Lecture -17
Law of Electromagnetic Induction

Lecture Delivered by

Topics

- Parallel Magnetic Circuits
- Law of Electro Magnetic Induction
- Lenz Law

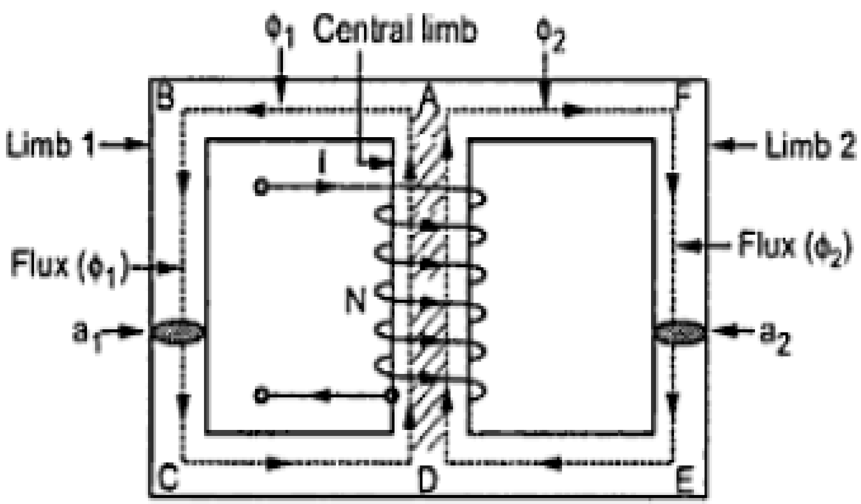
Objectives

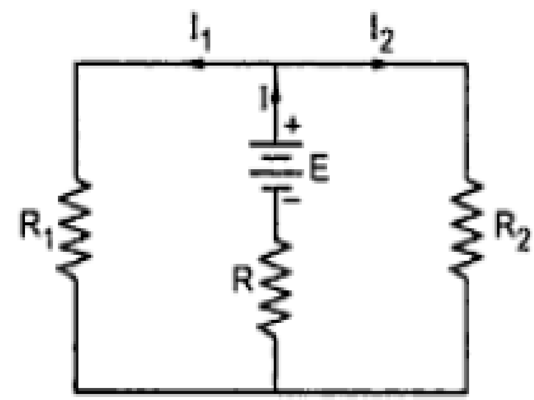
At the end of this lecture, student will be able to :

- Describe Parallel Magnetic Circuits
- Explain Magnetic leakage and Fringing
- State Law of Electromagnetic Induction and apply to electrical circuits
- State Lenz Law and apply to electrical circuits

Parallel Magnetic Circuits

- Magnetic circuit which has more than one path for the flux is known as a parallel magnetic circuit.
- At point A, the total flux Ø, divides into two parts $\emptyset_1$ and $\emptyset_2$.





Parallel Magnetic Circuits

- The mean length of the path ABCD = $l_1\ m$
- The mean length of the path AFED = l_2m
- The mean length of the path AD= $l_c m$
- The reluctance of the path ABCD=S_1
- The Reluctance of path AFED = S_2
- The Reluctance of path AD = S_c
- The total m.m.f produced = NI AT

$$\boldsymbol{Flux = \frac{M.M.F}{Reluctance}}$$

So, M.M.F = $\emptyset \times \boldsymbol{S}$

For path ABCDA, NI = $\emptyset_1 S_1 + \emptyset S_c$

Where $S_1 = \frac{l_1}{\mu a_1}, S_2 = \frac{l_2}{\mu a_2}\ and\ S_c = \frac{l_c}{\mu a_c}$

Generally $a_1 = a_2 = a_c$= area of cross –section

Parallel Magnetic Circuits

$$Total\ M.M.F = M.M.F\ required\ \ by\ central\ limb + M.M.F\ required\ by\ any\ one\ of\ outer\ limbs$$

$$NI = \ (NI)_{AD} + (NI)_{ABCD}\ or\ (NI)_{AFED}$$

$$NI = \ \emptyset S_c + [\emptyset_1 S_1 or\ \emptyset_2 S_2]$$

- Thus same m.m.f produces different fluxes in two parallel branches. For such parallel branches,

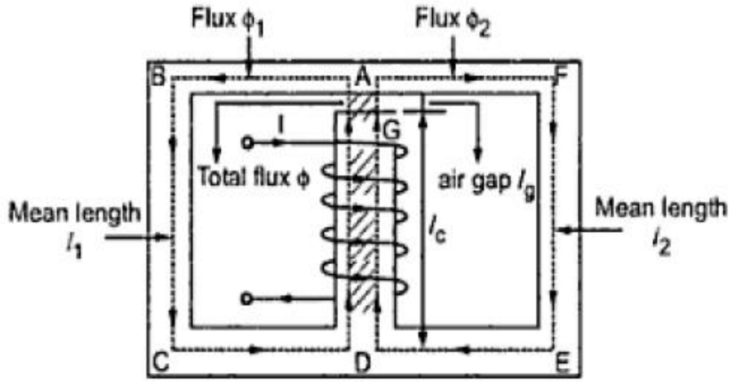
$$\emptyset_1 S_1 = \emptyset_2 S_2$$

Parallel Magnetic Circuits with air gap

- Path GD= iron path = I_c
- Path GA= Air gap = I_g
- The total flux produced is $\emptyset$.

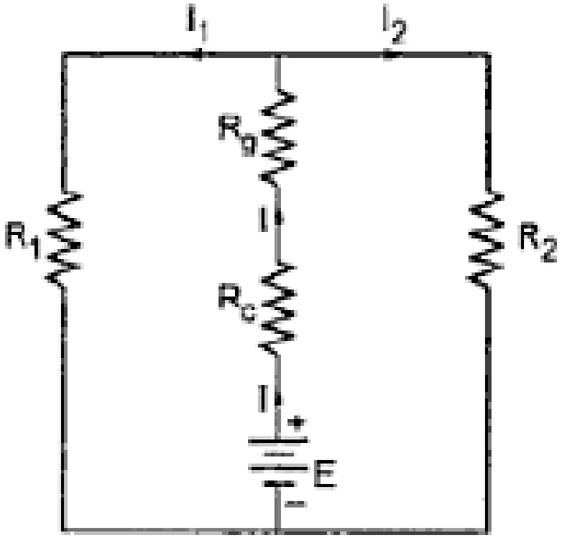
It gets divided at A into $\emptyset_1$ and $\emptyset_2$.

$$\emptyset = \emptyset_1 + \emptyset_2$$



- The reluctance of central limb is now,

$$S_c = S_i + S_g = \frac{l_c}{\mu a_c} + \frac{l_g}{\mu a_c}$$



- Hence m.m.f of central limb is now,

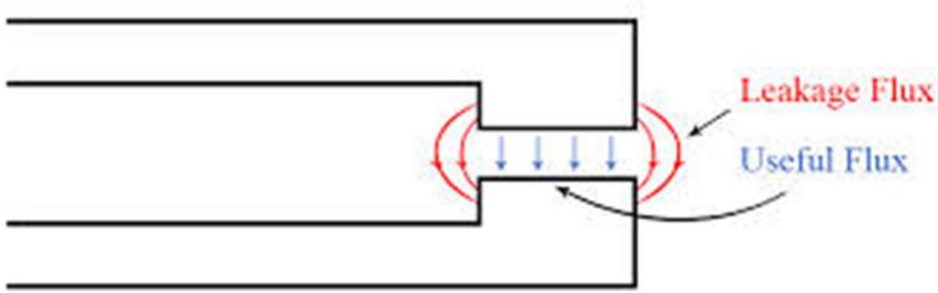
$$(m.m.f)_{AD} = (m.m.f)_{GD} + (m.m.f)_{GA}$$

- Hence the total m.m.f can be expressed as

$$(NI)_{total} = (NI)_{GD} + (NI)_{GA} + (NI)_{ABCD} \; or (NI)_{\text{.}}$$

Magnetic Leakage

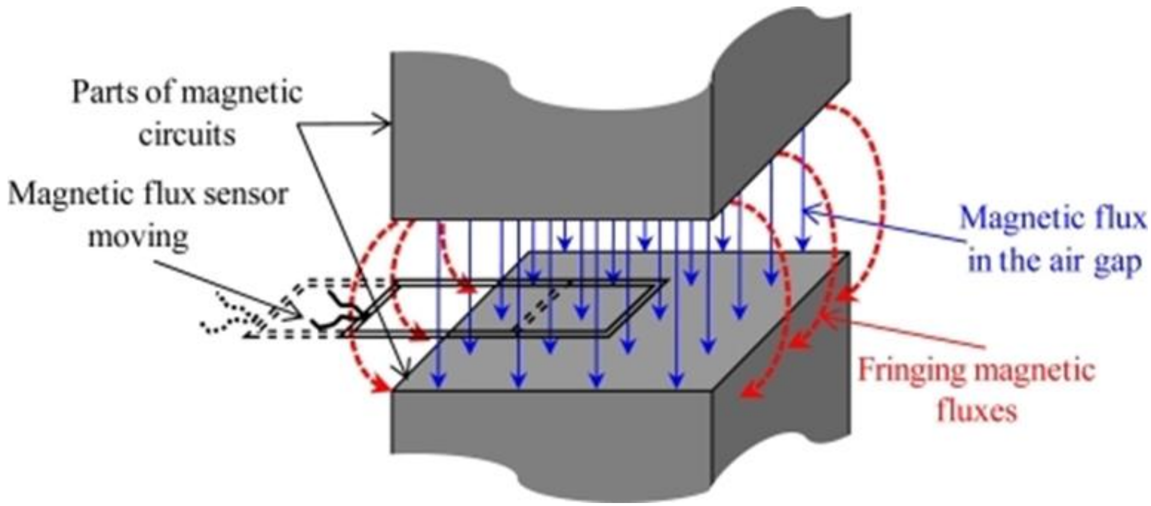
- Flux which leaks and completes its path through surrounding air or medium instead of the desired path is called the leakage flux



- The ratio of the total flux ($\emptyset_T$) to the useful flux ($\emptyset_u$) is defined as the leakage coefficient of Hopkinson's coefficient or leakage factor of that magnetic circuit $$\aleph = \frac{\emptyset_T}{\emptyset_u}$$

Magnetic Fringing

- Tendency of flux to bulge out at the edges of the air gap is called magnetic fringing



It has two effects

- It increases the effective cross sectional area of the air gap
- It reduces the flux density in the air gap

Faraday’s Experiment

- Michael Faraday, was an english scientist who contributed to the fields of electromagnetism and electrochemistry. His main discoveries include those of electro magnetic induction ,diamagnetism and electrolysis

Michael Faraday
(22 September 1791- 25 August 1867)

First Law

Whenever the number of magnetic lines of force (flux) linking with a coil or circuit changes, an E.M.F gets induced in that coil or circuit

Second Law

The magnitude of the induced E.M.F is directly proportional to the rate of change of flux linkages .

$$\boldsymbol{Flux\ linkages = Flux \times Number\ of\ turns\ of\ coil}$$

Faraday's Laws

- The initial flux linking with a coil is $\emptyset_1 -$ Initial flux linkages = N$\emptyset_1$
- In time interval t, the flux linkage with the coil changes from $\emptyset_1$ to $\emptyset_2$.

final Flux Linkages = N$\emptyset_2$

Therefore, Rate of change of flux linkages $= \frac{N\emptyset_2 - N\emptyset_1}{t}$

$$\boldsymbol{e \propto \frac{N\emptyset_2 - N\emptyset_1}{t}\,;\, e = K\frac{N\emptyset_2 - N\emptyset_1}{t}\,;\, e = N\frac{d\emptyset}{dt}}$$

Where K as unity to get units of e as volts, $d\emptyset$ is change in flux and dt is change in time hence $({}^{d\emptyset}/{}_{dt})$ is rate of change of flux.

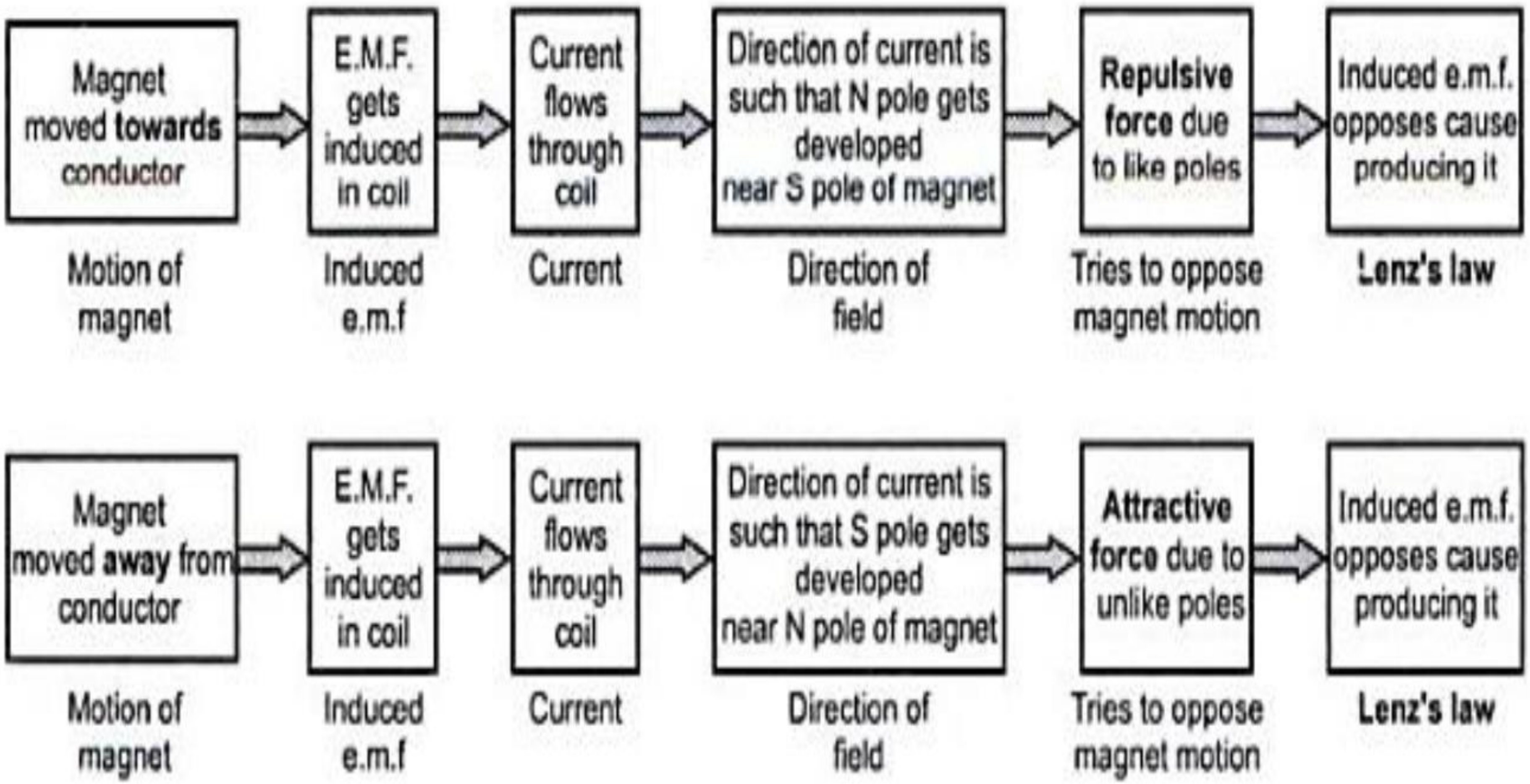
$$\boldsymbol{e = -N\frac{d\emptyset}{dt}\ volts}$$

Lenz Law

- The Direction of an induced e.m.f produced by the electromagnetic induction is such that it sets up a current which always opposes the cause that is responsible for inducing the e.m.f.
- Therefore, the induced e.m.f always opposes the cause producing it, which is represented by a negative sign, mathematically

$$\boldsymbol{e = -N \frac{d\emptyset}{dt}}$$

Block Diagram of Lenz Law



Summary

- A magnetic circuit which has more than one path for the flux is known as a parallel magnetic circuit
- Whenever the number of magnetic lines of force (flux) linking with a coil or circuit changes, an E.M.F gets induced in that coil or circuit
- The magnitude of the induced E.M.F is directly proportional to the rate of change of flux linkages
- The self induced e.m.f lasts till the current in the coil is changing The direction of such induced e.m.f can be obtained by Lenz's law