3055 BA SANGAM COLLEGE

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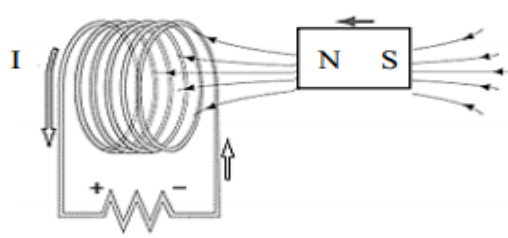
WORKSHEET 22

SCHOOL: BA SANGAM COLLEGE **YEAR: 13**
SUBJECT: PHYSICS **NAME OF STUDENT: ____________________**

STRAND	**STRAND 7: ELECTROMAGNETIC INDUCTION AND ALTERNATING CURRENT THEORY**
SUB-STRAND	**7.1 ELECTROMAGNETIC INDUCTION**
LEARNING OUTCOME	To learn various methods of inducing voltage

Effects of Electromagnetic Induction

- Electromagnetic induction is used to generate electricity
- For example, in hydropower station.
- Induction involves a change in magnetic flux in or near a circuit or coil.
- An induced voltage is produced which can cause a current if the circuit is complete.
- Current is induced in the solenoid when the magnet is moved either in or out (no current when stationary)



INDUCED VOLTAGE (EMF)

- When a force moves a conductor in a magnetic field, a voltage is induced across the ends of the conductor.
- Use Flemings right hand rule
- The size of induced emf (voltage) across AB is given by:
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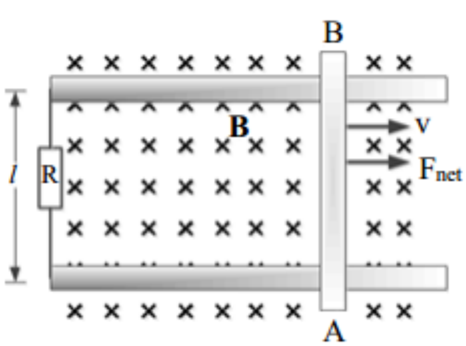


$$F_{Electrical} = F_{Magnetic}$$
$$Eq = Bvq$$
$$E = Bv$$
$$\frac{V}{l} = Bv$$
$$\therefore V = Bvl$$

$$\frac{V}{l} = E \ (d = l)$$

Therefore

$$\therefore V = Bvl \sin \theta$$

Where: $V = \varepsilon =$ induced emf (V)

B = magnetic field (T)

v = speed of conductor (m/s)

l = length of conductor in magnetic field (m)

θ = Angle (degree)

The power is given by;

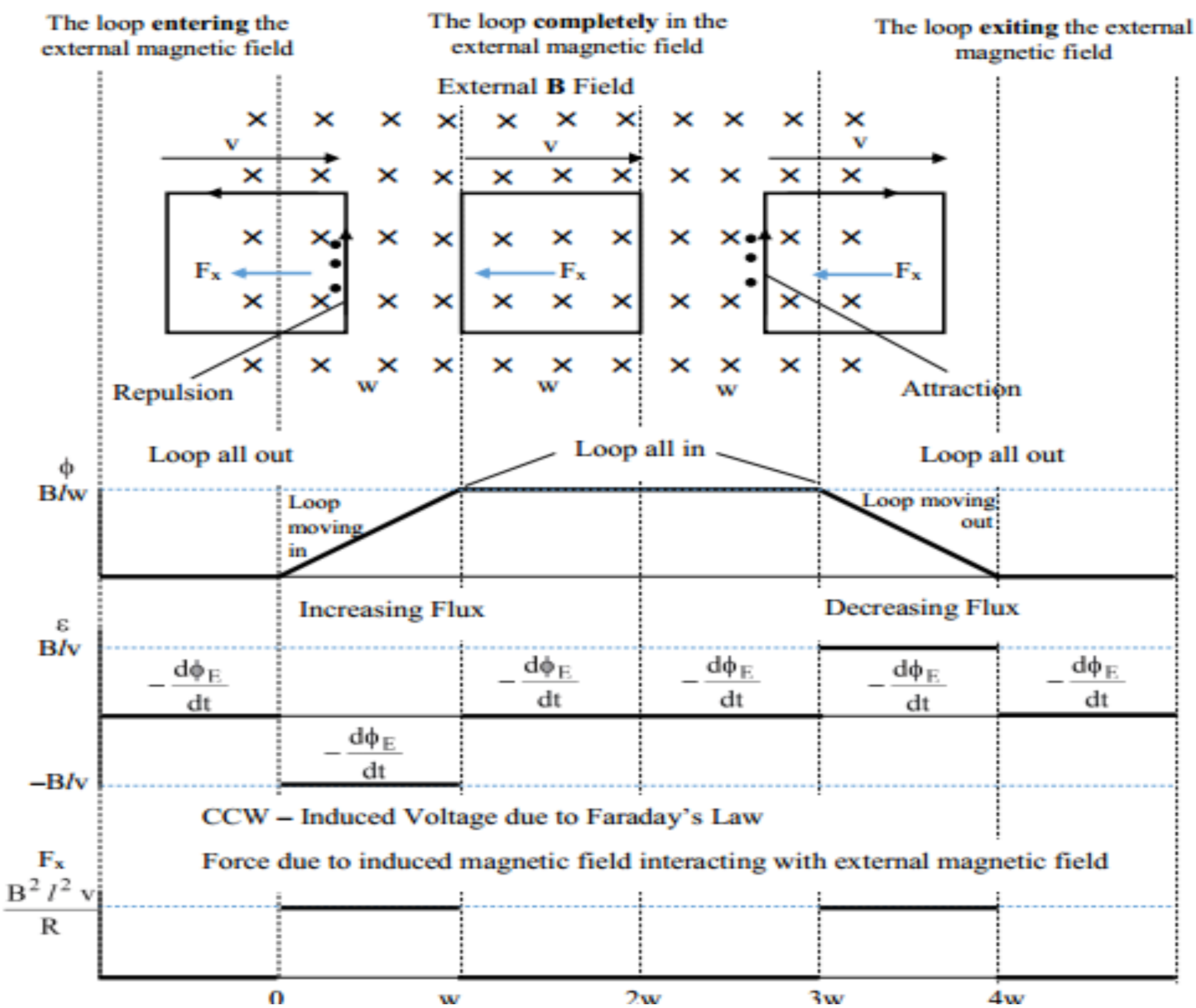
$$P = VI = I^2 R = \frac{V^2}{R}$$

Hence, the energy dissipated by the conductor is given by;

$$E = Pt$$

LOOP IN MAGNETIC FIELD

- For voltage to be induced in a loop inside a magnetic field, there needs to be a change in magnetic flux
- When the loop is completely in the magnetic field there is no induced current



EXAMPLE

A square loop of wire 0.5 m by 0.5 m moves into uniform magnetic field of 0.8 T, at steady speed of 0.1 ms^{-1}. An induced voltage V, develops between point A and B on the wire loop.

a) Calculate the size of induced voltage (emf) and the direction of induced current in the loop as the loop is:

i. Entering the magnetic field.

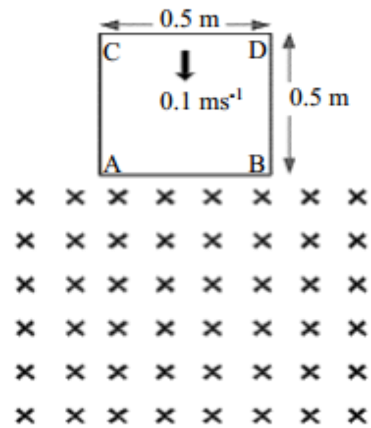
ii. Completely in the field.

iii. Leaving the field.

b) Calculate the size of current if 2 Ω resistor is connected.

c) Determine the power induced.

d) Calculate the energy dissipated in 0.8 s.



Solution

a)

i. As AB enters the field

$$V = Blv$$
$$= 0.8 \times 0.5 \times 0.1$$
$$= 0.04\,V$$

The direction of the induced current will be anticlockwise.

ii. When the square loop is completely in the magnetic field there is no induced voltage or current.

iii. As CD leaves the field the induced voltage is still equal to 0.04 V but the direction of induced current is clockwise.

b) Using Ohms Law: $V = \varepsilon = IR$

$$I = \frac{V}{R}$$
$$I = \frac{0.04}{2} = 0.02\ A$$

c) Power

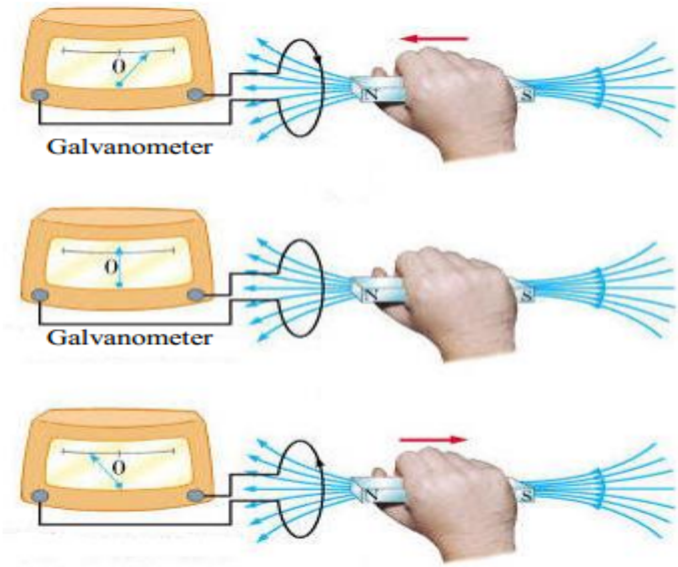
$$P = I^2 R$$
$$= (0.02)^2 \times 2$$
$$= 8\times10^{-4}\ W$$

d) Energy dissipated

$$E = Pt$$
$$= 8\times10^{-4}(0.8)$$
$$= 6.4\times10^{-4}\,J$$

Faraday's Electromagnetic Induction Law

- Michael Faraday discovered that varying a magnetic field with time, an electric field could be generated. This phenomenon is known as electromagnetic induction
- Faraday showed that current is induced in the loop when a relative motion exists between the bar magnet and the loop
- no current is registered in the galvanometer when a bar magnet is stationary with respect to the loop.



Faraday's Law states that the emf induced around a loop of conductor is proportional to the rate of change of the magnetic flux through the area.

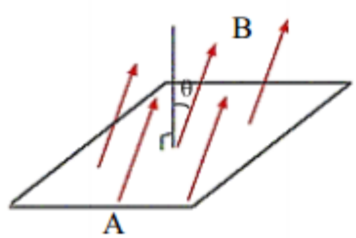
Mathematically:

$$\varepsilon = -\frac{d\phi_B}{dt}$$

If the circuit is a coil consisting of N loops then

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

Suppose a loop enclosing an area, A, lies in a uniform magnetic field, B, as shown in the diagram. The magnetic flux through the loop is equal to $BA\cos\theta$; hence the induced emf can be expressed as:



$$\varepsilon = -\frac{d}{dt}(BA\cos\theta)$$

From this expression, we can see that an emf can be induced in the circuit in several ways;

- Changing the magnitude of B with time.
- Changing the area enclosed by the loop can change with time.
- Changing the angle θ between B and the normal to the loop can change with time.

EXAMPLE

1. The plane of a rectangular coil 6.0 cm x 8.0 cm, is perpendicular to the direction of a magnetic field, B. If the coil has 100 turns and a total resistance of 10 Ω, what rate must the magnitude of B change to induce a current of 0.20 A in the winding of the coil?

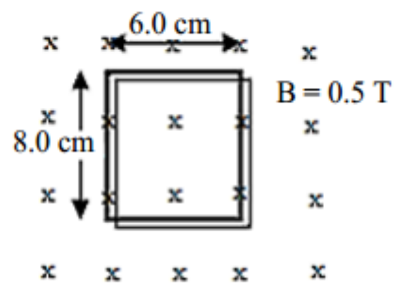


Figure 7.9

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

[Compute the area, voltage induced in 10 Ω resister and flux]

$A = 0.06 \times 0.08 = 4.8 \times 10^{-3}\ m^2$ $\quad V = IR = 0.2 \times 10 = 2\ V$ $\quad \phi_B = BA = B\,(4.8 \times 10^{-3})$

$$V = \varepsilon = -\frac{100 \times B\left(4.8 \times 10^{-3}\right)}{t}$$

$$2 = -\frac{100 \times B\left(4.8 \times 10^{-3}\right)}{t}$$

$$2 = (0.48)\,\frac{B}{t}$$

$$\frac{B}{t} = 4.17\,Ts^{-1}$$

2. A square solenoid of 100 turns of wire and side 5.0 cm long is placed perpendicular to a changing magnetic field of strength 0.50 T.

a) How much flux passes through each turn of wire?

b) The magnetic field is reduced to zero, in a time of 0.10 s. Calculate the voltage induced in the solenoid.

c) If the square solenoid has a resistance of 2 Ω, what is the induced current?

Solution

a) $\phi_B = BA$
$= 0.5\,(0.05 \times 0.05)$
$= 1.25 \times 10^{-3}$ Wb

b) $\varepsilon = -N\dfrac{d\phi}{dt}$
$= -100\left(\dfrac{0 - 1.25 \times 10^{-3}}{0.1}\right)$
$= 1.25\text{V}$

c) $I = \dfrac{V}{R}$
$= \dfrac{1.25}{2}$
$= 0.63\text{A}$

<u>EXERCISE</u>

1. A rectangular loop of area 0.01 m^2 is placed on the table where the magnetic field of magnitude 0.4 T is perpendicular to the plane of the loop.

a) What is the maximum flux through the loop?

b) If the magnetic field through the loop is reduced from 0.4 T to zero in 0.2 s, what is the magnitude of voltage induced in the coil?

2.

A square solenoid of 50 turns of wires and sides 5 cm long is placed perpendicular to a magnetic field of strength 0.5 T.

a) Determine the flux passes through the coil?

b) The magnetic field is reduced to zero during a time of 0.1 s. What is the induced voltage in the solenoid?

3.

A flexible conducting circular loop of radius 10 cm is in a magnetic field of strength 0.2 T. The loop is quickly pulled outwards at two points directly opposite each other until it closes. It takes 0.1 s to close the loop.

a) Explain why an emf is induced in the loop.

b) Calculate the magnitude of the induced emf in the loop.