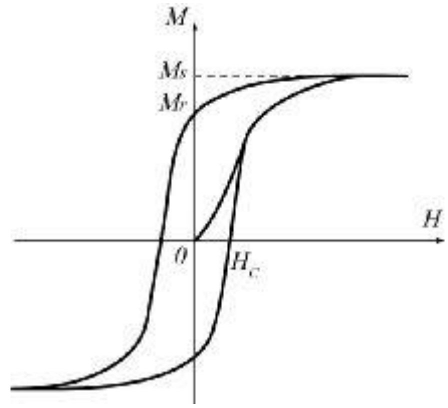
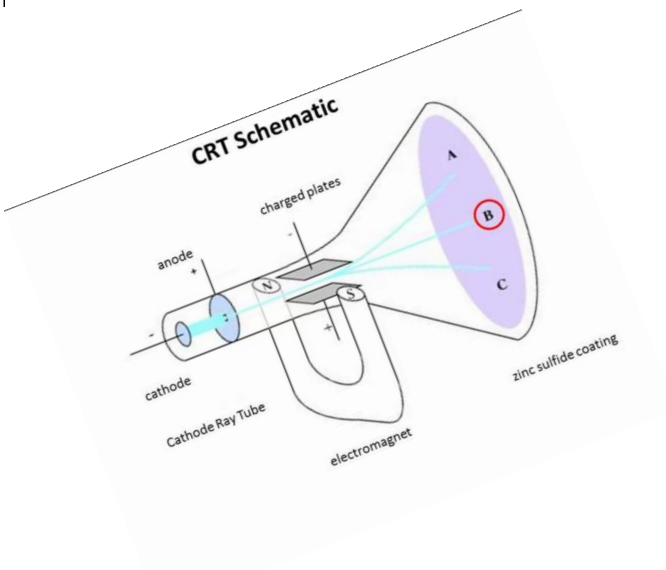
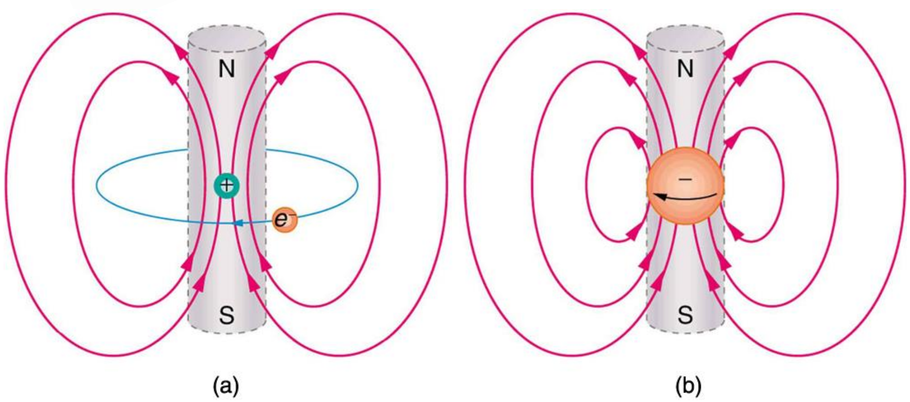
XII PHYSICS

LECTURER – PHYSICS, AKHSS, K

affan_414@live.com
https://promotephysics.wordpress.com





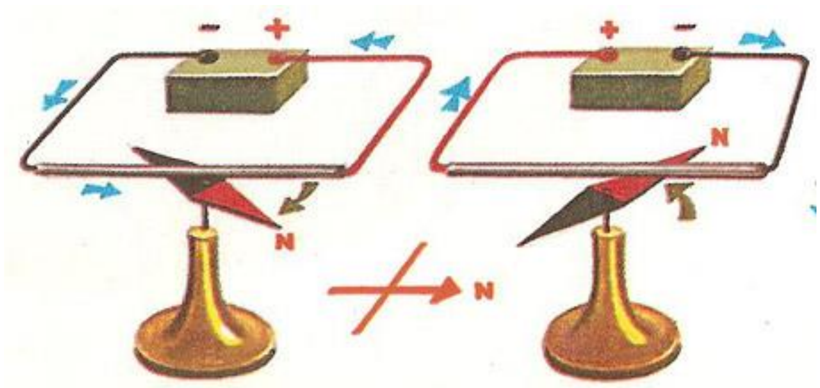


[MAGNETISM AND ELECTROMAGNETISM] CHAPTER NO. 14

OERSTED's EXPERIMENT

During a lecture demonstration, on April 21, 1820, while setting up his apparatus, Hans Christian Ørsted (often rendered Oersted in English) noticed that when he turned on an electric current by connecting the wire to both ends of the battery, a compass needle held nearby deflected away from magnetic north, where it normally pointed. The compass needle moved only slightly, so slightly that the audience didn't even notice. But it was clear to Oersted that something significant was happening.

Oersted was intrigued by his observation. He didn't immediately find a mathematical explanation, but he thought it over for the next three months, and then continued to experiment, until he was quite certain that an electric current could produce a magnetic field

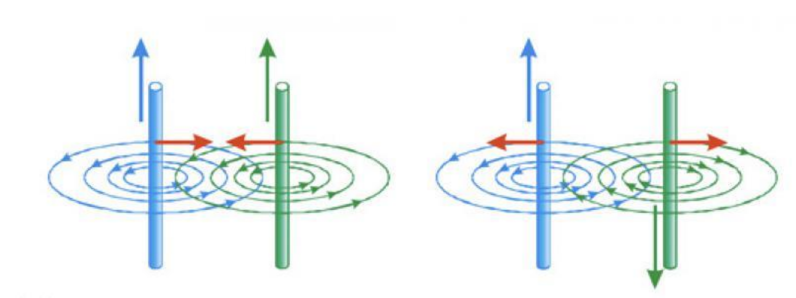


On July 21, 1820, Oersted published his results in a pamphlet, which was circulated privately to physicists and scientific societies. His results were mainly qualitative, but the effect was clear–an electric current generates a magnetic force.

(Reference: APS NEWS, July 2008 (Vol. 17, No. 7) This Month is Physics History July 1820: Oersted and electromagnetism)

AMPÈRE's EXPERIMENT

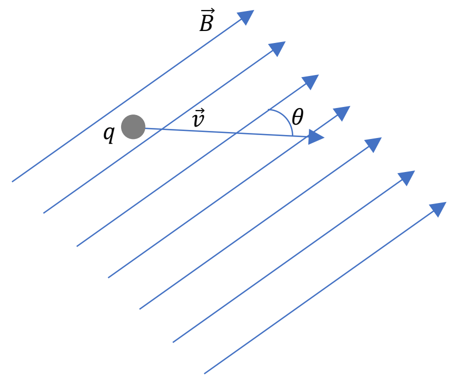
Influenced by Ørsted serendipity discovery, Ampere deduced that if a wire with a current exerted a magnetic force on a compass needle, two such wires also should interact magnetically. He found that parallel currents flowing, in wires, in the same direction attract each other, while currents flowing in opposite directions repel.



(Reference: http://www.juliantrubin.com/bigten/ampereexperiments.html)

FORCE ON A CHARGE MOVING IN A UNIFORM MAGNETIC FIELD

Consider a particle having a charge of magnitude 'q' moving with velocity 'v' is about to enter in a uniform magnetic field, the magnetic field of induction is 'B'. As it enters the magnetic field, it will experience a force of deflection perpendicular to the plane formed by velocity and magnetic field vectors. The force can be given as,



$$\vec{F}_B = q(\vec{v} \times \vec{B})$$

In magnitude form,

$$|\vec{F}_B| = qvB\sin\theta$$

This force depends directly upon the charge, velocity, magnetic field of induction and sine of angle between velocity and magnetic field vector.

We may also define "Magnetic field of induction" here,

$$B = \frac{F}{qv\sin\theta}$$

Its unit is,

$$B = \frac{N}{C(m/s)}$$

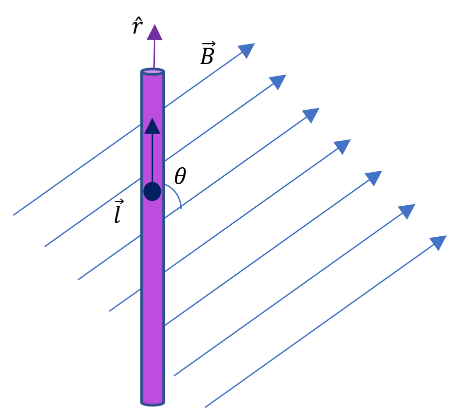
Or,

$$B = N/Am \ = Tesla(T)$$

Force on a Current Carrying Conductor

Consider a conductor of length 'l' carrying current 'I' is placed in a uniform magnetic field, the magnetic field of induction is 'B'. Since current carrying conductor has moving charges in it, so accordingly each charge will experience a deflecting force in this field and the conductor as a whole will deflect perpendicular to the plane formed by velocity and magnetic field vectors.

To start, we may use equation for the force acting on an individual charge particle,



$$\vec{F}_B = q(\vec{v} \times \vec{B})$$

The total charge through the conductor can be written as,

$$q = N_V Ale$$

where, N_V is the total charge particles per unit volume (or Particle density)

$$\vec{F}_B = N_V Ale(\vec{v} \times \vec{B})$$

$$\vec{F}_B = N_V Ale(v\hat{r} \times \vec{B})$$

Since length and velocity have same direction, therefore we may switch their magnitudes in cross product,

$$\vec{F}_B = N_V A v e(l\hat{r} \times \vec{B})$$

$$\vec{F}_B = N_V A v e(\vec{l} \times \vec{B})$$

$$\vec{F}_B = N_V A \left(\frac{l}{t}\right) e(\vec{l} \times \vec{B})$$

$$\vec{F}_B = \frac{N_V A l e}{t}(\vec{l} \times \vec{B})$$

$$\vec{F}_B = \frac{q}{t}(\vec{l} \times \vec{B})$$

$$\vec{F}_B = I(\vec{l} \times \vec{B})$$

In magnitude form,

$$F_B = IlB\sin\theta$$

TORQUE ON A CURRENT CARRYING COIL

When a current carrying coil is placed in a magnetic field, it experiences a couple which produce torque in the coil. Due to this phenomenon we can convert electrical energy into mechanical energy.

Consider a rectangular conducting coil of length ‘l’ and breadth ‘b’ placed in a magnetic field. Let us allow current of strength ‘I’ passes through it. By using concept of force on current carrying conductor placed in a magnetic field separately on each side of coil we can find the torque acting on the coil.

For side PQ:

For this side the force experienced by the conductor would be,

$$\vec{F}_B = I(\vec{l} \times \vec{B})$$

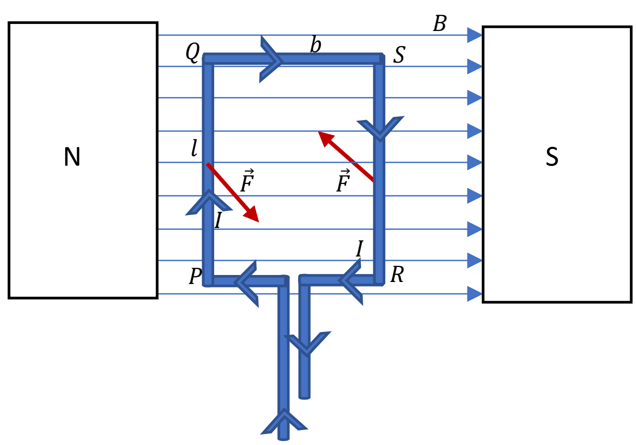
In magnitude form,

$$F_B = IlB\sin\theta$$

Since the angle between the length and magnetic field vector is 90^o, therefore,

$$F_B = IlB$$

The direction of this force would be out of the plane of the paper, as shown in figure.

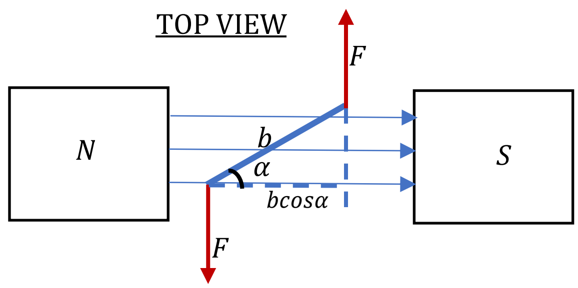


For side RS:

For this side the force experienced by the conductor would be same as it was for side PQ, since length, current and magnetic field are same. Therefore,

$$\vec{F}_B = I(\vec{l} \times \vec{B})$$
In magnitude form,
$$F_B = IlB\sin\theta$$
Since the angle between the length and magnetic field vector is 90^o, therefore,
$$F_B = IlB$$
The direction of this force would be into the plane of the paper, as shown in figure.

Torque:
Now since these two forces are equal in magnitude, opposite in direction acting along the different line of action will constitute a couple, which in result produce torque and let the coil rotate.



Since the torque is given as,
$$\tau = Fd$$
where, d is the perpendicular distance between the couple forces. Here according to diagram, the perpendicular distance between the forces is bcosα, therefore,
$$\tau = F_B(b\cos\alpha)$$
$$\tau = (IlB)(b\cos\alpha)$$
$$\tau = IB(lb)\cos\alpha$$
$$\tau = IBA\cos\alpha$$
For 'N' turns,
$$\tau = BINA\cos\alpha$$

J.J THOMSON EXPERIMENT
CALCULATION OF CHARGE – TO – MASS (e/m) RATIO

J.J Thomson determines experimentally the charge – to – mass ratio of an electron on the basis of fact that when an electron enters into the uniform magnetic field then it experiences a deflecting force and moves in a curved path.

Experimental Setup:
It consists of a discharge tube in which vacuum is created. At one end a cathode filament coil is used to emit electrons by the process of thermionic emission. At the other end a ZnS (Zinc Sulfide) as florescence screen is used to locate the position of electron. A uniform perpendicular magnetic field is also applied.

Working:
Electrons are accelerated by applying 1000 volt at a slit A and 500 volts at slit B. These accelerated electrons pass through the slits and strike the screen at point O. When magnetic field is applied on the beam then it deviates from its path and strike the screen at point O'.

Mathematical Expression:
To find the velocity of electrons we may apply the following two methods so that we can find e/m ratio easily.

i) Potential Difference Method:

$$\text{Kinetic Energy} = \text{Work done}$$
$$\frac{1}{2}mv^2 = qV$$

where, $V \equiv$ Potential Difference,

$$v^2 = \frac{2qV}{m}$$
$$v = \sqrt{\frac{2eV}{m}} ------ (1)$$

ii) Velocity Selector Method
If electric field applied perpendicular to the magnetic field in such a way that the charge particle comes back to its original position then at that point we can write,

$$F_E = F_B$$
$$qE = qvB\sin\theta$$

Since, $q = e$ and $\theta = 90^O$, therefore,

$$eE = evB$$
$$v = \frac{E}{B} ------ (2)$$

Calculation of e/m ratio
We know that if a charge 'q' is moving with velocity 'v' in a magnetic field 'B' then magnetic force experiences by the charge will be,

$$F_B = qvB\sin\theta$$

Since this force is responsible for a charge to move in a circular path of radius 'r' therefore we can write,

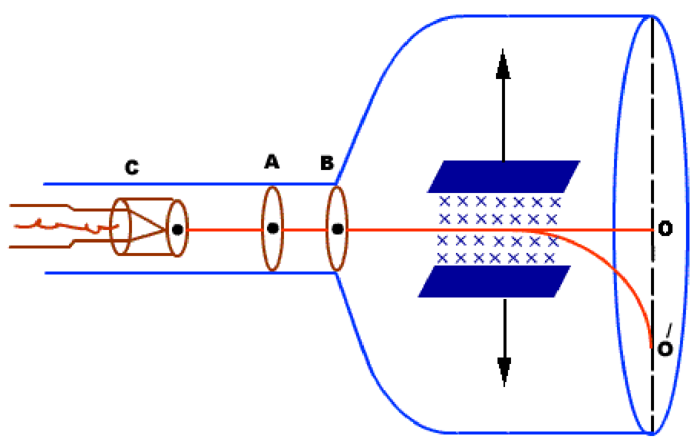
$$F_B = F_C$$
$$qvB\sin\theta = \frac{mv^2}{r}$$

Since magnetic field is applied perpendicular to the direction of motion of the charge, $(\theta = 90^o)$ therefore,

$$qvB = \frac{mv^2}{r}$$

Charge of electron is represented by 'e' hence,

$$evB = \frac{mv^2}{r}$$
$$eB = \frac{mv}{r}$$
$$\frac{e}{m} = \frac{v}{rB} ------ (3)$$



For velocity we can use both equations (1) & (2) and then find the result accordingly.
Substituting value of velocity from equation (1) to equation (3), we get

$$\frac{e}{m} = \frac{v}{rB}$$

$$\frac{e}{m} = \frac{\sqrt{\frac{2eV}{m}}}{rB}$$

$$\frac{e^2}{m^2} = \frac{2eV/m}{r^2B^2}$$

$$\frac{e^2}{m^2} = \frac{2eV}{mr^2B^2}$$

$$\frac{e}{m} = \frac{2V}{r^2B^2} ------ (4)$$

Also, substituting velocity from equation (2) to equation (3), we get,

$$\frac{e}{m} = \frac{v}{rB}$$

$$\frac{e}{m} = \frac{E/B}{rB}$$

$$\frac{e}{m} = \frac{E}{rB^2} ------ (5)$$

<u>Radius of the circular Path</u>

The radius of the circular path followed by the electron is given as,

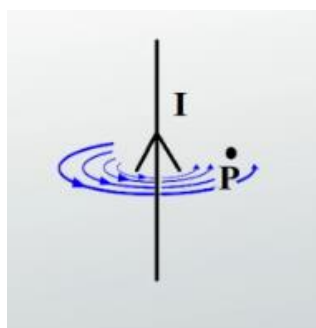
$$r = \frac{b^2}{2a}$$

BIOT-SAVART LAW

Biot and Savart experimentally found moving charge (or current in a conductor) induces a magnetic field and that the magnitude of magnetic field of induction is given as,

$$B \propto 2I$$

$$B \propto \frac{1}{r}$$



combining both (1) and (2)

$$B \propto \frac{2I}{r}$$

$$B = \left(\frac{\mu_o}{4\pi}\right)\frac{2I}{r}$$

$$B = \frac{\mu_o I}{2\pi r}$$

where μ_o = permeability of free space $= 4\pi \times 10^{-7}$web/Am.

AMPERE'S CIRCUITAL LAW

A current carrying conductor has a magnetic field around it. Ampere's law provides the relation between the magnetic flux density and the current enclosed.

Mathematically,

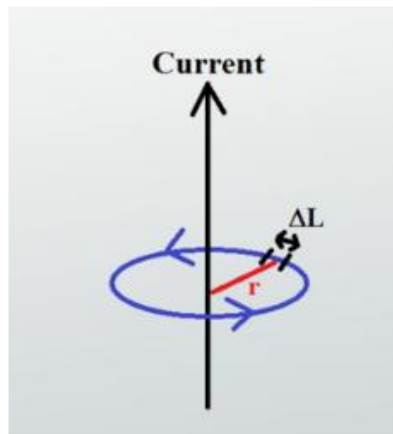
$$\sum \vec{B}.\Delta\vec{L} = \mu_o \times I$$

Ampere's law is somewhat analogous to Gauss' law of electrostatics and it helps to determine the magnetic field of induction.

Mathematical Treatment:

Consider a straight conductor of length L let a current I is flowing through it than magnetic field produce around it in the form of concentric rings. To prove Ampere's law we divide this ring into small length elements 'ΔL', such that it becomes $\Delta L_1, \Delta L_2, \Delta L_3, \dots, \Delta L_N$.

Now taking dot products of magnetic field of induction with these length elements, so we get



$$\vec{B}.\Delta\vec{L_1} = B\Delta L_1 \cos\theta$$
$$\vec{B}.\Delta\vec{L_1} = B\Delta L_1 \cos 0^o$$
$$\vec{B}.\Delta\vec{L_1} = B\Delta L_1$$

Similarly,

$$\vec{B}.\Delta\vec{L_2} = B\Delta L_2$$
$$\vec{B}.\Delta\vec{L_3} = B\Delta L_3$$

.

.

.

$$\vec{B}.\Delta\vec{L_N} = B\Delta L_N$$

Now taking sum of both sides, we get,

$$\sum \vec{B}.\Delta\vec{L} = B\Delta L_1 + B\Delta L_2 + B\Delta L_3 + \cdots + B\Delta L_N$$
$$\sum \vec{B}.\Delta\vec{L} = B(\Delta L_1 + \Delta L_2 + \Delta L_3 + \cdots + \Delta L_N)$$
$$\sum \vec{B}.\Delta\vec{L} = B(\sum \Delta L)$$
$$\sum \vec{B}.\Delta\vec{L} = B(2\pi r)$$
$$\sum \vec{B}.\Delta\vec{L} = \left(\frac{\mu_o I}{2\pi r}\right)(2\pi r)$$
$$\sum \vec{B}.\Delta\vec{L} = \mu_o \times I$$

Hence, "The sum of the dot products of the tangential component of magnetic field of induction and length of an element of a closed curve taken in the magnetic field is μ_o times the current which passes through the area bounded by this curve."

APPLICATIONS OF AMPERE'S LAW

FIELD DUE TO A SOLENOID

A solenoid is a long hollow cylinder on which wire is wounded. the turns of the winding are closely spaced. The magnetic field produced by the solenoid in the middle of the solenoid is stronger and uniform, but it is weaker and negligible outside the solenoid because magnetic lines are crowded and runs parallel with the axis of solenoid inside, but they diverge outside the solenoid.

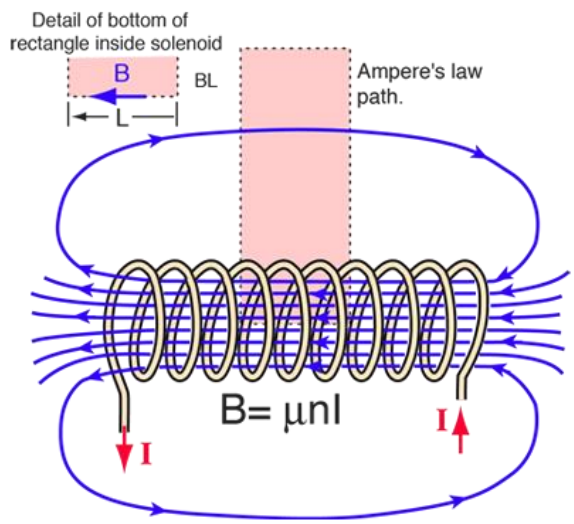
In order, to determine the magnetic field B, consider a rectangular path pqrsp as shown in figure. This loop is called Amperian Loop, let this path be divided into four elements of lengths $\Delta L_1, \Delta L_2, \Delta L_3$ and ΔL_4 as shown in figure.

By using Ampere's law,

$$\sum \vec{B}.\Delta\vec{L} = \mu_o \times I \text{ --------------- } (1)$$

L.H.S of Ampere's law can be written as,

$$\sum \vec{B}.\Delta\vec{L} = \vec{B}.\Delta\vec{L_1} + \vec{B}.\Delta\vec{L_2} + \vec{B}.\Delta\vec{L_3} + \vec{B}.\Delta\vec{L_4}$$



For PQ:

$$\vec{B}.\Delta\vec{L_1} = B\Delta L_1 \cos\theta$$
$$\vec{B}.\Delta\vec{L_1} = B\Delta L_1 \cos 0^o$$
$$\vec{B}.\Delta\vec{L_1} = B\Delta L_1$$

For QR:

$$\vec{B}.\Delta\vec{L_2} = B\Delta L_2 \cos 90^o$$
$$\vec{B}.\Delta\vec{L_2} = 0$$

For RS:

$$\vec{B}.\Delta\vec{L_3} = 0$$
$$\because B = 0$$

For SP:

$$\vec{B}.\Delta\vec{L_4} = B\Delta L_2 \cos 90^o$$
$$\vec{B}.\Delta\vec{L_4} = 0$$

Now equation (1) can be written as,

$$\sum \vec{B}.\Delta\vec{L} = B\Delta L_1 + 0 + 0 + 0$$
$$\sum \vec{B}.\Delta\vec{L} = BL_1$$

∵ The number of turns are N,

∴ Current would be 'NI'

Now Ampere's law can be written as,

$$BL_1 = \mu_o NI$$
$$B = \frac{\mu_o NI}{L_1}$$
$$B = \mu_o nI$$

where, $n = \frac{N}{L}$ is no. of turns per unit length (turn density)

FIELD DUE TO TOROID:

A toroid or a toroidal coil is circular solenoid. When a current pass from a toroid circular magnetic lines of induction form inside the toroid.

For determining the field B outer side, inner side and within toroid, let us consider Amperian loops in the form of circle as shown in figure.

1) Field at the Outer side of Toroid:

As we can see there is no net current that passes through this loop,

$$I = 0$$

Hence,

$$B = 0$$

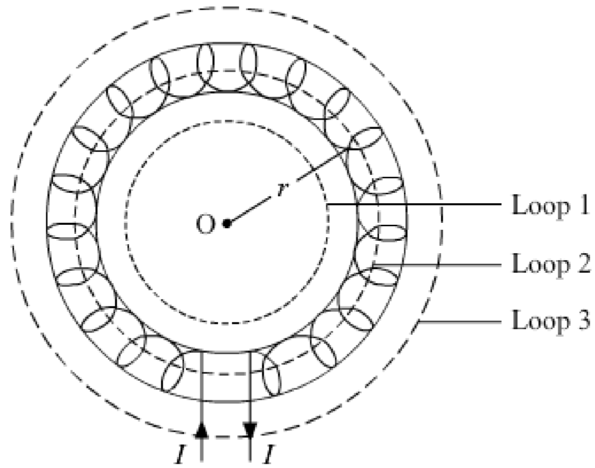
2) **Field at the inner side of Toroid:**
As we can also see there is no net current that passes through this loop,

$$I = 0$$

Hence,

$$B = 0$$

3) **Field within Toroid:**
The magnetic field within toroid is uniform and strong. To find magnetic field within toroid let the whole Amperian loop divided into number of small elements of length ΔL such that the magnetic field B which is tangent to this curve becomes parallel to ΔL. The radius 'R' of Amperian loop would be the average distance of inner and outer radius of toroid.



By using Ampere's law,

$$\sum \vec{B}.\Delta\vec{L} = \mu_o \times I \text{--------------- (1)}$$

L.H.S of Ampere's law can be solved as,

$$\vec{B}.\overrightarrow{\Delta L_1} = B\Delta L_1 \cos\theta$$
$$\vec{B}.\overrightarrow{\Delta L_1} = B\Delta L_1 \cos 0^o$$
$$\vec{B}.\overrightarrow{\Delta L_1} = B\Delta L_1$$

Similarly,

$$\vec{B}.\overrightarrow{\Delta L_2} = B\Delta L_2$$
$$\vec{B}.\overrightarrow{\Delta L_3} = B\Delta L_3$$
.
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.
$$\vec{B}.\overrightarrow{\Delta L_N} = B\Delta L_N$$

Hence, we may take sum for both sides, which will be,

$$\sum \vec{B}.\Delta\vec{L} = B\Delta L_1 + B\Delta L_2 + B\Delta L_3 + \cdots + B\Delta L_N$$
$$\sum \vec{B}.\Delta\vec{L} = B(\Delta L_1 + \Delta L_2 + \Delta L_3 + \cdots + \Delta L_N)$$
$$\sum \vec{B}.\Delta\vec{L} = B(\sum \Delta L)$$
$$\sum \vec{B}.\Delta\vec{L} = B(2\pi R)$$

Since, the toroid has 'N' no. of turns,
hence, the total current would be 'NI'
Now, equation (1) can be written as,

$$B(2\pi R) = \mu_o NI$$
$$B = \frac{\mu_o NI}{2\pi R}$$

ELECTROMAGNETIC INDUCTION

When magnetic flux changes through the coil then it induces emf and induced current in the coil. This process is called electromagnetic induction.
Faraday's Law of Electromagnetic Induction

1. *Whenever flux changes through the coil then it produces emf in the coil which remain if the flux changes through the coil and becomes zero when flux becomes constant.*
2. *The magnitude of this induced emf is directly proportional to the rate of change of magnetic flux through the coil and the number of turn of the coil.*

Mathematically,

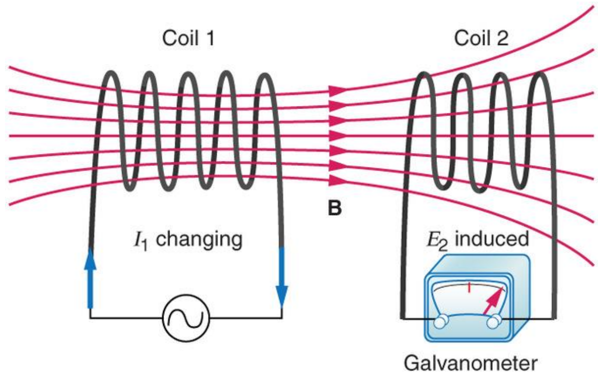
$$\xi = -N\frac{\Delta\phi}{\Delta t}$$

where minus sign is due to Lenz's law.

MUTUAL INDUCTION

"The effect in which a changing current in the primary coil induces an emf in the secondary coil is called mutual induction."

The coil which has changing cufrrent, is called primary coil and the coil in which emf is induced is called secondary coil. The induced emf produced in the secondary coil is directly proportional to the rate of change of current in the primary coil.



Mathematically,

$$\xi_s \propto -\frac{\Delta I_p}{\Delta t}$$

$$\xi_s = -M\frac{\Delta I_p}{\Delta t}$$

where 'M' is called mutual inductance.

Mutual Inductance (Mutual Induction Co-efficient):

"Mutual inductance is the measure of induced emf in the secondary coil due to change in the magnitude of current in the primary coil."

Mutual inductance depends on the number of turns of the two coils, area of the coil distance between the coils and the material of the core.

Mathematical Form:

Let the rate of change of the current in the primary coil is ΔI_p then the induced emf in the secondary coil will be,

$$\xi_s = -M\frac{\Delta I_p}{\Delta t} \text{---------------} (1)$$

if N_s is the number of turns of the secondary coil then according to the

$$\xi_s = -N_s\frac{\Delta \phi_s}{\Delta t} \text{---------------} (2)$$

Equating (1) and (2)

$$-N_s\frac{\Delta \phi}{\Delta t} = -M\frac{\Delta I_p}{\Delta t}$$

$$N_s \Delta \phi = M \Delta I_p$$

$$M = \frac{N_s \Delta \phi_s}{\Delta I_p}$$

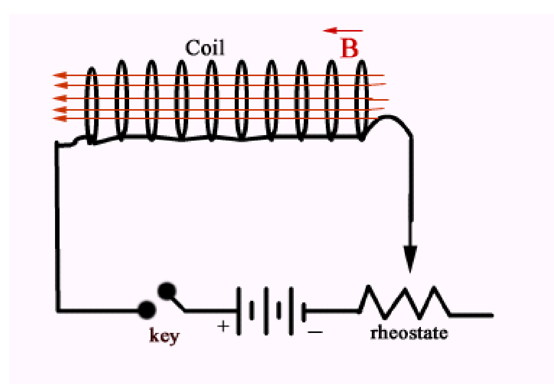
Unit of Mutual Inductance,

$$M = \frac{\text{weber}}{\text{ampere}} = \text{Henry(H)}$$

SELF-INDUCTION

"When the change in magnetic flux induces emf in the same coil due to change in current for any reason then this effect is called self-induction."

According to the Lenz's law the emf opposes the change that cause it and therefore known as back emf.



Mathematically,

$$\xi \propto -\frac{\Delta I}{\Delta t}$$

$$\xi = -L\frac{\Delta I}{\Delta t}$$

The constant 'L' is the self-inductance or inductance of the coil.

Self-Inductance (Or Self-Induction Co-efficient):

The measure of the ability of a coil to induce back emf per rate of change of current is known self-inductance.

The self-inductance depends upon the number of turns of the coil, dimension of the coil and permeability of the core material.

Mathematical Form:

$$\xi = -L\frac{\Delta I}{\Delta t}$$

According to Faraday's law,

$$\xi = -N\frac{\Delta \phi}{\Delta t}$$

Equating (1) and (2),

$$-N\frac{\Delta \phi}{\Delta t} = -L\frac{\Delta I}{\Delta t}$$

$$N\Delta\phi = L\Delta I$$

$$L = N\frac{\Delta \phi}{\Delta t}$$

Unit of Self-Inductance,

$$L = \frac{\text{weber}}{\text{ampere}} = \text{Henry(H)}$$

<u>TRANSFORMER</u>

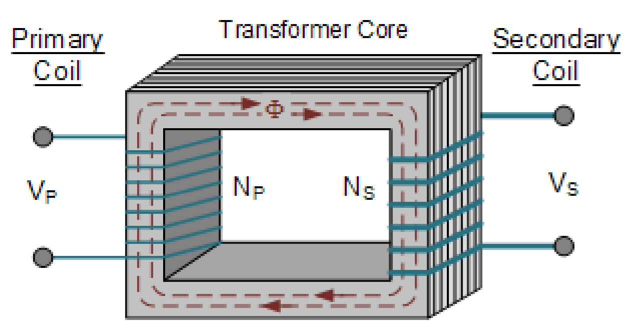
"A transformer is a device that steps up (increases) or steps down (decreases) alternating input voltage."

Principle:

Transformer works on the principle of mutual induction.

Construction:

1) Soft Iron Core: It is a laminated frame (thin staples) of soft iron in the form of rectangular or circular core.
2) Primary Coil: These are pure copper (insulated) wires wound on any one arm of the core. The input is supplied at primary coil and it has 'N_p' no. of turns.
3) Secondary Coil: These are also pure copper (insulated) wires wound on any one arm of the core. The output voltage is taken from secondary coil. It has 'N_s' no. of turns.



Transformer Construction

Operation:
The changing input current changes the magnetic field in the iron frame. As iron is easily magnetized therefore it guides the change in magnetic field and the magnetic flux to the secondary coil and thus induces emf in the secondary coil.

According to Faraday's law if the number of turns of primary coil is 'N_p' and no. of turns of secondary coil is 'N_s' then the induced emf in the primary and the secondary coil can be written as,

$$\xi_s = -N_s \frac{\Delta\phi}{\Delta t} \text{ --------------- } (1)$$

also,

$$\xi_p = -N_p \frac{\Delta\phi}{\Delta t} \text{ --------------- } (2)$$

Equation (1) ÷ (2)

$$\frac{\xi_s}{\xi_p} = \frac{N_s}{N_p}$$

For step-up transformer; $(\mathbf{N_s > N_p})$
For step-down transformer; $(\mathbf{N_s < N_p})$

Efficiency of Transformer:
If the emf of primary coil is ξ_p and emf of secondary coil is ξ_s while current I_p and I_s are flowing through them respectively, then the efficiency of transformer can be written as,

$$\text{Efficiency} = \frac{\text{Output power}}{\text{Input power}} \times 100$$

$$\eta = \frac{\xi_s I_s}{\xi_p I_p} \times 100$$

Types of Transformer:
There are two types of transformer,

1) **Step-up Transformer**
   If the number of turns of the secondary coil is greater as compared to the number of turns of primary coil, then output voltage increases. This type of transformer is called step up transformer. $(\mathbf{N_s > N_p})$
2) **Step-down Transformer**
   If the number of turns of the secondary coil is less as compared to the number of turns of secondary coil, then output voltage decreases. This type of transformer is called step up transformer. $(\mathbf{N_s < N_p})$

*Another type of transformer is usually discussed as Center Tapped Transformed which is used to get different values of output voltage.

Sources of Power Loss in Transformer:
Practically transformers always have energy losses, therefore efficiency of transformer is less than 100%. Following are the sources of power loss in transformer,

1. **Eddy Current:**
Eddy current induced on the surface of iron core due to the variation of magnetic flux, this produces heating and reduces the amount of power.
This loss can be minimized using laminated core, which is made by thin sheets sperated by a layer of insulating varnish.

2. **Hysteresis Loss:**
Each time the direction of magnetization of the core is reserved, some energy is wasted in overcoming internal friction this is called Hysteresis loss.
By using special alloy (permalloy) for the core material this loss can be minimized.
3. **Heat Loss (i^2R)**
Using thick wires can minimize this loss.
4. **Flux Loss:**
Some flux of primary coil loss in the surrounding and the flux transfer to the secondary coil is less.

MOTIONAL EMF

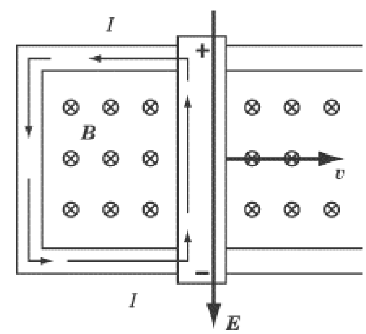
If a conductor is moved in a region or space where magnetic field changes then according to the Faraday's law emf is induced which induces current in the conductor. This induced emf is called motional emf.

Mathematically,

If the length of the conductor is 'l' moving in the magnetic field of B then,

$$\xi = \frac{\text{work done}}{\text{charge}} \text{ ----------(1)}$$

$$\xi = \frac{Fd\cos\theta}{q}$$



Since, 'F' and 'd' are parallel i.e. $\theta = 0^o$ and $\cos 0^o = 1$, then

$$\xi = \frac{Fd}{q}$$

Here, $d = l$ and $F = qvB\sin\theta$, putting values in equation (1)

$$\xi = \frac{qvB\sin\theta L}{q}$$

$$\xi = vBL\sin\theta$$

A.C GENERATOR

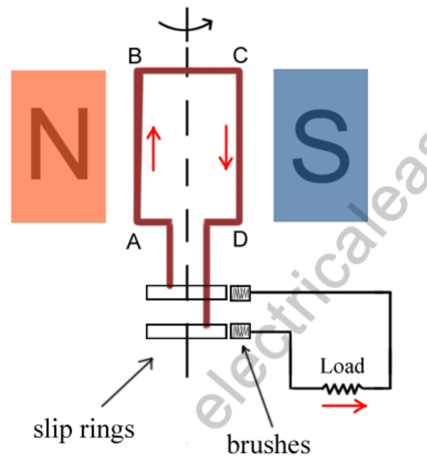
"An electromechanical device which produces alternating emf and current by using mechanical energy."

PRINCIPLE

It works on the principle of Faraday's law of induction that whenever magnetic flux changes through a coil an induced emf and current produced in it.

Construction/Main Components

An A.C generator consists of following main components.



1. **Field Magnet:**
A strong permanent magnet is used to produce strong uniform magnetic field.
2. **Armature:**
It consists of soft iron frame on which wire is wound in the form of coil in which emf is induced.
3. **Slip Rings:**
The two ends of the coil are joints to two metallic circular rings called slip rings which rotate with the rotation of the coil.

4. **Carbon Brushes:**
Two carbon brushes which are in contact with the slip rings, are used to collect current from the slip ring.

Working
When, the coil of A.C generator rotates by a mechanical means in magnetic field, the magnetic flux through the coil changes and a motional emf in induced in the coil. Due to this motional emf an induced current also produced and flows through the coil and is collected by slip rings.
When the coil convers angular displacement from 0^o to 90^o then induced emf increases from 0 to maximum and when coil covers angular displacement from 90^o to 180^o then induced emf decreases from maximum to zero. During the next half cycle the polarity reverses and in this way alternating current and emf is induced.

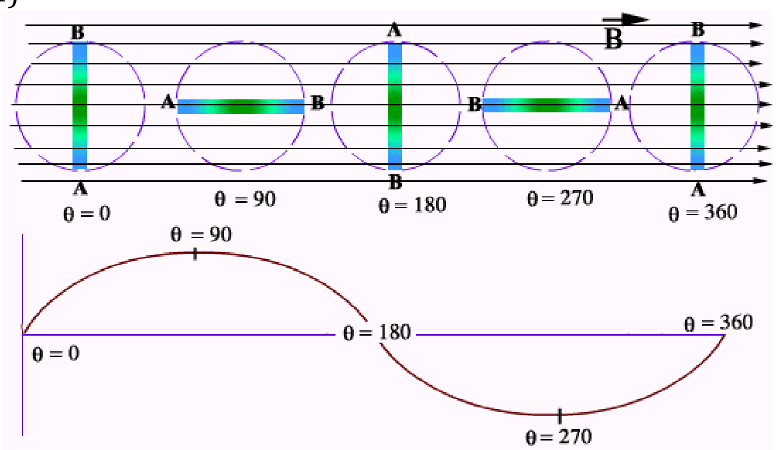
Mathematical Expression
Consider a rectangular coil of 'N' number of turns having length 'l' and breadth 'b' is rotating in a magnetic field 'B' with an angular velocity 'ω' about an axis of rotation passing through the center of the width 'b' then induced motional emf 'ξ' can be written as,

$$\xi = vBl\sin\theta$$

This motional emf is induced in two wires, therefore we can write,

$$\xi = 2vBl\sin\theta \text{--------(1)}$$

but $v = r\omega$ and $r = \frac{b}{2}$



$$\therefore v = \frac{b}{2}\omega$$

$$\xi = 2\frac{b}{2}\omega Bl\sin\theta$$

Here, $b \times l = A$ (Area of the coil)

$$\xi = \omega BA\sin\theta$$

For 'N' no. of turns,

$$\xi = N\omega AB\sin\theta$$

Since, $\theta = \omega t$

$$\therefore \xi = N\omega AB\sin\omega t \text{---------(2)}$$

When $\sin\omega t = 1$, then $\xi = \xi_{max}$

$$\xi_{max} = N\omega AB$$

Putting above values in equation (2)

$$\xi = \xi_{max}\sin\omega t$$

In terms of frequency we know that $\omega = 2\pi f$

$$\therefore \xi = \xi_{max}\sin(2\pi ft)$$

TYPES OF A.C GENERATOR

1) **Magneto:**
Any small generator employing a permanent magnet is commonly called a magneto and it is used in ignition system of petrol engines, motor bikes and motor boats, etc.

2) **Alternators:**

The field magnets of large generators are electromagnets and these generators are called alternators. The performance of A.C generator is more satisfactory when the armature is stationary, and the field magnet rotates around the armature. Stationary armature is called stator and rotating magnet roto.

D.C GENERATOR

By replacing the slip rings of an A.C generator by a simple split ring, or commutator, the generator can be made to produce a direct current through the external circuit. A generator modified for this function is called D.C. generator.

ELECTRIC MOTOR

An electric motor is the device which converts electrical energy into mechanical energy. It works under the principle that when a current is passed through a coil capable of rotation in a magnetic field of induction, experiences a couple which is the reverse phenomena of A.C generator.