Chapter = 15

ELECTROMAGNETISMS

ELECTROMAGNITIMS

Definition: -

The branch of physics which deals with the study of magnetic field due to moving charges is known as electromagnetism. OR

The branch of physics which deals with magnetisms (field) produced by the electric current is known as electromagnetisms. OR

Electromagnetisms is the study of magnetic effects of electric current.

Purpose: -

To inter-relates electricity and magnetism.

History: -

This branch of physics was introduced by Danish physics "H.C.Oersted" and "Ampere" of France in 1820.

MAGNET

Definition: - An object which attracts other objects made of iron, nickel and cobalt is known as magnet. OR

It is a material or object that produces magnetic field.

History: - It was first of all naturally found in a place "Magnesia" situated in modern Turkey by a **Shepherd.**

Old Name: - Its old name was "LODESTONE" meaning "Leading stone" having directional properties.

Meaning: - The word magnet in "Greek" meant "stone from magnesia".

PROPERTIES OF MAGNET

(i) It has two poles i-e North Pole and South poles.
(ii) Like poles repel while un-like poles attract each other.
(iii) On freely suspended it sets itself along N-S direction.
(iv) It produces a magnetic field around itself.
(v) The magnetism at poles is greater than at middle.
(vi)A single pole of a magnet cannot be obtained.

TYPES OF MAGNET

(i) Natural magnet .
(ii) Artificial magnet OR Electromagnet.

Electromagnet: - The magnet which is produced due to moving charges or electric current.

Magnetisms: - The study of magnetic properties is known as magnetisms.

Note: - **(i) A static charge produces only electric field.(ii)A moving charge produce electric filed as well as magnetic field both.**

MAGNETIC FIELD

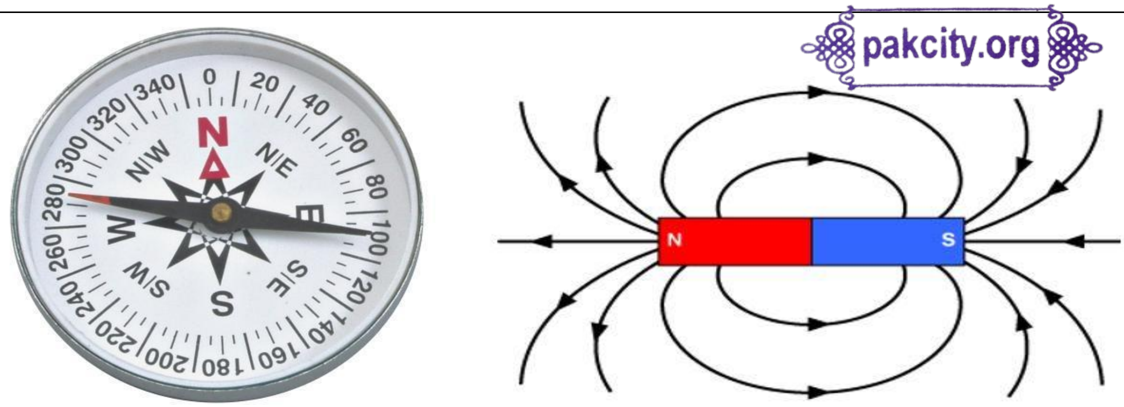
Definition: - A region around a magnet with in which it can exert its influence upon a magnetic material. OR

The space surrounding a magnet in which its magnetic effect is felt is known as magnet field. OR

Any region in which magnetic effect is felt is known as magnetic field.

Quantity:- It is a vector quantity.

Trace out: - It can be traced out by means of a small test magnet such as compass needle.
Representation:- It is represented by lines of force as shown in figure 15.1.



Magnetic force: - The force which is produced due to the magnet. OR
The force which is produce by the motion of charged particle within the magnetic field is known as magnetic force.

Steady current: - A current which has constant intensity in the circuit is known as steady current. OR
Steady current means constant current, not changing with time. OR
The continuous and constant flow of free electrons in a circuit is known as steady current. OR
The current due to charge having uniform motion is known as steady current.

MAGNETIC EFFECT 0F STEADY CURRENT

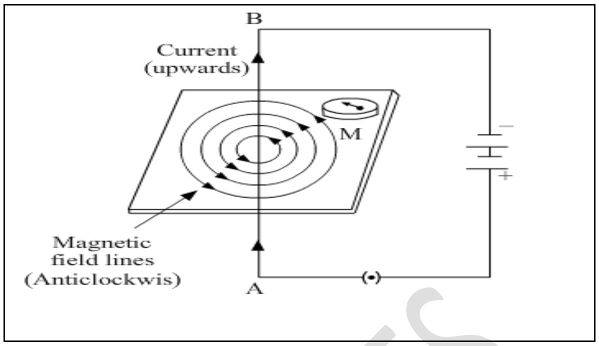
The magnetic field produced by steady current can be mapped by the following experiments.

MAGNETIC FIELD DUE TO A STRAIGHT STEADY CURRENT CARRYING WIRE

History:- This effect was first of all introduced by a **DANISH** physicist "**H.C. OERSTED**" in 1820 .

Apparatus: -

- A piece of card board.
- Straight wire.
- Iron filings.
- Variable battery.



Working: - When the current is allowed to pass through the wire. Sprinkle iron filings on cardboard will be attracted by the wire, which shows that magnetic field is produced around the wire. The iron filing arranges themselves in concentric circles.

Shape of field: - Concentric circles

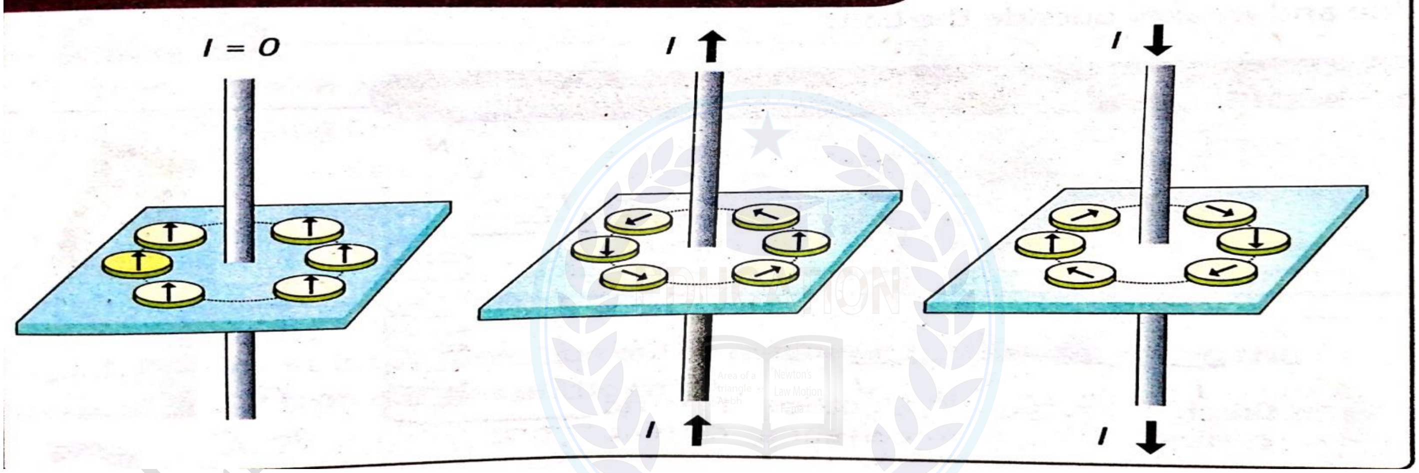
Factor: - The intensity (strength) of the magnetic field around the wire is directly proportional to the magnitude of the current flowing in the wire i.e

$$B \propto I$$

Traced out:- The magnetic field around the current carrying straight wire can be also traced by

means of a magnetic compass.

Figure 15.3 - Magnetic field of straight wire



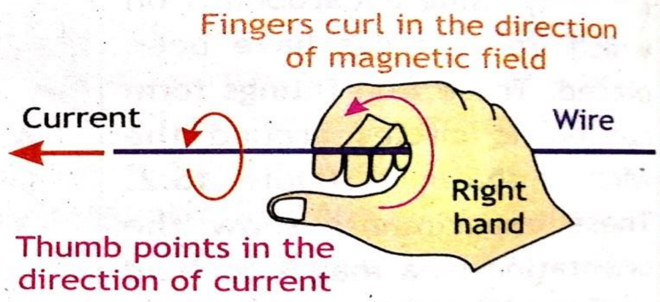
Direction: - The direction of the magnetic field may be clock wise or anti-clock wise. The direction of the magnetic field is found by a rule known as **right hand rule**.

RIGHT HAND RULE

Statement: - "If current carrying wire is grasped in the right hand with the thumb pointing in the direction of current then fingers encircle the wire shows the direction of the magnetic field" as shown in figure.

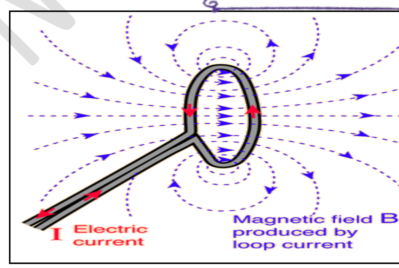
RIGHT-HAND RULE I

Right-hand rule for the magnetic field from a current carrying wire: Put your thumb in the direction of current and curl your fingers around the wire, the curled fingers will show the direction of magnetic field. This rule is for direction of conventional current or flow of positive charges. For electronic current flow the same rule is applied but with left hand.



Right-hand rule - I for the magnetic field from a current carrying wire.

MAGNETIC FIELD DUE TO A CURRENT CARRYING COIL



History: - This concept was first of all introduced by **Ampere**.

Coil:- When the straight wire bend into a circular form it is called loop or coil.

Apparatus: -

(i) Coil **(ii)** Battery as shown in figure

Working: - When D.C is allowed to pass through the coil, the coil becomes a magnet, having one pole as N-pole and other pole as S-pole.

Shape of magnet: - Bar magnet.

Factors: -

Number of turns: - Greater the number of turns in the coil stronger will be the magnetic field and vice versa i-e $B \propto N$.

Amount of current: - Greater the current passing the coil stronger will be the magnetic field and vice versa i-e $B \propto I$.

Traced out:- Coil magnet field can be also traced out by means of a magnetic compass.

Direction: - Its magnetic field direction can be find out by using right hand rule.

THE MAGNETIC FIELD DUE TO A SOLENOID

History: - This concept was first of all introduced by **Ampere.**

Solenoid: - A cylindrical spring is known as solenoid.

Apparatus: -

- Cylindrical spring

- Battery

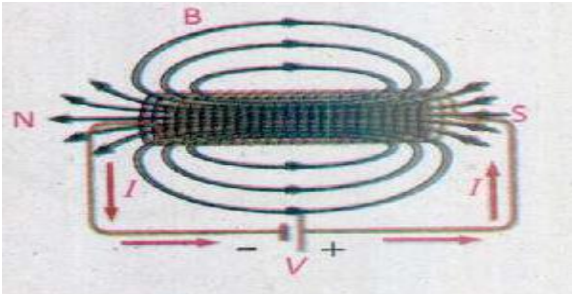
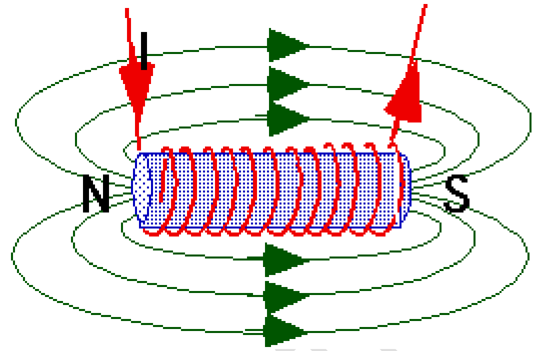


Fig. 15.4: Magnetic field due to a solenoid

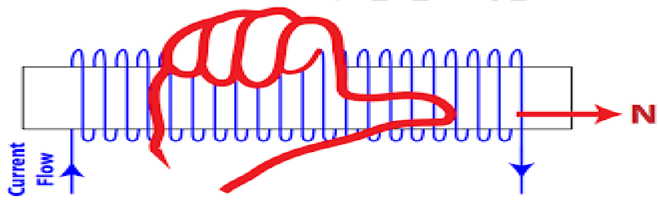


Working: - When the D.C is allowed to pass through the solenoid then the magnetic field is produced. As a solenoid consist of a number of turns. This magnetic field is the sum of magnetic field produced in each turns.

Shape of magnet: - Bar magnet.

N	S

Direction: - Its magnetic field direction can be find out by using right hand rule.



Factors: -

(i) Number of turns in solenoid (N) i.e. $B \propto N$

(ii) Current (I) i.e. $B \propto I$.

FORCE ON A CURRENT CARRYING CONDUCTOR IN A MAGNETIC FIELD

History: - This effect was introduced by "**H.C. Oersted**" in 1850.

Cause: - Due to interaction between the two fields.

Arrangement: -

- U-Shaped magnet.
- Straight wire (conductor).
- Battery.

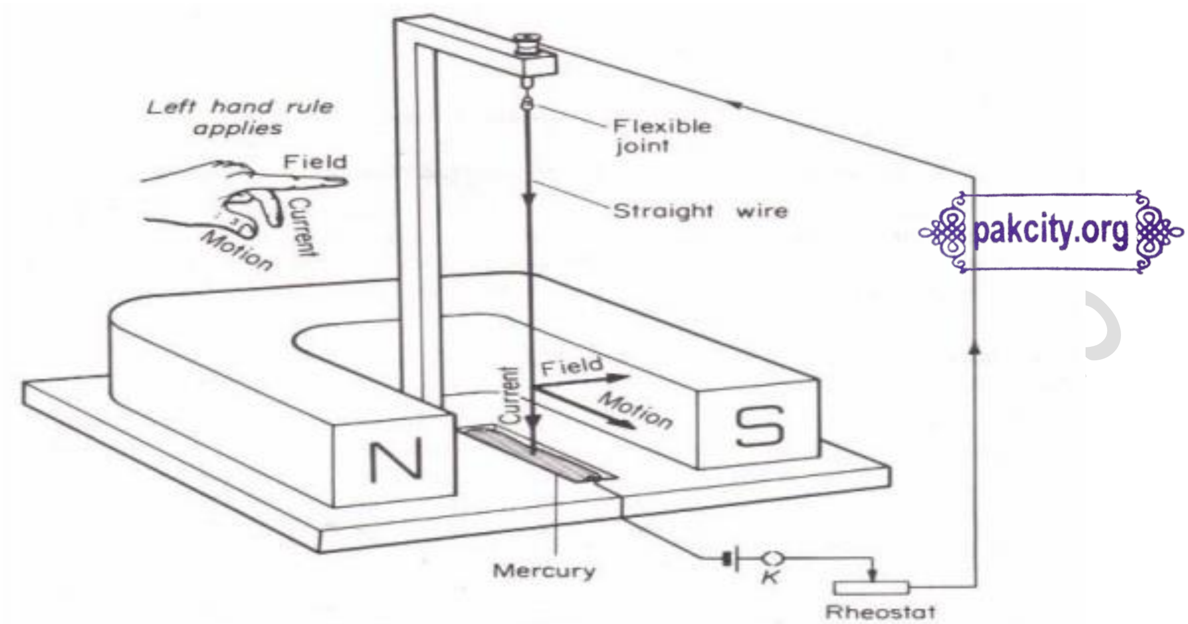


Fig.(15.6 A)

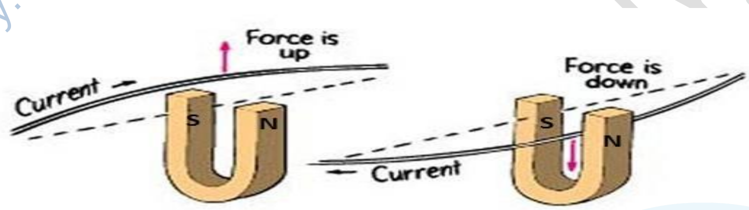


Fig. (15.6 A)

Working: -

Let a conductor of length "L" is placed in a magnetic field "B".

- When the current flowing through the conductor is zero then the force on conducting wire is zero. i-e $F_m = 0$
- When the switch is "ON" the current " **I** " starts to flow in the conductor and will be pushed to one side. If the direction of current is reversed the push on conductor also reverses. Similarly if the north and south poles reversed, the push reverses.

Mathematical form: -

- "$\mathbf{F_m}$" shows the magnetic force on the wire.
- "**B**" shows the strength of magnetic field.
- "**I**" show the current through the wire.

- **"L"** shows the length of the wire.

Factors: -

i. The magnetic field (B): - $F_m \propto B$ .... (1)
ii. The current in wire (I): - $F_m \propto I$ .... (2)
iii. The length of the wire (L): - $F_m \propto L$ .... (3)
iv. Sine of angle between "I" and "B" :- $F_m \propto \sin\theta$ .... (4)

By combining equation 1, 2, 3 and 4 we get

Constant = k = 1

$$F_m \propto ILB \sin\theta$$
$$F_m = \text{constant } ILB \sin\theta$$
$$F_m = k\, ILB \sin\theta \quad \text{.............} \quad (5)$$

For SI units k = 1. Then equation (5) becomes

$$F_m = ILB \sin\theta \quad \text{..........................} \quad (6)$$

Maximum Magnetic Force:- The force will be maximum when the angle between the current direction and magnetic field is $\theta = 90^0$.

$\sin(90^0) = 1$

-

$$F_m = ILB \sin(90^0)$$
$$F_m = ILB(1) = F_m = ILB \quad \text{..............} \quad (7)$$

For B magnetic field: - From equation (7)

$$B = \frac{F_m}{IL}$$

Unit: - The SI unit of "B" is $NA^{-1}m^{-1}$ known as tesla i-e $1NA^{-1}m^{-1} = \frac{1N}{1A \times 1m}$ = 1T (tesla).

Direction of F_m: - The direction of "F_m" can be find out by using "**Fleming's left hand rule**".

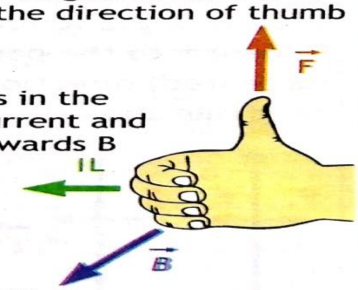
FLEMING'S LEFT HAND RULES

Statement: -Stretch the thumb, forefinger, and the middle finger of the left hand mutually at right angles to each other. If the forefinger points in the direction of the magnetic field, the middle finger in the direction of current, then the thumb would indicate the direction of the force acting on the wire as shown in figure.

RIGHT-HAND RULE III

Right-hand rule for the force on a current carrying conductor: Outstretch the fingers of right hand in the direction of current then bend the fingers in the direction of magnetic field (through the shorter angle between them) then the extended thumb will give the direction of force on the current carrying wire. This rule is for direction of conventional current or flow of positive charges. For electronic current flow, the same rule is applied but with left hand.

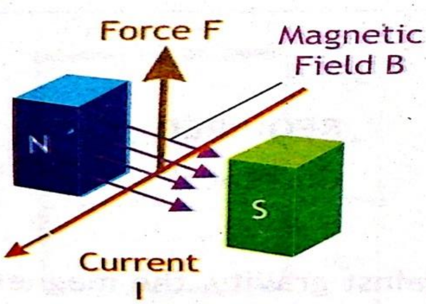
Magnetic force is in the direction of thumb

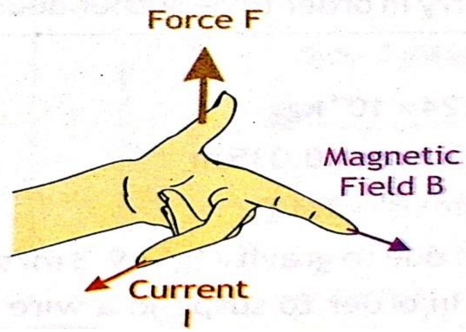


Right-hand rule (III) for the force on a current carrying conductor

Fleming's Left hand rule

Fleming's left hand rule can also be used to represent the direction of force. The thumb and the first two fingers of the left hand are set at right angles to each other. With the first finger pointing in the direction of the field, the second finger pointing in the direction of current, the thumb will give the direction of force.





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TURNING EFFECT ON A CURRENT CARRYING COIL IN A MAGNETIC FIELD

When a current carrying pivoted coil or loop is placed in a uniform magnetic field it experience a torque.

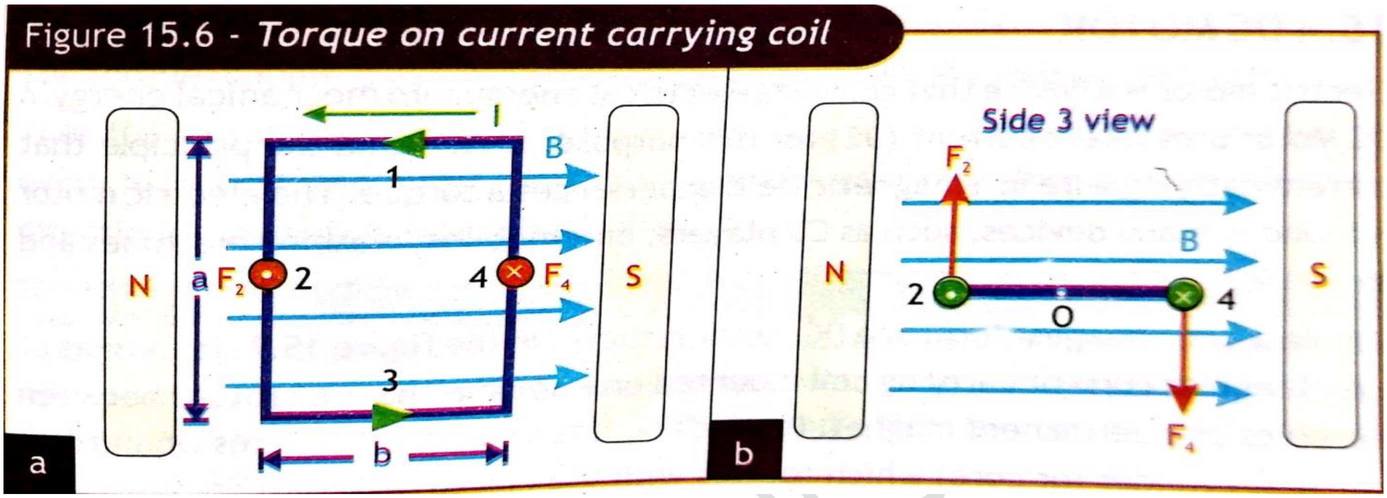
Reason: - This torque is produced due to the interaction between the magnetic field of the permanent magnetic and the electromagnet.

Explanation:-

Apparatus: -

- Permanent magnet

- Rectangular coil having four sides (1,2,3 and 4) having length “a” and width “b”.
- Battery
- Figure 15 .3:-



Working:- When the current is allowed to pass through the coil (loop) then magnetic field is produced in it.

(i) The forces on the sides “**1**” and “**3**” are zero because they are parallel to the field.

$F_1 = F_3 = \text{Bib } \sin\theta$............................ (S)

$\sin(0^0) = 0$

$F_1 = F_3 = \text{Bib } (0)$

$F_1 = F_3 = 0$

(iii) The magnetic forces on the sides “**2**” and “**4**” are maximum because they are perpendicular to the field.

$F_2 = F_4 = \text{Bib } \sin\theta$............................ (R)

$\text{Sin } (90^0) = 1$

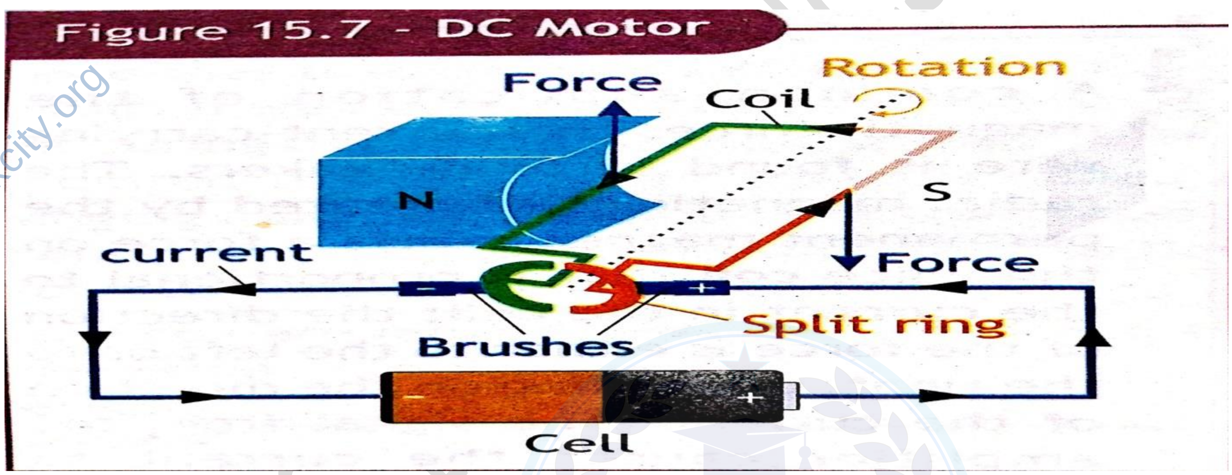
$F_2 = F_4 = \text{Bib } \sin(90^0)$

$F_2 = F_4 = \text{Bib}$

D.C Motor OR DIRECT CURRENT MOTOR

History: - D.C motor was first of all design by British physicist **William Sturgeon** in **1832**.
Definition: - An electrical device which converts electrical energy into mechanical energy is known as D.C motor.
Principle: - It works on the principle that current carrying coil or wire in a magnetic field experiences a torque.
Construction: - It consists of

- Permanent magnet
- Rectangular coil ABCD.
- Copper split rings "S_1" and "S_2".
- Brushes "X" and "Y".
- Figure 15.9.



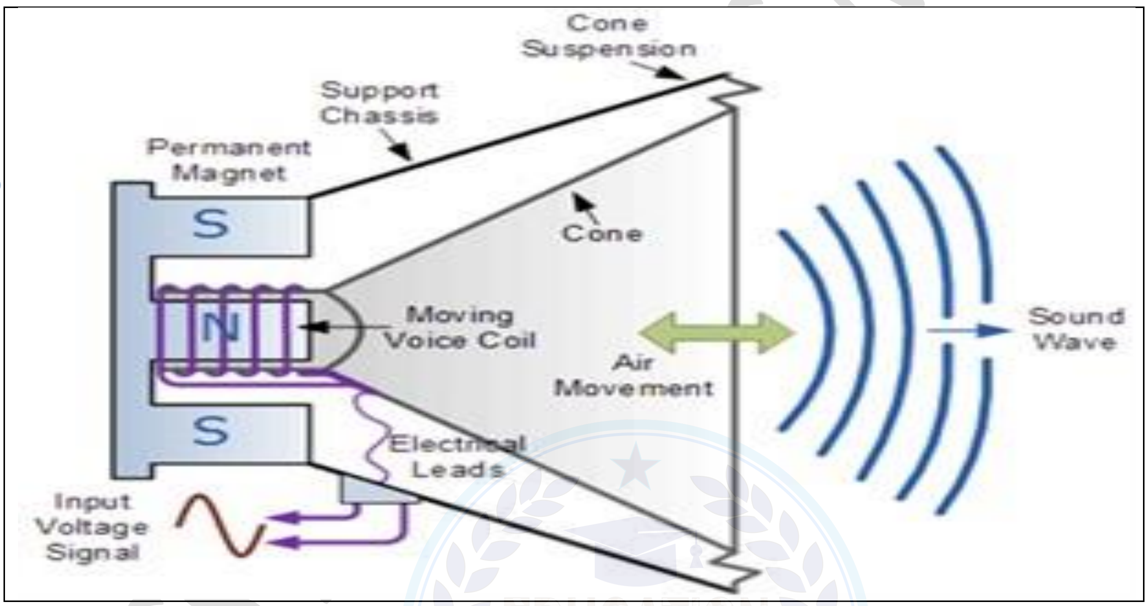
Working: - When the current is passing through the coil, the interaction between the electromagnet and permanent magnet causes armature to rotate. In this way D.C motor coverts the electrical energy into mechanical energy, which can be used for different types of work.
Uses: - It is used in

i. Air cooler
ii. Electric fans
iii. Washing machine
iv. Radar
v. Water pump
vi. Tape recorder
vii. Telephones etc.

MOVING COIL LOUD SPEAKER

History: - It was first of all design by a **German** physicist **E.W. Siemens** in **1874**.
Definition: - "It is an electrical device which converts electrical signals to sound waves."
Principle: - A current carrying conductor experiences a force in a magnetic field.
Construction: - It consists of

- **i.** Permanent magnet with a central cylindrical pole.
- **ii.** Coil on tube
- **iii.** Paper cone
- **iv.** Current leads (input voltage signal)
- **v.** Casing as shown in figure.



Working: - When an alternating current from a radio or a record player passes through the coil it forces the paper cone to move in or out, depending on the current direction. This motion of the paper cone, thus sets up sound waves in the surrounding air of the same frequency as that of the alternating current.
Uses: - It is used in

- i. Radio
- ii. T.V
- iii. Mobile
- iv. Telephone
- v. Ear phones etc.

ELECTROMAGNETIC INDUCTION

History: - This phenomenon was first of all introduced by a **"British"** physicist "**Michael Faraday**" in **1831**.

Purpose: - To inter-relates magnetism and electricity.

Definition: - The phenomenon in which e.m.f is produced due to relative motion of coil and magnet is known as electromagnetic induction. OR

The process in which an e.m.f is induced in a coil by changing the magnetic flux passing through it is known as electromagnetic induction. OR

The process of generating an induced current in a circuit by changing the number of magnetic lines of force passing through it is known as electromagnetic induction.

Cause: - Change of magnetic flux due to relative motion.

INDUCED CURRENT

The current produced in loop/coil due to induced e.m.f is known as induced current. OR

The current induces in the loop/coil due to changing magnetic flux is known as induced current.

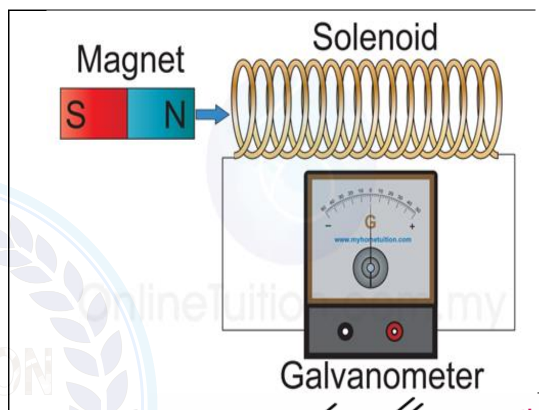
Explanation: - The phenomenon of electromagnetic induction can be demonstrated by a simple experiment.

Apparatus: -

(i)A loop of wire connected to a galvanometer

(ii)Bar magnet

Figure:-



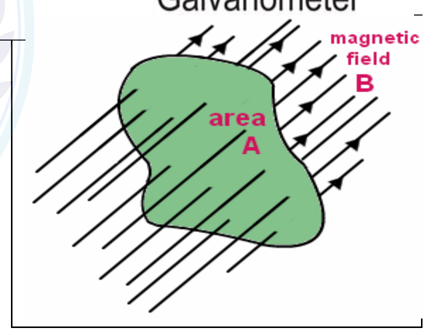
MAGNETIC FLUX

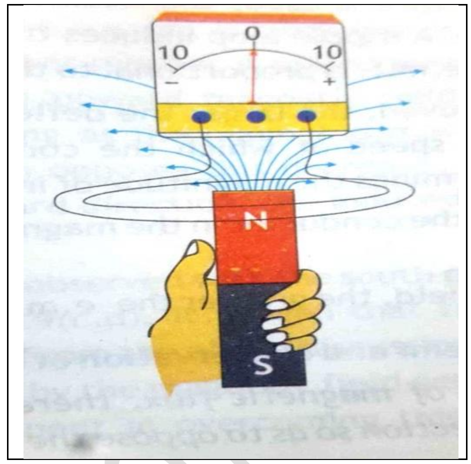
Definition:-

The number of magnetic lines passes through a certain area is known as magnetic flux.

Symbol: - It is denoted by "$Ø_m$".

Figure:-





(1).If both magnet and coil at rest:-

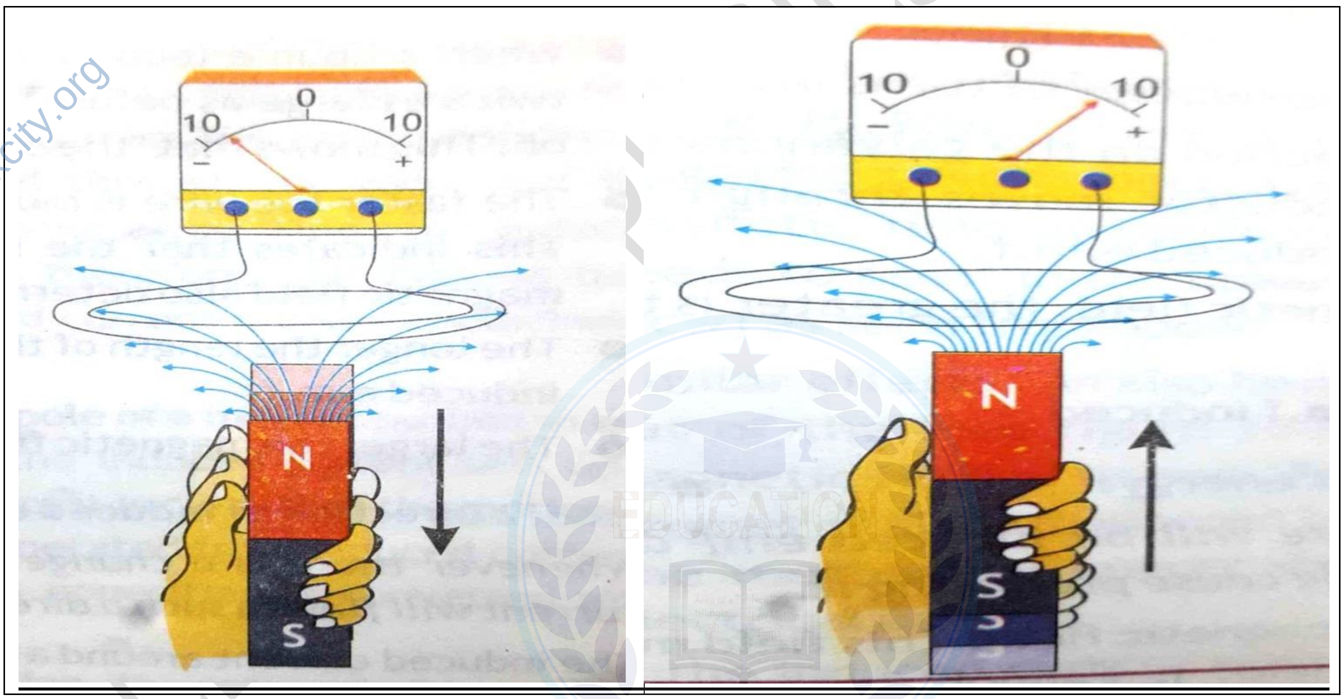
Then the magnetic lines of force are passing through the coil at constant rate. We see no current in galvanometer as shown in figure.

(2)If the magnet is at rest and the loop/coil is moving:-

If the coil is moved either towards or away from the magnet. In this case the magnetic lines of force are changing through the loop. So we can see current in galvanometer.

(3)If the loop is at rest and the magnet is moving:-

When the magnet is moved either toward or away from the loop. In this case the magnetic lines of force are changing through the loop. So we see current in galvanometer as shown in fig.



Conclusion: - From the above experiments/observations we can conclude that a current is setup in the circuit as long as there is relative motion between the magnet and the loop. The relative motion between the magnet and the loop results in change in magnetic flux.

FACTORS AFFECTING MAGNITUDE OF INDUCED emf

From experiments it is cleared that the magnitude of induced e.m.f depends upon the following factors.

(1) Number of turns in the coil (N):- e.m.f $\propto$ N

(2) The speed (V) of motion of the magnet or coil:- e.m.f $\propto$ V

(3) Length (L) of conductor in the magnetic field:- e.m.f $\propto$ L

(4) The strength of magnetic field (B):- e.m.f $\propto$ B

FARADAY LAW OF ELECTROMAGNETIC INDUCTION

History: - This law was presented by a British physicist **Michael Faraday** in 1830.
Purpose: - To find the magnitude of induce e.m.f.
Statement: - The magnitude of induced emf is directly proportional to the negative time rate of change of magnetic flux in a close circuit.
Mathematical form: - Induced e.m.f ∝ - rate of change of magnetic flux

$$E \times -\frac{\Delta\phi}{\Delta t}$$

$$E = \text{constant}\left(-\frac{\Delta\phi}{\Delta t}\right)$$

$$E = (1)\left(-\frac{\Delta\phi}{\Delta t}\right)$$

$$E = -\frac{\Delta\phi}{\Delta t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

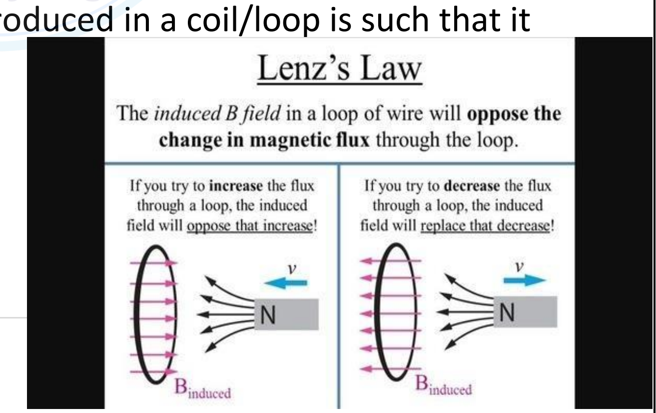
If the coil consists of N-number of turns then equation (1) becomes

$$E = -N\frac{\Delta\phi}{\Delta t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

In equation (2) the negative sign shows the direction/ polarity of the induced current.

Len's Law

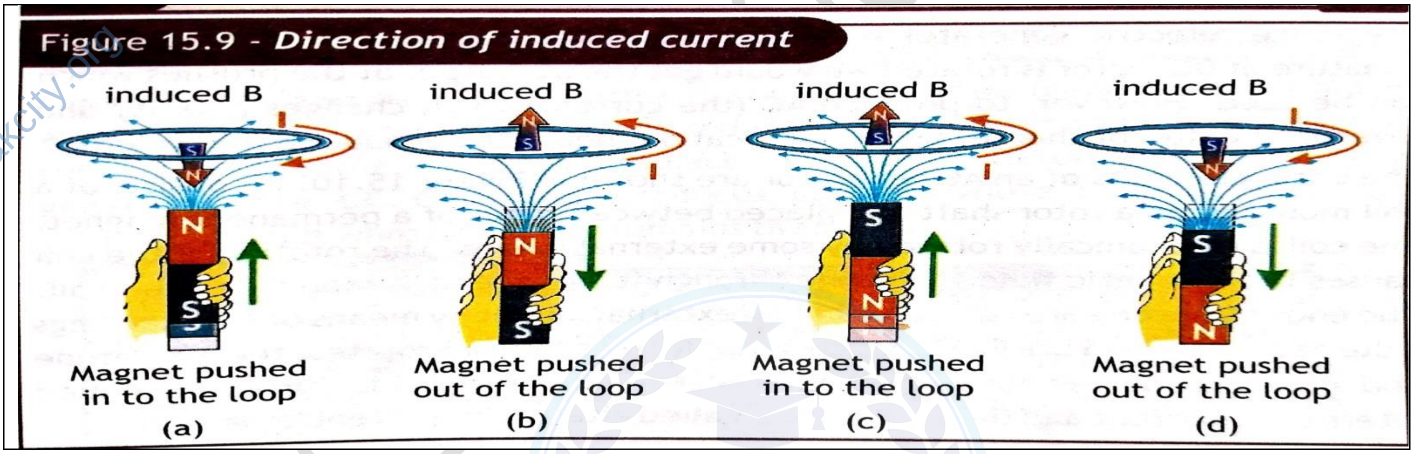
History: - This law was presented by a Russian physicist **Enrich Lenz** in 1834.
Purpose: - To find the direction of induced current.
Base: - It is based on law of conservation of energy.
Statement: - "The direction of induced current produced in a coil/loop is such that it opposes the causes that produce it".



RELATION BETWEEN DIRECTION OF INDUCED e.m.f LAW OF CONSERVATION OF ENERGY

When we push the magnet towards the coil, then as a result current induce in the coil. Now according to Lenz's law this pushing is the change that induced current and this induced current will oppose the push. Similarly if we pull the magnet away from the coil, then as a result the induce current will again oppose this pull.

Therefor in general whether we pull or pull the magnet, it motion will be opposed and hence the agent that cause the magnet to move, either towards or away from the coil must work done in order to overcome the opposition. Now according to law of conservation of this work done on the system must be equal to the internal energy (electrical energy) produced in the coil.



A . C GENERATOR OR ALTERNATING CURRENT GENERATOR

History: -It was first of all design by an American electrical engineer "NIKOLA TESLA" in 1888.

Definition: - "It is an electrical device which converts mechanical energy into electrical energy".

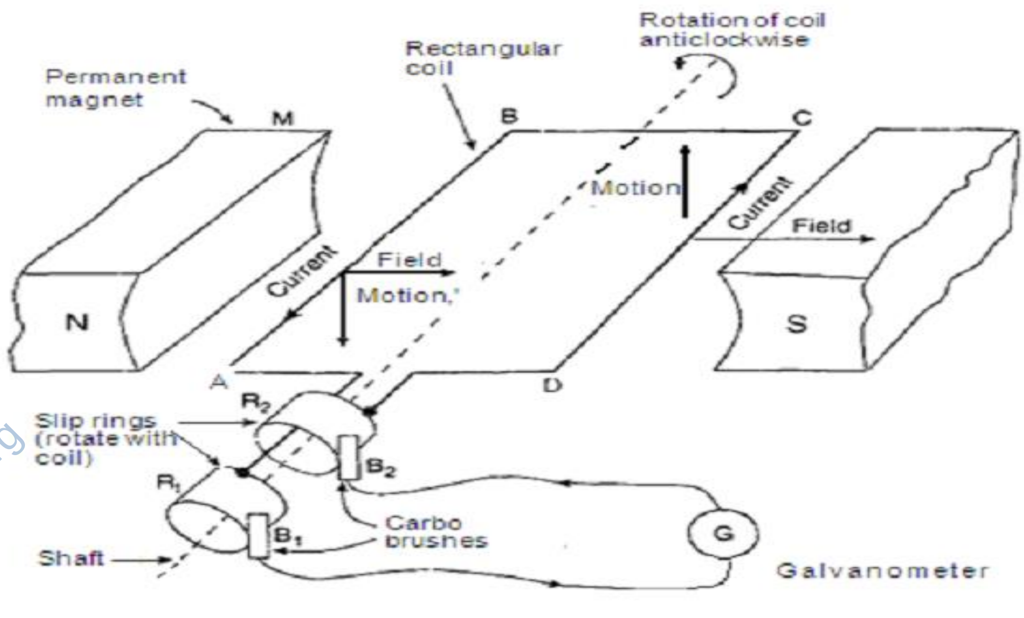
Principle: - Its basic principle is electromagnetic induction.

Construction:- It consists of

(i) Rectangular coil.

(ii) Permanent magnet
(iii) Carbon brushes
(iv) Slip rings

Figure (U): -



A.C. generator

Working: - When the coil rotates between the poles of the magnet, it causes the change of magnetic flux. This change of magnetic flux induced e.m.f in the coil and current is produced in the coil. This induced current change its direction after every half-cycle i-e when the coil is rotated is produced in the circuit.

Uses: - It is used in

- Power station i-e Warsak, Turbela etc to convert the kinetic energy of water falls to electrical energy.
- Homes etc to convert the chemical energy of gas, petrol, diesel into electrical energy.

MUTUAL INDUCTION

Definition: - The phenomenon in which e.m.f is induced in a secondary coil due to the change in current in the primary coil is known mutual induction. OR

The phenomenon in which e.m.f is induced in one circuit or coil due to the change in current in another circuit or coil is known mutual induction. OR The ratio of e.m.f induced in secondary coil to the rate of change of current in primary coil is known as mutual induction.

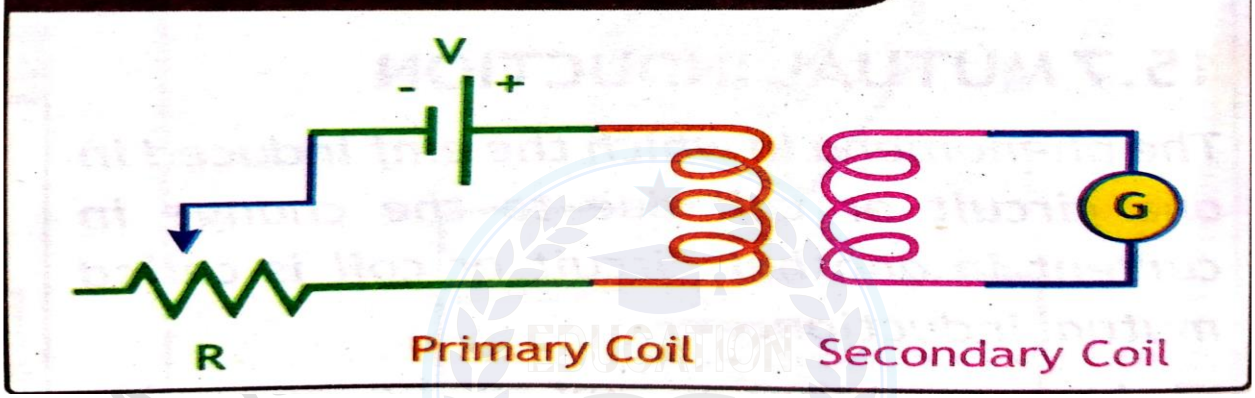
Symbol:- It is denoted by "M".

Mathematical Form:-

$$M = \frac{\varepsilon_S}{\frac{\Delta I_P}{\Delta t}}$$

Explanation: - Consider the two coils placed side by side as shown fig (R). The coil which is connected to a battery is called the primary coil while the other that has no source of e.m.f is called the secondary coil. When the switch is open, there are no magnetic field lines passing through any of the coils. When the switch is closed a magnetic field is setup around the primary coil due to the flow of electric current. Some of the magnetic lines of force pass through the secondary coil. An induced current according to Faraday's law of electromagnetic induction will be produced momentarily and hence induces e.m.f as shown in fig (15.13).

Figure 15.13 - Mutual Induction



Induced e.m.f produced in secondary coil:- From experiments

$$\varepsilon_s \propto -\frac{\Delta I_P}{\Delta t}$$

$$\varepsilon_s = -Constant\ \frac{\Delta I_P}{\Delta t}$$

$$\varepsilon_s = -M\ \frac{\Delta I_P}{\Delta t} \quad \text{..................} \quad (1)$$

Constant = M

In equation (1)

(i) "M" is the constant of proportionality and is known as co-efficient of mutual induction.

(ii) The negative sign tells us that the induced current is always in opposite direction to the original current flow.

For "M":- Equation (1) becomes

$$M = \frac{\varepsilon_S}{\frac{\Delta I_P}{\Delta t}} \quad \ldots\ldots\ldots\ldots\ldots (2)$$

Unit:- It SI unit is henry (H).

Henry:-

Definition:- The mutual induction of two coils will be one henry, if the current is changing at the rate of one ampere per second in the primary and causes an induced emf of one volt in the secondary.

Symbol:- It is denoted by "H".

$$1\,H = \frac{1\,V \times 1\,s}{1A} = \frac{Vs}{A}$$

Factors: - The induce e.m.f depends upon the following factors.

- Number turns in the two coils.
- Cross-sectional area of each coil.
- Distance between the two coils.

TRANSFORMER

History: - It was first of all made by **William Stanley in 1885**.

Purpose: -

- To make the electrical energy for useful use.
- To help in electrical energy transmission.

Definition: - "It is an electrical device which is used to step up or step down A.C voltage".

Principle: - Its basic principle is "mutual induction".

Construction: - It consists of

i. Iron core

ii. To separate coils "P" and S are tightly wounded around the iron core .

- "P" shows the primary coil (to which voltage is given).
- "S" shows the secondary coil (at which voltage is developed or induced).

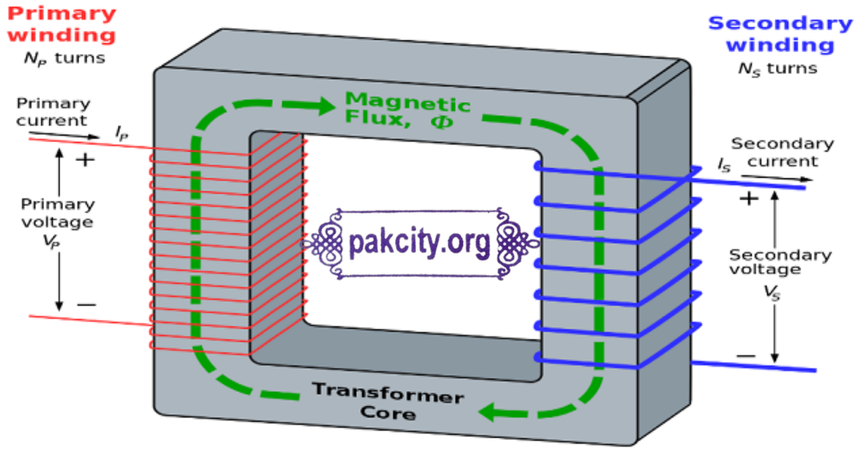


Figure: -

Working: - When the input A.C voltage is supplied across the primary coil , then an A.C flows in the primary coil. This current produces a continuously changing magnetic flux which cause an induce e.m.f in the secondary coil due to mutual induction. The magnitude of output voltage across the secondary coil depends upon the ratio between numbers of turns in the two the coils.

Formula: - $\frac{Ns}{Np} = \frac{Vs}{Vp}$ -------(1)

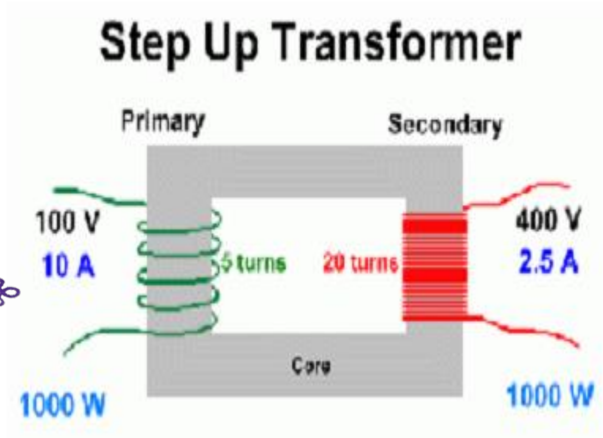
In equation (I)

- "N_s" shows the number of turns in the secondary coil.
- "N_p" shows the number of turns in the primary coil.
- "V_p" shows the voltage across the primary coil.
- "V_s" shows the voltage across the secondary coil.

TYPES OF TRANSFORMER

There are two types of transformer which are given below.

Step-up transformer: - The transformer whose output voltage is greater than its input voltage is known as step-up transformer.

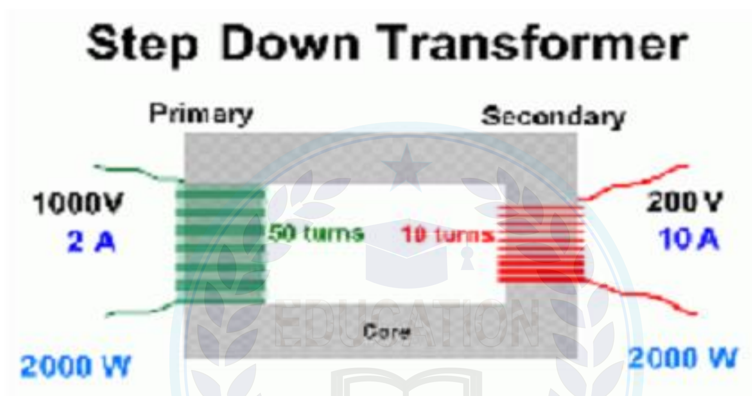


(If $N_s > N_p$ step-up transformer)

Uses: - They are used in

- Power house
- Dams etc

Step-down transformer: - The transformer whose input voltage is greater than its output voltage is known as step-down transformer.



(If $N_p > N_s$ step-down transformer)

Uses: - They are used in poles near our houses for domestic purposes.

CONCEPTUAL QUESTIONS

Q#01:- Differentiate between electric and magnetic fields.

ELECTRIC FIELD	MAGNETIC FIELD
Its source is electric charge.	Its source is magnet and moving electric charge.
It is denoted by "$\vec{E}$".	It is denoted by "$\vec{B}$"
Its units N/C.	Its unit is tesla.
It is represented by electric lines of force.	It is represented by magnetic lines of force.
It exerts electric force on test charge.	It exerts electric force on test charge.
It is measured by electro-meter.	It is measured by magneto-meter.
It is a medium dependent field.	It is a medium independent field.

Q#02:- Can an electron at rest be set into motion with a magnet field?

Ans:- Statement:- No an electron at rest cannot be set into motion with a magnet field.

Reason:- It is because the velocity of an electron is zero (v =0 m/s).

Explanation:- As we know that the force on an electron in a magnetic field is

$$F_m = qvB \sin\theta \text{ .... (1)}$$

As Velocity = v = 0 m/s then equation becomes.

$$F_m = q\,(0)B \sin\theta = 0$$

Conclusion:- As conclusion we find that an electron at rest cannot be set into motion with a magnet field.

Q#03:-Which is more likely to show deflection in compass needle, AC current or DC current? Explain.

Ans:- Statement:- D.C is more likely to show deflection in compass needle.

Reason:- It is because D.C has constant magnitude and unchanging direction.

Explanation:- As we know that In a direct current, the charges flows in one direction only. Due to which D.C has constant magnitude and unchanging direction. So the magnetic field produced by D.C will also not changed. So the compass needle will show much stable deflection.
On the other hand at low A.C frequency the compass needle will deflect in one way and (direction) and other way (direction) but at higher frequency only small vibration can be detect.
Conclusion:- As conclusion we find that **D.C** is more likely to show deflection in compass needle.

Q#04:-A constant magnetic field is applied to a current carrying conductor. What angle should the wire make with the field for the field for the force to be (a) Maximum (b) Minimum .

Ans:- (a) Statement:- The magnetic force will be maximum when the wire carrying a current is placed perpendicular to the magnetic field B .
Reason:- Because angle= $\theta = 90^0$ between the "L" and "B".
Explanation:- As we know that

F= BIL sinθ ... ... (2)
F = BIL sin (90)
F = BIL (1)
F = BIL

Sin(90)= 1

Conclusion:- As conclusion we find that the magnetic force will be maximum when the wire carrying a current is placed perpendicular to the magnetic field B .

(b) Statement:- The magnetic force will be zero when the wire carrying a current is placed parallel to the magnetic field B .
Reason:- Because angle= $\theta = 0^0$ between the "L" and "B".
Explanation:- As we know that

F= BIL sinθ ... ... (1)
F = BIL sin (0)
F = BIL (0)
F = 0

Sin (0)= 0

Conclusion:- As conclusion we find that the magnetic force will be zero when the wire carrying a current is placed parallel to the magnetic field B .

Q#05:- Why does a compass needle points North?

Ans:- Statement:- A compass needle points North.

Reason:- It is because **"Like magnetic poles repel each other while Un-like poles attract each other".**

Explanation:- As we know that a magnetic compass needle is a magnetized iron needle, which is so pivoted that it can turn freely in the horizontal plane. This needle comes to rest along the north-south direction. A compass needle is often used to study the magnetic field.

The earth behaves like a bar magnetic. The magnetic S-pole of this bar magnet is at the geometrical North Pole of the earth. The magnetic N-pole of the earth's bar magnet is at its geometric South Pole. Note that the magnetic and geographic poles do not coincide, they are somewhat away from one another.

Conclusion:- As conclusion we find that a compass needle points North.

Q#06:- How can a magnetic field be used to generate electric current?

Ans:- Statement:- A magnetic field can be used to generate electric current.

Reason:- It is because of

(i) Electromagnetic induction.

(ii) Rate of change of magnetic flux produce an electric current.

Explanation:-

(i) By pushing the bar magnet towards the loop or away from the loop will induce emf and current in the loop due to change magnetic flux.

(ii) By pushing the loop or moving away (pulling away) the loop from the bar magnet induce emf and current in the loop due to change magnetic flux.

Conclusion:- As conclusion we find that a magnetic field can be used to generate electric current.

Q#07:- What would happen if we use a slip ring to drive a DC motor?

Ans:- Statement:- If we use a slip ring instead of split rings to drive a DC motor. The coil will oscillate not rotate along single direction.

Reason:- It is because of both the slip and split rings have different function.
Explanation: - As we know that a split-rings makes the current change direction every half-rotation and is used in DC motor. Slip-ring is a continuous ring which provides a continuous transfer of electrical power and is used in A.C generator. To keep the torque in one direction, split rings are used. If we use a slip ring instead of split rings to drive a DC motor. The coil will oscillate not rotate along single direction, that is why split rings are not suitable to use in D.C motor.

Conclusion:- As conclusion we find that if we use a slip ring instead of split rings to drive a DC motor. The coil will oscillate not rotate along single direction.

Q#08:-The primary coil of a transformer is connected to a DC battery. Is there an emf induced in the secondary coil ? Why?

Ans:- Statement:- When the primary coil of a transformer is connected to a DC battery. There will be no an emf induced in the secondary coil.

Reason:- It is because Change of magnetic flux is zero i-e $\Delta\Phi$ **= 0**
Explanation:- As we know that From Faraday law of electromagnetic induction.

$$\text{e.m.f} = \frac{Change\ of\ magnetic\ flux}{Time}$$

$$\varepsilon = \frac{\Delta\Phi}{\Delta t} \quad \dots\dots\dots\dots (1)$$

If change of magnetic flux = $\Delta\Phi$ **= 0** then equation (1) becomes

$$\varepsilon = \frac{0}{\Delta t} = \mathbf{0}$$

Conclusion:- As conclusion we find that When the primary coil of a transformer is connected to a DC battery. There will be no an e.m.f induced in the secondary coil.

NUMERICAL QUESTIONS

Pb# 01:A 1.5 m long wire carries a current of 5 A, at right angle to a uniform magnetic field of 0.04 T. Determine the force exerted on the wire.

GIVEN DATA:-

Length of wire = l =1.5 m
Current = I = 5 A
Angle = θ = 90^0
Magnetic field = B = 0.04 T

REQUIRED DATA:-

Magnetic force = F_B **= ?**

SOLUTION:-

FORMULA:- As we know that

$$F_B = BIL \sin\theta \text{ ------------------- } (1)$$

Put values in the given equation

CALCULATION:-

$F_B = 0.04 \times 5 \times 1.5 \times \sin 90^0 = \frac{4}{100} \times 5 \times \frac{15}{10} \times 1$ $\sin 90^0 = 1$

$F_B = \frac{3}{10} = 0.3\ N$

RESULT:-

$F_B = 0.3$ N

Pb# 02:A wire carrying a direct current of 10.0 A is suspended 5.0 m east between a house and a garage perpendicular to the Earth's magnetic field of 5.0 × 10^{-5} T. What is the magnitude of the force that acts on the conductor?

GIVEN DATA:-

Current = I = 10 A
Length = L = 5.0 m
Magnetic field = B = 5.0×10^{-5} T

REQUIRED DATA:-

Force = F = ?

SOLUTION:-

FORMULA:- As we know that

F_B = BIL sin θ ------------------- (1)

Put the values in equation (1)

CALCULATION:-

$F_B = 5.0 \times 10^{-5} \times 10 \times 5 \times \sin 90^0 = 5 \times 10^{-5} \times 50 \times 1$ $\quad$ $\sin 90^0 = 1$

$F_B = 225 \times 10^{-5} = 2.25 \times 10^{-3}$ N

RESULT:-

$F_B = 2.25 \times 10^{-3}$ N

Pb# 03:A 10 cm wire at 30^0 to uniform magnetic field of 0.06 T is exerted by a force of 0.024 N. What is the current flowing through the wire?

GIVEN DATA:-

Length of wire = L = 10 cm = $\frac{10}{100}$ = 0.10 m
Angle = $\theta = 30^0$
Magnetic Field = B = 0.06 T
Force = F = 0.024 N

REQUIRED DATA:-

Current = I =?

SOLUTION:-

FORMULA:-

F_B = BIL sin θ ------------------- (1)

CALCULATION:-

From equation (1) we have

$I = \frac{F}{BLsin\theta}$ $\quad$ put values in the given equation

$I = \frac{0.024\ N}{0.06 \times 0.10 \times \sin 30^0} = \frac{0.024\ N}{0.06 \times 0.10 \times \frac{1}{2}} = \frac{24}{1000} \times \frac{100}{6} \times \frac{100}{10} \times \frac{2}{1}$

$I = \frac{24}{6} \times 2 = 8$ A

RESULT:-

I = 8 A

Pb# 04:-If the current through the primary coil changes from -5 A to + 5 A in 0.05 s, such that the induced emf is 2.8 V. What is the mutual inductance?

Initial current = I_i = -5 A

Final current = I_f = + 5 A

Total change in current $= \Delta I = I_f - I_i = 5 - (-5) = 5 + 5 = 10$ A

Time = Δt = 0.05 sec

Induced emf = $\mathcal{E}$ = 2.8 V

REQUIRED DATA:-

Mutual inductance = M =?

SOLUTION:-

FORMULA:-

As we know that $\mathcal{E} = M \times \frac{\Delta I}{\Delta t}$

$\Rightarrow \quad M = \mathcal{E} \times \frac{\Delta t}{\Delta I}$ ------------------- (1)

Put values in equation (1)

CALCULATION:-

$M = 2.8 \times \frac{0.05}{10} = \frac{28}{10} \times \frac{5}{100} \times \frac{1}{10} = \frac{14}{1000} = 14 \times 10^{-3}$ H

M = 14 mH

RESULT:-

Mutual inductance = M = 14 mH

Pb#05: A transformer connected to a 120 V AC line is to supply 9600 V for a neon sign. (a) What is the ratio of secondary to primary turns of the transformer? (b) If the transformer consisted of 275 primary windings, how many secondary windings would there be?

GIVEN DATA:-

(a) Primary voltage = V_p =120 v

Secondary voltage V_s = 9600 v

(b) Number of primary winding $N_p = 275$

REQUIRED DATA:-

(a) $\frac{Ns}{Np} = ?$

(b) Number of secondary winding = N_s = ?

SOLUTION:-

FORMULA:-

As we know that $\frac{Ns}{Np} = \frac{Vs}{Vp}$ ------------ (1)

CALCULATION:-

(a) Put values in equation (1)

$$\frac{Ns}{Np} = \frac{Vs}{Vp} = \frac{9600}{120} = \frac{80}{1}$$

(b) $\frac{Ns}{Np} = \frac{Vs}{Vp}$ put values in the given equation

$\Rightarrow \frac{Ns}{275} = \frac{9600}{120} = \frac{80}{1}$

$\Rightarrow N_s = 80 \times 275 = 22000$

RESULT:-

$N_s = 22000$

Pb# 06:How many turns would you want in the secondary coil of a transformer having 400 turns in the primary, if it were to reduce the voltage from 220 V AC to 3.0 V AC?

GIVEN DATA:-

Number of turns in primary coil = $N_P = 400$

Input (primary) voltage = $V_p = 220$ V

Output (secondary) voltage = $V_s = 3.0$ V

REQUIRED DATA:-

Number of turns in secondary coil = N_S = ?

SOLUTION:-

FORMULA:- As we know that

$$\frac{Ns}{Np} = \frac{Vs}{Vp} \text{ ----------- (1)}$$

CALCULATION:-

Put values in equation (1)

$$\frac{Ns}{400} = \frac{3}{220}$$

$$Ns = \frac{3}{220}\times 400 = \frac{120}{22} = \frac{60}{11} = 5.5$$

RESULT:-

Ns = 5.5 turns

Pb# 07:A transformer steps down a main supply of 220 V AC to operate a 12 V AC lamp. Calculate the turns ratio of the windings.

GIVEN DATA:-

Input primary voltage = V_p = 220 V

Output secondary voltage = V_s = 12 V

REQUIRED DATA:-

Turns ratio = $\frac{Ns}{Np}$ = ?

SOLUTION:-

FORMULA:- As we know that

$$\frac{Ns}{Np} = \frac{Vs}{Vp} \quad \text{----------- (1)}$$

CALCULATION:-

Put values in equation (1)

$$\frac{Ns}{Np} = \frac{12}{220} = 0.06$$

RESULT:- $\frac{Ns}{Np}$ **= 0.06**