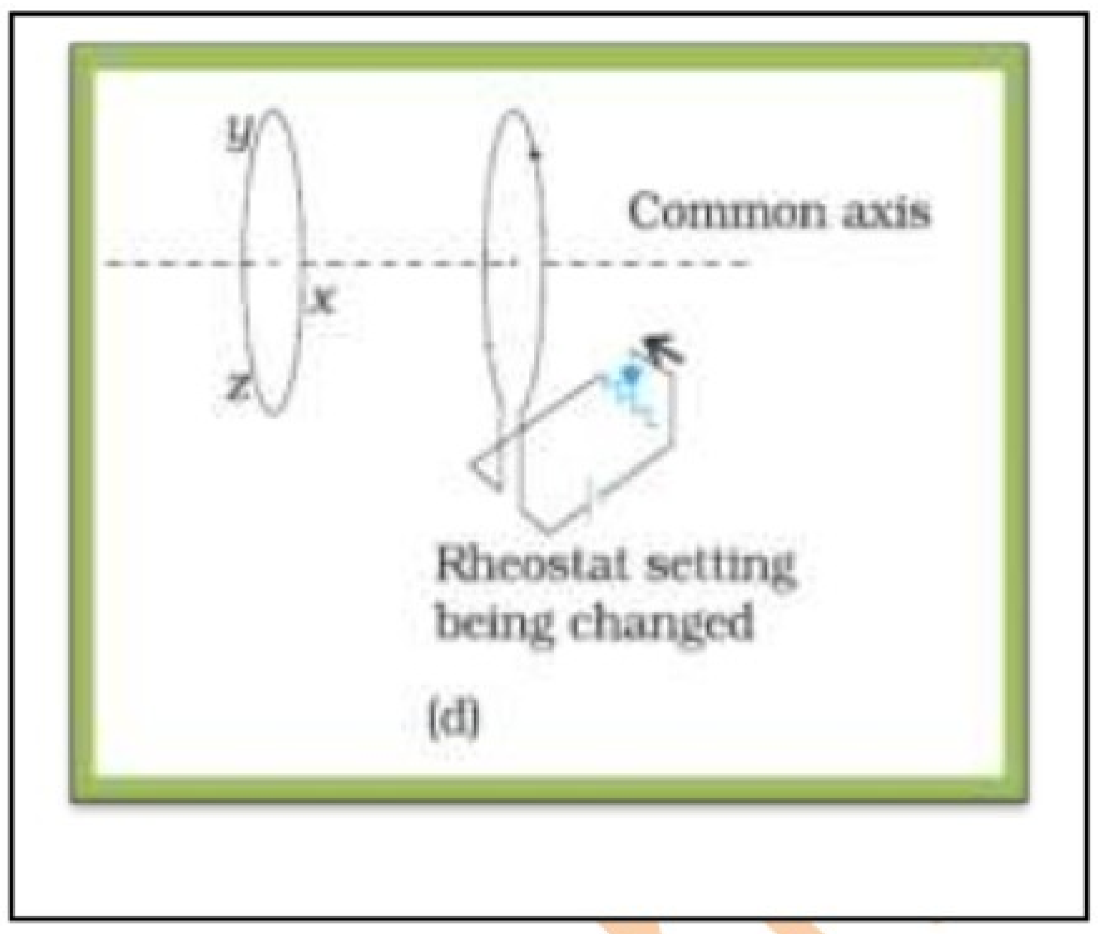
c)



Sol.

Direction: yzxy

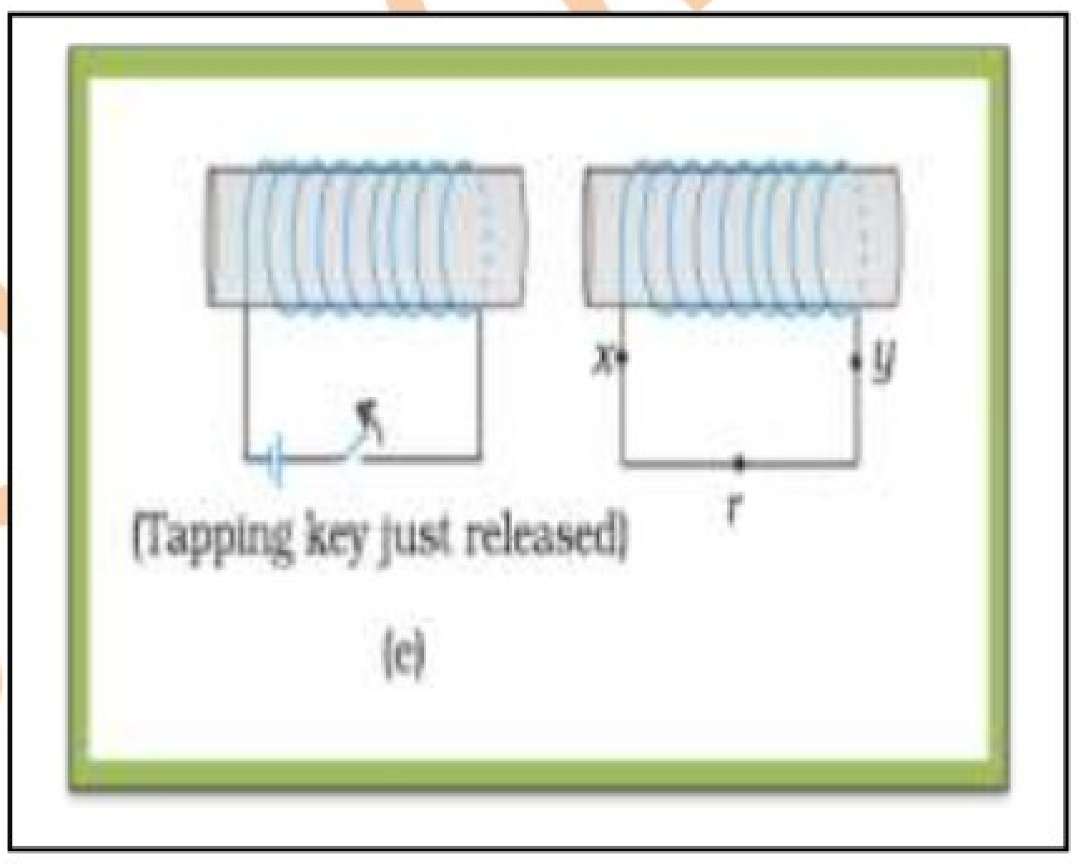
d)



Sol.

Direction: zyxz.

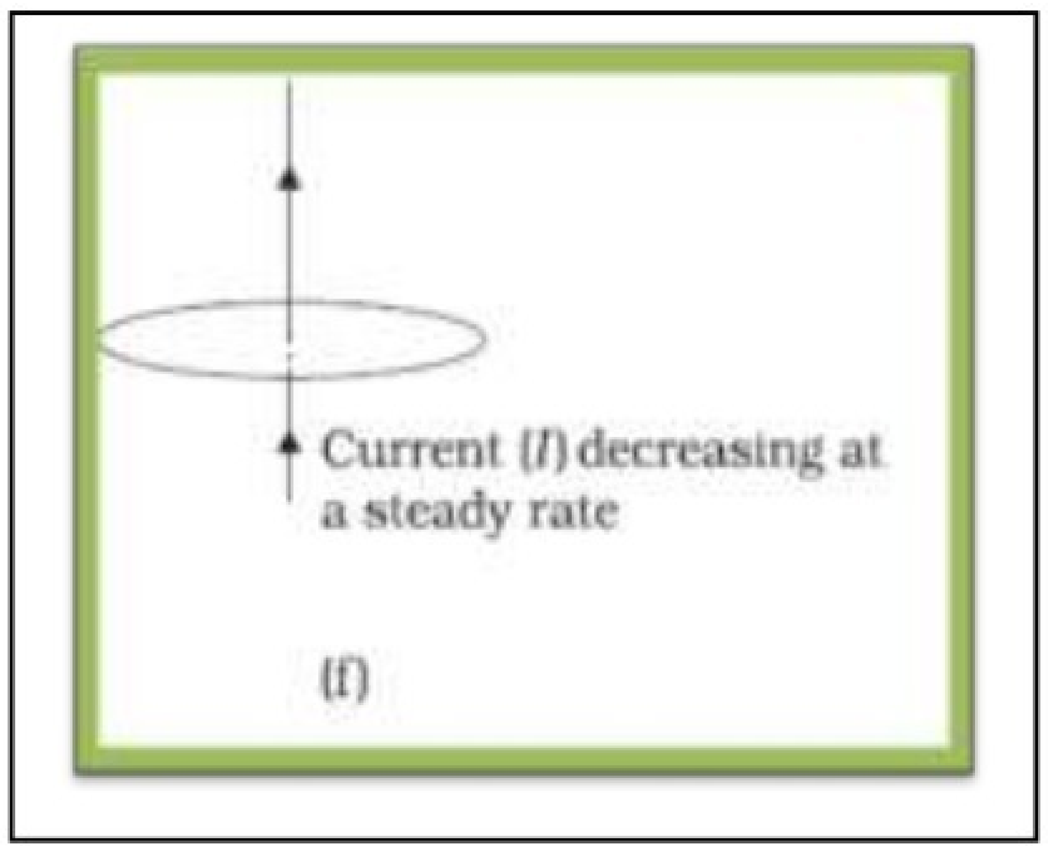
e)



Sol.

Direction: xryx

f)



Sol.

Direction: No induced current.

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

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

A circular loop being deformed into a narrow straight wire.

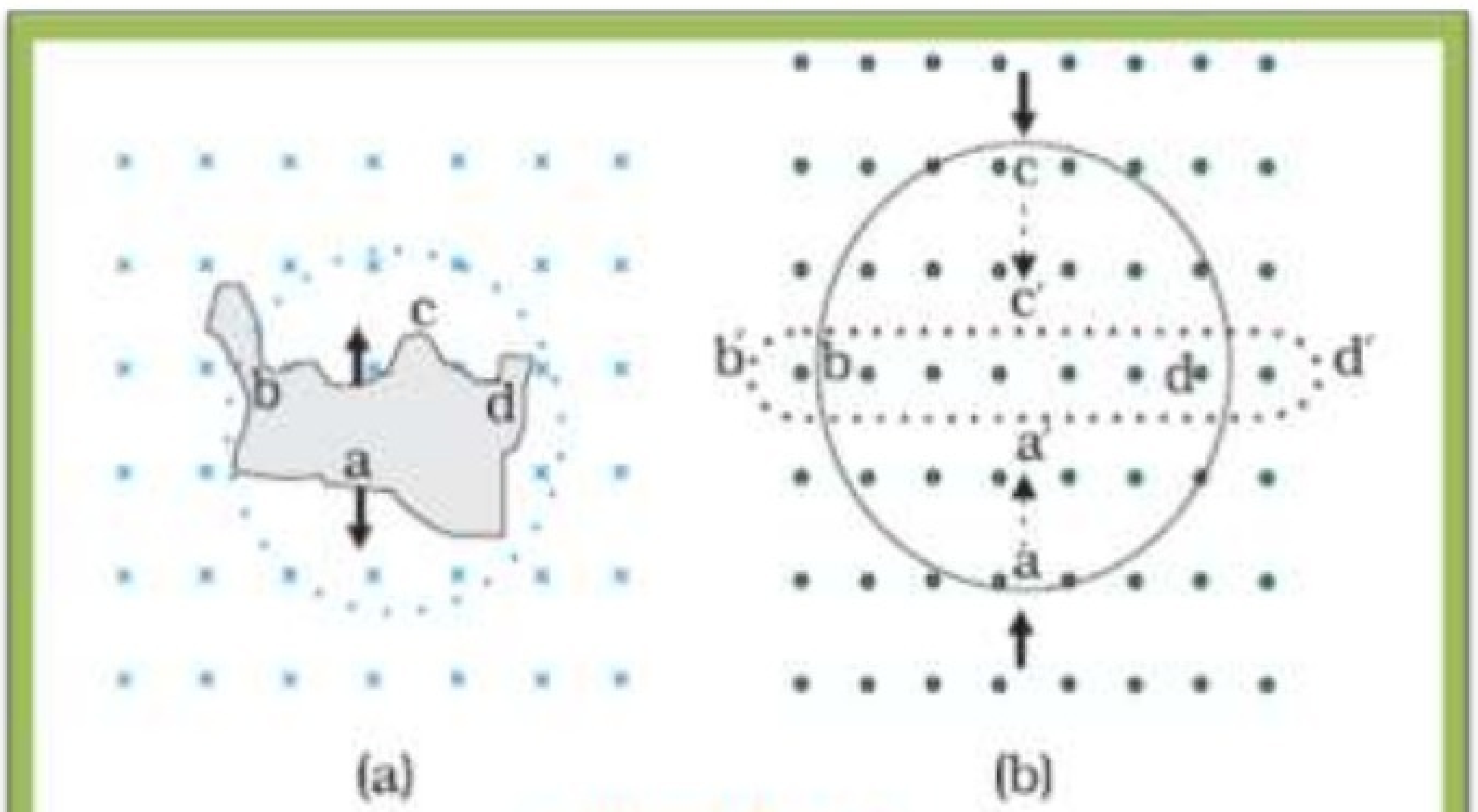


FIGURE 6.19

Sol.

German physicist Heinrich Friedrich Lenz gave us a law known as Lenz's law, stating:
"The polarity of induced emf is such that it tends to produce a current which opposes the change in magnetic flux that produced it."
Lenz's law opposes the very cause that causes it.

a) Since the passing flux is increasing, the direction of induced current as per Lenz's law will be: **adcba**.
b) Since the passing flux is decreasing, the direction of induced current as per Lenz's law is: **a'd'c'b'a'**.

6.3. A long solenoid with 15 turns per cm has a small loop of area 2.0 cm2 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?

Sol.

Given:
n = 15 turns / cm
a = 2 sq. cm
dt = 0.1 s
Ii = 2 A
If = 4 A
Ө = 0

We kn
$\Phi = B.A.\cos\Theta$ ……………………………….(1)
Before calculating flux, we need to determine initial and final B.
Initial magnetic field, $Bi = \mu_o nIi$
Substituting the values
Bi = (4π x 10-7).(1500).(2)
Or Bi = 3.77×10^{-3} T
Now
Final magnetic field, Bf = (4π x 10-7).(1500).(4)
= 7.54×10^{-3} T
Now calculating initial and final fluxes by substituting the corresponding values of B in eq. (1)
Initial value of flux = Bi.A.cos0
= $(3.77\times10^{-3}).(2\times10^{-4})$
= 7.54×10^{-7} Wb
Final value of flux = Bf.A.cos0
= $(7.54\times10^{-3}). (2\times10^{-4})$
= 1.51×10^{-6} Wb
Therefore induced emf
E = Difference in flux / Corresponding time interval
Or E = $[(1.51\times10^{-6}\text{ Wb}) – (7.54\times10^{-7}\text{ Wb})] / 0.1$
Or E = 7.56×10^{-6} V

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–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?

Sol.

Given:
length = 8 cm
breadth = 2 cm
B = 0.3 T
velocity = 1 cm / s
Area of the loop
A = 0.0016 sq. m

The loop is moving with the given velocity. As long as the loop lies completely in the magnetic field, no emf will be induced as there is no change in the flux. But the moment it starts slipping into the outer space, the flux passing through the loop decreases and an emf is induced. Since the circuit is not complete, current will not flow.

Value of initial flux = BAcos0
= 0.3 x 0.0016
= 0.00048 Wb
Value of final flux = 0, (because no part of loop now lies in given magnetic field)
Considering the given cases

a) In this case the time elapsed is
t = distance / speed
= 2 / 1
= 2 s

So induced emf

$E = d\Phi / dt$

$E = (0.00048 – 0) / 2$

Or $E = 2.4\text{x}10^{-4}$ V

The voltage will last 2 seconds.

b) Here the time elapsed is

$t = 8 / 1$

$= 8$ s

Thus induced emf

$E = d\Phi / dt$

$E = 0.00048 / 8$

Or $E = 6\text{x}10^{-5}$ V

The voltage will last 8 seconds.

6.5. 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.

Sol.

Given:

r = 1 m

w = 400 rad / s

B = 0.5 T

$\Phi = B.A.\cos 0$

$= 0.5 \text{ x } 3.14 \text{ x } 1 \text{ x } 1$

= 1.571 Wb

$\Phi = B.A.\cos 180$

= -1.571 Wb

w = 400

Or f = 400 / 2 x 3.14 = 63.66 / s

Therefore

E = [1.571 – (- 1.571)] / 0.0314

Or E = 100 V

6.6. 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 10 Ω, calculate the maximum value of current in the coil. Calculate the average power loss due to Joule heating. Where does this power come from?

Sol.

Given:

r = 8 cm

N = 20 turns

w = 50 rad / s

B = 0.03 T

R = 10 ohms

Flux through N turns is given by

Φ =NBAcoswt

Induced emf E = dΦ / dt

Or E = - wNAB sin wt

For maximum induced emf

sinwt = 1

Therefore

$E_{max} = 50 \times 20 \times 3.14 \times 0.08 \times 0.08 \times 0.03$

Or $E_{max} = 0.603$ V

Average induced emf

E_{avg} = zero over each cycle

When the current is allowed to flow

Maximum value of current

$I_{max} = E_{max} / R$

Or $I_{max} = 0.603 / 10$

Or $I_{max} = 0.0603$ A

Average power loss

$P_{avg} = E_{max} . I_{max} / 2$

$= [(0.603).(0.0603)] / 2$

$= 0.0182$ W

The induced current in the loop produces a torque opposing the rotational motion. This is countered by the rotor rotating the coil, and the power is dissipated as heat in the coil.

6.7. 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.

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?

Sol.

Given:

$l = 10$ m
$v = 5$ m / s
$H = 0.3 \times 10^{-4}$ Wb m^2

a) Einst = Blv
= (0.00003).(10).(5)
$= 1.5 \times 10^{-3}$ V

b) West to east.

c) Eastern end.

6.8. 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, give an estimate of the self-inductance of the circuit.

Sol.

Given:
dI = 5 – 0 = 5 A
dt = 0.1 s
Eavg = 200 V
We know
E = L.dI/dt
Substitution yields
L = 4 H

6.9. 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?

Sol.

Given:

M = 1.5 H
dI = 20 A
dt = 0.5 s

d(NΦ) / dt = d(MI) / dt
Putting the values
d(NΦ) = 30 webers

6.10. 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°.

Sol.

Given:
v = 500 m / s
l = 25 m
B = 0.0005 T
I = 30 degrees

Vertical component of B, Bv = 0.0005 x sin30
= 0.00025 T

Therefore voltage
E = Bv.l.v
Or E = 0.00025 x 25 x 500
Or NΦ E = 3.125 volts