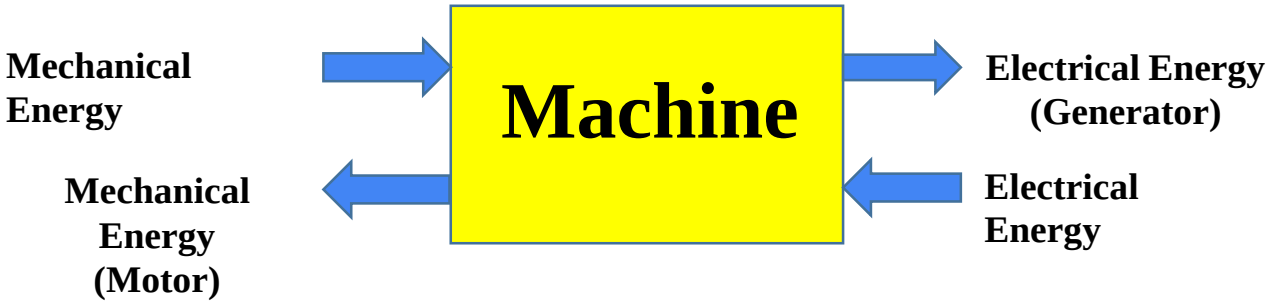
Electrical Machine Fundamentals

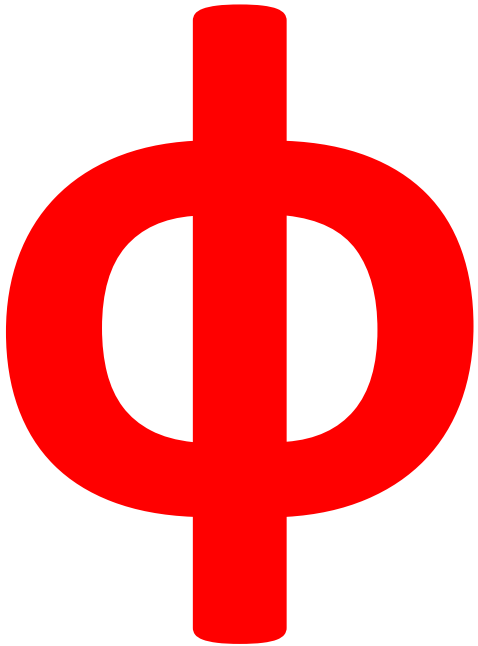
Md. Arafat Rahman
Lecturer, EEE department

Machine ?

Machine is a device which converts the mechanical energy into electrical energy or converts electrical energy into mechanical energy.



The main thing of Electrical Machine (Energy Conversion) is Magnetic Flux



Magnetic Flux

Magnetic flux Density

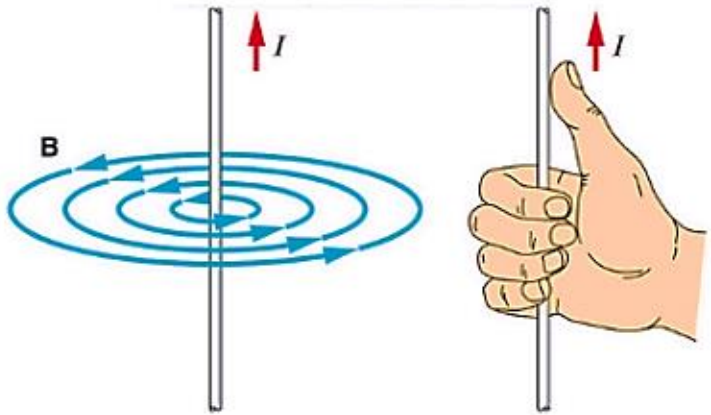
The number of flux lines per unit area, called the flux density

$$B = \frac{\Phi}{A}$$

$B = \text{Wb/m}^2 = \text{teslas (T)}$

$\Phi = \text{webers (Wb)}$

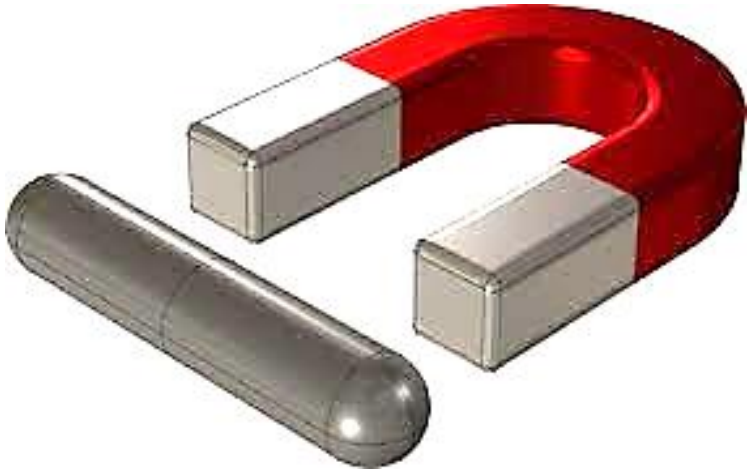
$A = \text{m}^2$

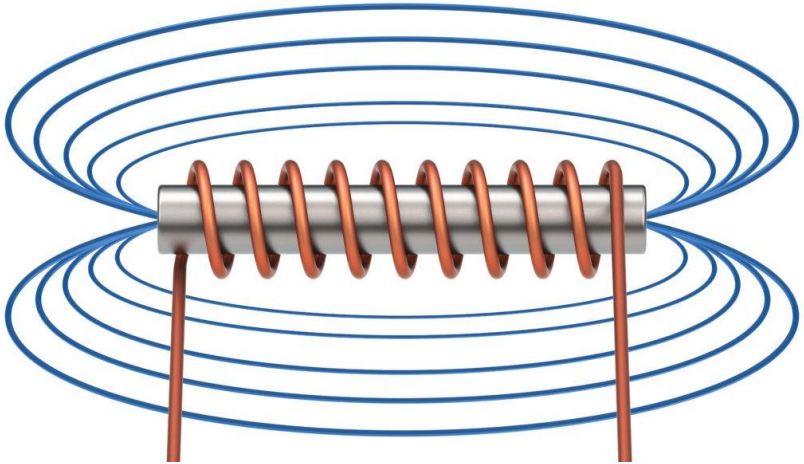


- Right hand thumb rule shows that the magnetic flux lines get the direction along the bent fingers when thumb denotes the direction of the current flow

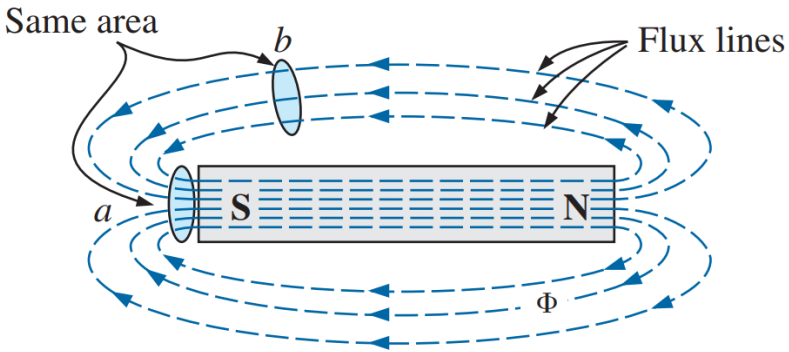
➢ Magnet

1) **Permanent Magnet (Uncontrollable)**
2) **Electromagnet (Controllable)**

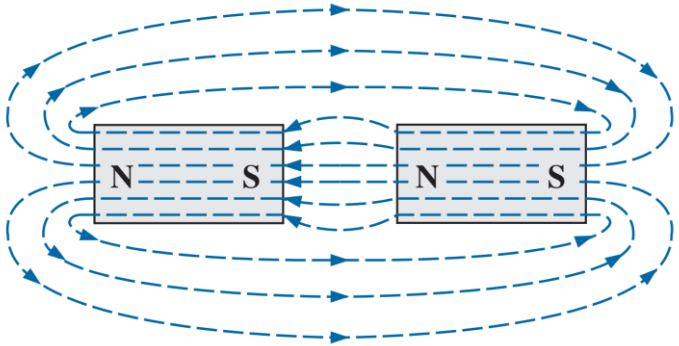




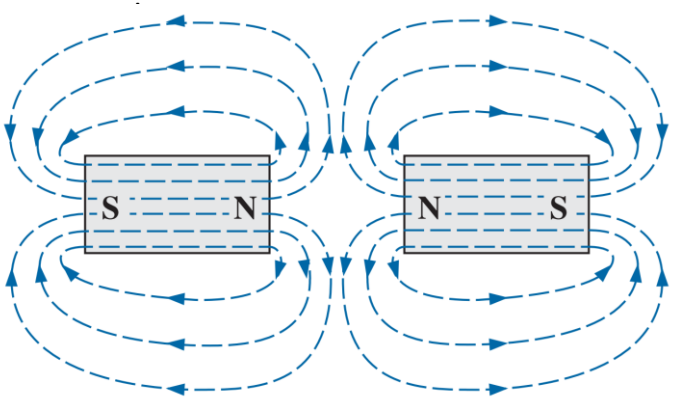
Flux Distribution



Flux distribution for a permanent

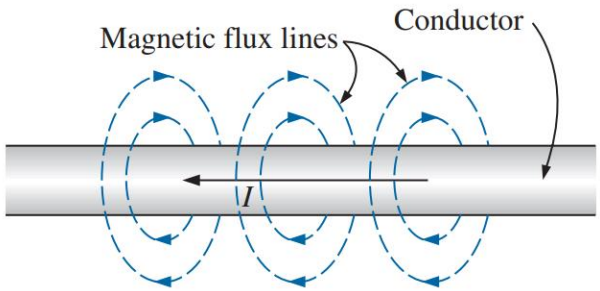


Flux distribution for two adjacent, opposite poles

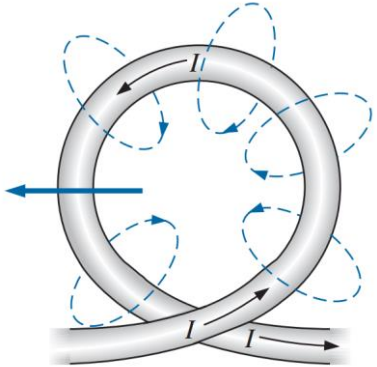


Flux distribution for two adjacent, like poles

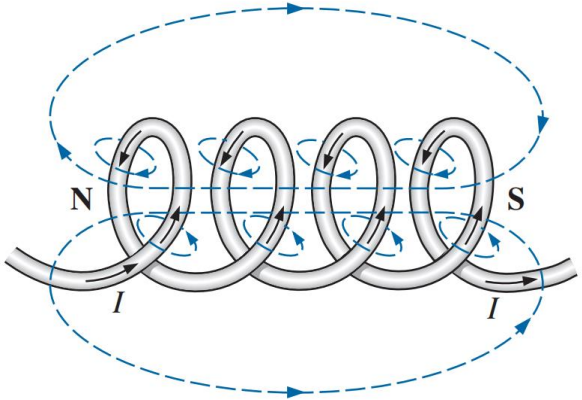
Flux Distribution Contd.



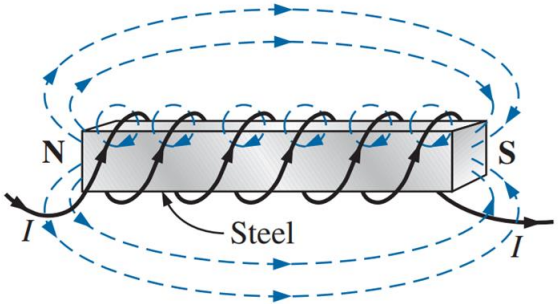
Magnetic flux lines around a current carrying conductor



Flux distribution of a single-turn coil



Flux distribution of a current carrying coil



Electromagnet

Electromagnet

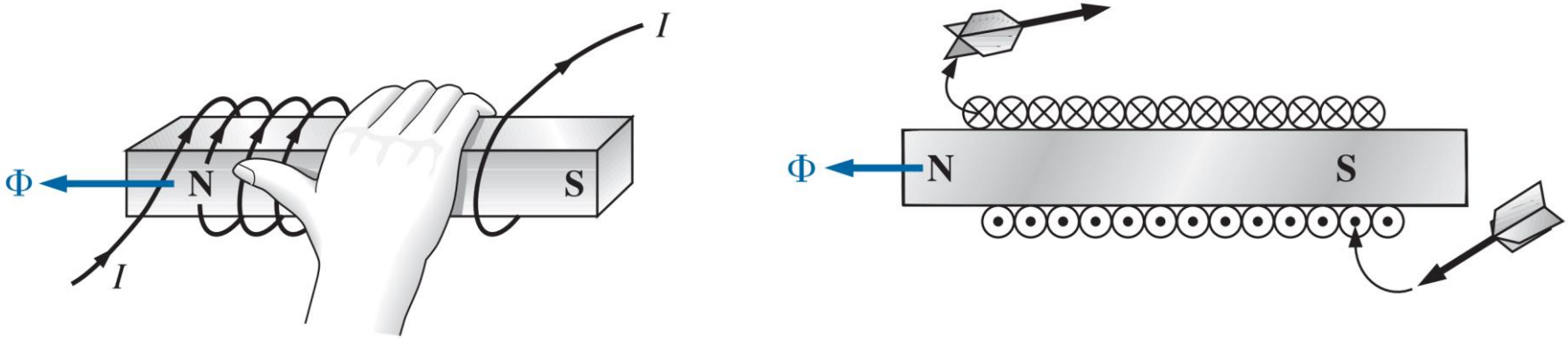
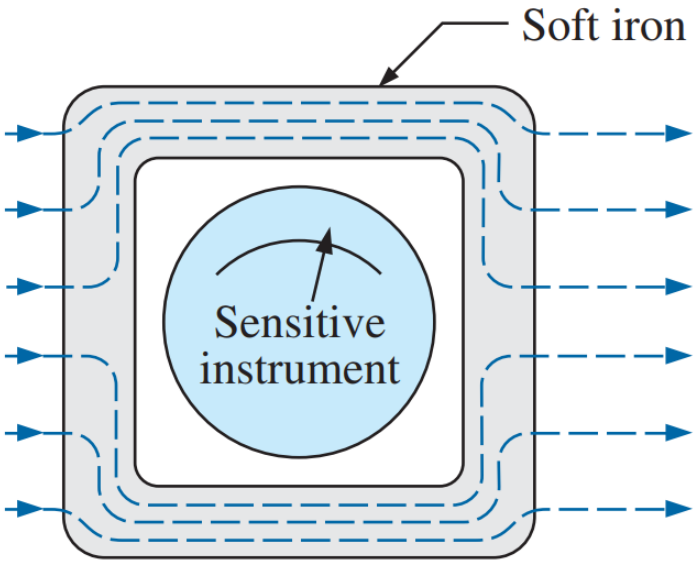
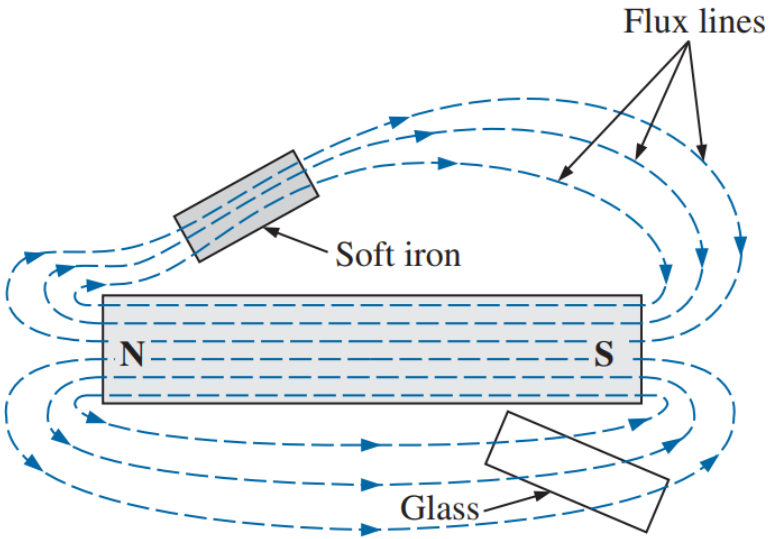


Fig: Determining the direction of flux for an electromagnet

Flux Distribution through soft iron



Effect of a magnetic shield on the flux distribution



Effect of a ferromagnetic sample on the flux distribution of a permanent magnet

Faraday's Law of Electromagnetic Induction

If a conductor is moved through a magnetic field so that it cuts magnetic lines of flux, a voltage will be induced across the conductor. The greater the number of flux lines cut per unit time (by increasing the speed with which the conductor passes through the field), or the stronger the magnetic field strength (for the same traversing speed), the greater will be the induced voltage across the conductor. If the conductor is held fixed and the magnetic field is moved so that its flux lines cut the conductor, the same effect will be produced.

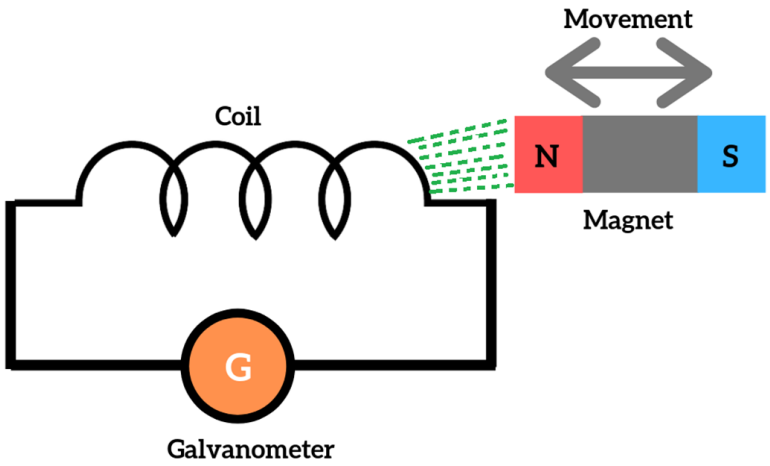


Fig: Generating an induced voltage by moving a magnet around a coil

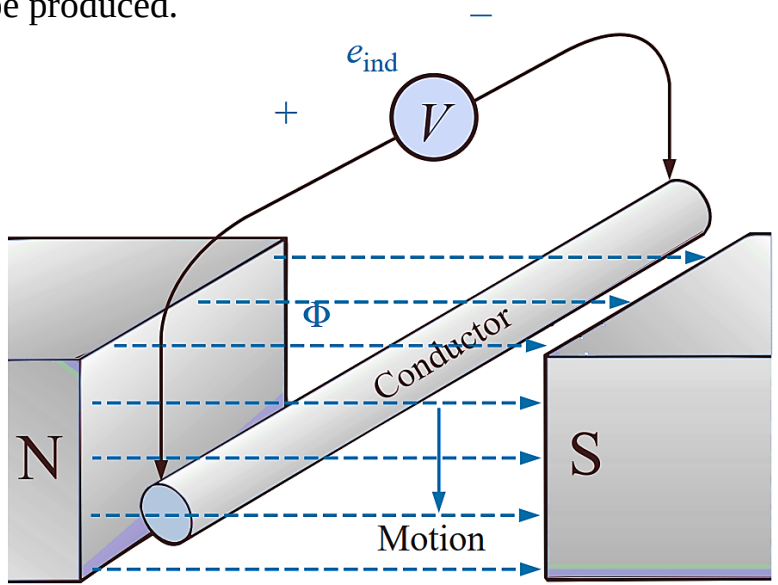
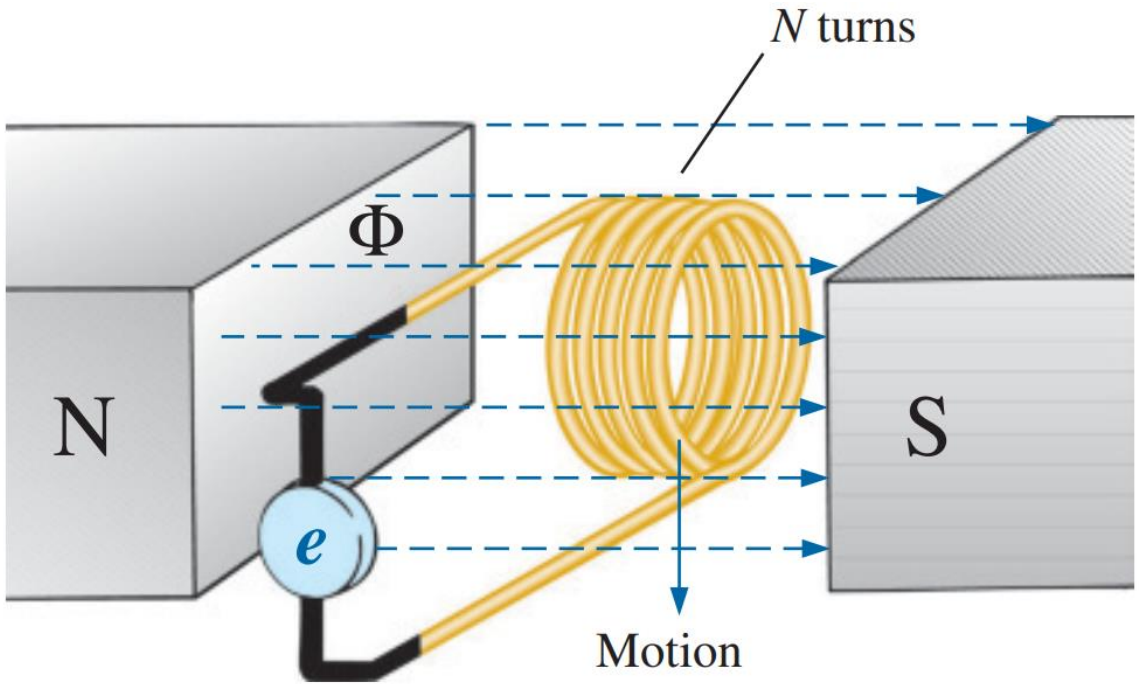
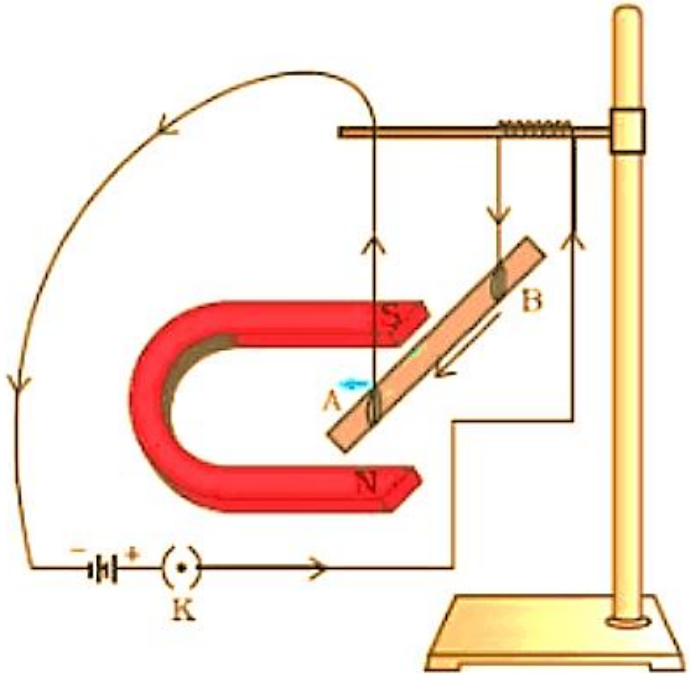


Fig: Generating an induced voltage by moving a conductor through a magnetic field

Faraday's Law of Electromagnetic Induction

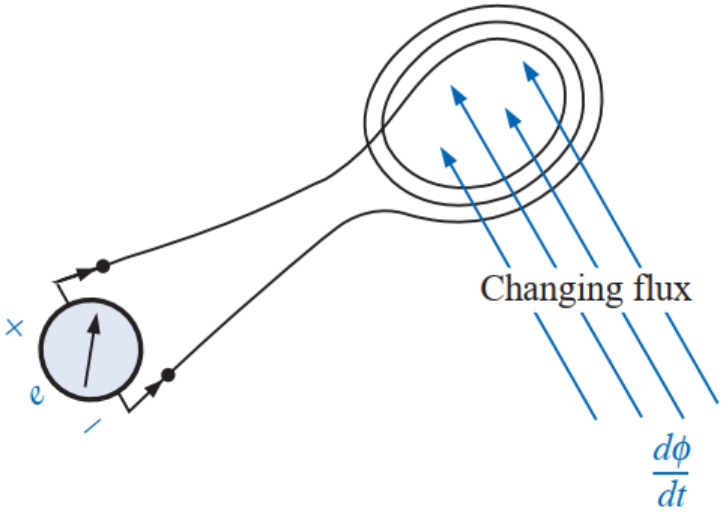


Faraday’s Law of Electromagnetic Induction



Faraday's Law of Electromagnetic Induction

$$e = N\frac{d\phi}{dt}$$



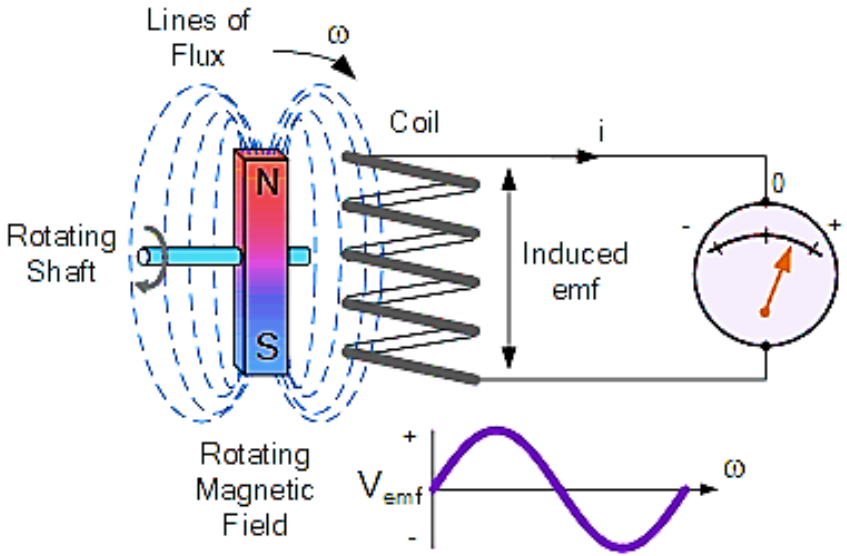
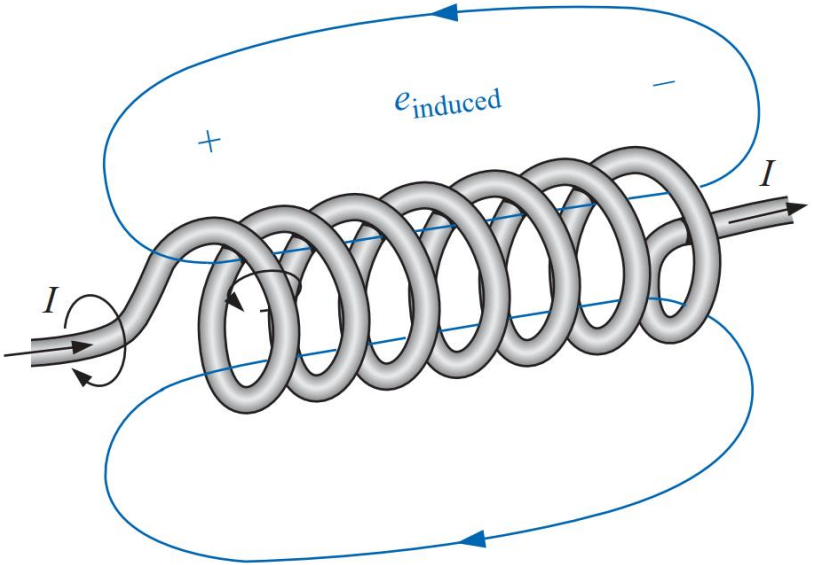


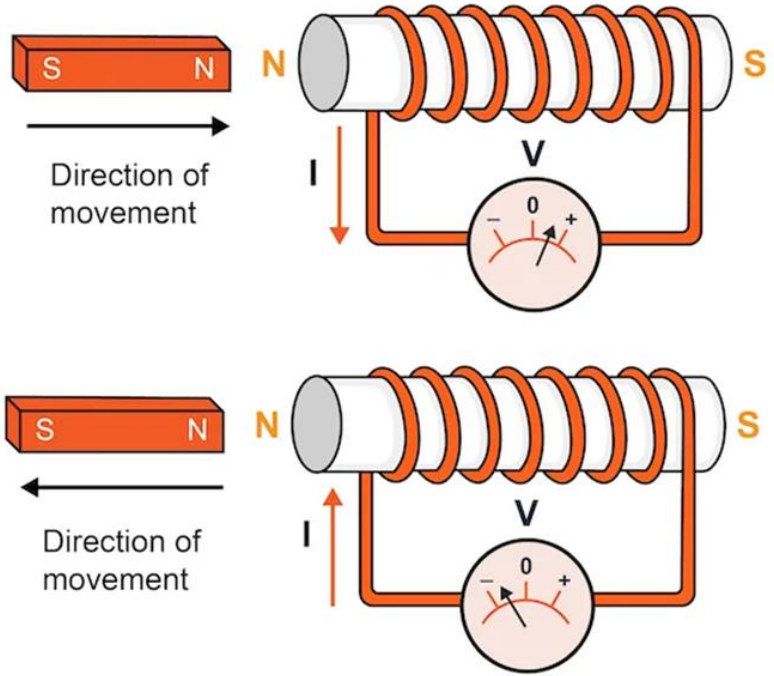
Fig: Generating an induced voltage by moving a magnet around a coil

Lenz's Law

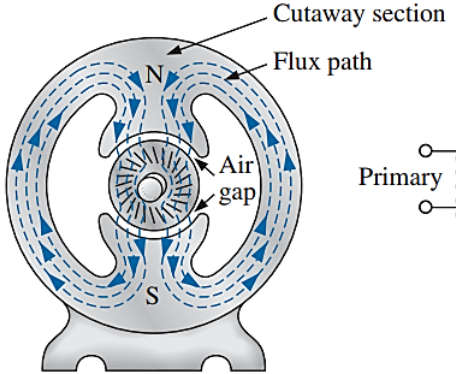
An induced effect is always such as to oppose the cause that produced it.

The polarity of this induced voltage tends to establish a current in the coil that produces a flux that will oppose any change in the original flux.

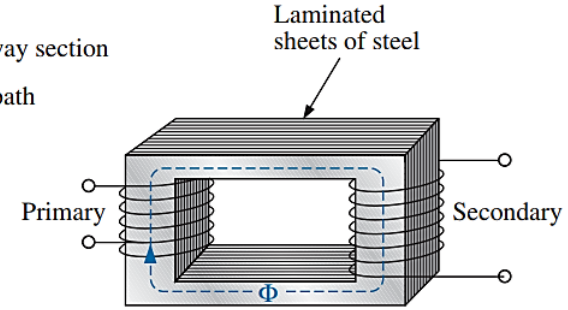




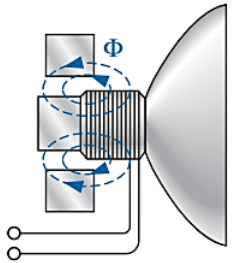
Application of magnetic effects



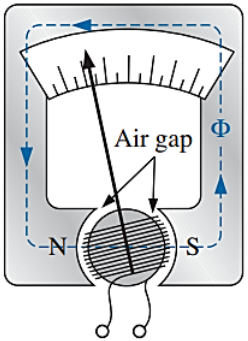
Generator



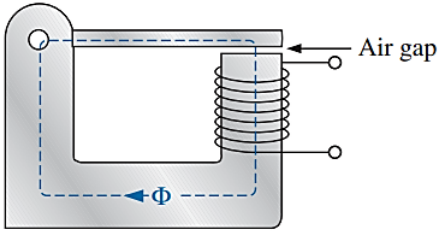
Transformer



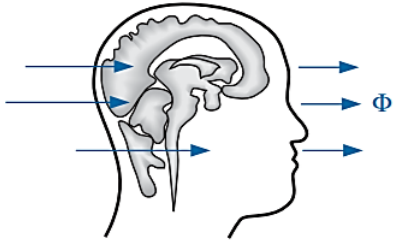
Loudspeaker



Meter movement

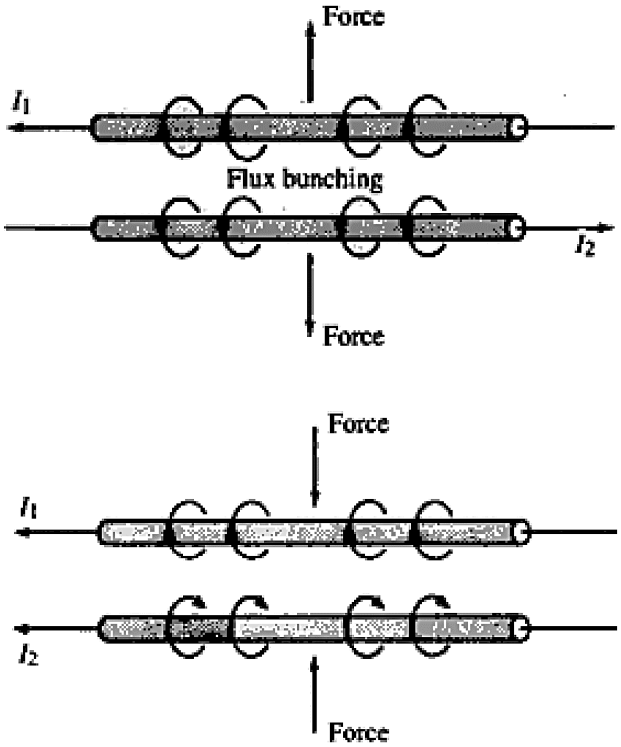


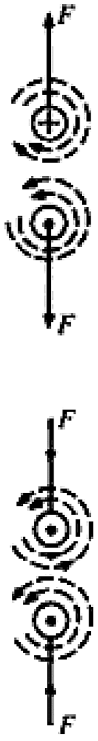
Relay



Medical Applications: Magnetic resonance imaging.

Ampere’s Force Law

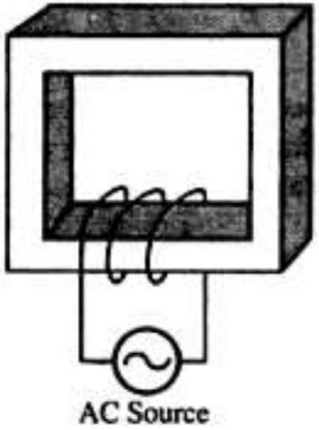


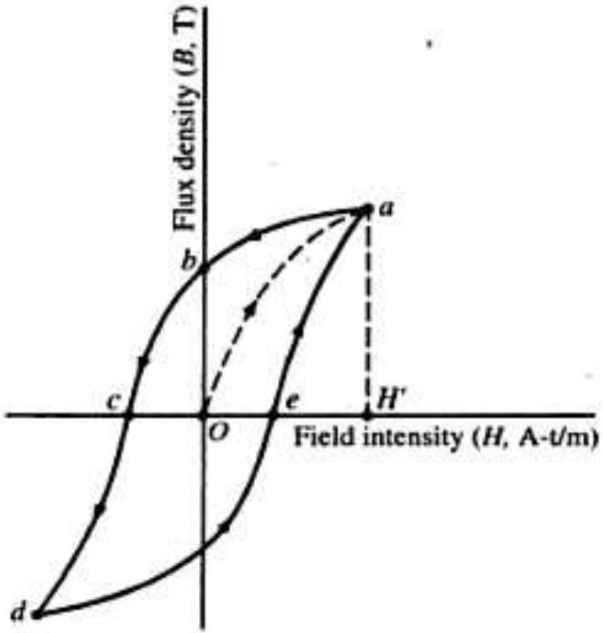


The force of attraction or repulsion between two current-carrying wires is called Ampere's force law.

- When two or more sources of magnetic fields are arranged so that their fluxes, or a component of their fluxes are parallel within a common region, a mechanical force will be produced that tends to either force the sources together or force them apart.
- A force of repulsion will occur if the two magnetic sources have components of flux that are parallel and in the same direction and flux bunching will occur in the common region.
- A force of attraction will occur if the two magnetic sources have components of flux that are parallel and in the opposite direction and subtraction of flux will occur in the common region.

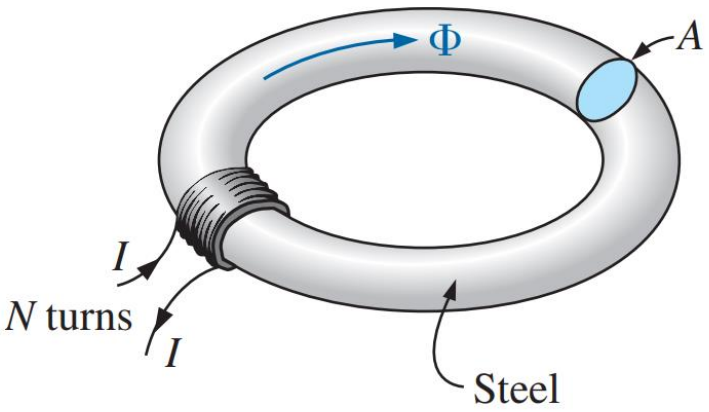
Hysteresis

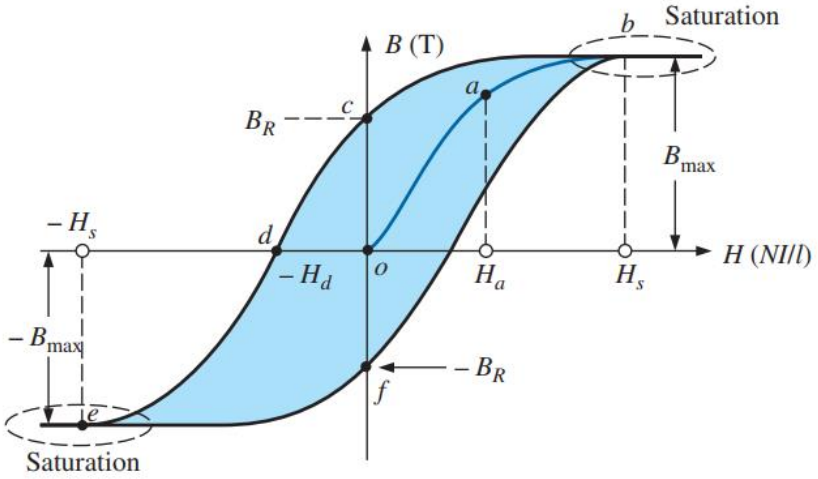




$$H\uparrow = \frac{NI\uparrow}{l}$$

Hysteresis


Φ
A
I
N turns
I
Steel


B (T)
b
Saturation
a
c
B_R
B_{max}
$-H_s$
d
H (NI/l)
$-H_d$
o
H_a
H_s
$-B_{max}$
$-B_R$
f
e
Saturation

Equations of Magnetic Circuit

$$\Phi = \frac{\mathcal{F}}{\mathcal{R}}$$

$$\boxed{\mathcal{F} = NI}$$

$\mathcal{F}$ = ampere-turns (At)
N = turns (t)
I = amperes (A)

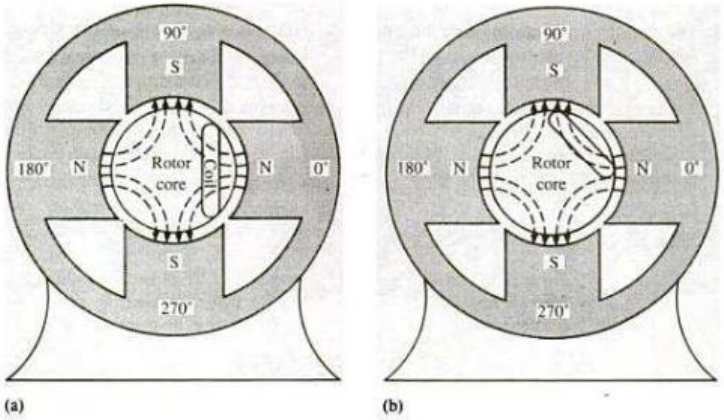
$$H = \frac{\mathcal{F}}{l}$$

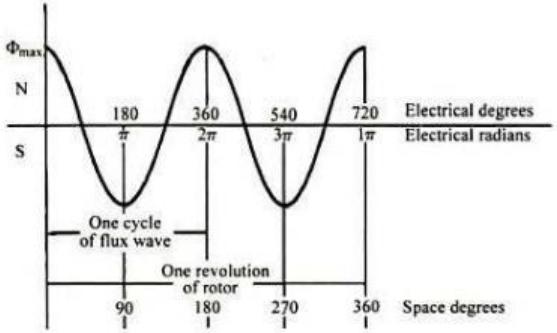
$$H = \frac{Nl}{l}$$

$$B = \mu H$$

$$\mathcal{F} = NI$$

Electrical & Mechanical Degree





Electrical Degree $= \frac{P}{2} \times$ **Mechanical Degree**

$$\theta_e = \frac{P}{2} \times \theta_m$$