Topic 17 - Electromagnetic Induction

1 Faraday's law of electromagnetic induction

Faraday's law of electromagnetic induction states that the induced e.m.f. is proportional to the rate of change of magnetic flux linkage

$$\text{induced e.m.f.} = -\frac{d\Phi}{dt}$$

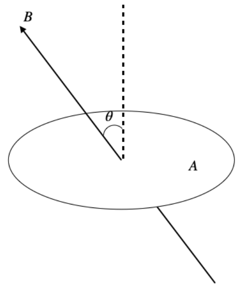
where Φ is the **magnetic flux linkage**

2 Magnetic flux and magnetic flux linkage

2.1 Magnetic flux

Magnetic flux, ϕ is defined as the product of an area and the component of the magnetic flux density perpendicular to that area

For an area A where a uniform magnetic field with magnetic flux density B passes at an angle θ



$$\phi = BAcos\theta$$

2.2 Magnetic flux linkage

The **magnetic flux linkage,** Φ of a coil is the product of the magnetic flux through the voil and the numebr of turns of the coil

For a coil of N turns with uniform cross sectional area A

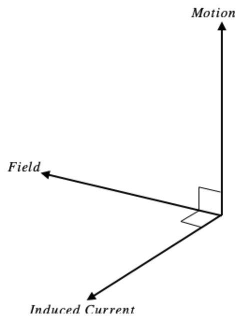
$$\Phi = N\phi$$

3 Determining direction of induced current

NOTE: there will only be an induced current if there is an induced e.m.f. and **the circuit is closed**

3.1 Fleming's right hand rule

DO NOTE QUOTE OFR ANSWERING QUESTIONS



3.2 Lenz's law

Lenz's law states that the direction of induced e.m.f. is such as to cause effects to oppose the change producing it

- a result of conservation of energy

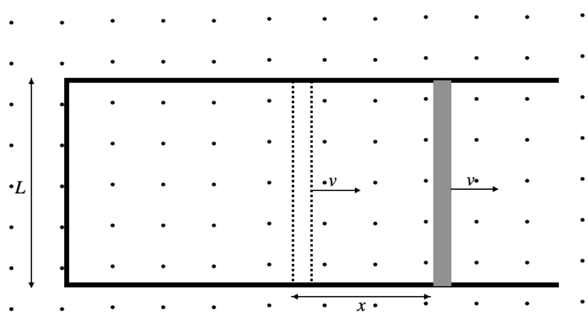
3.3 By first principles

- consider movement of free electrons inside a conductor
- consider direction of conventional current due to movement of conductor and hence electrons
- determine force on free electrons due to **Fleming's left hand rule**
- electrons will tend towards one end, while positive charge tends towards the other
- the separation of cahrge sets up an electric field.

NOTE THAT

- outside an e.m.f. source, current flows from **high to low** potential
- inside an e.m.f. source, current flows from **low to high** potential

4 Metal rod moving across uniform magnetic field



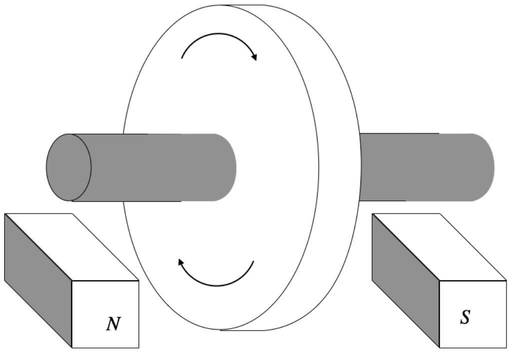
- the distance travelled by rod in time t is x
- the magnetic flux linkage in time t is

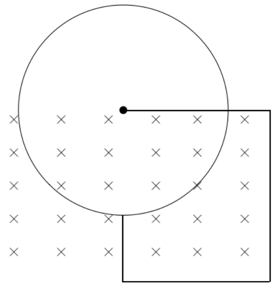
$$\Phi = BA = BLx$$

- The magnitude of induced e.m.f. is given by Faraday's law

$$|E| = \left| -\frac{d\Phi}{dt} \right| = BL\frac{dx}{dt} = BLv$$

5 Rotating disc in uniform magnetic field

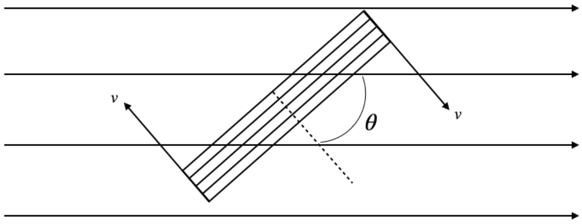




- the magnitude of induced e.m.f. is given by Faraday's law

$$|E| = \left| -\frac{d\Phi}{dt} \right| = B\frac{dA}{dt} = B\frac{\pi r^2}{T} = BAf = \frac{1}{2}Br^2\omega$$

6 Rotating coil in uniform magnetic field



- the magnetic flux linkage is given by

$$\Phi = NBAcos\theta = NBAcos\omega t$$

- By Faraday's law

$$E = -\frac{d\Phi}{dt}$$

$$= -\frac{d(NBAcos\omega t)}{dt}$$

$$= -NBA\frac{dcos\omega t}{dt}$$

$$= NBA\omega sin\omega t$$