ELECTROMAGNETIC INDUCTION

* Magnetic flux ϕ can be thought of as the total number of lines in a magnetic field that pass through a given area.
* Magnetic flux is the product of the magnetic flux density and the area normal to the lines of flux.
* For a uniform magnetic field of flux density B which makes an angle θ with an area A, the magnetic flux ϕ is given by the expression

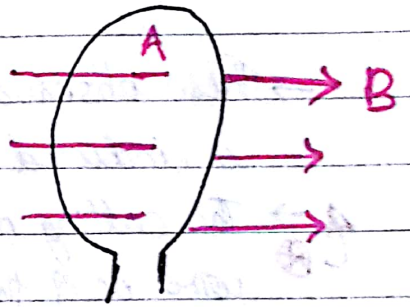
$$\phi = BA\sin\theta \quad \text{OR} \quad \phi = BA\cos\theta \quad [\text{depending on } \theta]$$

* The unit of magnetic flux is the Weber (Wb).
One Weber is equal to one tesla metre-squared.

$$1\ Wb = 1\ Tm^2$$

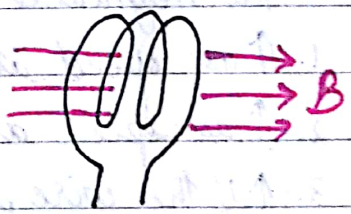
* With a coil of one turn, the flux through the coil is:

$$\text{flux} = B \times A$$



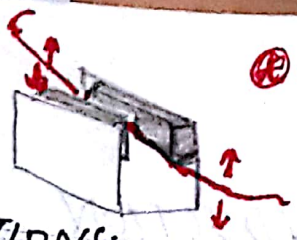
* For a coil of N turns, the flux through the coil is:

$$\text{flux} = B \times A \times N$$



* For a coil with N turns, the magnetic flux linkage is defined as the product of the magnetic flux & the number of turns.

$$\text{magnetic flux linkage} = N\phi = BAN\cos\theta.$$



* An emf is induced whenever there is a RELATIVE MOVEMENT between the magnet & the coil.

OBSERVATIONS:

* An e.m.f. is induced when:
  - the wire is moved through the magnetic field, across the face of the pole-pieces.
  - the magnet is moved so that the wire passes across the face of the pole-pieces.
* An e.m.f is NOT induced when:
  - the coire is held stationary between the pole-pieces
  - the magnet is moved so that the pole-pieces move along the length of the wire
  - the wire moves lengthways so that it does not change its position between the poles of the magnets.

→ These observations lead to the conclusion that an e.m.f is induced whenever lines of magnetic flux are cut.

→ The cutting may be caused by a movement of either the wire or of the magnet.

→ The magnitude of the e.m.f:

1. ↑ as speed at which wire is moved ↑.
2. ↑ as speed at which magnet is moved ↑.
3. ↑ if the wire is made into a loop with several turns
4. ↑ as the no. of turns on the loop ↑.
5. ↑ with ↑ cross-sectional area of coil
6. ↑ with ↑ strength of magnet.

∴ It can be concluded the magnitude of the induced e.m.f. depends on the rate at which magnetic flux lines are cut by a single wire or by using different numbers of turns of coire. The 2 factors are taken into account using magnetic flux linkage. ($N\phi$)

$\Delta(N\phi) = N\Delta\phi$

e.m.f can be induced by:

① changing B
② changing A of circuit
③ changing θ

* Summarised by Faraday's law of electromagnetic induction:

The e.m.f induced is proportional to the rate of change of magnetic flux linkage.

$$E \propto \frac{\Delta(N\Phi)}{\Delta t}$$

The constant of proportionality is −1 as explained by Lenz's Law.

Any induced current or induced emf will be established in a direction so as to produce effects which oppose the change that is producing it.

$$\therefore E = -\frac{\Delta(N\Phi)}{\Delta t}$$