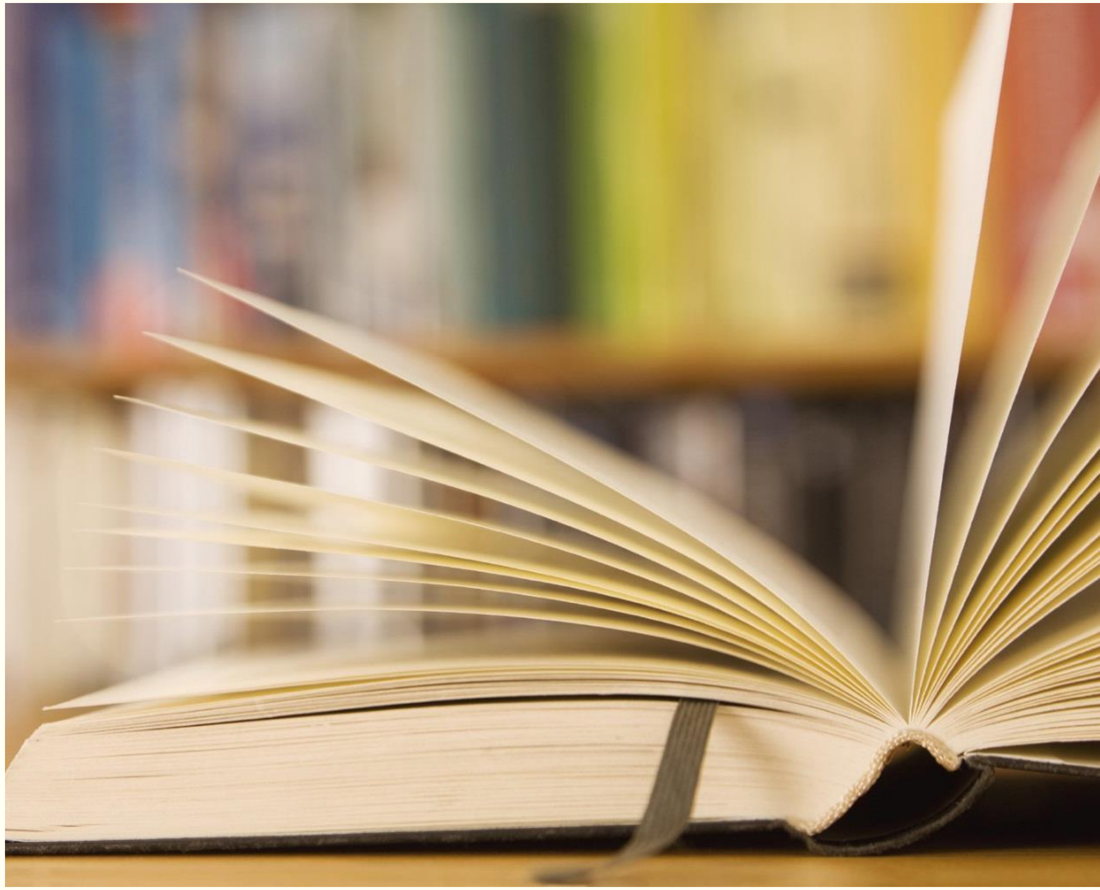
CHAPTER-5
MAGNETIC CIRCUIT

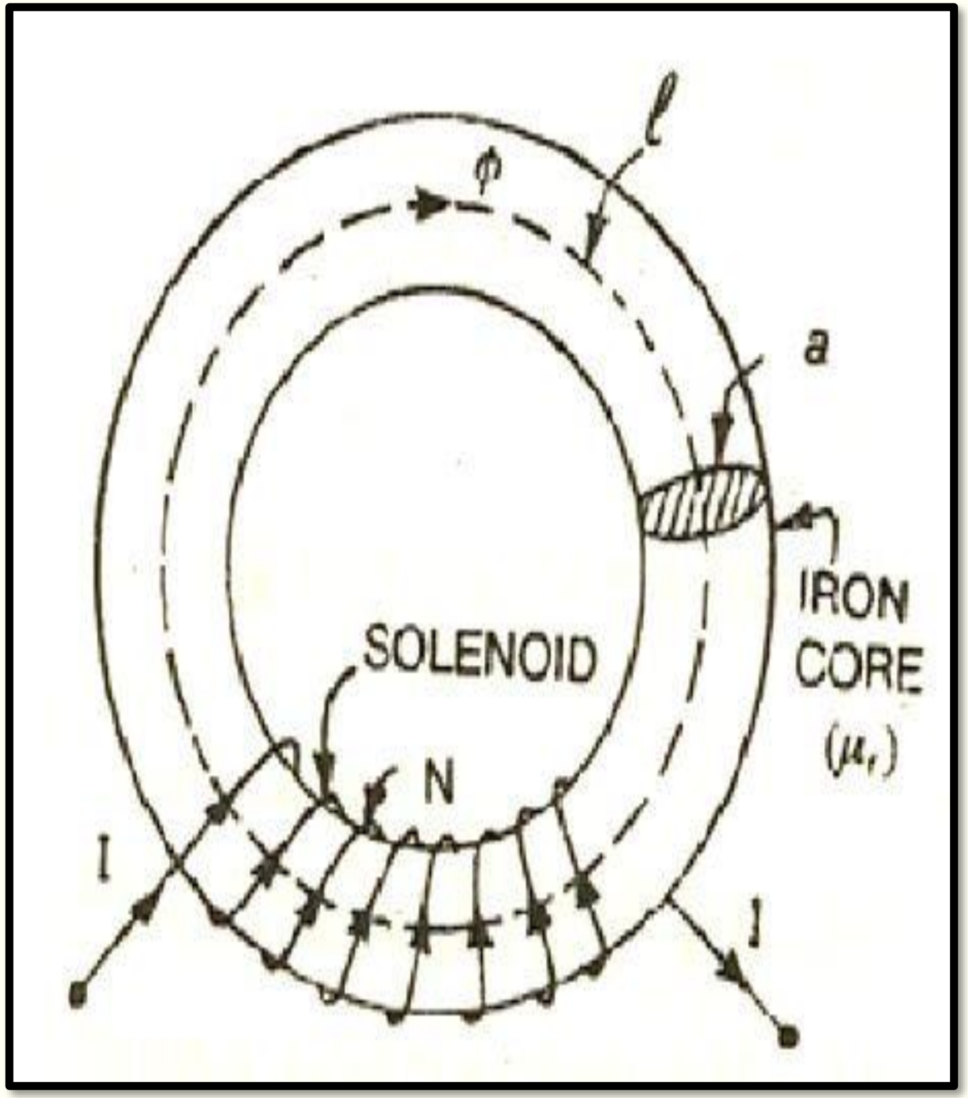
PREPARED BY:- PURVESH A VALAND



TERMS RELATED TO MAGNETIC CIRCUIT

- **Magnetic circuit:-** in fig an iron ring of **mean length l meter** and **cross sectional area of A meter square** is shown. The ring wound with a coil of **N number of turns.** The coil **carries current of I ampere**. **So magnetic flux** is produced in the ring.

- **Magnetic flux (ϕ) :-** Magnetic Flux is defined as the number of magnetic field lines passing through a given closed surface. It gives the measurement of the total magnetic field that passes through a given surface area. Here, the area under consideration can be of any size and under any orientation with respect to the direction of the magnetic field.



TERMS RELATED TO MAGNETIC CIRCUIT

- **MMF (magneto motive force) :-** just as electromotive force (emf) is necessary to pass current in electric circuit. **Magneto motive force (mmf) is necessary to establish flux in the magnetic circuit. Magneto motive force is the multiplication of current flowing through the coil and the number of turns of the coil.**

  mmf = I*N.

  unit of magneto motive force is **ampere turn** and its symbol is **Fm.**

- **Magnetic field strength or magnetic field intensity:-** it is the magneto motive force per meter length of the magnetic path. It is **denoted by letter H** and its unit is **ampere turn meter.**

  H = mmf / length.
  H = IN / l.

  l is the length of the magnetic flux path.

TERMS RELATED TO MAGNETIC CIRCUIT

- **Reluctance:-** **it is the property of the material to oppose the establishment of magnetic flux through it.** It is similar to resistance in electric circuit. Just as **R= E/I,** we have,

  Reluctance = mmf / flux.

  S = IN / Φ.

  its unit is **AT / Wb.**

- **Permeability:- The property of material to allow the magnetic flux to be produced through it is called permeability.**
  permeability of air or vacuum is taken as reference or base. it is **denoted by μ0** its value is **4π × 10-7**.

  permeability of any material is **denoted by μ**. It is called the **absolute permeability**.
  When the permeability of material is compared with that of the air or vacuum it is called **the relative permeability and it is denoted by μr.**

TERMS RELATED TO MAGNETIC CIRCUIT

- **<u>Relative Permeability:-</u> when the permeability of material is compared with that of air or vacuum it is called the relative permeability and it is denoted by letter μr.**

  Relative permeability = absolute permeability / permeability of air or vacuum.

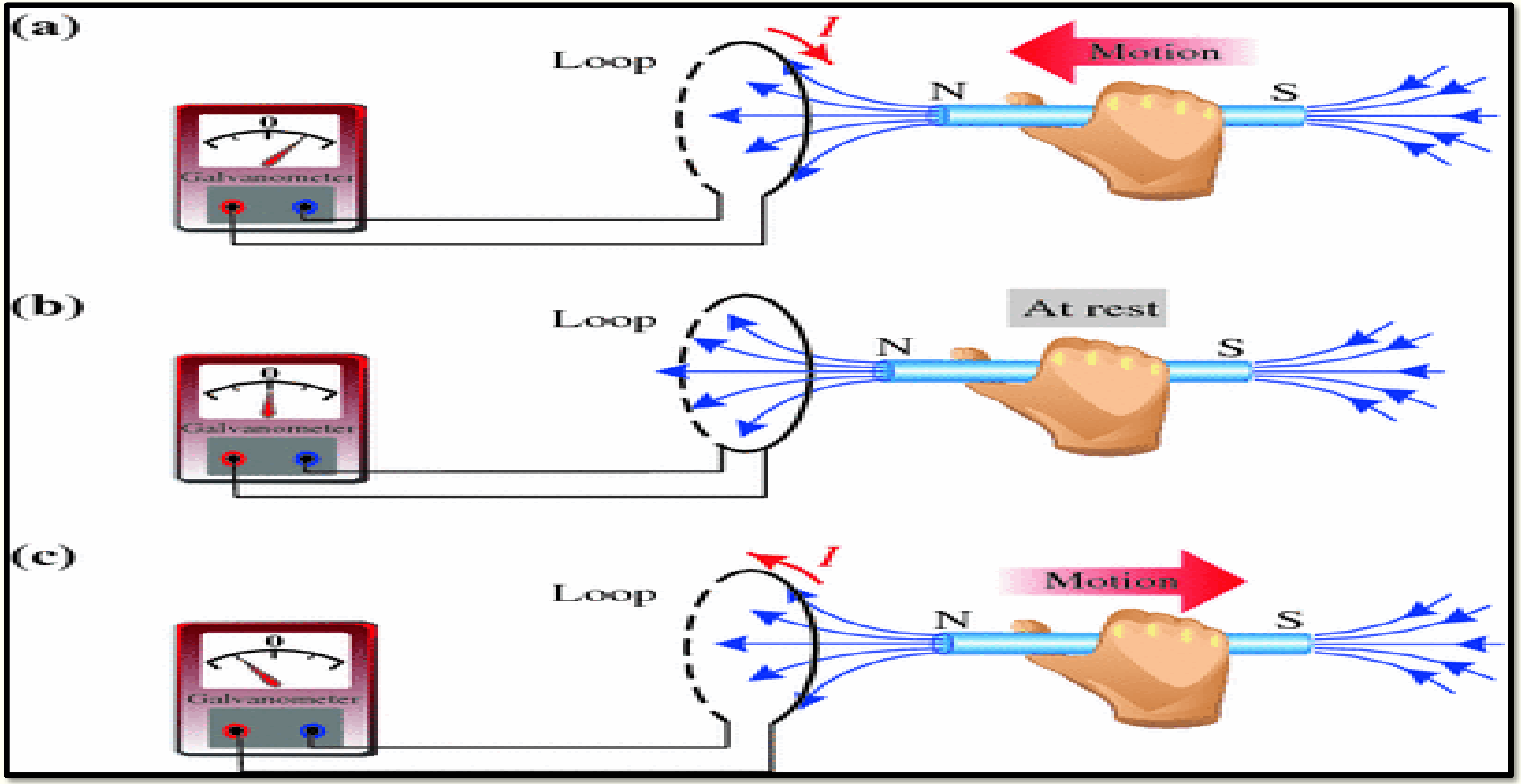
  $$\mu r = \mu / \mu o.$$
  $$\mu = \mu r * \mu o.$$

- **Permeance :- it is inverse of reluctance.**
  Permeance = 1 / Reluctance.

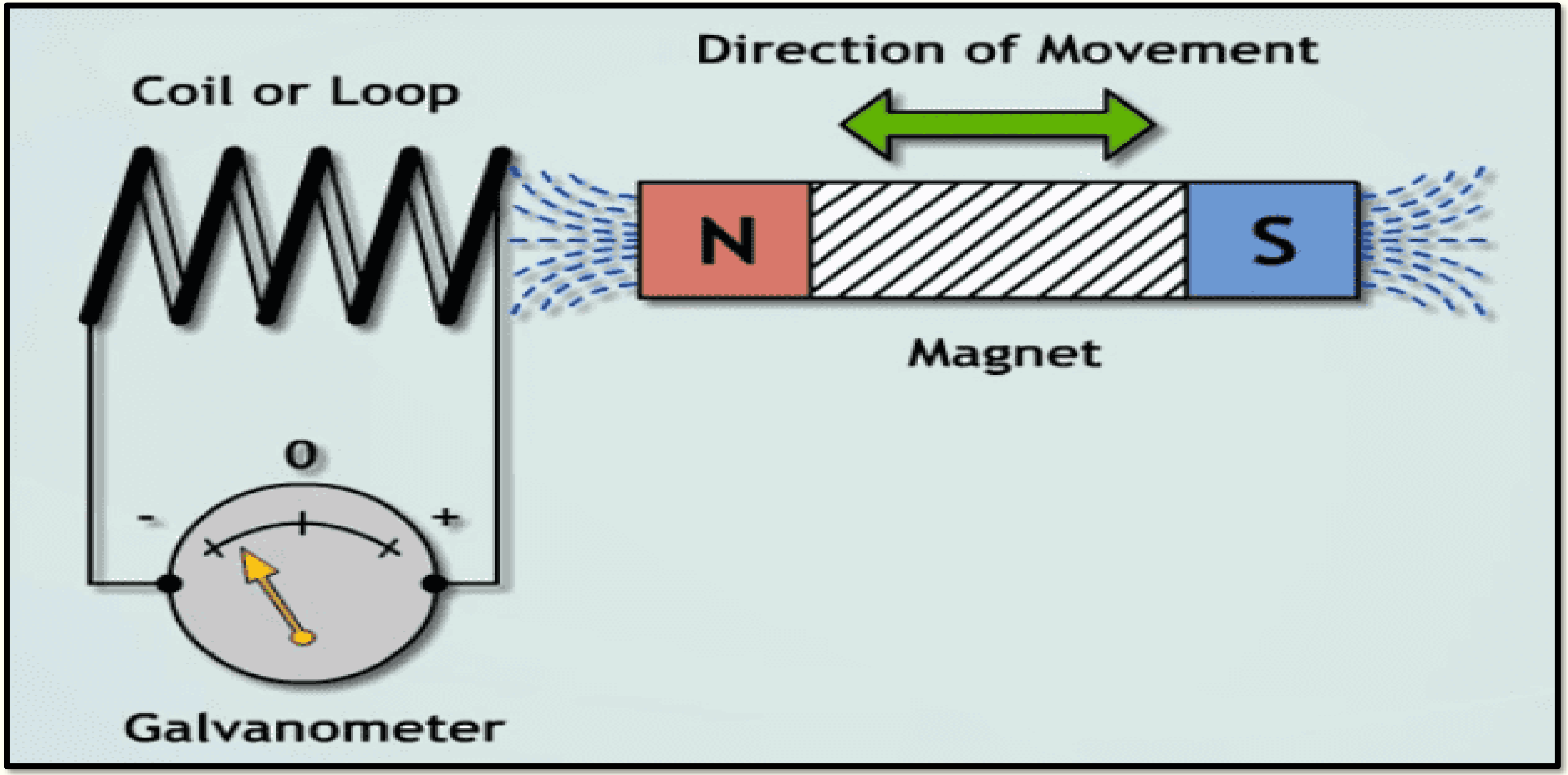
  it is **denoted by Δ.**

  $$\Delta = 1 / S.$$

FARDAY'S LAW OF ELECTROMAGNETIC INDUCTION



FARDAY'S LAW OF ELECTROMAGNETIC INDUCTION



FARDAY’S LAW OF ELECTROMAGNETIC INDUCTION

- **<u>1ST LAW:</u>-** whenever a current carrying conductor cuts the magnetic field emf Is induced in the conductor.
- **<u>2ND LAW:-</u>** e.m.f induced = rate of change of flux.

➢ Primary flux linkage = Nϕ1

➢ Secondary flux linkage= Nϕ2

➢ E.m.f induced = Nϕ2-Nϕ1/ t (time)

= N (ϕ2-ϕ1) / t (time)

$$\boxed{\varepsilon = -N \frac{\Delta \Phi}{\Delta t}}$$

LENZ'S LAW

- **Lenz's Law:** The **induced electromotive force with different polarities induces a current whose magnetic field opposes the change in magnetic flux through the loop in order to ensure that the original flux is maintained through the loop when current flows in it.**
- Lenz's Law is reflected in the formula of Faraday's law. Here the negative sign is contributed by Lenz's law. **The expression is**

$$\boxed{Emf = -N\left(\frac{\Delta\phi}{\Delta t}\right)}$$

- **Where,**
- Emf is the induced voltage (also known as electromotive force).
- N is the number of loops.

$$\Delta\phi \ \textit{Change in magnetic flux.}$$
$$\Delta t \ \textit{Change in time.}$$

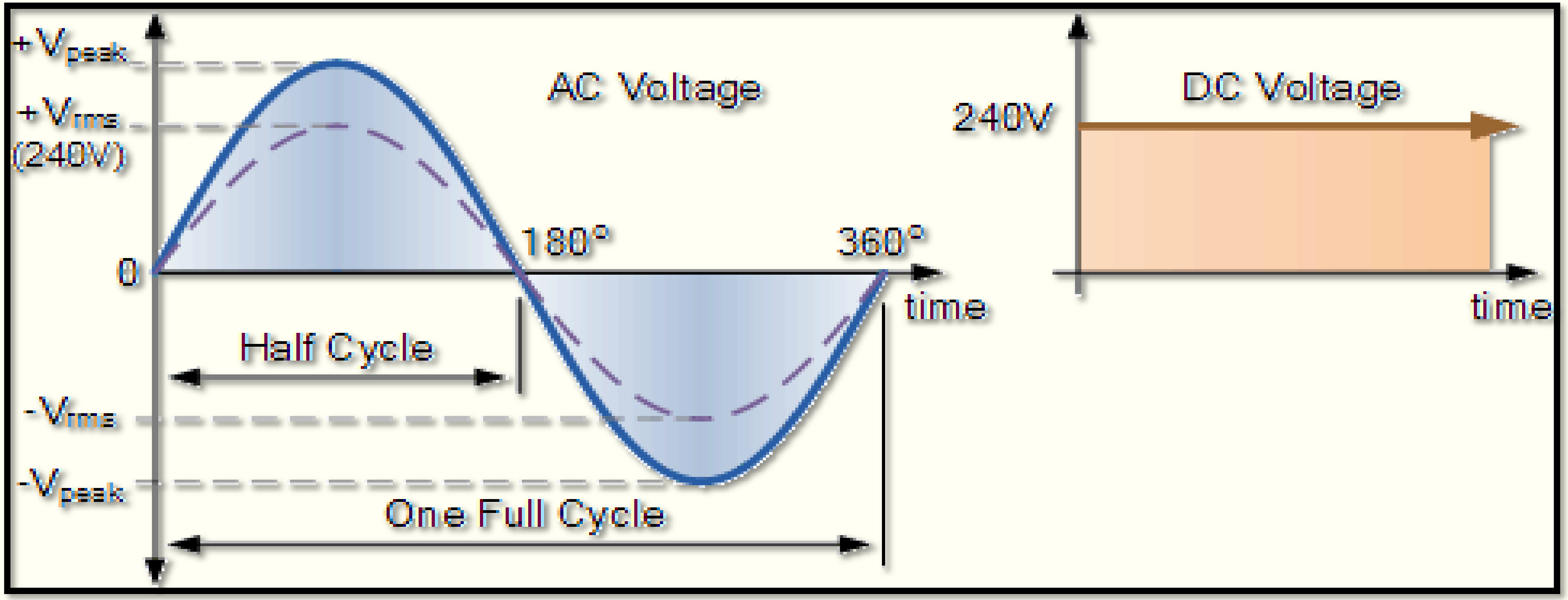
LENZ’S LAW

- **Lenz’s Law Application:** **Lenz’s law applications are plenty. Some of them are listed below:**

- Eddy current balances.
- Metal detectors.
- Eddy current dynamometers.
- Braking systems on train.
- AC generators.
- Card readers.
- Microphones.

TERMS RELATED TO A.C CIRCUIT

- **<u>Cycle:</u>** The emf induced increases from zero in one direction, becomes maximum and then reduce to zero. Afterwards, it increases in opposite direction, becomes maximum and then becomes zero. Afterwards it is repeated. This one complete alternation is called the cycle.



TERMS RELATED TO A.C CIRCUIT

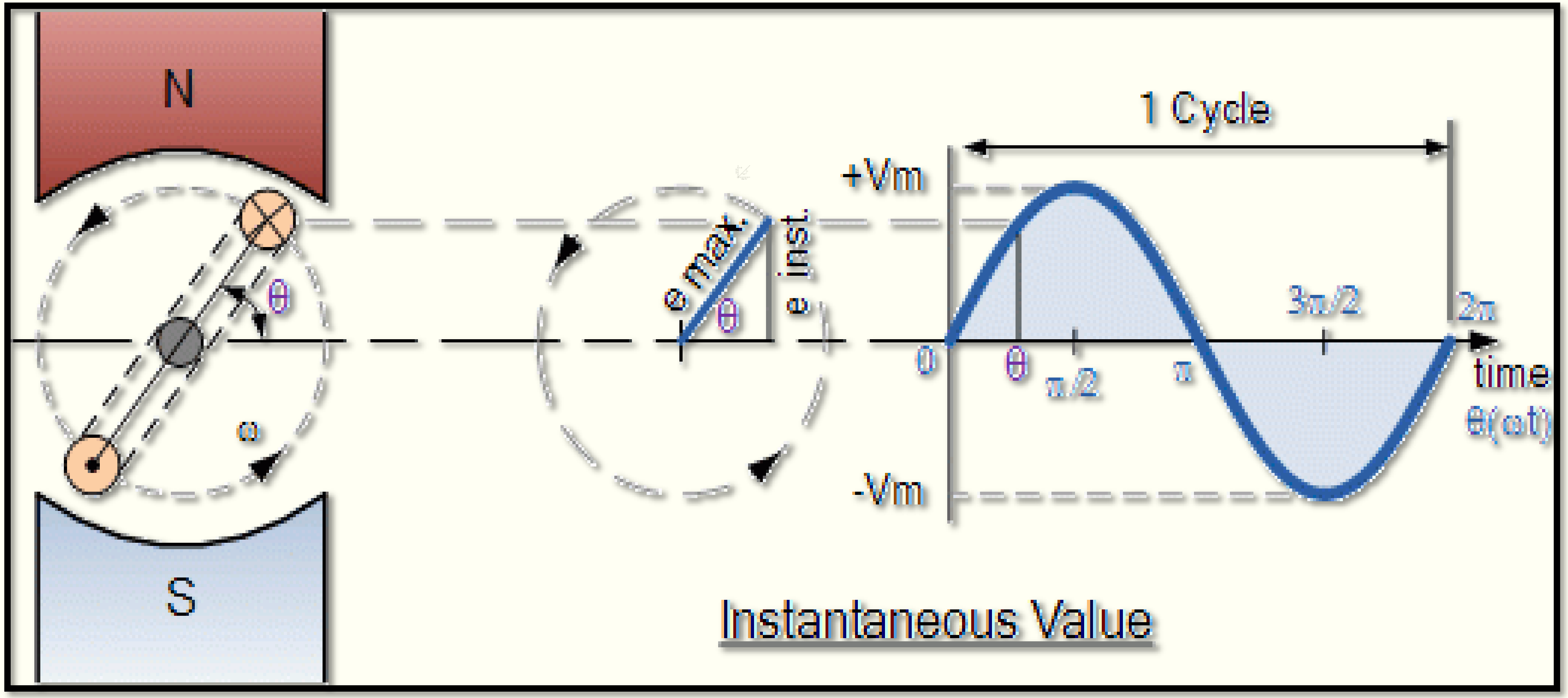
- **Time Period:** It is the time taken to complete one cycle. It is **represented by T and its unit is second.**

- **Frequency:** it is the number of cycles completed in one second. It is represented by **symbol f and its unit is Hertz.** in **our country frequency used is 50Hz, while in USA it is 60Hz.** In electronic oscillators very high frequency is used. it is in the **range of KHz and MHz.**

$$\boxed{f = \frac{1}{T}}$$

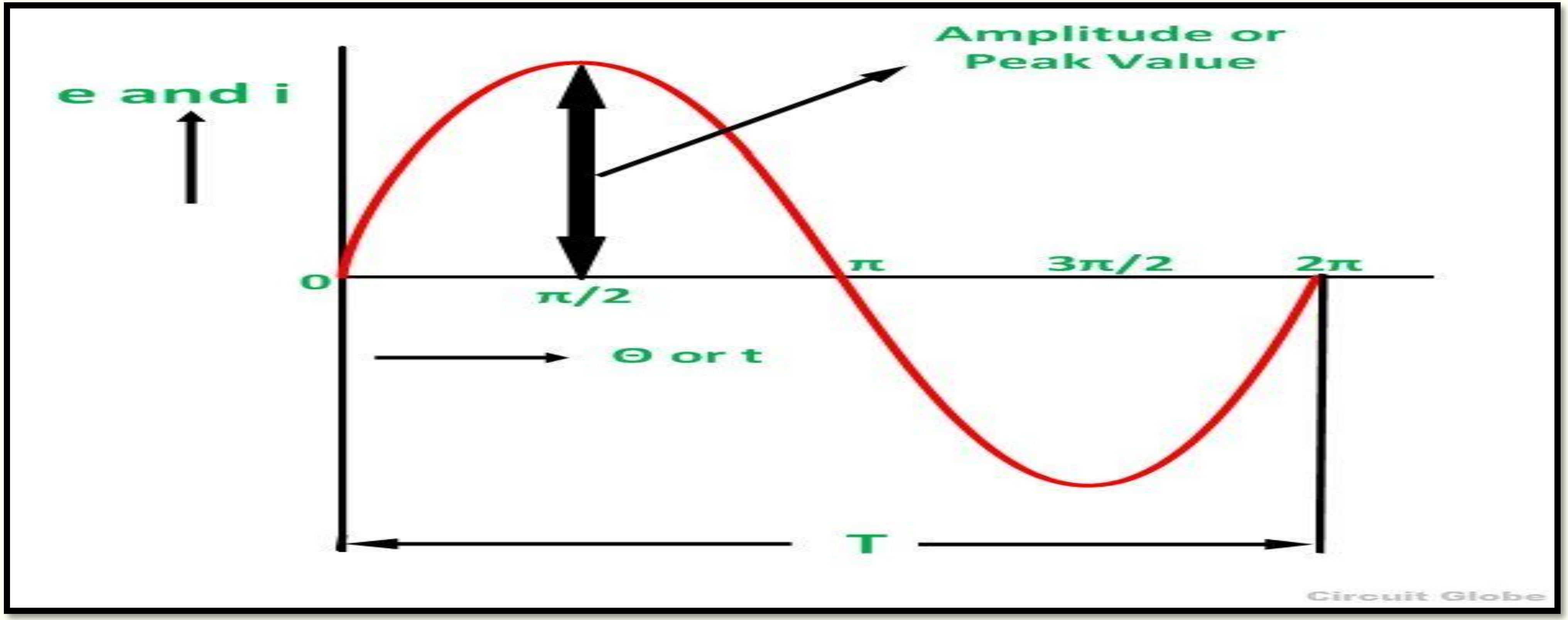
TERMS RELATED TO A.C CIRCUIT

- **Instantaneous Value:** It is the value of the quantity at **any time t.** it is indicated by the **lower case letter (e for emf, i for current etc.)**



TERMS RELATED TO A.C CIRCUIT

- **<u>Maximum Value or Amplitude:</u>** Maximum value of alternating quantity (emf, current or flux) is called maximum value or peak value or amplitude. In a cycle it occurs twice. One is positive maximum and the other is negative maximum. These two values are equal in magnitude.



ROOT MEAN SQURE (R.M.S VALUE OF A.C QUANTITY)

- **RMS VALUE OF A.C :** We have seen that the value of the alternating quantity changes instantaneously. Its effective value is represented by RMS value. For this heating effect of electric current is taken in to account.

- Let us assume that certain value of alternating current flows through a resistor for some period and as a result certain amount of heat is generated. Now we pass direct current through the same value of the resistor for the same time period to produce the same amount of heat. Then this value of direct current is known as effective value or RMS value of the alternating current.

- **Thus RMS value of the alternating current is defined as that value of the direct current which is required to be passed through a resistor to produce the same amount of heat produced by the alternating current when passed for the same period through the same value of resistor.**

- **I RMS = 0.707 Im**

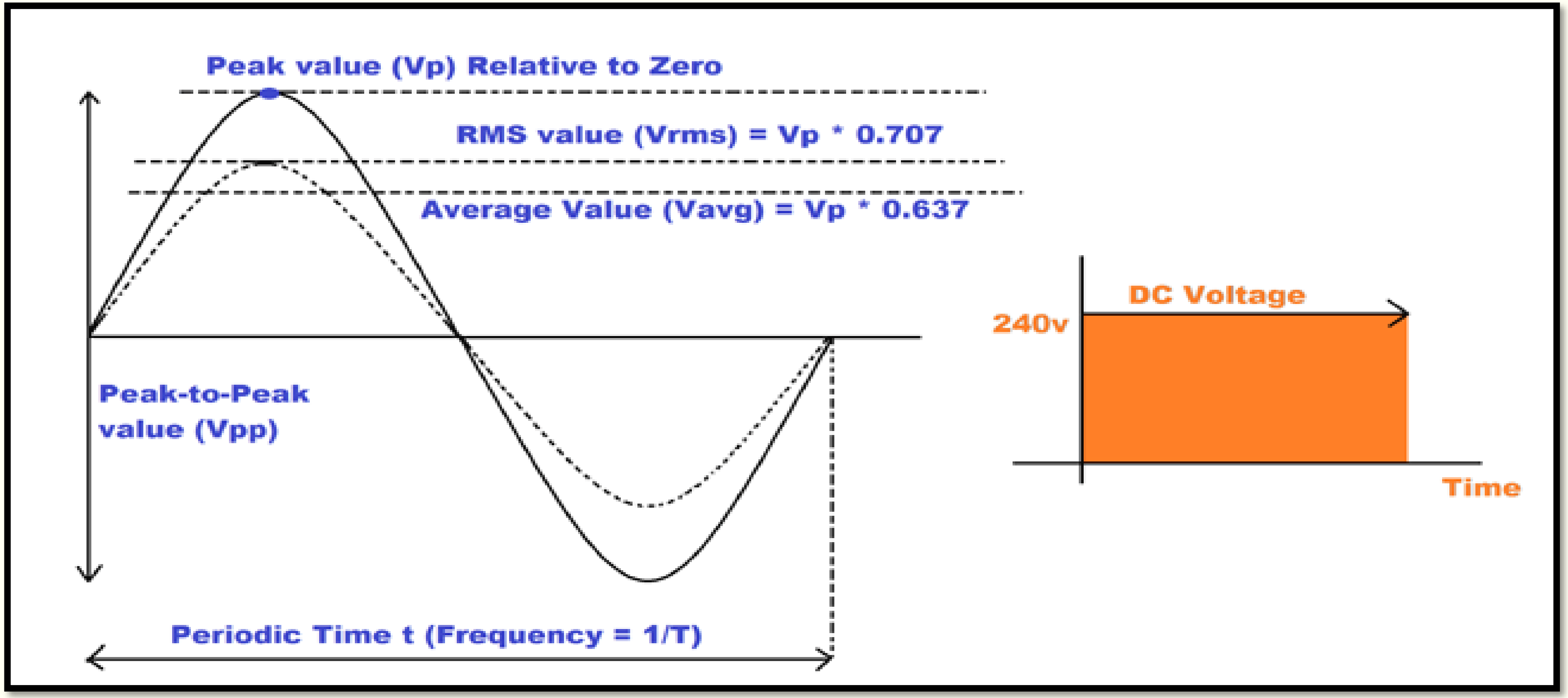
AVERAGE VALUE OF A.C QUANTITY

- **AVERAGE VALUE OF A.C:** Average value is found by considering the charge transfer. **Average value of electric current is defined as that value of direct current which transfer the same amount of charge in a circuit which is transmitted by an alternating current flowing through the same circuit for the same period.**

- The average value is fund by taking the area under the curve and dividing it by the base. Now for alternating waveform the sum of areas becomes zero, as there are two loops of equal area in positive and negative direction. So the average value is found by taking the area of one loop and dividing it by the corresponding base.

- **I avg = 0.637 Im**

R.M.S AND AVERAGE VALUE OF A.C QUANTITY



R.M.S and Average Value of A.C

TERMS RELATED TO A.C CIRCUIT

- **Peak Factor:** Peak Factor is **also known as Crest Factor or Amplitude Factor.** It is the **ratio between maximum value and RMS value of an alternating wave.**

$$\textbf{Peak Factor} = \frac{\text{Maximum Value}}{\text{R.M.S Value}}$$

- **For a sinusoidal alternating voltage:**

$$\frac{E_M}{0.707\,E_M} = \mathbf{1.414}$$

- **For a sinusoidal alternating current:**

$$\frac{I_M}{0.707\,I_M} = \mathbf{1.414}$$

TERMS RELATED TO A.C CIRCUIT

- **Form Factor:** The ratio between RMS value and Average value of an alternating quantity (Current or Voltage) is known as Form Factor.

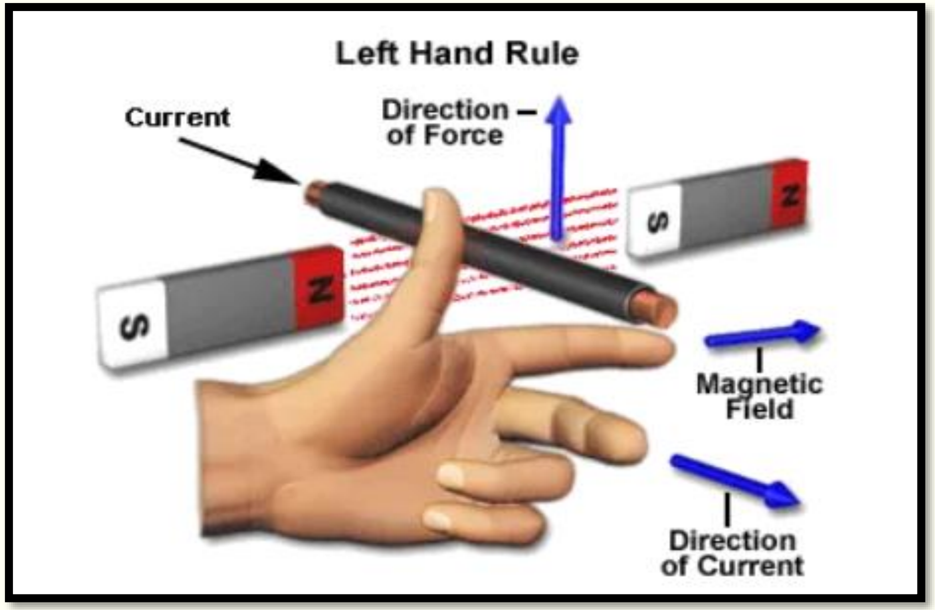
$$\text{Form Factor} = \frac{\text{RMS Value}}{\text{Average Value}}$$

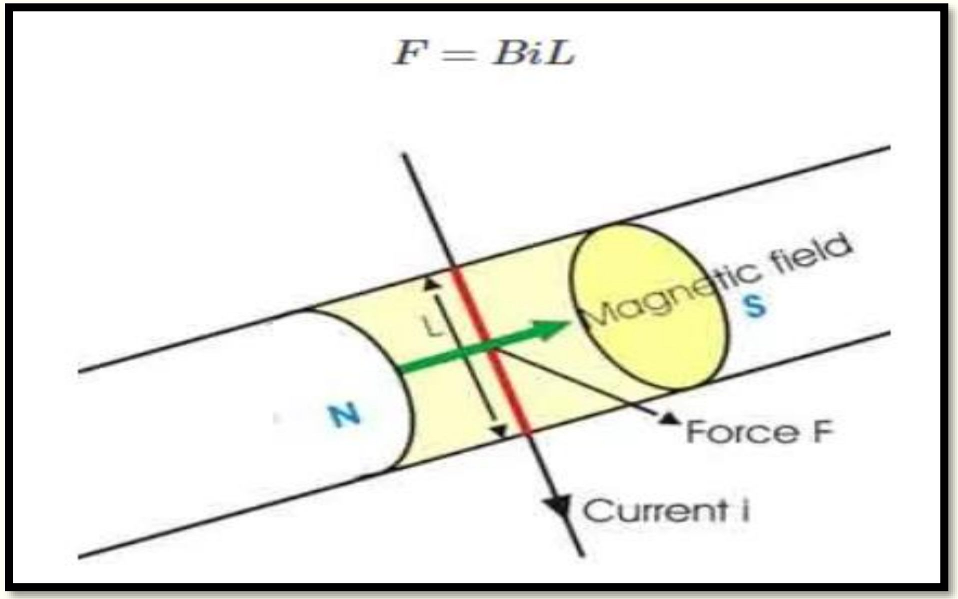
$$= \frac{0.707\ E_M}{0.637\ E_M} \text{ Or } \frac{0.707\ I_M}{0.637\ I_M} = 1.11$$

FLEMING’S LAW

- **<u>Fleming’s Left Hand Rule:</u>** It is found that whenever a current carrying conductor is placed inside a magnetic field, a force acts on the conductor, in a direction perpendicular to both the directions of the current and the magnetic field.

- In the figure below, a portion of a conductor of length ‘L’ is placed vertically in a uniform horizontal magnetic field of strength ‘H’, produced by two magnetic poles N and S. If the current ‘I’ is flowing through this conductor, the magnitude of the force acting on the conductor is:

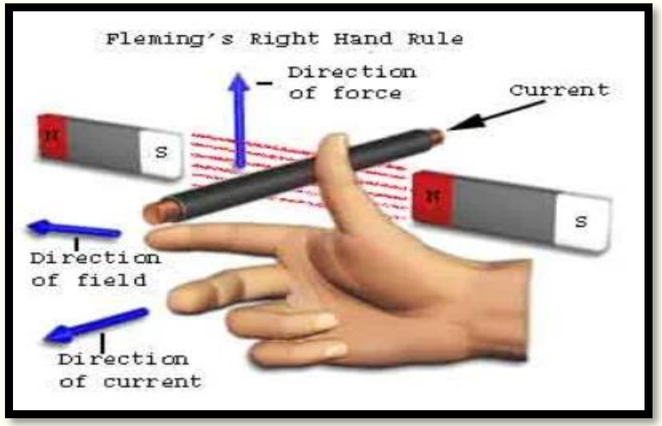




FLEMING’S LAW

- **<u>Fleming’s Right Hand Rule:</u>** As per Faraday’s law of electromagnetic induction, whenever a conductor moves inside a magnetic field, there will be an induced current in it. If this conductor gets forcefully moved inside the magnetic field, there will be a relation between the direction of applied force, magnetic field and the current.

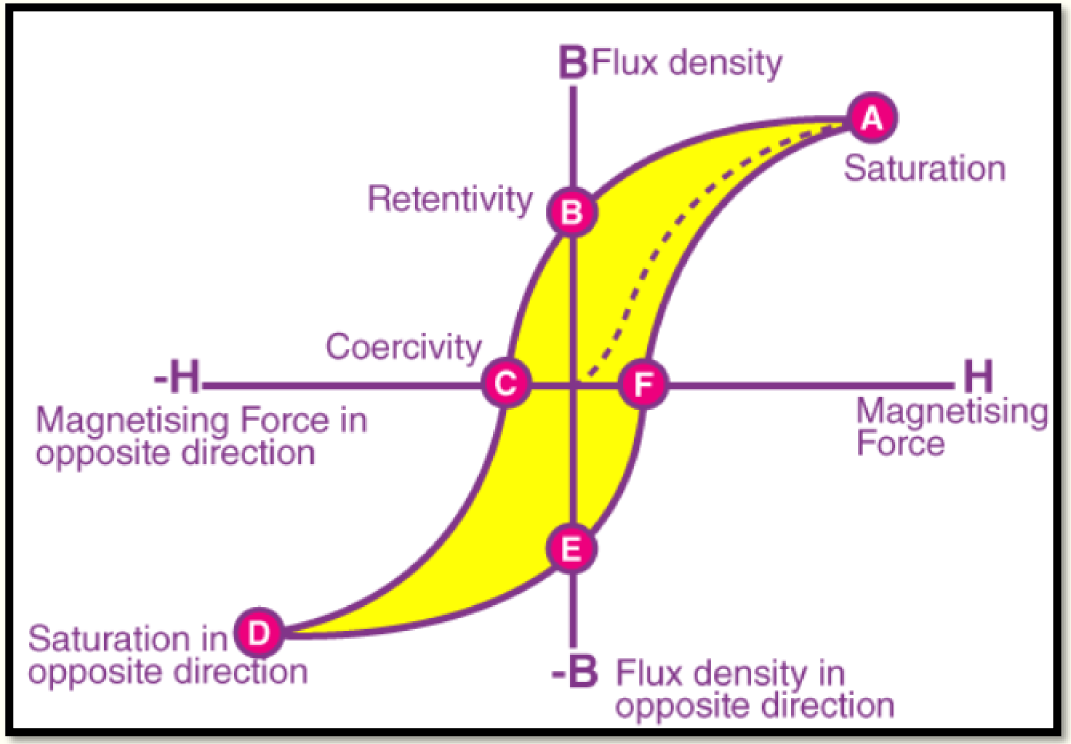
- This relation among these three directions is determined by Fleming’s right-hand Rule.



- This rule states “Hold out the right hand with the first finger, second finger and thumb at the right angle to each other. If forefinger represents the direction of the line of force, the thumb points in the direction of motion or applied force, then second finger points in the direction of the induced current”.

HYSTERISIS LOOP (B-H CURVE)

- **Hysterisis Loop:** The hysteresis loop shows the relationship between the magnetic flux density and the magnetizing field strength. The loop is generated by measuring the magnetic flux coming out from the ferromagnetic substance while changing the external magnetizing field.



HYSTERISIS LOOP (B-H CURVE)

- **Looking at the graph, if B is measured for various values of H and if the results are plotted in graphic forms then the graph will show a hysteresis loop.**
- The magnetic flux density (B) is increased when the magnetic field strength(H) is increased from 0 (zero).
- With increasing the magnetic field there is an increase in the value of magnetism and finally reaches point A which is called saturation point where B is constant.
- With a decrease in the value of the magnetic field, there is a decrease in the value of magnetism. But at B and H are equal to zero, substance or material retains some amount of magnetism is called retentivity or residual magnetism.
- When there is a decrease in the magnetic field towards the negative side, magnetism also decreases. At point C the substance is completely demagnetized.
- The force required to remove the retentivity of the material is known as Coercive force (C).
- In the opposite direction, the cycle is continued where the saturation point is D, retentivity point is E and coercive force is F.

HYSTERISIS LOOP (B-H CURVE)

- Due to the forward and opposite direction process, the cycle is complete and this cycle is called the hysteresis loop.
- **Advantages of Hysteresis Loop:**
- A smaller region of the hysteresis loop is indicative of less loss of hysteresis.
- Hysteresis loop provides a substance with the importance of retentivity and coercivity. The refore the way to select the right material to make a permanent magnet is made simpler by the heart of machines.
- Residual magnetism can be calculated from the B-H graph and it is, therefore, simple to choose material for electromagnets.
- **Retentivity:** The amount of magnetization present when the external magnetizing field is removed is known as retentivity. **It is a material's ability to retain a certain amount of magnetic property while an external magnetizing field is removed. The value of B at point b in the hysteresis loop.**

HYSTERISIS LOOP (B-H CURVE)

- **Coercivity:** The amount of reverse(-ve H) external magnetizing field required to completely demagnetize the substance is known as coercivity of substance. The value of H at point c in the hysteresis loop.

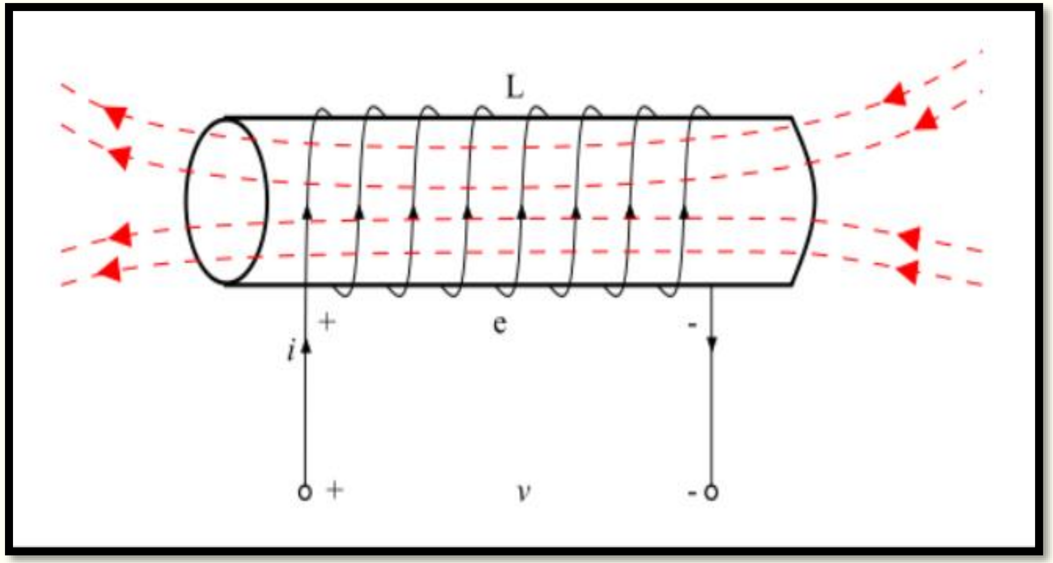
TYPES OF INDUCED E.M.F

- When a magnetic flux linking a conductor or coil changes, an electromotive force (EMF) is induced in the conductor or coil, is known as induced EMF. Depending upon the way of bringing the change in magnetic flux, the induced EMF is of two types
- **Statically Induced EMF**
- **Dynamically Induced EMF**
- **Statically Induced EMF:** When the conductor is stationary and the magnetic field is changing, the induced EMF in such a way is known as statically induced EMF (as in a transformer). It is so called because the EMF is induced in a conductor which is stationary. The statically induced EMF can also be classified into two categories.
- **Self Induced EMF**
- **Mutually induced EMF**

TYPES OF INDUCED E.M.F

- **Self induced EMF:** When an EMF is induced in the coil due to the change of its own magnetic flux linked with it is known as self-induced EMF.
- When a current flows in a coil, a magnetic field produced by this current through the coil. If the current in the coil changes, then the magnetic field linking the coil also changes. Therefore, according to Faraday's law of electromagnetic induction, an EMF being induced in the coil. The induced EMF in such a way is known as self-induced EMF.
- Mathematically, self-induced EMF is given by,

$$\boxed{e = L\frac{di}{dt}}$$



- Where, L is the self-inductance of the coil.

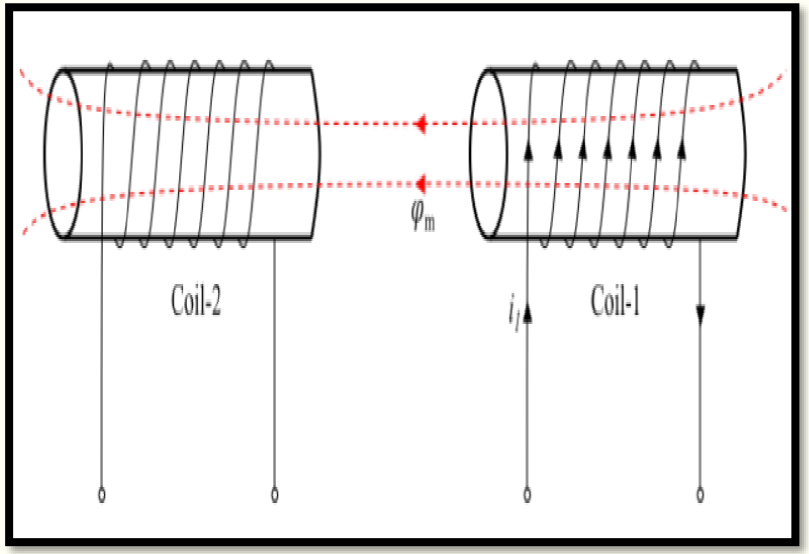
TYPES OF INDUCED E.M.F

- **Mutually Induced EMF:** When an EMF is induced in a coil due to changing magnetic flux of neighboring coil is known as mutually induced EMF.

- Consider two coils coil-1 and coil-2 placed adjacent to each other (see the figure). A fraction of the magnetic flux produced by coil-1 links with the coil-2. This magnetic flux which is common to both the coils 1 and 2 is known as mutual flux. Now, if the current in coil-1 changes, the mutual flux also changes and thus EMF being induced in both the coils. The EMF induced in coil-2 is known as mutually induced EMF, since it is induced due changing in flux which is produced by coil-1. Mathematically, the mutually induced EMF is given by,

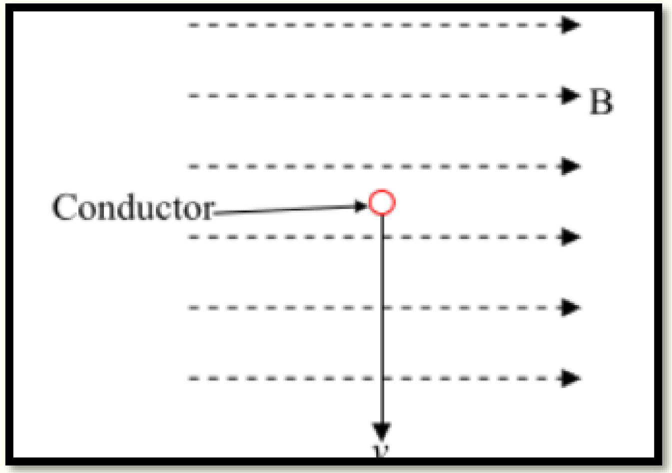
$$\boxed{e_m = M\frac{di_1}{dt}}$$

- Where, M is the mutual inductance between the coils.



TYPES OF INDUCED E.M.F

- **Dynamically Induced EMF:** When the conductor is moved in a stationary magnetic field so that the magnetic flux linking with it changes in magnitude, as the conductor is subjected to a changing magnetic, therefore an EMF will be induced in it. The EMF induced in this way is known as dynamically induced EMF (as in a DC or AC generator). It is so called because EMF is induced in a conductor which is moving (dynamic).



- Consider a conductor of length l meters moving with a velocity of v m/s at right angles to a uniform stationary magnetic field of flux density B Wb/m2.Let the conductor moves through a small distance dx in time dt seconds. Then,

TYPES OF INDUCED E.M.F

$\text{Area swept by conductor, } a = l \times dx \ \text{m}^2$

$\therefore \text{Magnetic flux cut by conductor, } d\psi = \text{Magnetic Flux Density} \ \times \ \text{Area Swept}$

$\implies d\psi = B\, l\, dx \ \text{Wb}$

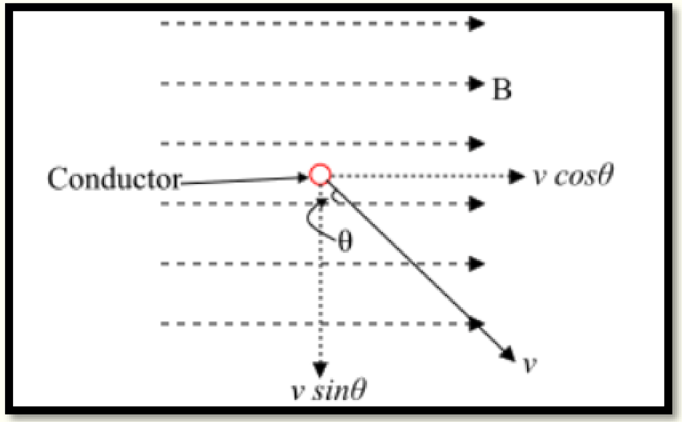
- Now, according to Faraday's law of electromagnetic induction, the induced EMF will be,

$e = N\frac{d\psi}{dt} = \frac{B\, l\, dx}{dt} \ (\because N = 1)$

$\because \frac{dx}{dt} = \text{Velocity } V$

$$\boxed{\therefore \ e = B\, l\, v \ \text{Volts}}$$

- Equation gives the dynamically induced EMF when the conductor moves at right angle to the magnetic field.



TYPES OF INDUCED E.M.F

- If the conductor moves at an angle &theta to the magnetic field, then the EMF induced due to only the perpendicular component of the velocity to the magnetic field.

$$\boxed{e = B\,l\,v\sin\theta}$$

COMPARISION BETWEEN ELECTRIC AND MAGNETIC CIRCUIT

Electric Circuit	Magnetic Circuit
The closed path foe electric current is called electric circuit.	The closed path for magnetic flux is called a magnetic circuit.
Current flows through the conductor. Unit of current is ampere.	Flux is produced in the material. Unit of flux is Weber.
Electromotive force (emf) is necessary to force current to flow in electric circuit. Its unit is volt.	Magneto motive force (mmf) is necessary to produce flux in the material. Its unit is ampere turn.
Property of material to oppose the flow of electric current is called resistance. Its unit is ohm.	Property of material to oppose the establishment of magnetic flux is called reluctance. Its unit is AT/Wb.
Conductance = 1/ resistance	Permeance = 1/ reluctance.
There is resistivity of material.	There is reluctivity of material.
Conductivity = 1 / resistivity	Permeability = 1 / reluctivity.
Current = emf / resistance.	Flux = mmf/ reluctance.