INTRODUCTION

The magnitude of the force of attraction or repulsion between two electric charges at rest was studied by Charles Coulomb. He formulated a law ,known as "**COULOMB'S LAW**".

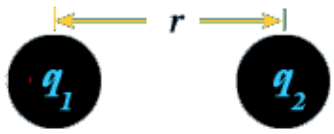
STATEMENT

According to Coulomb's law:

- The electrostatic force of attraction or repulsion between two point charges is directly proportional to the product of charges.
- The electrostatic force of attraction or repulsion between two point charges is inversely proportional to the square of distance between them.

MATHEMATICAL REPRESENTATION OF COULOMB'S LAW

Consider two point charges **q1** and **q2** placed at a distance of **r** from each other. Let the electrostatic force between them is **F**.



According to the first part of the law:

$$F \propto q_1 q_2$$

According to the second part of the law:

$$F \propto \frac{1}{r^2}$$

Combining above statements:

$$F \propto \frac{q_1 q_2}{r^2}$$

OR

$$F = K\frac{q_1 q_2}{r^2} \quad \text{----------(I)}$$

Where k is the constant of proportionality.

VALUE OF K

Value of **K** is equal to **$1/4\pi e_0$**

where **e_0** is permittivity of free space .Its volume is 8.85×10^{-12} c^2/Nm^2.
Thus in S.I. system numerical value of **K** is 8.98755×10^9 Nm^2c^{-2}.

OTHER FORMS OF COULOMB'S LAW

Putting the value of **$K = 1/4\pi e_0$** in equation (i)

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$

FORCE IN THE PRESENCE OF DIELECTRIC MEDIUM

If the space between the charges is filled with a non conducting medium or an insulator called "dielectric", it is found that the dielectric reduces the electrostatic force as compared to free space by a factor (**e_r**) called **DIELECTRIC CONSTANT.** It is denoted by e_r . This factor is also known as **RELATIVE PERMITTIVITY.** It has different values for different dielectric materials.
In the presence of a dielectric between two charges the Coulomb's law is expressed as:

$$F = \frac{1}{4\pi\varepsilon_0\varepsilon_r}\frac{q_1 q_2}{r^2}$$

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VECTOR FORM OF COULOMB'S LAW

The magnitude as well as the direction of electrostatic force can be expressed by using Coulomb's law by vector equation:

$$\vec{F}_{12} = \frac{1}{4\pi\varepsilon_0\varepsilon_r}\frac{q_1 q_2}{r^2}\hat{r}_{12}$$

Where $\vec{F}_{12}$ is the force exerted by **q1** on **q2** and $\hat{r}_{12}$ is the unit vector along the line joining the two charges from **q1** to **q2.**

ELECTRIC FIELD

When an electric charge is placed in space, the space around the charge is modified and if we place another test charge within this space, the test charge will experience some electrostatic force. The modified space around an electric charge is called 'ELECTRIC FIELD'.

For an exact definition we can describe an electric field as:

Space or region surrounding an electric charge or a charged body within which another charge experiences some electrostatic force of attraction or repulsion when placed at a point is called Electric Field.

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Electric Field

ELECTRIC INTENSITY

Electric intensity is the strength of electric field at a point.

Electric intensity at a point is defined as the force experienced per unit positive charge at a point placed in the electric field.

or

It may also be also defined as the electrostatic force per unit charge which the field exerts at a point.

Mathematically,

E=F/q

UNIT

N/C or Volt/m

The force experienced by a charge +q in an electric field depends upon.

1. magnitude of test charge (q)
2. Intensity of electric field (E)

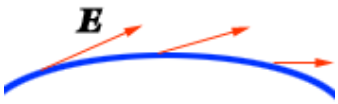
It is a vector quantity. It has the same direction as that of force.

ELECTRIC LINES OF FORCE

In order to point out the direction of an electric field we can draw a number of lines called electric lines of force.

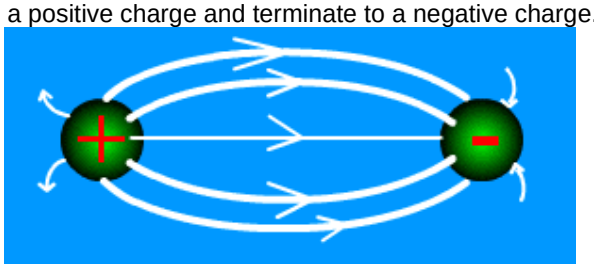
DEFINITION

An electric line of force is an imaginary continuous line or curve drawn in an electric field such that tangent to it at any point gives the direction of the electric force at that point.The direction of a line of force is the direction along which a small free positive charge will move along the line. It is always directed from positive charge to negative charge.

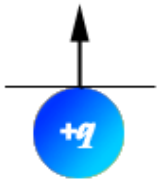


CHARACTERISTICS OF ELECTRIC LINES OF FORCE

- Lines of force originate from a positive charge and terminate to a negative charge.



- The tangent to the line of force indicates the direction of the electric field and electric force.
- Electric lines of force are always normal to the surface of charged body.



- Electric lines of force contract longitudinally.
- They and expand laterally.
- Two electric lines of force cannot intersect each other.
- Two electric lines of force proceeding in the same direction repel each other.
- Two electric lines of force proceeding in the opposite direction attract each other.
- The line of force are imaginary but the field it represents as real.
- There are no lines of force inside the conductor.

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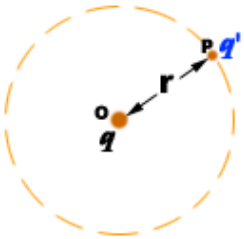
ELECTRIC INTENSITY DUE TO A POINT CHARGE

Consider a point charge q called SOURCE CHARGE placed at a point 'O' in space. To find its intensity at a point 'p' at a distance 'r' from the point charge we place a test charge 'q'.



The force experienced by the test charge q' will be:

$$F = Eq' \text{----}(1)$$

According to coulomb's law the electrostatic force between them is given by:

$$F = \frac{Kqq'}{r^2}$$

We know that:

$$E = \frac{F}{q'}$$

Or

$$E = \frac{1}{q'} \times F$$

Putting the value of 'F' we get :

$$E = \frac{1}{\cancel{q'}} \times \frac{Kq\cancel{q'}}{r^2}$$

$$E = \frac{Kq}{r^2}$$

But $K = \frac{1}{4\pi\varepsilon_o}$

$\because$

$$\boxed{E = \frac{1}{4\pi\varepsilon_o} \times \frac{q}{r^2}}$$

This shows that the electric intensity due to a point charge is directly proportional to the magnitude of charge q and inversely proportional to the square of distance.

EFFECT OF DIELECTRIC MEDIUM

If there is a medium of dielectric constant (ε_r) between the source charge and the field charge, intensity at a point will decrease ε_r times i.e.

$$\boxed{E = \frac{1}{4\pi\varepsilon_o\varepsilon_r} \times \frac{q}{r^2}}$$

VECTORIAL FORM

$$\boxed{\vec{E} = \frac{1}{4\pi\varepsilon_o\varepsilon_r} \times \frac{q}{r^2}\vec{r}}$$

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ELECTRIC FLUX

GENERAL MEANING OF ELECTRIC FLUX

In common language flux refers to the flow or stream of any thing from one point to another point. In the similar way electric flux is the total number of lines of force passing through a surface.

PHYSICAL MEANING OF ELECTRIC FLUX

In physical sense, electric flux is defined as:

"The total number of lines of force passing through the unit area of a surface held perpendicularly."

MATHEMATICAL MEANING OF ELECTRIC FLUX

Mathematically the electric flux is defined as:

"The dot product of electric field intensity (E) and the vector area (ΔA) is called electric flux."

$$\Delta\phi_e = \vec{E} \cdot \vec{\Delta A}$$

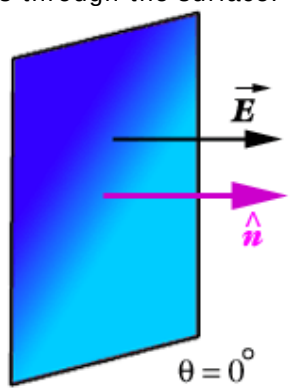
or

$$\boxed{\Delta\phi_e = E\ \Delta A\ \cos\theta}$$

Where θ is the angle between E and ΔA

MAXIMUM FLUX

If the surface is placed perpendicular to the electric field then maximum electric lines of force will pass through the surface. Consequently maximum electric flux will pass through the surface.



$$\phi_e = \vec{E} \cdot \vec{\Delta A}$$

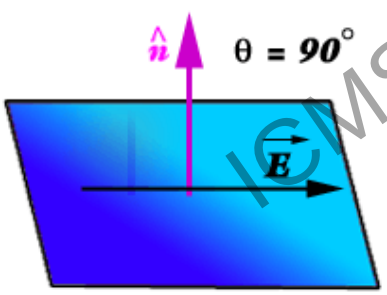
$$\phi_e = E\ \ \Delta A \cos 0^\circ$$

$$\phi_e = E\ \ \Delta A\ (1)$$

$$\boxed{\phi_e = E\ \ \Delta A}$$

ZERO FLUX

If the surface is placed parallel to the electric field then no electric lines of force will pass through the surface. Consequently no electric flux will pass through the surface.



$$\phi_e = \vec{E} \cdot \vec{\Delta A}$$

$$\phi_e = E\ \ \Delta A \cos 90^\circ$$

$$\phi_e = E\ \ \Delta A\ (0)$$

$$\boxed{\phi_e = 0}$$

Flux is a scalar quantity .

UNIT OF FLUX

$$\boxed{\frac{\text{Newton . meter}^2}{\text{Coulomb}}} \quad \text{OR} \quad \boxed{\text{Volt . meter}}$$

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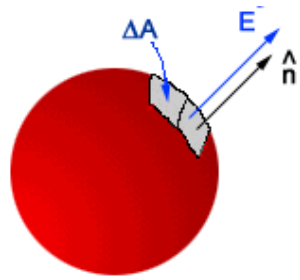
Electric Flux Through a Sphere

Consider a small positive point charge +q placed at the centre of a closed sphere of radius "r".

The relation $\Delta\phi_e = \vec{E} \cdot \vec{\Delta A}$ is not applicable in this situation because the direction of electric intensity varies point to point over the surface of sphere. In order to overcome this problem the sphere is divided into a number of small and equal pieces each of area ΔA. The direction of electric field in

each segment of sphere is the same i.e. outward normal.



Now we will determine the flux through each segment.

Electric flux through the first segment:

$$\Delta\phi_1 = \boldsymbol{E}\ \Delta\boldsymbol{A}\ \boldsymbol{cos}\,\theta$$

but $\theta = 0$

$$\Delta\phi_1 = \boldsymbol{E}\ \Delta\boldsymbol{A}\ \boldsymbol{cos}\,0$$

$$\Delta\phi_1 = \boldsymbol{E}\ \Delta\boldsymbol{A}\ \ (1)$$

$$\Delta\phi_1 = \boldsymbol{E}\ \Delta\boldsymbol{A}\ \ \text{.....}\ (i)$$

Electric flux through the second segment:

$$\Delta\phi_2 = \boldsymbol{E}\ \Delta\boldsymbol{A}$$

Similarly,
Electric flux through other segments:

$$\Delta\phi_3 = \boldsymbol{E}\ \Delta\boldsymbol{A}$$

$$\vdots$$

$$\Delta\phi_n = \boldsymbol{E}\ \Delta\boldsymbol{A}$$

Being a scalar quantity, the total flux through the sphere will be equal to the algebraic sum of all these flux i.e.

$$\phi = \sum_{i=1}^{i=n} \phi_i$$

$$\phi = \sum_{i=1}^{i=n} (\boldsymbol{E}\ \Delta\boldsymbol{A})_i$$

$$\phi = \ \boldsymbol{E} \sum_{i=1}^{i=n} (\Delta\boldsymbol{A})_i$$

But $E = \dfrac{1}{4\pi\varepsilon_o} \bullet \dfrac{q}{r^2}$

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$$\phi = \frac{1}{4\pi\varepsilon_o}\frac{q}{r^2}\sum_{i=1}^{i=n}(\Delta A)_i$$

As

$$\sum_{i=1}^{i=n}(\Delta A)_i = 4\pi r^2$$

(area of sphere)

$$\phi = \frac{1}{4\pi\varepsilon_o}\frac{q}{r^2}\,4\pi r^2$$

$$\phi = \frac{1}{\cancel{4\pi}\varepsilon_o}\frac{q}{\cancel{r^2}}\,\cancel{4\pi r^2}$$

$$\boxed{\phi = \frac{q}{\varepsilon_o}}$$

This expression shows that the total flux through the sphere is $1/\varepsilon_o$ times the charge enclosed (q) in the sphere.
The total flux through closed sphere is independent of the radius of sphere.

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Gauss's Law

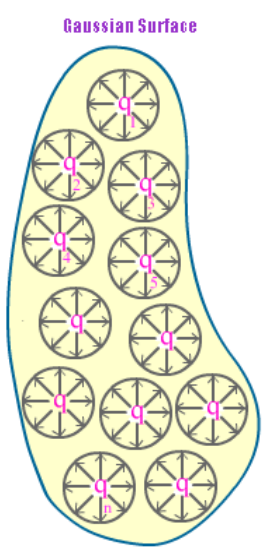
Gauss's law is a quantitative relation which applies to any closed hypothetical surface called Gaussian surface to determine the total flux (Ø) through the surface and the net charge (q) enclosed by the surface.

STATEMENT

"The total electric flux through a closed surface is equal to $1/\varepsilon_o$ times the total charge enclosed by the surface."

PROOF

Consider a Gaussian surface as shown below which encloses a number of point charges $q_1, q_2, q_3 \ldots\ldots q_n$
Draw imaginary spheres around each charge. Now we make use of the fact that the electric flux through a sphere is q/ε_o



Flux due to q_1 will be $Ø_1 = q_1/\varepsilon_o$

Flux due to q_2 will be $Ø_2 = q_2/\varepsilon_o$

Flux due to q_3 will be $Ø_3 = q_3/\varepsilon_o$

Flux due to q_n will be $Ø_n = q_n/\varepsilon_o$

Hence the total flux Øe will be the sum of all flux i.e

$$Ø = Ø_1 + Ø_2 + Ø_3 + Ø_4 \ldots\ldots\ldots + Ø_n$$

$$Ø = q_1/\varepsilon_o + q_2/\varepsilon_o + q_3/\varepsilon_o + \ldots\ldots\ldots + q_n/\varepsilon$$

$$Ø = 1/\varepsilon_o(q_1 + q_2 + q_3 + \ldots\ldots\ldots + q_n)$$

$$Ø = 1/\varepsilon_o \times (\text{total charge})$$

This shows that the total electric flux through a closed surface regardless of its shape or size is numerically equal to $1/\varepsilon_o$ times the total charge enclosed by the surface.

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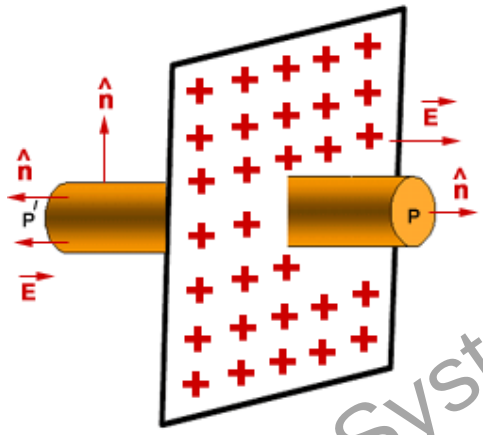
ELECTRIC INTENSITY DUE TO A SHEET OF CHARGES

Consider a plane infinite sheet on which positive charges are uniformly spread.
Let ,
The total charges on sheet = q
Total area of sheet =A
Charge density (σ)= q/A (charge per unit area)
Take two points p and p' near the sheet. Draw a cylinder from P to P'. Take this cylinder as a Gaussian surface. Consider a closed surface in front of cylinder such that p lies at one of its end faces.



The angle between E and normal n to the cylindrical surface is 90 .So the flux through the cylindrical surface:

$$Ø = E\,A\cos\theta$$
$$Ø = E\,A\cos 90$$
$$Ø = E\,A(0)$$
$$Ø = 0$$

The angle between E and normal n at the end of the surface P and P' is 0.hence the flux through one end surface P:

$$Ø_1 = E\,A\cos\theta$$
$$Ø_1 = E\,A\cos 0$$
$$Ø_1 = E\,A\,(1)$$
$$Ø_1 = E\,A$$

Similarly the flux through other end face P':

$$Ø_2 = E\,A$$

Since electric flux is a scalar quantity, therefore, total flux through both surfaces is:

$$Ø_t = \Delta Ø1 + \Delta Ø2$$
$$Ø_t = E\,A + E\,A$$
$$Ø_t = 2EA \text{ .....(i)}$$

According to gauss's law :

Total flux through a closed surface is $1/\varepsilon_o$ x (charge enclosed) i.e.

$$Ø_t = 1/\varepsilon_o \times q \text{.....(ii)}$$

Comparing equations (i) and (ii)

$$2EA = 1/\varepsilon_o \times q$$
$$E = q/\varepsilon_o \times 1/2A$$

or

$$E = q/\varepsilon_o\, 2A$$
$$E = (q/A) \times 1/2\,\varepsilon_o$$

But q/A = σ, therefore,

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$$E = \frac{\sigma}{2\varepsilon_o}$$

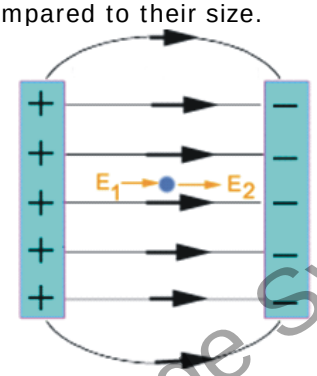
In vector format:

$$\vec{E} = \frac{\sigma}{2\varepsilon_o}\hat{r}$$

Which is the expression for electric intensity due to a infinite sheet of charge.

ELECTRIC INTENSITY BETWEEN TWO OPPOSITELY CHARGED PLATES

Consider two oppositely charged plates placed parallel to each other. Let these plates are separated by a small distance as compared to their size.



Surface density of charge on each plate is 'σ'. Since the electric lines of force are parallel except near the edges, each plate may be regarded as a sheet of charges.

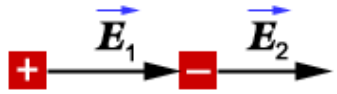
Electric intensity at a point between the plates due to positive plate:

$$E_1 = \frac{\sigma}{2\varepsilon_o}$$

Electric intensity at a point between the plates due to negative plate:

$$E_2 = \frac{\sigma}{2\varepsilon_o}$$

Since both intensities are directed from +ve to –ve plate hence total intensity between the plates will be equal to the sum of E_1 and E_2



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$$E = E_1 + E_2$$

$$E = \frac{\sigma}{2\varepsilon_o} + \frac{\sigma}{2\varepsilon_o}$$

$$E = \frac{\cancel{2}\sigma}{\cancel{2}\varepsilon_o}$$

$$\boxed{E = \frac{\sigma}{\varepsilon_o}}$$

In vector formate

$$\boxed{\vec{E} = \frac{\sigma}{\varepsilon_o}\hat{r}}$$

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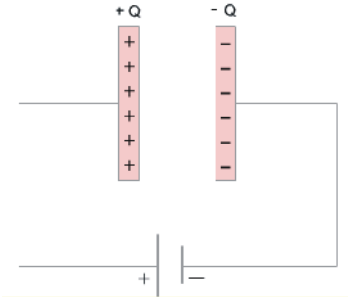
CAPACITOR

CAPACITOR

Capacitor is an electronic device, which is used to store electric charge or electrical energy
A system of two conductors separated by air or any insulating material forms a capacitor as shown below:



WE CANNOT STORE ELECTRIC CHARGE ON A SINGLE CONDUCTOR

The size of a conductor required to store large amount of electric charge becomes very inconvenient because as the charge increases potential of plate also increases. Electric charge generated by a machine can not be stored on a conductor beyond a certain limit as its potential rises to breaking value and the charge starts leaking to atmosphere.

PRINCIPLE OF CAPACITOR

The principle of capacitor is based on the fact that the potential of a conductor is greatly reduced and its capacity is increased without affecting the electric charge in it by placing another earth connected conductor or an oppositely charged conductor in its neighborhood. This arrangement is therefore able to store electric charge.
Capacitor are designed to have large capacity of storing electric charge without having large dimensions.

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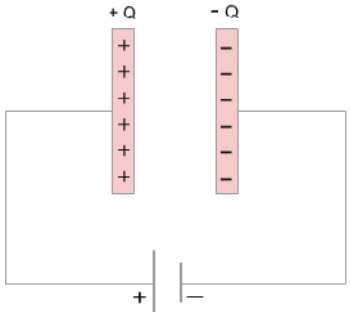
PARALLEL PLATE CAPACITOR

A parallel plate capacitor consists of two conducting plates of same dimensions. These plates are placed parallel to each other. Space between the plates is filled with air or any insulating material (dielectric). One plate is connected to positive terminal and other is connected to negative terminal of power supply. The plate connected to positive terminal acquires positive charge and the other plate connected to negative terminal acquires equal negative charge .The charges are stored between the plates of capacitor due to attraction.



DEPENDENCE OF CHARGE STORED IN A CAPACITOR

Electric charge stored on any one of the plates of a capacitor is directly proportional to the potential difference between the plates . i.e.,

$$Q \alpha V$$

OR

$$Q = (\text{constant})\ V$$

$$Q = CV$$

Where C = capacitance of capacitor

CAPACITANCE OF CAPACITOR

The ability of a capacitor to store electric charge between its plates is its capacity or capacitance.

DEFINITION

The capacitance of a capacitor is defined as:

"The ratio of electric charge stored on any one of the plates of capacitor to potential difference between the plates."

Mathematically

$$C = Q / V$$

UNIT OF CAPACITANCE

In S.I. system unit of capacitance is

Coulomb / volt

OR

Farad

Farad is a large unit therefore in general practice we use small units

(1) uF (microfarad) 1 uF = $1x10^{-6}$ F

(2) uuF (Pico farad) 1 uuF = $1x10^{-12}$ F

CAPACITANCE OF A PARALLEL PLATE CAPACITOR

Consider a parallel plate capacitor as shown below:

Let

The area of each plate = A

The separation between plates = d

Medium = air

Surface density of charge on each plate = σ

The electric field intensity between the plates of capacitor is given by

$$E = \sigma / \varepsilon_o$$

Potential difference between the plates of capacitor can be calculated by the following relation

$$V = Ed$$

Putting the value of "E"

$$V = (\sigma / \varepsilon_o) \times d$$

But $\sigma = Q / A$

$$V = Qd / A.\varepsilon_o$$

$$A\varepsilon_o V = Qd \text{.....(a)}$$

We know that

The electric charge stored on any one of plate of capacitor is

$$Q = CV \text{.....(b)}$$

Putting the value of Q in (a)

$$A\varepsilon_o V = CVd$$

$$Cd = A\varepsilon_o$$

$$C = A\varepsilon_o / d$$

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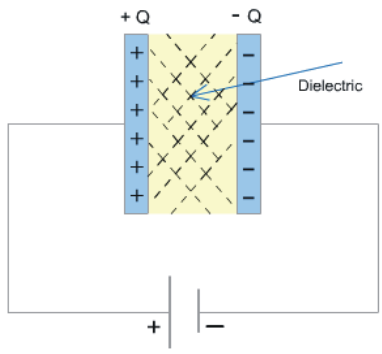
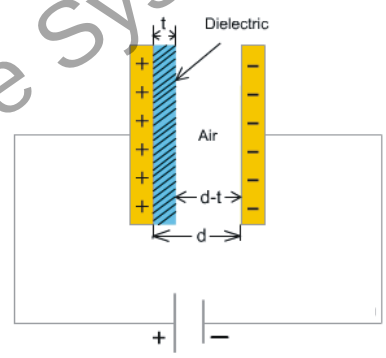
CAPACITANCE IN THE PRESENCE OF DIELECTRIC

1-When dielectric is completely filled between the plates

Let the space between the plates of capacitor is filled with a dielectric of relative permittivity εr.
The presence of dielectric reduces the electric intensity by εr times and thus the capacitance increases by εr time.



1- When dielectric is partially filled between the plates



Electric field without dielectric:

$$E_1 = \frac{\sigma}{\varepsilon_0}$$

Electric field with dielectric:

$$E_2 = \frac{\sigma}{\varepsilon_0 \varepsilon_r}$$

Since potential difference between the paltes is:

$$V = V_1 + V_2$$

But $V = E\,d$

Therefore,

$$V = E_1 d_1 + E_2 d_2$$

As

$d_1 = (d-t)$

$d_2 = t$

$$V = \frac{\sigma}{\varepsilon_0}(d-t) + \frac{\sigma}{\varepsilon_0 \varepsilon_r} t$$

$$V = \frac{\sigma}{\varepsilon_0}\left(d-t + \frac{t}{\varepsilon_r}\right)$$

$$V = \frac{\sigma}{\varepsilon_0}\left\{d + t\left(\frac{1}{\varepsilon_r} - 1\right)\right\}$$

But $\sigma = q/A$

$$V = \frac{q}{A\varepsilon_0}\left\{d + t\left(\frac{1}{\varepsilon_r} - 1\right)\right\}$$

Also $q = CV$

$$V = \frac{CV}{A\varepsilon_0}\left\{d + t\left(\frac{1}{\varepsilon_r} - 1\right)\right\}$$

$$\boxed{C = \frac{A\varepsilon_0}{\left\{d + t\left(\frac{1}{\varepsilon_r} - 1\right)\right\}}}$$

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CONCLUSION

1- Capacitance can be increased by increasing the dimensions of plates.

$$C \propto A$$

2- Capacitance can be increased by decreasing the separation between the plates.

$$C \propto 1/d$$

3- Capacitance of a capacitor increases by the presence of dielectric medium between the plates.

$$C \propto \varepsilon_r$$

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Chapter No. 13

ELECTRIC CURRENT

ELECTRIC CURRENT

"Electric current is defined as the amount of electric charge passing through a cross section of a conductor in unit time."

In other words

"The rate of flow of electric charge through a cross section of a conductor is called Electric Current".

Mathematically

Electric current = electric charge / time

$$I = \frac{Q}{t}$$

Unit of electric current is AMPERE.

1 ampere = 1 coulomb / 1 sec

AMPERE

In S.I system unit of electric current is ampere.

Ampere is defined as:

"Current through a conductor will be 1 ampere if one coulomb of electric charge passes through any cross section of conductor in 1 second."

1 ampere = 1 coulomb / 1 sec

DIRECTION OF CURRENT

There are two types of current.

ELECTRONIC CURRENT

Electronic current flows from negative to positive terminal.

CONVENTIONAL CURRENT

Direction of conventional current is taken from higher potential to the lower potential.

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RESISTANCE

RESISTANCE

Opposition offered by the material of conductor in the flow of electric current is called resistance. Resistance opposes the flow of current through a conductor. Resistance of a conductor is due to the collision of free electrons with the atoms of the conductor.

It is denoted by "R"

FACTORS ON WHICH RESISTANCE DEPENDS

(1) Length of conductor

Resistance of a conductor is directly proportional to the length of conductor.

$$R \propto L \text{.....(a)}$$

(2) Area of cross section of conductor

Resistance of a conductor is inversely proportional to area of cross section of conductor.

$$R \propto 1 / A \text{.....(b)}$$

Combining (a) and (b)

$$R \alpha \frac{L}{A}$$

OR

$$\boxed{R \alpha \rho \frac{L}{A}}$$

Where

ρ = resistivity of material of conductor

RESISTIVITY

Resistivity is an electrical property of material .

It is defined as the resistance of a material or conductor of 1 cubic meter volume.

Or

It is the resistance of a conductor of unit length and unit area.

Or

Resistivity of a conductor is the resistance of 1 meter long conductor whose area of cross section is I meter square

Unit:

ρ **= ohm x m**

Different materials have different values of resistivity. A very high value of resistivity indicates high electrical resistance

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RESISTANCE AND TEMPERATURE

Resistance of a conductor is directly proportional to temperature.

Reason:

With the increase in temperature, vibrational motion of the atoms of conductor increases. Due to increase in vibration, probability of collision between atoms and electrons increases. As a result, resistance of conductor increases.

VARIATION IN RESISTANCE OF A MATERIAL AT DIFFERENT TEMPERATURES:

(1) Increase in resistance of a conductor is directly proportional to original resistance.

$$\Delta R \propto R_1 \text{.....(a)}$$

(2) Change in resistance is directly proportional to change in temperature.

$$\Delta R \propto \Delta T \text{.....(b)}$$

Combining (a) and (b)

$$\Delta R \propto R_1 \Delta T$$

$$\Delta R = \text{(constant) } R_1 \Delta T$$

Here constant = α

$$\Delta R = \alpha R_1 \Delta T$$

Where α = temperature coefficient

As $\Delta R = R_2 - R_1$

and

$\Delta T = T_2 - T_1$

We get

$$R_2 - R_1 = \alpha R_1 (T_2 - T_1)$$

$$R_2 = R_1 + \alpha R_1 (T_2 - T_1)$$

$$R_2 = R_1 \{1 + \alpha T_2 - T_1)\}$$

When $T_1 = 0$ and $T_2 = t$

$$R_t = R_0 [1 + \alpha((t - 0)]$$

$$R_t = R_0 \{1 + \alpha t\}$$

TEMPERATURE COEFFICIENT

Fractional change in resistance per unit original resistance per degree change of temperature is called

temperature coefficient

$$\Delta R = \alpha R_1 \Delta T$$

$$\alpha = \Delta R / R_1 \Delta T$$

UNIT

1/ K OR 1/ ^{0}C

OHM'S LAW

INTRODUCTION

Ohm's law is a quantitative relation between the potential difference across the ends of a conductor and electric current flowing through it.

STATEMENT

According to Ohm's law,

"The electric current passing through a conductor is directly proportional to the potential difference between the ends of conductor, if physical conditions of conductor remain constant."

$$I \alpha V$$

MATHEMATICAL REPRESENTATION

According to Ohm's law,

$$I \alpha V$$

$$I = kV$$

Where K = constant and it is called conductivity of material of conductor.

$$V = I / K$$

or

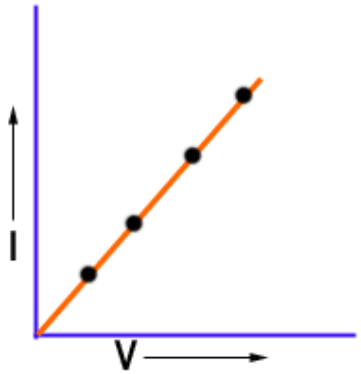
$$V = I \times 1 / K$$

[but 1/K = R (resistance of conductor)]

$$V = I \times R$$

GRAPHICAL REPRESENTATION

Graph between electric current and potential difference is a straight line.



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SERIES COMBINATION OF RESISTORS

CHARACTERISTICS

- In series combination of resistors there is only one path for the flow of electric current.

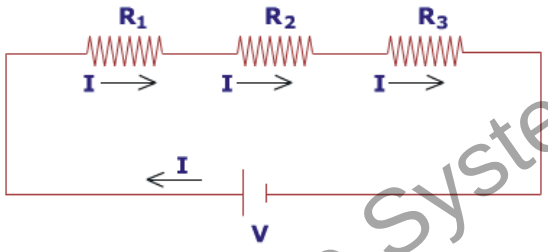
- Electric current passing through each resistor is same.
- Potential difference across each resistor is different and it depends upon the value or resistance.
- Equivalent resistance of circuit is always greater than any of the resistance connected in the circuit.

DISADVANTAGE OF SERIES COMBINATION

In series combination, if one resistance is damaged then the other resistors will not work.

EQUIVALENT RESISTANCE OF CIRCUIT

Consider three resistances R_1, R_4 and R_3 connected to one another in series circuit as shown below.



Let the circuit is connected to a power supply of voltage 'V' and an electric current 'I' is passing through the circuit.

Potential difference across R_1 is V_1
Potential difference across R_2 is V_2
Potential difference across R_3 is V_3
The sum of these Potential differences is equal to 'V'.

$$V = V_1 + V_2 + V_3$$

According to Ohm's law V = IR
Putting the value of V, we get,

$$IR_e = IR_1 + IR_2 + IR_3$$

OR

$$R_e = R_1 + R_2 + R_3$$

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PARALLEL COMBINATION OF RESISTORS

CHARACTERISTICS

- In parallel combination of resistors there are more than only one paths for the flow of electric current.
- Electric current passing through each resistor is different and it depends upon the value or resistance.
- Potential difference across each resistor is the same.
- Equivalent resistance of circuit is always smaller than any of the resistance connected in the circuit.

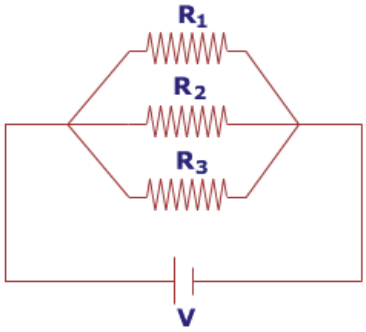
ADVANTAGE OF PARALLEL

COMBINATION

In parallel combination, if one resistance is damaged then the other resistors will work properly because there are more than one path for the flow of electric current.

EQUIVALENT RESISTANCE OF CIRCUIT

Consider the resistance R_1, R_2 and R_3 connected to one another in parallel circuit as shown below:



Let the circuit is connected to a power supply of voltage 'V' and an electric current 'I' is passing through the circuit.

Electric current passing through R_1 is I_1
Electric current passing through R_2 is I_2
Electric current passing through R_3 is I_3
The sum of all three currents is equal to 'I'.

$$I = I_1 + I_2 + I_3$$

According the Ohm's law I = V/R
Putting the value of I, we get,

$$V/R_e = V/R_1 + V/R_2 + V/R_3$$

$$\frac{\cancel{V}}{R_e} = \cancel{V}\left[\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right]$$

$$\boxed{\frac{1}{R_e} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

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ELECTROMOTIVE FORCE

DEFINITION

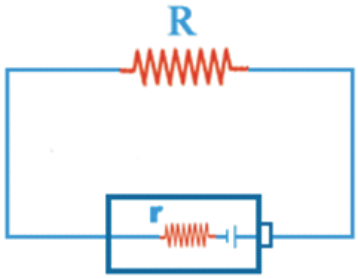
We know that when electric current is passed through a conductor, energy is dissipated in the form of heat energy. Hence for maintaining a steady current continuous source of energy is required. This source when connected across the resistance maintains a P.D of constant value across its ends and hence supplies energy at the rate at which it is dissipated. The devices such as dry cell, battery or electric generator are the source of emf .This strength of these sources is known as emf.

Suppose "q" coulomb of charge requires an amount of work "W" joule to be transported through the source then emf in volts is given by:

$$EMF = W / q$$

EMF AND TERMINAL POTENTIAL DIFFERENCE

Consider a source of emf connected to a resistance “R” through which a steady current “I” flows as shown below:



Let the emf of source is E

Potential difference across resistance R is V

We know that

A source of emf also has some resistance which is due to electrolytes and electrodes. Therefore some useful energy of emf-source is used in passing the current through the source.

Let the internal resistance of the source is “r”

Potential drop across emf source = V_r

Since,

$$E = V + Vr$$

OR

$$V = E - Vr$$

As $Vr = Ir$

$$\boxed{V = E - Ir}$$

Where V = terminal potential difference

When no current is drawn from the source then emf and terminal potential difference are equal.

If the current is passing through the circuit then the terminal potential difference is less than that of the emf of the source.

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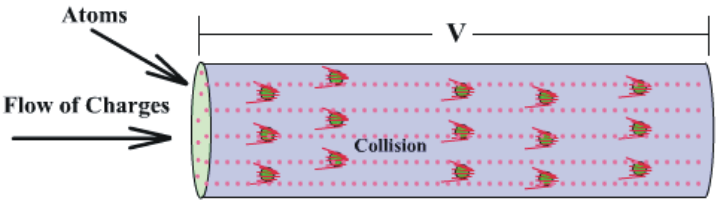
Power Dissipation in Resistors

When an electric current passes through a conductor, some useful electrical energy is dissipated in the form of heat energy. This loss of electrical energy is due to the collision of charges with the atoms of conductor. Loss of electrical energy in unit time is referred to as “power dissipation in resistor”.



EXPRESSION FOR POWER LOSS

Let ’q’ amount of electric charge passes through a conductor in unit time, the electric current through the conductor is given by:

$$I = q/t$$

Or

$$q = I \times t \text{ ..... (1)}$$

During the flow of electric current energy lost in the form of heat is equal to q x V, where V is the potential difference across the ends of conductor.

$$\text{Energy lost} = q \times V$$

Putting the value of q, we get

Energy lost = I x t x V

Energy lost/t = VI

But Energy /t = Power

Power = VI

POWER LOSS IN TERMS OF CURRENT AND RESISTANCE

According to Ohm's law V = IR. putting the value of V, we get

Power = (IR)I

Power = I^2R

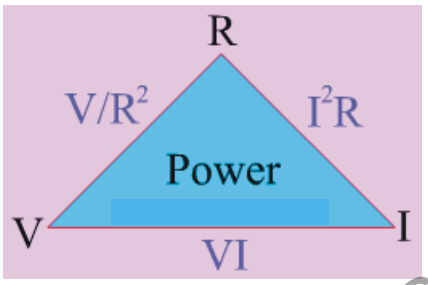
POWER LOSS IN TERMS OF RESISTANCE AND POTENTIAL DIFFERENCE

As power = VI and according to Ohm's law I = V/R, putting the value of i, we get

Power = VI

Power = V (V/R)

Power = V^2/R



UNIT OF POWER

In SI system unit of power is Watt.

Other large units are:

1. Kilowatt KW (1000 watt)
2. Megawatt W(10^6 watt)

Chapter No. 14

MAGNETIC FLUX

DEFINITION

Magnetic flux ($\Delta\phi$) is equal to total number of magnetic lines of force passing through an area 'A' of any shape.

EXPLANATION

Consider an area 'A', placed in a magnetic field. Let this area is divided into small segments each of area ΔA.

Flux through ΔA is the product of area and the normal component of field B i.e.

$$\Delta\phi = BCos\theta.\Delta A$$

Or

$$\Delta\phi = B.\ \Delta A$$

Now flux over whole area A is the sum of fluxes through all elements ΔA i.e.

$$\phi = \Delta\phi_1 + \Delta\phi_2 + \Delta\phi_3 + ...$$

$$\phi = B_1.\ \Delta A_1 + B_2.\ \Delta A_2 + B_3.\ \Delta A_3 + ...$$

Or

$$\phi = \Sigma\ B.\ \Delta A$$

Unit of magnetic flux is WEBER.

FLUX DENSITY

DEFINITION:

It is the number of magnetic lines of force passing through unit area of a surface. It is denoted by

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(B). Flux through an area A is given by.

$$\phi = \Sigma B.\ \Delta A$$

This is the relation b/w flux density (B) and magnetic flux (ϕ).

Taking B to be uniform.

$$\phi = B\Sigma\ \Delta A$$

or

$$\phi = B.A$$

or

$$B = \phi/A$$

Unit of B is weber/m^2 or Tesla.
Flux density over a small element of area taken perpendicular to the field is magnetic field of indication. i.e.

$$B = \Delta\phi/\Delta A$$

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DETERMINATION OF e/m OF AN ELECTRON

INTRODUCTION

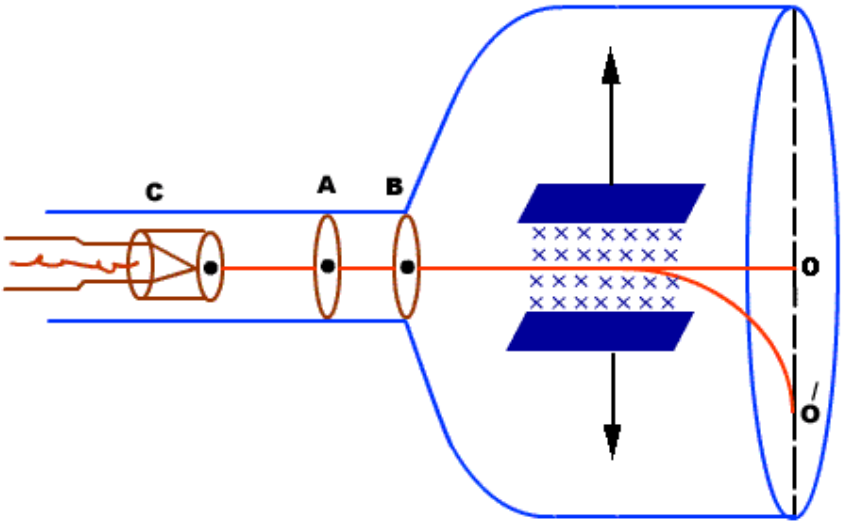
J.J Thomson was the first scientist who measured charge to mass ratio (e/m) of an electron.

PRINCIPLE

When a narrow beam of charged particles are projected at constant speed (v) across a magnetic field in a direction perpendicular to the field, the beam of particles experiences a force, which makes them move in a circular path.

APPARATUS

It consists of a highly evacuated glass tube, fitted with electrodes. Electrons are produced by heating a tungsten filament electrically. Electrons are made to accelerate and form a beam by passing through discs A and B. They are passed through electric and magnetic field. Finally they fall on zinc sulphide screen.



THEORY

Actually electrons moving side ways are also directed towards the screen by applying a –ve potential on a hollow cylinder (c) open on both sides surrounding the filament. Electrons are accelerated by applying a potential difference of above 1000 V between the filament and disc A. A further potential difference of 500 V is applied between the discs A and B. The arrangement focuses the beam to the hole of the disc B from where it is further proceeds to a straight line. When beam of electrons enters a magnetic field it moves in a circular track. The force experienced by the electron is

$$F_m = evB \text{--------} (1)$$

This magnetic field provides necessary centripetal force to electron so that it follows a circular path.

$$\textbf{i.e. } F_m = F_c$$

$$evB = mv^2/r$$

$$eB = mv/r$$

$$e/m = v/Br \text{ -----} (2)$$

By knowing the values of v, B and r, value of e/m can be determined.

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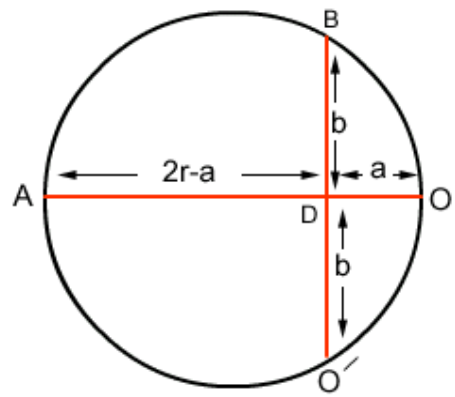
RADIUS OF CURVATURE OF PATH

If r is the radius of curvature of circular path, 'a' is the distance b/w 'O' and 'O/', and 'b' is the distance b/w electron gun and screen then by using the property of chord:

$$AD \times OD = BD \times DO$$

$$(2r-a)(a) = b.b$$

$$2ra-a^2 = b$$



Since 'a' is very small as compared to '2r', so we neglect 'a^2'.

$$2ra = b^2$$

$$r = b^2/2a$$

DETERMINATION OF THE VELOCITY (FIRST METHOD)

The electrons are first accelerated by applying a potential (V) b/w discs A and B before entering the magnetic field.

$$K.E = V.e$$

Or

$$1/2mv^2 = Ve$$

$$v = (2Ve/m)^{1/2}$$

Putting the value of v in eq. (2)

$$e/m = v/Br$$

$$e/m = (2Ve/m)^{1/2}/Br$$

Squaring on both sides

$$e^2/m^2 = 2Ve/m/B^2r^2$$

or

$$e/m = 2Ve/B^2r^2$$

PARTICLES SELECTOR METHOD

This is a more accurate method as compared to the above method. In this method, the beam is passed through crossed electric and magnetic field. The electric field is so adjusted that the light spot comes back to 'O' from 'O/'. i.e. electron beam passes and straight without deflection.

Force on electron by electric field

$$F_e = Ee$$

Force on electron by magnetic field

$$F_m = Bev$$

Since both forces balance each other

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$$F_m = F_e$$

$$Bev = Ee$$
$$V = E/B$$

Putting the value in eq. (2)

$$e/m = v/Br$$

$$e/m = E/B/Br$$

$$e/m = E/B^2r$$

NUMERICAL VALUE OF e/m

After substituting the values we get

$$e/m = 1.75888x10^{11}\ C/Kg$$

BIOT SAVART LAW

BIOT SAVART LAW

Consider a long straight conductor carrying current I. Then magnetic field is in the form of circle.

BIOT SAVART found that the magnitude of field B is directly proportional to twice of current I and inversely proportional to the distance r.

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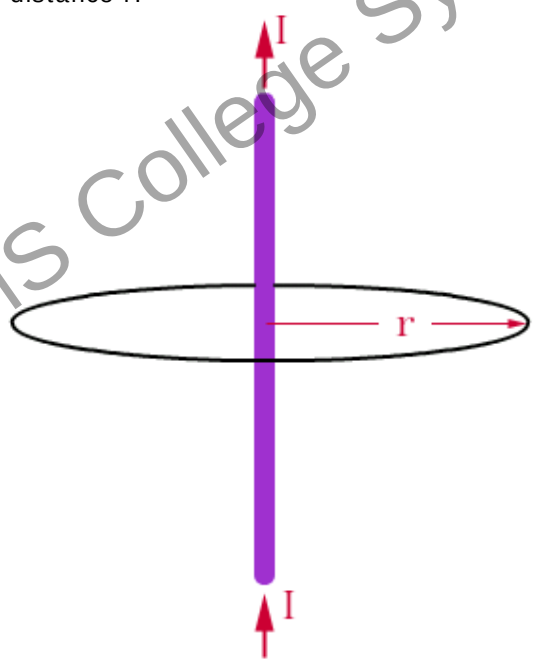

B α 2I

And

B α 1/r

B α 2I/r

$$B = \mu_o/4\pi.2I/r$$

μ_o is called permeability of free space.
$\mu_o / 4\pi$ is proportionality constant. Its value is 10^{-7}.

AMPERE'S LAW

STATEMENT:

This law states:

"The sum of products of tangential component of B and length element Δl of a closed curve is μ_o times the current enclosed."

μ_o = permeability of free space.

Its value is $4\pi * 10^{-7}$.

Its unit is Henry/m^2.

Mathematically.

$$\Sigma(B.\Delta l) = \mu_o I$$

PROOF OF AMPERE'S LAW

Let the circular field B be divided in to small elements Δl. Now tangential component of B

$$B_x = B\cos\theta$$

Multiplying length element Δl with tangential component of B, we have,

$$\mathbf{B.\ \Delta l = B\cos\theta.\ \Delta l}$$

But, θ is negligible i.e. $\theta = 0$

$$\mathbf{B.\ \Delta l = B\cos(0^o).\ \Delta l}$$

$$\mathbf{B.\ \Delta l = B\ (1)\ .\ \Delta l}$$

$$\mathbf{B.\ \Delta l = B.\ \Delta l}$$

For the complete curve, the sum of their products will be,

$$\mathbf{\Sigma B.\ \Delta l = \Sigma B.\ \Delta l}$$

$$\mathbf{= B\Sigma.\ \Delta l}$$

$$\mathbf{but,\ B = \mu_o/4\pi.2I/r}$$

$$\mathbf{and\ \Sigma\Delta l = 2\pi r}$$

$$\mathbf{\Sigma B.\Delta l = \mu_o/4\pi.2I/r} \times \mathbf{2\pi r}$$

$$\mathbf{\Sigma B.\Delta l = \mu_o} \times \mathbf{I}$$

This is mathematical form of Ampere's law.

MAGNETIC FIELD OF INDUCTION DUE TO SOLENOID

SOLENOID

A solenoid is a long tightly wound cylindrical coil of wire.

FIELD DUE TO SOLENOID

When a current is passed through a solenoid the magnetic field is produced, which is strong and uniform inside, while it is negligibly weak outside.

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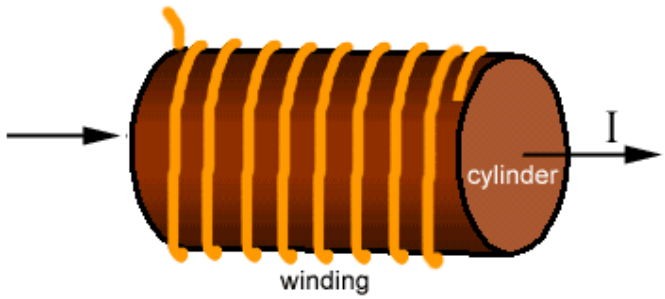

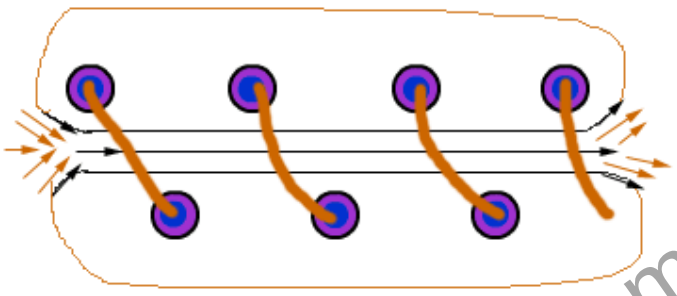

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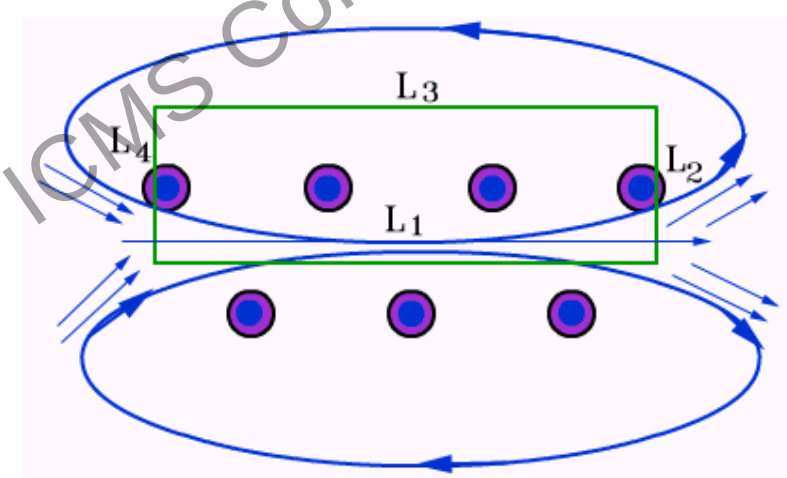
EXPRESSION FOR FLUX DENSITY (B)

To calculate B consider a rectangular path a, b, c and d. The path consists of for length elements l_1, l_2, l_3 and l_4. Let us calculate the product $(B.\Delta l)$ for each element.

For element l_1



$$(B.\Delta l)_1 = Bl_1 Cos\theta$$

Since B is along the axis of l_1. i.e. $\theta = 0$

$$(B.\Delta l_1) = Bl_1 Cos0$$

$$(B.\Delta l_1) = Bl_1(1)$$

$$(B.\Delta l_1) = Bl_1$$

For element l_2:

$$(B.\Delta l)_2 = Bl_2 Cos\theta$$

Since l_2 is perpendicular to B i.e. $\theta = 90^o$

$$(B.\Delta l)_2 = Bl_2 Cos90^o = Bl_2 (0) = 0$$

For element l_3:

$$(B.\Delta l)_3 = Bl_3 Cos\theta$$

Since B is negligible i.e. B = 0 outside the coil.

$$(B.\Delta l)_3 = 0.\ l_3 Cos\theta$$

$$(B.\Delta l)_3 = 0$$

For element l_4:

$$(B.\Delta l)_4 = Bl_4 Cos\theta$$

Since l_4 is perpendicular to B i.e. $\theta = 90^o$.

$$(B.\Delta l)_4 = Bl_4 Cos90^o = Bl_4(0) = 0.$$

Now, applying ampere's circuital law:

$$\Sigma (B.\Delta l)_n = \mu_o \text{ (current enclosed)}$$

$$B.l_1 + 0 + 0 + 0 = \mu_o \text{ (current enclosed)}$$

$$B.l_1 = \mu_o \text{ (current enclosed)}$$

Now, if number of turns per unit length = n
And if current in each turn = I
Then current enclosed by the loop abcda = nIl_1.

$$B.l_1 = \mu_o (nIl_1)$$

$$B = \mu_o nI$$

This is the expression for flux density of solenoid. It shows,

B is uniform with in a long solenoid.

The direction of B is along the axis of solenoid.

FIELD DUE TO A CURRENT IN TOROID

TOROID

A toroid is a solenoid wound on a circular support.

FIELD IN TOROID

When a current is passed, circular strong uniform magnetic field is setup inside the coil. The field outside the turns of toroid is zero.

EXPRESSION FOR B

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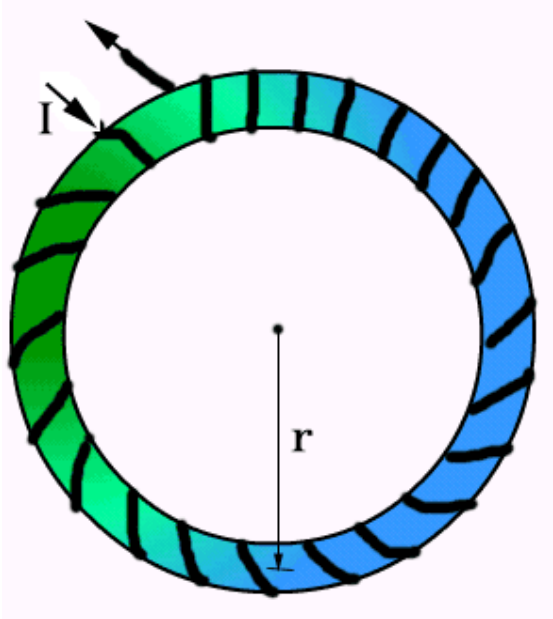
To compute B, consider a circular loop of radius 'r'. Let the length of loop be divided in to a number of very small elements (Δl).



Now for each element.

$$(B.\Delta l) = B\Delta l\cos\theta$$

But as B is circular and its direction is parallel to Δl. i.e. $\theta = 0$

$$(B.\Delta l) = B.\Delta l\cos 0$$

$$(B.\Delta l) = = B.\Delta l\ (1)$$

$$(B.\Delta l) = B.\Delta l$$

Now applying Ampere's law:

$$\Sigma(B.\Delta l)_n = \mu_o\ (\text{current enclosed})$$

As B is constant for all element Δl.

$$B\ \Sigma(\Delta l)_n = \mu_o\ (\text{current enclosed})$$

But $\Sigma(\Delta l)$ = total length of circular loop = $2\pi r$.

$$B.2\pi r = \mu_o\ (\text{current enclosed})$$

Now if total number of turns = N and current through each turns = I

Current enclosed by toroid = NI

$$B.2\pi r = \mu_o.\ NI$$

$$B = \mu_o\ NI / 2\pi r$$

This equation shows that B is not uniform with in the coil at it varies with 'r'.

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A.C GENERATOR

DEFINITION

A Generator is a device which converts mechanical energy into electrical energy.

WORKING PRINCIPLE

A.C Generator works on the principle of electromagnetic induction (motional emf). In generator an induced emf is produced by rotating a coil in a magnetic field. The flux linking the coil changes continuously hence a continuous fluctuating emf is obtained.

CONSTRUCTION

A.C Generator consists of the following parts.

Powerful field magnet with concave poles.

Armature:

It is a rectangular coil of large number of turns of wire wound on laminated soft-iron core of high permeability and low hysteresis loss.

Slip rings:

The ends of the coil are joined to two separate copper rings fixed on the axle (S1 & S2).

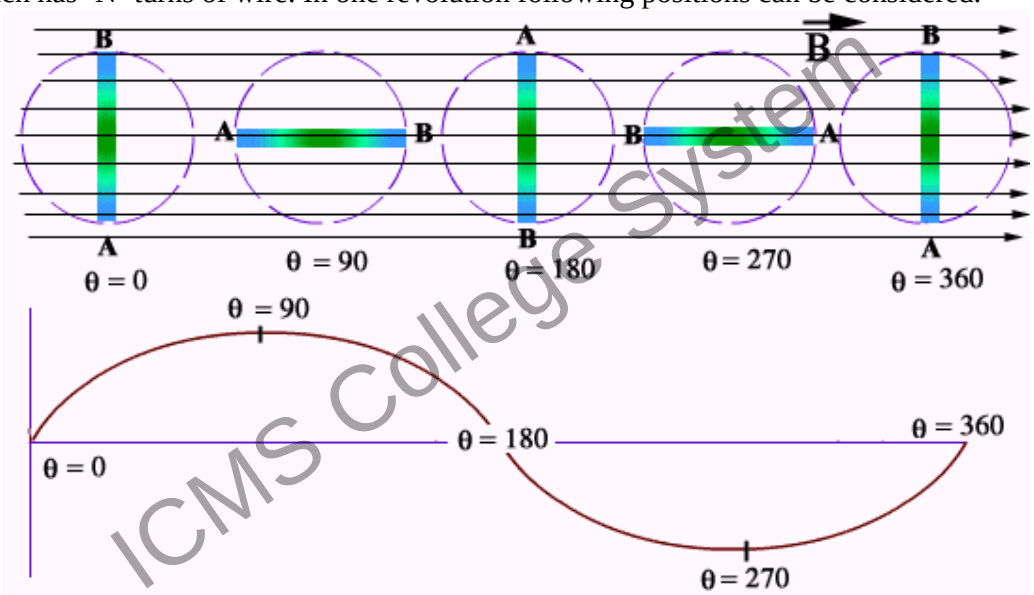
Carbon brushes:

Two carbon brushes remain pressed against each of the rings which form the terminals of the external circuit.

Diagram.

WORKING

In order to determine the magnitude and direction of induced e.m.f, let us consider the different positions of the coil which has 'N' turns of wire. In one revolution following positions can be considered.



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When initially coil is vertical, the length arms AC and BD are moving parallel to the lines of force maximum number of lines link the coil, but rate of change of flux is zero, hence emf is zero.

As the coil moves from this position, sides AC and BD begin to cut the lines of force and induced emf is setup till it is maximum when the coil is horizontal. It has rotated 90°, 1st quarter is completed.

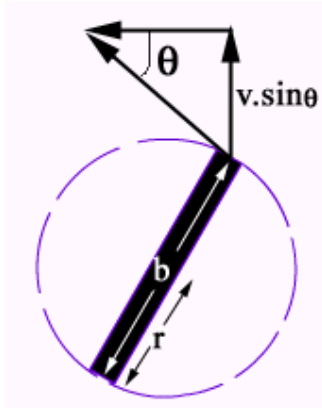
Further rotation decreases the value of emf, until at the end of 2nd quarter, when coil is vertical, it has rotated 180°, the emf is again zero.

As the coil rotates further from position 3 to position 4, an emf is again induced, but in reverse direction, because AC and BD are cutting the magnetic lines in opposite direction. The reverse emf reaches to –ve peak value at the end of 3rd quarter. The coil is horizontal and angle of rotation is 270°.

On further rotation, the emf again decreases and becomes zero when the coil returns back to its original position after rotating 360°.

This shows that the coil of generator produces induced emf which reverse its direction 2*f times in one

cycle. Where f = frequency of rotation of coil.



EXPRESSION FOR EMF IN A.C. GENERATOR

Consider a coil ABCDA of 'N' turns rotating in a uniform magnetic field B with a constant angular speed 'ω'. Let the length of the coil is 'l' and its breadth is 'b'.

To calculate emf in sides AC and BD we proceed as follows:

$$\text{Motional emf} = BvlSin\theta$$

$$\text{Emf in side AC} = BvlSin\theta = \xi_1$$

$$\text{Emf in side BD} = BvlSin\theta = \xi_2$$

$$\text{Emf induced in the coil} = \xi_1 + \xi_2$$

$$= BvlSin\theta + BvlSin\theta$$

$$\xi = 2\,BvlSin\theta$$

If coil has 'N' turns, emf will increase N times

$$\xi = 2\,BvlNSin\theta \text{ ––––(1)}$$

If angular velocity of coil is 'ω' and it takes time 't' to cover angle θ then

$$\theta = \omega t \text{ also}$$

$$V = r\omega \text{ and } r = b/2$$

$$V = b/2\omega$$

Putting the value of q and V in eq. (1)

$$\xi = 2B\,(b/2\omega)lNsin(\omega t)$$

$$\xi = \omega B(b*l)sin(\omega t)$$

$$\xi = NB\omega(b.l)sin\omega t$$

$$\xi = NB\omega Asin\omega t \text{ –(2)}$$

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this is the expression for the induced emf in the coil of an A.C generator at any instant.

If f = no. of rotation per sec. Then we have $\omega=2\pi f$

$$\xi = V = NB\omega A\sin(2\pi ft) – (3)$$

for maximum emf $\theta = 90^o$ or 270°

or $2\pi ft = \pi/2$ or $3\pi/2$

and $\sin 90^o = \sin \pi/2 = +1$

$\sin 270^o = \sin 3\pi/2 = -1$

$$\xi_o = V_o = NB\omega A(1)$$

$$\xi_o = V_o = +- NB\omega A$$

+- = shows direction of induced current

Relation b/w ξ and ξ_o

$$\xi = NB\omega A\sin(2\pi ft)$$

$$\xi = \xi_o\sin(2\pi ft)$$

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ELECTROMAGNETIC INDUCTION- LAWS OF ELECTROMAGNETIC INDUCTION

DEFINITION

In 1830 Joseph Henry and Faraday observed that an E.M.F. is setup in a coil placed in a magnetic field whenever the flux through the coil changes. This effect is called Electromagnetic Induction. If the coil forms a part of a close circuit, the E.M.F. causes a current to flow in the circuit.

E.M.F. setup in the coil is called "induced E.M.F" and the current thus produced is termed as "Induced Current".

Experiments show that the magnitude of E.M.F. depends on the rate at which the flux through the coil changes. It also depends on the number of turns on the coil.

There are various ways to change magnetic flux of a coil such as;

(1) By changing the relative position of the coil with respect to a magnet.

(2) By changing current in the coil itself.

(3) By changing current in the neighbouring coil.

(4) By changing area of a coil placed in the magnetic field etc.

FARADAY'S LAW OF ELECTROMAGNETIC INDUCTION

Faraday was the first scientist who performed a number of experiments to discover the facts and figures of electromagnetic induction, he formulated the following law:

When magnetic flux changes through a circuit, an emf is induced in it which lasts only as long as the change in the magnetic flux through the circuit continues.

Quantitatively, induced emf is directly proportional to the rate of change of magnetic flux through the coil. i.e.

$$\text{Average emf} = -N\Delta\phi/\Delta t$$

Where N = number of turns in the coil.

The negative sign indicates that the induced current is such that the magnetic field due to it opposes the magnetic flux producing it.

LENZ'S LAW

Lenz's law infact describes that in order to produce an induced emf or induced current some external source of energy must be supplied otherwise no current will induce.

Lenz's law states that"

"The direction of induced current is always such as to oppose the cause which produces it".

That is why a –ve sign is used in Faraday's law.

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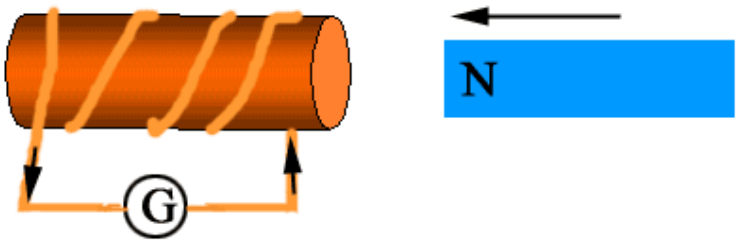
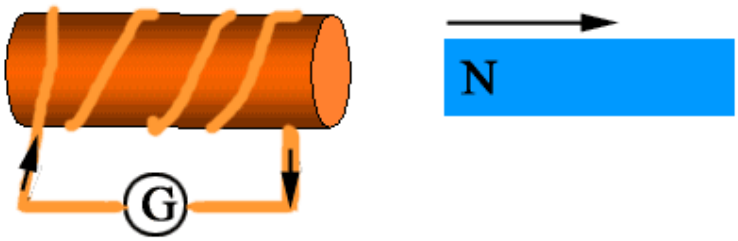
EXPLANATION

Consider a bar magnet and a coil of wire.

a. When the N-pole of magnet is approaching the face of the coil, it becomes a north face by the induction of current in anticlockwise direction to oppose forward motion of the magnet.



b. When the N-pole of the magnet is receding the face of the coil becomes a south pole due to a clockwise induced current to oppose the backward motion.



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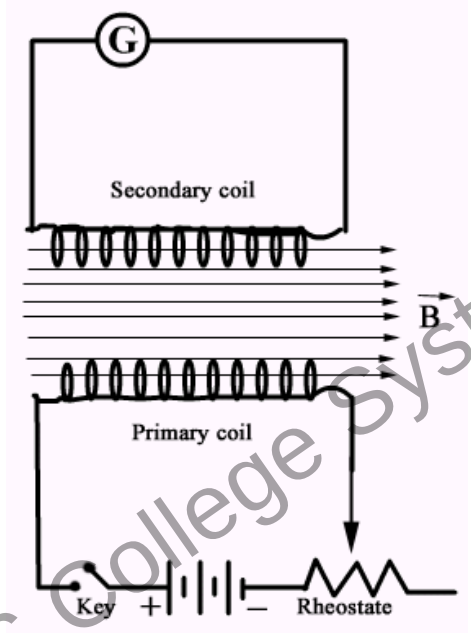
MUTUAL INDUCTION

DEFINITION

It is the phenomenon in which a change of current in one coil causes an induced emf in another coil placed near to the first coil. The coil in which current is changed is called primary coil and the coil in which emf is induced is called secondary coil.

EXPLANATION

Consider two coils placed near each other as shown in figure. When current is passed through the primary coil, magnetic flux is produced. This magnetic flux is also linked with the secondary coil. If the current is changed by varying the resistance in the primary circuit, the magnetic flux also change. As this changing flux is linked with the secondary coil, it induces an emf in it. This phenomenon of inducing emf in a coil by changing current in another coil is known as mutual inductance.



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MATHEMATICAL REPRESENTATION

Emf induced by mutual induction phenomenon is directly proportional to the change of electric current in the primary coil.

$$(emf)_s \propto -\Delta I_p/\Delta t$$

$$(emf)_s = -M\, \Delta I_p/\Delta t$$

where M = mutual inductance of two coils.

MUTUAL INDUCTANCE

Mutual inductance is defined as the ratio of emf induced in the secondary coil to the rate of change of electric current in the primary coil.

$$M = (emf)_s/\Delta I_p/\Delta t$$

Value of 'M' depends upon the number of turns of secondary coil, their cross-sectional area and their closeness to each other.

Unit of mutual inductance is Henry.

HENRY

The mutual inductance of two coils is one Henry if a current at the rate of one ampere per second in the

primary causes an induced emf of one volt in the secondary.

SELF INDUCTION

SELF INDUCTION

Self induction is that phenomenon in which a change in electric current in a coil produces an induced emf in the coil itself.

MATHEMATICAL REPRESENTATION:

Self induced emf in a coil is directly proportional to the rate of change of electric current in the coil.i.e.

$$\text{Emf a} - \Delta I/\Delta t$$

$$\text{Or emf} = -L\,\Delta I/\Delta t$$

Where, L = self inductance of the coil.

SELF INDUCTANCE

Self inductance of a coil is defined as the ratio of self-induced emf to the rate of change of current in the coil.

$$\text{Self inductance} = \text{emf}/\ \Delta I/\Delta t$$

It is denoted by 'L' and it depends upon the physical characteristics of the coil.

Unit of self inductance is Henry.

HENRY

The self inductance of a coil is one henry if a current change of one ampere per second through it produces an emf of one volt in it.

1 henry = 1volt/1amp/sec

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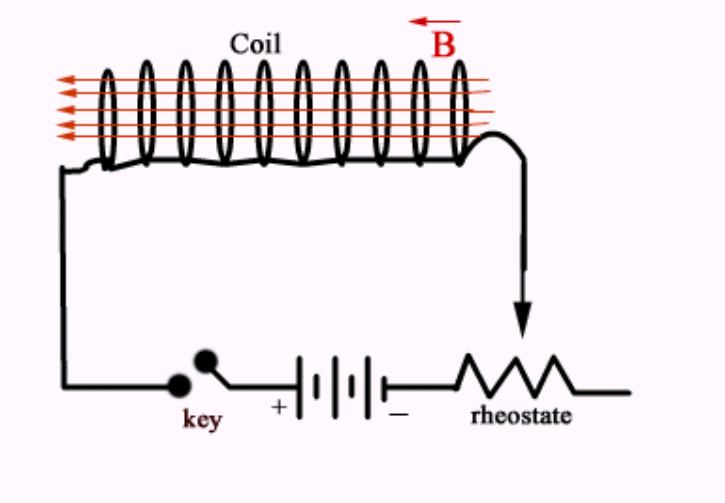
EXPLANATION OF SELF INDUCTION

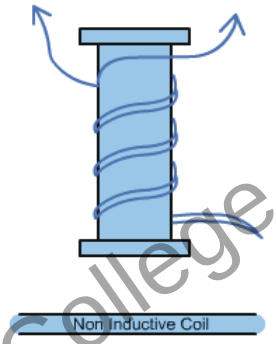
Consider a coil connected to a battery through a rheostat as shown in figure. The current through the coil produces a magnetic flux which links with the coil itself. If we vary the resistance in the circuit, the current through the coil changes and the magnetic flux through the coil also change. This change in flux indicates an emf in the coil itself. Such an emf is called self-induced emf and the phenomenon is called self induction.



NON INDUCTIVE WINDING

In electrical devices which are based on the principle of wheat stone bridge, self inductance imparts problems which is the main cause in the incorrect measurement of resistance and potential difference. Due to self induced EMF the needle of measuring device vibrates and the equilibrium is delayed.

To minimize their self inductance, coils of bridge and resistance boxes are so wound as to set up extremely small magnetic fields. The wire is doubled back on itself before being coiled up. Such coil is said to be non-inductive.



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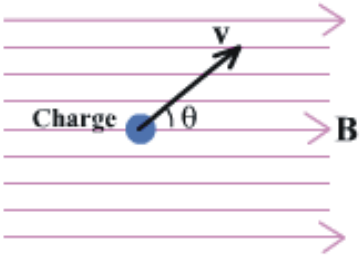
In this type of winding, current flows in opposite directions in double wires and consequently the negative flux produced by the two wires is neutralized.

FORCE ON A CHARGE MOVING IN UNIFORM MAGNETIC FIELD

When a charged particles moves across a magnetic field, a magnetic force is experienced by the charged particle.
The magnitude of force on the charge depends on the following factors:



- Magnetic force is directly proportional to the magnitude of charge.

$$F \alpha q$$

- Magnetic force is directly proportional to the velocity of the charged particle.

$$F \alpha V$$

- Magnetic force is directly proportional to the intensity of magnetic field or magnetic flux density.

$$F \alpha B$$

- Magnetic force is directly proportional to the sinθ

$$F \alpha \sin\theta$$

Combining above statements:

$$F \alpha qVB\sin\theta$$

OR

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

$$\vec{F} = (constant)\, q(\vec{V} \times \vec{B})$$

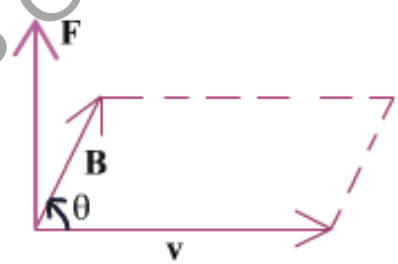
Here the value of constant is unity i.e. 1

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

$$\vec{F} = (1)\, q(\vec{V} \times \vec{B})$$

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

The direction of force will be perpendicular to the plane formed by B and v.



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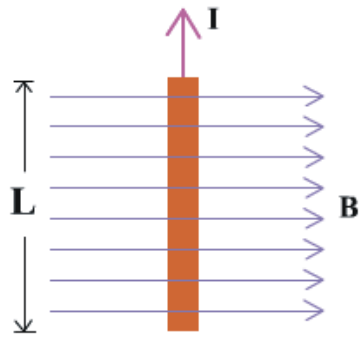
FORCE ON A CURRENT CARRYING CONDUCTOR PLACED IN A UNIFORM MAGNETIC FIELD

Consider a conductor of length “L”, area of cross section “a” placed in a uniform magnetic field of “B”. Let there are “n” number of charges (e) per unit volume and an electric current “I” is passing through it.



Volume of conductor = V = area x length = a x L
Number of electrons = N = n . Volume
Charge on each electron = e
Total charge = q= Ne
We know that the force experienced by a charge in a uniform magnetic field is

Putting the value of "q"

$$F = Ne\ (vBSin\theta)$$
$$F = nV.\ e(vBSin\theta)$$
$$F = ne\ .\ aL\ (vBSin\theta)$$
$$F = naLe\ (v\ B\ Sin\theta)$$

Now consider the length of conductor (L) as a vector quantity in the direction of velocity vector.

$$F = nave(L_v B\ Sin\theta)$$
$$F = nave(LB\ Sin\theta)$$

Since
S = vt
v = s / t
v = L / t
Putting the value of v

$$F = na(L/t)e\ (L\ B\ Sin\theta)$$
$$F = naLe/t\ (L\ B\ Sin\theta)$$

Since naLe = q
Therefore,

$$F = q/t\ (L\ B\ Sin\theta)$$

Also q / t = I

$$F = I\ (L\ B\ Sin\theta)$$
$$F = B\ I\ L\ Sin\theta$$

The expression clearly indicates that the force acting on the wire when placed in a uniform magnetic field is perpendicular to the plane formed by the L and B. i.e. F is perpendicular to L and also perpendicular to B.

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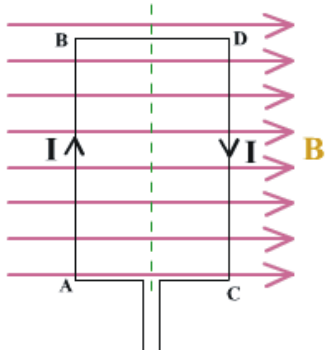
TORQUE PRODUCED IN A CURRENT BEARING COIL IN A UNIFORM MAGNETIC FIELD

Consider a rectangular coil of wire through which an electric current 'I' is being passed. The coil is placed in a uniform magnetic field of magnitude "B".



The vertical side AB of the coil experiences a force F which is directed perpendicular into the paper. There is an equal and opposite force F on side CD. Since the plane of coil is parallel to the magnetic field therefore there is no force on either side AC and BD.
Force on AB and CD will produce torque in these arms.

Torque on AB

$$\tau_{AB} = r\,F$$

$$\tau_{AB} = \frac{b}{2} F$$

But $F = BIL \sin\theta$

In this case L perpendicular to B i.e. $\theta = 90$, hence

$$F = BIL \quad (1)$$

$$F = BIL$$

$$\tau_{AB} = b/2\,(BIL) \ldots\ldots\ldots\ldots (1)$$

Similarly

$$\tau_{CD} = b/2\,(BIL) \ldots\ldots\ldots\ldots (2)$$

These two torque result in a couple in the coil and the coil starts moving (rotating) in magnetic field. Since both the torque are trying to rotate the coil in the same direction, therefore the total torque produced in the coil will be the sum of all the individuals torque.

$$\tau = \tau_{AB} + \tau_{CD}$$

$$\tau = b/2\,(BIL) + b/2\,(BIL)$$

$$\tau = 2/2\,b\,(BIL)$$

$$\tau = IB\,(Lb)$$

but Lb = area of coil = A

$$\tau = IBA$$

If there are "N" number of turns of wire in the coil then the torque will becomes N times

$$\tau = BINA$$

When the coil makes an angle α with the direction of magnetic field, the torque will become

$$\tau = BINA\cos\alpha$$

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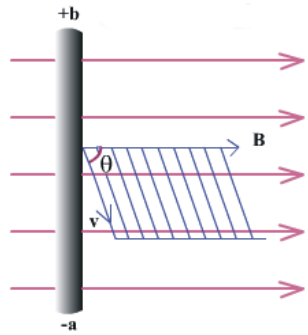
MOTIONAL EMF

When a conductor is moved across a magnetic field, a potential difference is setup across its ends.
This potential difference is called 'motional EMF'.

EXPRESSION FOR MOTIONAL EMF

Consider a wire of length "L" moving across the magnetic field of induction B with a velocity v as shown in diagram



FORCE ON FREE ELECTRON

Each free electron of the wire is moving within the wire and experience a force exerted by magnetic field.

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

For electron we have
q = -e

$$\vec{F} = -e(\vec{V} \times \vec{B})$$

$$\vec{F} = e(\vec{B} \times \vec{V})$$

from b to a

These electrons gradually accumulate at the end "a" and leaving the other end "b". In this way point "b" acquires positive charge and point "a" acquires equal negative charge.
This accumulation of electrons will continue till the force of electric field balances the force due to the motion of wire. Thus a potential difference is setup form point b to point a.

POTENTIAL DIFFERENCE

We know
Potential Difference = work done per unit charge
Let the total charge flows through the wire is "q" therefore,

$$P.D = Work/Charge$$

$$P.D = Fd/q$$

$$P.D = \cancel{e}(\vec{B} \times \vec{V})\, L/\cancel{e}$$

$$P.D = L(\vec{B} \times \vec{V})$$

Or

$$P.D = BVL\sin\theta$$

This is called motional EMF

Therefore, motional EMF = $BVl\sin\theta$

If the wire is moving at right angle to the field, $\theta = 90$

Motional EMF = BVL

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TRANSFORMER

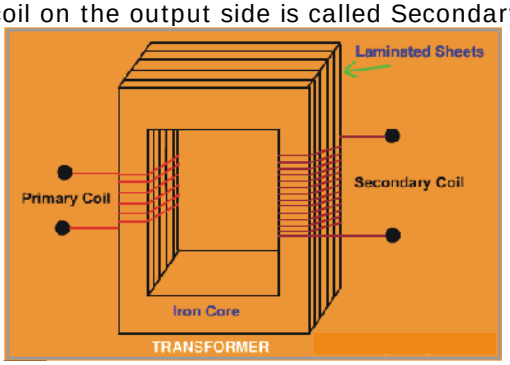
A transformer is a device which is use to convert high alternatic voltage to a low alternatic voltage and vice versa.

WORKING PRINCIPLE

Transformer works on the principle of mutual induction of two coils. When current in the primary coil is changed the flux linked to the secondary coil also changes. Consequently an EMF is induced in the secondary coil.

CONSTRUCTION

A transformer consists of a rectangular core of soft iron in the form of sheets insulated from one another. Two separate coils of insulated wires, a primary coil and a secondary coil are wound on the core. These coils are well insulated from one another and from the core. The coil on the input side is called Primary coil and the coil on the output side is called Secondary coil.



WORKING

Suppose an alternatic voltage source Vp is connected to primary coil. Current in primary will produce magnetic flux which is linked to secondary. When current in primary changes, flux in secondary also changes which results an EMF Vs in secondary. According to Faradays law EMF induced in a coil depends upon the rate of change of magnetic flux in the coil. If resistance of the coil is small then the induced EMF will be equal to voltage applied.

According to Faradays law

$Vp = Np\ \Delta\Phi / \Delta t$ ---------- (1)

Where Np = Number of turns in primary coil.

Similarly, for secondary coil.

$Vs = Ns\ \Delta\Phi / \Delta t$ ---------- (2)

Dividing equation (1) by equation (2)

$Vp / Vs = Np / Ns$

This expression shows that the magnitude of EMF depends upon the number of turns in the coil.

TYPES OF TRANSFORMER

There are two types of transformer:

Step up transformer

Step down transformer

STEP UP TRANSFORMER

A transformer in which Ns>Np is called a step up transformer. A step up transformer is a transformer which converts low alternatic voltage to high alternatic voltage.

STEP DOWN TRANSFORMER

A transformer in which Np>Ns is called a step down transformer. A step down transformer is a transformer which converts high alternatic voltage to low alternatic voltage.

Chapter No. 15

WHEAT-STONE BRIDGE

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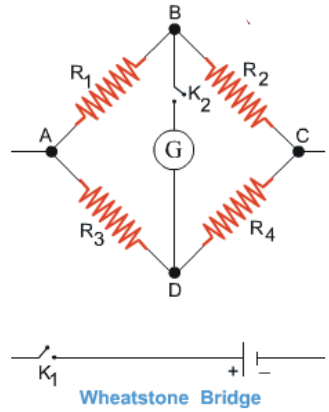
WHEAT-STONE BRIDGE

Wheat stone bridge is an electrical circuit. In wheat-stone bridge four resistance R_1, R_2, R_3 and R_4 are connected end to end with each other to form a closed loop. A sensitive galvanometer "G" connected between their junctions as shown. The circuit is proved with two keys "K_1" and "K_2". Generally wheat-stone bridge is used to determine unknown resistances.



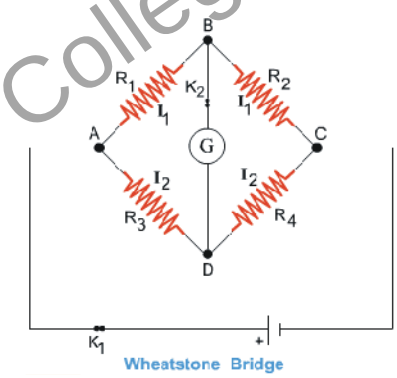
BALANCED WHEAT-STONE BRIDGE

When 'K_1' is connected, no current passes through the galvanometer because K_2 is disconnected. When 'K_1' and 'K_2' are connected and no current flows through the galvanometer, the condition of bridge is called "Balanced condition". It is possible only when the potential difference between the terminals of galvanometer is zero or potential of point 'B' = potential of point 'D' i.e.

$$V_B - V_D = 0$$

or

$$V_B = V_D$$



RELATION AMONG RESISTANCES IN BALANCED CONDITION

$$R_1/R_2 = R_3/R_4$$

EXPRESSION FOR BALANCED BRIDGE

FROM FIGURE:

- R_1 & R_2 are connected in series. Reason: (only one path for the flow of current)
- R_3 & R_4 are connected in series.
- R_1 & R_3 are connected in parallel. Reason: (two paths for the flow of current)
- R_2 & R_4 are connected in parallel.

Let current I_1 flows through R_1 & R_2 and I_2 through R_3 & R_4.

When bridge is balanced,

potential of point 'B' = potential of point 'D'

Therefore,

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$$V_{AB} = V_{AD} \qquad \text{but}[V = IR]$$

$$IR_1 = I_2R_3 \text{----------(I)}$$

Similarly,

$$V_{BC} = V_{CD}$$

or

$$I_1R_2 = I_2R_4 \text{----------(II)}$$

Dividing equation (i) by equation (ii)

$$\frac{\cancel{I_1}R_1}{\cancel{I_1}R_2} = \frac{\cancel{I_2}R_3}{\cancel{I_2}R_4}$$

$$\boxed{\frac{R_1}{R_2} = \frac{R_3}{R_4}}$$

APPLICATIONS OF WHEATSTONE BRIDGE

A number of resistance measuring devices have been devised on the principle of wheat-stone bridge. For example :

- Meter bridge
- Post office box
- Potentiometer
- Carey Foster's bridge
- Callendar bridge
- Griffith's bridge

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MOVING COIL GALVANOMETER

GALVANOMETER

Galvanometer is an electromechanical instrument which is used for the detection of electric currents through electric circuits. Being a sensitive instrument, Galvanometer cannot be used for the measurement of heavy currents. However we can measure very small currents by using galvanometer but the primary purpose of galvanometer is the detection of electric current not the measurement of current.

WORKING PRINCIPLE

Galvanometer works on the principle of conversion of electrical energy into mechanical energy. When a current flows in a magnetic field it experiences a magnetic torque. If it is free to rotate under a controlling torque, it rotates through an angle proportional to the current flowing through it.

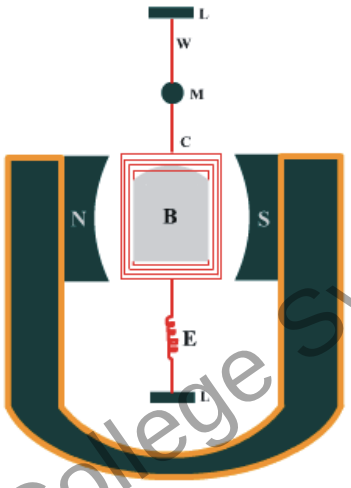
ESSENTIAL PARTS OF GALVANOMETER

There are five essential parts of a Galvanometer.

1. A U-shaped permanent magnet with concave poles.
2. Flat rectangular coil of thin enameled insulated wire 'C'.
3. A soft iron cylinder 'B'.
4. A pointer or needle.
5. A scale.

CONSTRUCTION

The flat rectangular coil of thin enameled insulated wire of suitable number of turns wound on a light nonmetallic or aluminum frame is suspended between the cylindrically concave poles of magnet by a thin phosphor bronze strip. One end of the wire of the coil is soldered to strip. The other end of the strip fixed to the frame of the galvanometer and connected to an external terminal. It serves as one leas current lead through which the current enters or leaves the coil. The other end of the wire of the coil is soldered to a loose and soft spiral of wire connected to another external terminal. The soft spiral of a wire serves as the other current lead. A soft-iron cylinder, coaxial with the pole pieces, is placed within the frame of the coil and is fixed to the body of the galvanometer. In the space between it and the pole pieces, where the coil moves freely, the soft iron cylinder makes the magnetic field stronger and radial such that into whatever position the coil rotates, the magnetic field is always parallel to its plane.



Internal structure of galvanometer

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WORKING

When a current passes through the galvanometer coil, it experiences a magnetic deflecting torque, which tends to rotate it from its rest position. As the coil rotates it produces a twist in the suspension strip. The twist in the strip produces an electric restoring torque. The coil rotates until the elastic restoring torque due to the strip does not equal and cancels the deflecting magnetic torque, then it attains equilibrium and stops rotating any furthers.

$$\text{Deflecting magnetic torque} = BINA\cos\alpha$$

where

B = Strength of the magnetic field.

I = Current in the coil.

A = Area of the coil.

N = Number of turns in the coil.

α = The angle of deflection of the coil.

The restoring elastic torque is proportional to the angle of twist of the suspension strip

According to Hook's Law

$$\text{Restoring torque} = C\theta$$

Where

θ = Angle of twist.

C = torque per unit twist.

Under equilibrium condition :

$$\tau_m = \tau_c$$

Putting the values of torque

$$BINA \cos\alpha = C\theta$$

$$I = C\theta / BNA \cos\alpha \longrightarrow (i)$$

If the magnetic field were uniform (as with flat pole pieces) α would continuously increase with θ and $\cos\alpha$ factor would not be constant. Then the current "I" would not be proportional to "θ" and the scale of the galvanometer not linear. However, due to the radial magnetic field the plane of the coil is always parallel to the field irrespective of the position of the coil rotates. So "α" the angle between the plane of the coil and direction of the field is always zero. Hence $\cos\alpha = 1$. The equation (i) therefore, reduces to:

$$I = C\theta / BAN$$

Since C, B, A and N are constant for a galvanometer, therefore,

$$I \alpha \theta$$

Thus current through the coil is directly proportional to the angle of twist of the suspension (or deflection) θ.

SENSITIVITY OF GALVANOMETER

Sensitivity of galvanometer is defined as the current in micro ampere required to consume one millimeter deflection on a scale placed 1m away from the mirror.

TO INCREASE SENSITIVITY OF GALVANOMETER

Now we know that :

$I = C\theta/BNA$

Sensitivity will be large if for small value of current (I) θ in large. To increase "θ", we should decrease C/BNA. So,

(i) "C" should be small: For this long wire of small area of cross section should be used. But "C" constant is too small.

(ii) Area of coil should is large: But this makes size of galvanometer large.

(iii) "N" Number of turns of coil should be increased: But this increases the weight of coil.

(iv) "B" should be large: This is achieved by:

(a) Using powerful magnet.

(b) Introducing iron core in coil.

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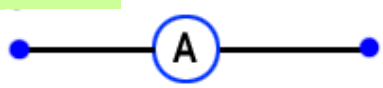
AMMETER

Ammeter is an electrical measuring device, which is used to measure electric current through the circuit. It is the modified form of galvanometer

CONNECTION OF AMMETER IN CIRCUIT

An ammeter is always connected in series to a circuit.

SYMBOL



CONVERSION OF GALVANOMETER INTO AMMETER

Since Galvanometer is a very sensitive instrument therefore it can't measure heavy currents. In order to convert a Galvanometer into an Ammeter, a very low resistance

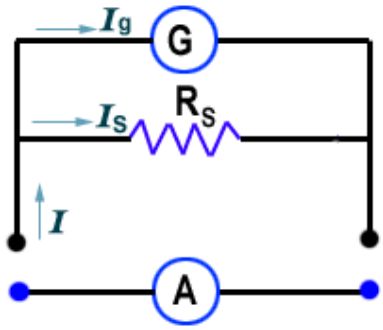
known as "shunt" resistance is connected in parallel to Galvanometer. Value of shunt is so adjusted that most of the current passes through the shunt. In this way a Galvanometer is converted into Ammeter and can measure heavy currents without fully deflected.

VALUE OF SHUNT RESISTANCE

Let resistance of galvanometer = R_g and it gives full-scale deflection when current I_g is passed through it. Then,

$$V_g = I_g R_g \text{ -------(i)}$$

Let a shunt of resistance (R_s) is connected in parallel to galvanometer. If total current through the circuit is I.



Then current through shunt:

$$I_s = (I - I_g)$$

potential difference across the shunt:

$$V_s = I_s R_s$$

or

$$V_s = (I - I_g) R_s \text{ -------(ii)}$$

But

$$V_s = V_g$$

$$(I - I_g) R_s = I_g R_g$$

$$R_s = \frac{I_g}{I - I_g} R_g$$

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VOLT METER

Voltmeter is an electrical measuring device, which is used to measure potential difference between two points in a circuit.

CONNECTION OF VOLTMETER IN CIRCUIT

Voltmeter is always connected in parallel to a circuit.

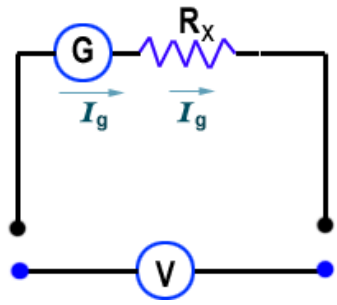
SYMBOL

CONVERSION OF GALVANOMETER INTO VOLTMETER

Since Galvanometer is a very sensitive instrument, therefore it can not measure high potential difference. In order to convert a Galvanometer into voltmeter, a very high resistance known as "series resistance" is connected in series with the galvanometer.

VALUE OF SERIES RESISTANCE

Let resistance of galvanometer = R_g and resistance R_x (high) is connected in series to it. Then combined resistance = $(R_g + R_x)$.



If potential between the points to be measured = V and if galvanometer gives full-scale deflection, when current "I_g" passes through it. Then,

$$V = I_g (R_g + R_x)$$
$$V = I_g R_g + I_g R_x$$
$$V - I_g R_g = I_g R_x$$
$$R_x = (V - I_g R_g) / I_g$$

$$R_X = \frac{V}{I_g} - R_g$$

Thus R_x can be found.

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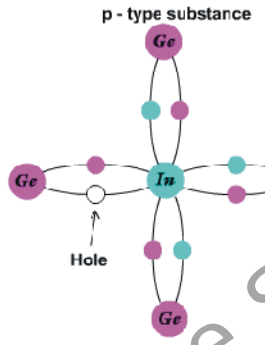
FUNDAMENTALS OF ELECTRONICS

ELECTRONICS

Electronics is the branch of physics which deals with development of electron-emitting devices, there use and control of electron flow in electrical circuits. Electronics also deals with semiconductors, diode, rectifiers etc.

p-TYPE SUBSTANCE

If a trivalent element from the IIIrd group such as Gallium (Ga) or Indium (In) is added to pure crystals of germanium (Ge) or silicone (Si), three electrons of impurity form covalent bonds with three atoms of (Ge) or (Si), while there exist a vacancy for an electron in the fourth bond. This vacant space is called Hole. This hole behaves like a positive charge and can move in the structure of substance. Such a substance is called a p-type substance.



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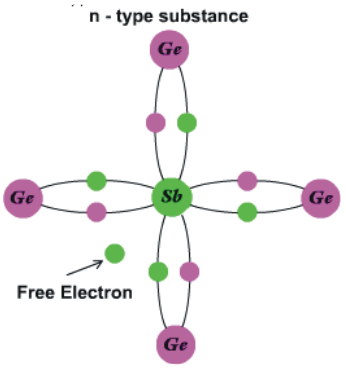
n-TYPE SUBSTANCE

If a pentavalent element from the Vth Group such as Antimony (Sb) is added to pure geranium (Ge) or silicone (Si), then four electrons of (Sb) will form covalent bonds with four (Ge) or (Si) atoms. The fifth electron of 'Sb' is free to move which makes (Ge) or (Si) a good conductor. This type of material is called n-type substance.



RECTIFIER

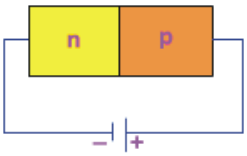
A rectifier is a device which is used to convert alternating current (AC) into direct current (DC). PN-junction diode is used as a rectifier.

RECTIFICATION

The process of converting alternating current into direct current is called rectification.

FORWARD BIASING

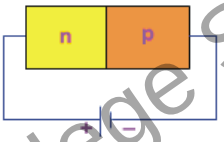
when n-type end of pn-junction is connected to negative terminal and p-type end with positive terminal of a (DC) supply, then the height of potential barrier reduces and provides easy flow of electric charge that is pn-junction conducts electricity. In this condition pn-junction is said to be Forward Biased.



Forward bias

REVERSE BIASING

When p-type end of pn-junction is connected to the negative terminal and n-type end with positive terminal of a (DC) supply. The height of potential barrier increases to maximum and the flow of electric charge across the junction will become zero. In this condition a pn-junction diode is called Reverse Biasing.



Reverse bias

DOPING

Addition of an element of group IIIrd-A or Vth-A to Ge or Si crystals to convert them into semiconductor substance (p-type or n-type) is called Doping. Normally impurity is in very small quantity. There are two types of impurities that are added to geranium or silicon:

- DONOR IMPURITY
- ACCEPTOR IMPURITY

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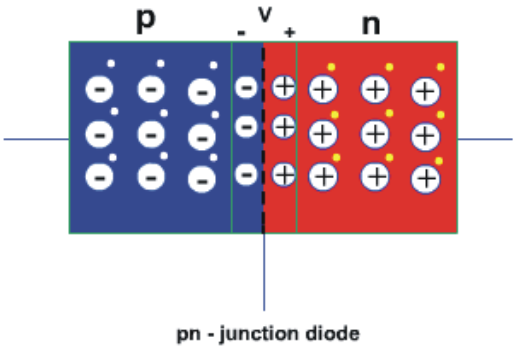
pn - junction diode or semiconductor diode

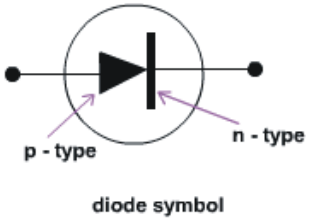
INTRODUCTION

A pn - junction diode is an electronic device formed from a p-type and an n-type substance semiconductor. A semiconductor diode has the property of one way conduction i.e. it allows electric current to flow in only one direction.

FABRICATION OF pn-JUNCTION

A pn-junction is fabricated by placing a small amount of indium on a plate or wafer of n -type germanium. Indium on heating at 550°C melts and diffuses through a small part of the n-type germanium. Indium being a p-type impurity, converts the part of the n-type germanium to p-type material. Thus a junction is formed between p-type section and an n-type section of germanium. A brass-base is used to fix the pn-junction to which leads are attached as shown:





The whole apparatus is sealed in a glass tube or a metallic tube.

WORKING OF pn-JUNCTION DIODE

As we know that a p-type substance has excess of mobile positive charge or holes and n-type substance has an excess of negative charge or electrons, the electrons from n-type and holes from p-type sections flow across the junction and combine. In this way a layer of positive charges is formed on the n-type and a layer of negative charges on p-type material.
Due to induction of these layers a potential barrier is now developed across the junction and further flow of charges is prevented from one side to the other.

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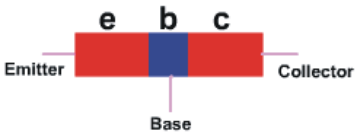
Explain the construction and working of transistor

TRANSISTORS

A three terminal semiconductor electronic device is called transistor. Transistors are widely used in electronic appliances such as computers, radio, audio video equipment, bio medical instrument etc.

CONSTRUCTION

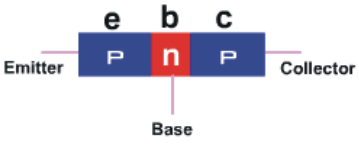
A transistor is a three layer semiconductor which consist a very thin central layer of one type of semiconductor material sandwiched between two relatively thick layer of second type.

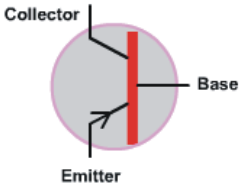


TYPES OF TRANSISTORS

pnp-TRANSISTORS

In this type of transistors n-type semi-conductor piece is sandwiched between two piece of p-type semiconductor layers.





npn-TRANSISTORS

In this type of transistors p-type semi conductor piece is sandwiched between two piece of n-

type semiconductor layers.

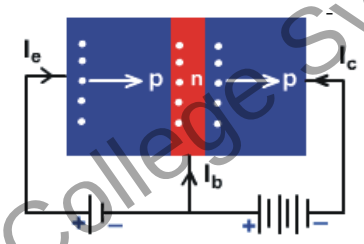
ESSENTIAL PARTS OF TRANSISTORS

There are three essentials parts of a transistor

- Base: It is the central layer denoted by b.
- Emitter: It is the outer layer denoted by e.
- Collector: It is the outer layer denoted by c.

WORKING

Consider any one of the transistors for example a pnp-transistor. Let the two p-end are connected to two batteries as shown in diagram. The forward bias causes the holes in the p-type emitter to flow towards the base which constituent Ie current. These holes cross into the n-type base, they try to combine with electrons but the base is lightly doped and is very thin.



Working of pnp-transistor

Therefore only few holes combine with electrons and the remaining holes cross into the collector and generates collector current Ic. In this way almost the entire emitter current flows in the collector circuit. From the above description it is clear that:

$$I_e = I_b + I_c$$

Thus there are two current paths through a transistor. One is the base-emitter path or input and the other is the collector-emitter path or output.

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PAIR PRODUCTION

DEFINITION

When a photon strikes a heavy nucleus, it disintegrates and produces a pair of an electron and a positron. Electron and positron always move in opposite directions so that the momentum is conserved. This phenomenon is called pair production or materialization of energy.

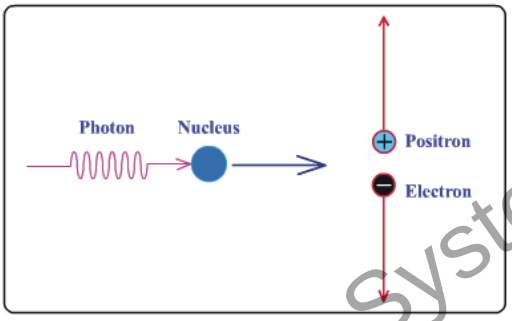
POSITRON

A positron is an antiparticle of an electron. It is also called a positive electron

ROLE OF NUCLEUS

The role of the nucleus is just to share some energy and momentum in order to conserve the two quantities.

COLLISION GEOMETRY



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ENERGY EXPRESSION FOR PAIR PRODUCTION

Let us suppose that the energy of incident photon is $E = h\upsilon$ (where υ = frequency of photon)
Now we suppose that the rest mass energies of electron and positron are respectively,

$$Ee^- = m_o c^2$$
$$Ee^+ = m_o c^2$$

Where m_o = rest mass of electron/positron
c = velocity of light
e^- = symbol for electron
e^+ = symbol for positron

The energy of photon also provides additional energy to the pair of electron and positron so that they can move in their paths in opposite direction.
Their respective kinetic energies are:

$$(K.E)e^- = (K)e^-$$
$$(K.E)e^+ = (K)e^+$$

Since the process of pair production obeys the rules of elastic collision, therefore, in this process energy is also conserved, thus, total energy of striking photon is given by,

$$E = Ee^- + Ee^+ + (K.E)e^- + (K.E)e^+$$

$$h\upsilon = m_o c^2 + m_o c^2 + (K)e^- + (K)e^+$$

$$h\upsilon = 2m_o c^2 + (K)e^- + (K)e^+$$

But the value of $m_o c^2$ is equal to 0.51 Mev

$$h\upsilon = 2(0.51\ Mev) + (K)e^- + (K)e^+$$

$$h\upsilon = 1.02\ Mev + (K)e^- + (K)e^+$$

This expression clearly indicates that no pair production will takes place if energy of incident

photon is less than 1.02 Mev. It means that to observe pair product, a photon must have 1.02 Mev of energy.

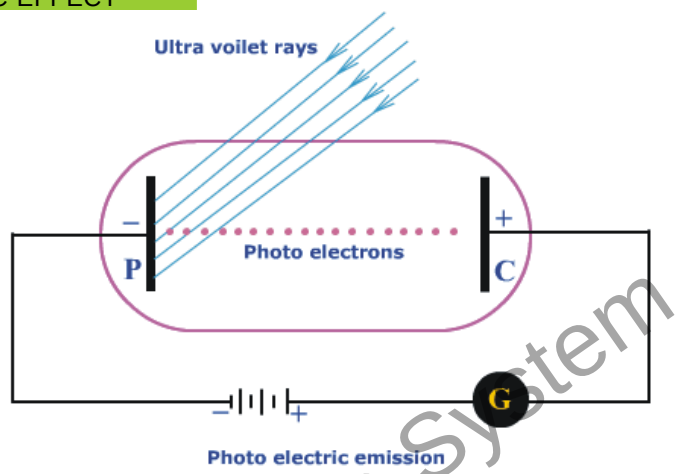
PHOTO ELECTRIC EFFECT

DEFINITION

When ultraviolet light falls on certain metals, electrons are emitted. This phenomenon in which certain metals emit electrons when exposed to light of suitable frequency, is called PHOTO ELECTRIC EFFECT.

In short, ejection of electrons by means of light is called 'photo electric effect'.

EXPERIMENTAL ARRANGEMENT TO OBSERVE PHOTOELECTRIC EFFECT



If suitable light is allowed to fall on plate 'P', it will give out photo electrons as shown in the figure. The photo electrons are attracted by the collector 'C' connected to the +ve terminal of a battery. The glass tube is evacuated. When the collector 'C' is kept at +ve potential, the photo electrons are attracted by it and a current flows in the circuit which is indicated by the galvanometer.

THRESHOLD FREQUENCY

Threshold frequency is defined as the minimum frequency of incident light which can cause photo electric emission i.e. this frequency is just able to eject electrons without giving them additional energy.

It is denoted by ν_o.

WORK FUNCTION

Minimum amount of energy which is necessary to start photo electric emission is called Work Function. If the amount of energy of incident radiation is less than the work function of metal, no photo electrons are emitted.

It is denoted by ϕ_o. Work function of a material is given by $\phi_o = h\,\nu_o$.

It is a property of material. Different materials have different values of work function. Generally, elements with low I.P values have low work function such as Li, Na, K, Rb, and Cs.

STOPPING POTENTIAL

The negative potential of the plate 'C' at which the photo electric current becomes zero is called stopping potential or cut-off potential. Stopping potential is that value of retarding potential difference between two plates which is just sufficient to halt the most energetic photo electrons emitted.

It is denoted by "V_o".

DEPENDENCE OF PHOTO ELECTRONS

The number of photo electrons depends upon:

- The nature of material

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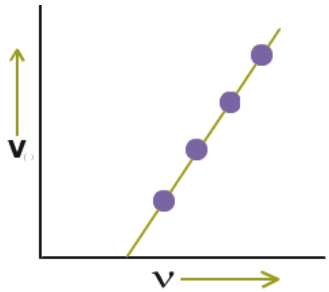
- The frequency of incident radiation
- The intensity of incident radiation
- Potential difference b/w the electrons

EFFECT OF FREQUENCY

The graph shows that a threshold frequency 'ν_o' is a minimum frequency below which no electrons escape from the metal surface. The photo electric effect occurs above the frequency while ceases below this frequency.



PHOTOCELL

INTRODUCTION

A photocell is a practical application of the phenomenon of photoelectric cell.

CONSTRUCTION

A photocell consists of an evacuated sealed glass tube containing a wire anode and a concave cathode of suitable emitting material such as Cesium (Cs) The material of cathode responds to a given frequency range.

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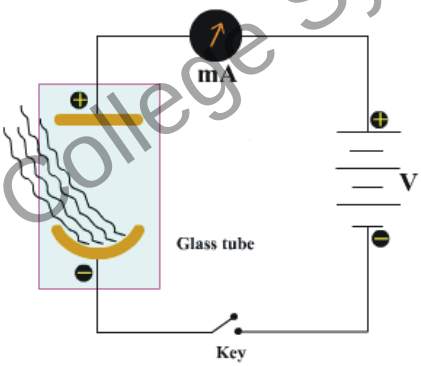


Photo Cell

WORKING

When light of frequency greater than the threshold frequency of the cathode material falls on the cathode, photoelectrons are emitted. These electrons are collected by the anode and an electric current starts flowing in the external circuit. The current increases with the increase in the intensity of light. The current would stop, if the light does not fall on the cathode.

USES OF PHOTOCELL

A photocell can be used in any situation where beam of light falling on it is interrupted or broken by any mean.

- To count vehicles passing a road.
- To count items running on a conveyer belt.
- To open doors automatically in a building such as banks or other commercial buildings or offices.
- To operate burglar alarms.
- To produce sound in movies.

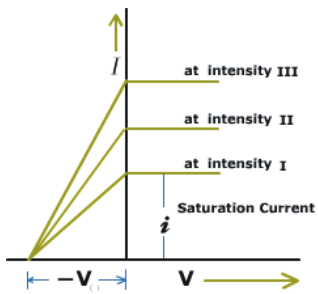
EFFECT OF INTENSITY

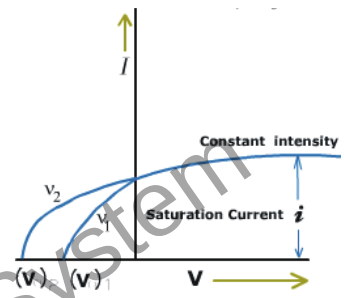
If we draw the photo electric curve by plotting the photo electric current 'I' verses the accelerating voltage 'V', the graph so obtained is shown below. Graph shows that there is a saturation current for different intensities and even when V=0, there is some photo electric current i_0. The curve shows that the stopping potential is independent of the intensity of radiation.

If these curves are plotted for different frequencies V1 and V2 but with same intensity (graph on right), the curve shows the behavior as shown:

* The saturation current depends upon intensity and not on frequency.

However, the stopping potential becomes more negative from (Vo)1 to (Vo)2 with the increase in frequency.





OTHER FUNDAMENTAL LAWS OF PHOTO ELECTRIC EMISSION

- The no. of electrons emitted per second i.e. photo current is proportional to the intensity of incident light.
- If frequency of incident radiation is below threshold frequency, no photo electric emission will take place.
- The max. velocity or max. K.E of photoelectrons depends on the frequency of radiation not on intensity. K.E. Increases with the increase in frequency.
- The rate at which the electrons are emitted from a photo cathode is independent of its temperature.

This shows that photo electric effect is entirely different from thermionic emission.

- For a given metal surface, stopping potential (V_0) is directly proportional to frequency but independent of intensity.

EINSTEIN'S PHOTOELECTRIC EQUATION

According to Plank's quantum theory, light is emitted from a source in the forms of bundles of energy called photons. Energy of each photon is $E = h\nu$.

Einstein made use of this theory to explain how photo electric emission takes place.

According to Einstein, when photons of energy $E = h\nu$ fall on a metal surface, they transfer their energy to the electrons of metal. When the energy of photon is larger than the minimum energy required by the electrons to leave the metal surface, the emission of electrons take place instantaneously.

He proposed that an electron absorbs one whole photon or none. The chance that an electron may absorb more then one electron is negligible because the number of photons is much lower than the electron. After absorbing the photon, an electron either leaves the surface or dissipates its energy within the metal in such a short interval that it has almost no chance to absorb second photon. An increase in intensity of light source simply increases the number of photon and the number of photo electrons but no increase in the energy of photo electron. However, increase in frequency increases the energy of photons and photo electrons.

According to Einstein's explanation of photoelectric emission, a photon of energy 'E' performs two

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operations:
1. Removes the electron from the surface of metal
2. Supplies some part of energy to move photo electron towards anode
Since minimum amount of energy to remove electron from a surface is equal to work function, we can write Einstein equation as:
Energy Supplied = Energy Consumed in ejecting an electron + maximum Kinetic energy of electron

$$E = \text{work function} + (K.E)_{max}$$

But $\phi_o = h\nu_o$, $E = h\nu$ and $K.E_{max} = 1/2\ mv_o^2$

$$h\nu = h\nu_o + 1/2\ mv_o^2 \quad \text{---------- (1)}$$

$$h\nu - h\nu_o = 1/2\ mv_o^2$$

$$h(\nu - \nu_o) = 1/2\ mv_o^2 \quad \text{---------- (2)}$$

Also $1/2\ mv_o^2 = V_o.e$

Where V_o = stopping potential

$$h(\nu - \nu_o) = V_o.e \quad \text{---------- (3)}$$

As $\nu = \frac{C}{\lambda}$ and $\nu_o = \frac{C}{\lambda_o}$ Where λ = Wave length of incident light
λ_o = cut off wave length

$$h\left(\frac{c}{\lambda} - \frac{c}{\lambda_o}\right) = V_o.e$$

$$hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_o}\right) = V_o.e \quad \text{---------- (4)}$$

$$V_o.e = \frac{hc}{\lambda} - \phi_o \quad \text{---------- (5)}$$

$$V_o.e = h\nu - \phi_o \quad \text{---------- (6)}$$

Equations from (1) to (6) are identical and are known as Einstein's photoelectric equations.

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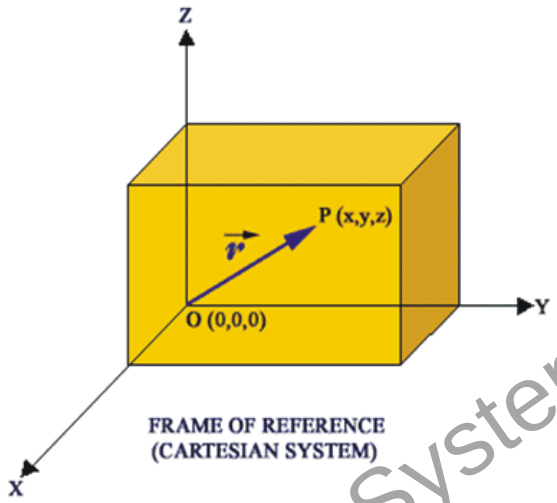
THEORY OF RELATIVITY

FRAME OF REFERENCE

Motion of a body is always described with reference to some well defined coordinate system. This coordinate system is referred to as 'frame of reference'. In three dimensional space a frame of reference consists of three mutually perpendicular lines called 'axes of frame of reference' meeting at a single point or origin. The coordinates of the origin are O(0,0,0) and that of any other point 'P' in space are P(x,y,z).The line joining the points O and P is called the position vector of the point P with respect to O.



FRAME OF REFERENCE
(CARTESIAN SYSTEM)

INERTIAL FRAME OF REFERENCE

A frame of reference that remains at rest or moves with constant velocity with respect to other frames of reference is called 'INERTIAL FRAME OF REFERENCE'. An inertial frame of reference is actually an un accelerated frame of reference. Newton's laws of motion are valid in all inertial frames of reference. In this frame of reference a body does not acted upon by external forces. All inertial frames of reference are equivalent for the measurement of physical phenomena.

Example

- Our earth.
- A space shuttle moving with constant velocity relative to the earth.
- A rocket moving with constant velocity relative to the earth.

NON-INERTIAL FRAME OF REFERENCE

A frame of reference is said to be a non-inertial frame of reference when a body, not acted upon by an external force is accelerated. In non-inertial frame of reference, Newton's laws of motion are not valid.

Example

SPECIAL THEORY OF RELATIVITY

The part of relativistic mechanics which is related to uniform motion, is called 'Special Theory of Relativity'.

POSTULATES OF SPECIAL THEORY OF RELATIVITY

Einstein proposed his famous theory of special relativity in the year 1905. Einstein's special theory of relativity is based on the following fundamental postulates:

- There is no preferred or absolute inertial frame of reference i.e. all inertial frames are equivalent for the description of all physical laws such as Newton's laws as well as Maxwell's electromagnetic equations.
- The speed of light in vacuum is the same for all observers in uniform translational relative motion and is independent of the motion of the observer and the source.

GENERAL THEORY OF RELATIVITY

The part of relativistic mechanics which is related to accelerated motion, is called 'General Theory of Relativity'.

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CONSEQUENCES OF SPECIAL THEORY OF RELATIVITY

We observe that in the development of special theory of relativity, frames of reference in relative motion with a constant speed V have been used. If the speed V becomes large enough to approach the velocity of light C, then the Galilean's transformations are found to be noticeably wrong. To correct the state of affairs it will be necessary to introduce a factor called 'Lorentz Factor' or 'Relativistic factor'.

Lorentz Factor is equal to: $\sqrt{1-\frac{v^2}{c^2}}$

This factor is in fact a measure of departure of Galilean's transformation. If $\frac{v}{c}$ is much smaller than as it is in our common situations, then $\frac{v^2}{c^2}$ is so small that the relativistic factor is essentially equal to unity. Under these conditions the classical and the relativistic physics predict nearly identical results. However when V approaches c (e.g.: V = C/5), Then the Galilean transformation will be incorrect.

Based on these considerations, if we interpret the result of special theory of relativity we end up in some very interesting consequences. Without going to make actual mathematical calculation, We may summarize the important consequences of the theory of special relativity which are as under:

MASS VARIATION

According to the special theory of relativity, the mass of an object in a frame of reference at rest is called its rest mass m_o. if this mass is measured by an observation moving with a constant speed V relative to the object, then it will not remain constant if the speed V is comparable to C. The mass m in the moving frame will vary according to the mass variation given by:

$$m = \frac{m_o}{\sqrt{1-\frac{v^2}{c^2}}}$$

Where
m = mass of object in motion
m_o = rest mass of object

This mass variation formula shows that mass changes with the velocity and not in general a constant nor the same for all observes but it is quantity that:

(a) depend upon the reference frame from which the body is being observed.

(b) is greater then or equal to the rest mass m_o when the body is at rest in the frame of reference from which the body is being observed.

LENGTH CONTRACTION

In the theory of special relativity it has been found that the measurement of length of a rod in a stationary frame of reference is not the same when the rod is measured by the observer in the moving frame of reference with the velocity relative to the rod, provided the measurement is made along the direction of motion.

Hence, if L_o is the length of rod in the frame at rest, and L is the length of same rod in the moving frame, then:

$$l = l_o\sqrt{1-\frac{v^2}{c^2}}$$

where
l_o = length of object in rest
l = length of object in motion

Since v/c is less then unity, the length L is less then L_o i.e. there is a contraction in length along the direction of motion. This is called the Lorentz-Fitzgerald contraction.

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above equation tells us that an observer past whom a system is moving with a speed v measures object in the moving system to be shortened in length along the direction of motion by a factor:

$$\sqrt{1-\frac{v^2}{c^2}}$$

It is important to note that only the dimension along the line of motion is changed and there is no change in the other two perpendicular directions.

With the development of special theory of relativity it became apparent that there is no physical contraction of the moving objects. There is, however, an apparent contraction of body for an observer where there is a relative motion of the object and the observer. In the natural sense the observer in moving frame cannot detect the contraction because in this frame it does not exist; where is in the rest frame, it does exist, but the measuring rod in the moving system has shrunk too further we must note that for moderate velocities ($v/c<<1$)of the objects the contraction in length is negligible as observed in our every day observation.

TIME DILATION

Time is regarded as an absolute quantity in classical mechanics whereas in the special theory of relativity it is considered to be a relative entity based on the measurement of time in frame of references in relative motion.

The time interval between two events taking place at the same point in space as timed with a clock at rest with respect to that point is called the proper time interval and is denoted $\Delta t_o = T_o$. Time measured with a clock in motion with respect to the events is known as relativistic time it is represented by $\Delta t = T$. Both of the time intervals T_o & T refer to the time elapsed between the same pair of events occurring in the two frames moving with a relative speed v. then, according to special relativity the two times are related by the formula:

$$T = \frac{T_o}{\sqrt{1-\frac{v^2}{c^2}}}$$

Where
T = Time in motion
T_o = Time at rest

Above equation represents, what we call as the time dilation phenomena. According to the time dilation formula we mean that from the point of view of an observer at rest, the time of the observer in motion is dilated i.e. the clocks in moving frame run slowly and the Lorentz factor $\sqrt{1-\frac{v^2}{c^2}}$ Gives us the ratio of the rates of clocks for normal speeds, this factor is so close to unity (1.00) that we are quite unable to detect time dilation effect, but for speed comparable to the speed of light c the time dilation effect is quite significant.

We can now conclude that for every observer his own clock in his frame of reference run faster than do any other clocks which are moving relative to him. We may also note that every observer may consider himself to be at rest and consider all that moves as moving relative to him. This is actually an outcome of the principle of special relativity stated earlier: Every observer is equivalent to every other observer.

MASS ENERGY RELATION

In the beginning of this section we have stated the postulates of relativity that the speed of light is a universal constant. We cannot reach speeds greater than the speed of light by the relativistic addition of velocities. The equation is how to reconcile with this result of special relativity with Newton's second law, F=ma? It would be seen that any constant force, no matter how small, applied for a considerably very long time, should continuously accelerate any mass 'm' at a rate a=f/m until the speed was arbitrarily very large. Einstein, concluded that energy has inertia i.e. the more energy a body possess, the more inertia that body will display. Since, inertia is a property of matter, which is associated with mass. Thus from Einstein's argument mass is simply a property attributed to the total energy of the body and only the total energy is required, to know the total mass of the body. Thus, in special theory of relativity total energy and mass are

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related by the famous Einstein's equation.

$$E = mc^2$$

From this relation between mass and energy it has been predicted that any process that changed the mass by a detectable amount would involve huge amounts of energy. For example, a mass change of 1.00 gram is equal to an energy change of 9×10^{13} joules.

UNCERTAINTY PRINCIPLE

INTRODUCTION

In classical physics it is generally assumed that position and momentum of a moving object can be simultaneously measured exactly i.e. no uncertainties are involved in its description. But in microscopic world it is not possible. It is found that however refined our instruments there is a fundamental limitation to the accuracy with which the position and velocity of microscopic particle can be known simultaneously. This limitation was expressed by a German physicist Werner Heisenberg in 1927 and known as 'Heisenberg's uncertainty principle'.

In microscopic particles we can observe two types of uncertainties viz.

- Uncertainty in position and momentum
- Uncertainty in energy and time

STATEMENT

- Uncertainty in position and momentum

According to Heisenberg's uncertainty principle:

It is impossible to determine both position and momentum of an electron simultaneously. If one quantity is known then the determination of the other quantity will become impossible.

MATHEMATICAL REPRESENTATION

Let

Δx = uncertainty in position

ΔP = uncertainty in momentum

According to Heisenberg's uncertainty principle:

The product of the uncertainty in position and the uncertainty in momentum is in the order of an amount involving h, which is Planck's constant.

$$\Delta P \times \Delta x \geq h / 2\pi \text{ ———— (i)}$$

EXPLANATION

It is not difficult to understand the phenomenon of uncertainty. Consider an example in which we are going to see the position of an electron. We measure the position an electron is measured with light and observing the light that it reflects. The light disturbs its momentum.

Heisenberg considered an electron that has a definite, known momentum and that passes under a powerful microscope. He realized that measuring the position of an elementary particle alters its momentum in a random manner.

This technique allows the position to be specified with an accuracy comparable to the wavelength of light used in the experiment. However, when the photons are scattered from the electron, they alter its momentum, because the photons have a momentum of their own. The observer cannot calculate the extent of this disturbance, which is random.

Increasing the wavelength decreases the disturbance, because photons of longer wavelength have less momentum and energy. However, increasing the wavelength reduces the precision of the measurement of position. Decreasing the wavelength allows better position measurement, but increases the disturbance to the momentum.

UNCERTAINTY IN TIME AND ENERGY

Similar to uncertainty in position there is another principle of uncertainty which limits the accuracy in the measurement of time i.e. if ΔE is the energy uncertainty in time Δt then we have an expression similar to equation (i)

i.e.

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$$\Delta E \times \Delta t \geq h / 2\pi \text{ ———— (ii)}$$

RESULTS OF UNCERTAINTY PRINCIPLE

- It is impossible to chase an electron around the nucleus.
  - The principle describes the incompleteness of Bohr's atomic theory.
  - According to Heisenberg's uncertainty principle there is no circular orbit around the nucleus.
  - Exact position of an electron can not be determined precisely.

LIMITATIONS OF PRINCIPLE

Heisenberg's uncertainty principle is not applicable in our daily life. It is only applicable on micro objects i.e. subatomic particles.

The reason why the uncertainty principle is of no importance in our daily life is that Planck's constant 'h' is so small (6.625×10^{-34} joule-seconds) that the uncertainties in position and momentum of even quiet small (not microscopic objects) objects are far too small to be experimentally observed. For microscopic phenomena such as atomic processes, the displacements and momentum are such that the uncertainty relation is critically applicable.

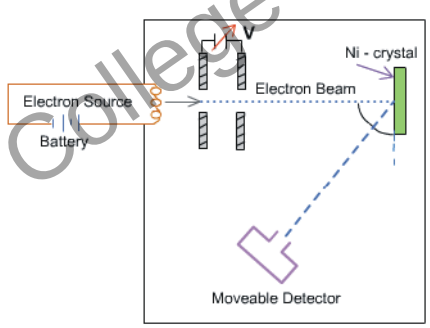
Davisson and Germer's Experiment

INTRODUCTION

In the year 1927, Davisson and Germer conducted their famous experiment which was the experimental verification of De-Broglie's hypothesis i.e. $\lambda = h/p$.

THE EXPERIMENT

Their experimental setup was enclosed in a vacuum chamber as shown below:



Davisson - Germer's Experimental Setup

A beam of electrons accelerated through the potential V were allowed to strike a nickel crystal. Measurements were made to count the number of electrons scattered by the crystal.

OBSERVATIONS

Davisson and Germer reported unexpected results that the electrons reflected very strongly at certain angles only and not at other directions.

Davisson and Germer further investigated properly oriented crystals to observe if could be possible to interpret that electron behave as waves of all wave lengths (λ) as given by De-Broglie's hypothesis. They calculated the wave length of electron from the known accelerating potential V by applying the relation:

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$$\frac{1}{2} m_o v^2 = V e$$

OR

$$v = \sqrt{\frac{2 V e}{m_o}}$$

Using De - Broglie's equation

$$\lambda = \frac{h}{m_o v}$$

Putting the value of v

$$\lambda = \frac{h}{m_o \sqrt{\frac{2 V e}{m_o}}}$$

$$\lambda = \frac{h}{\sqrt{\frac{2 V e m_o^2}{m_o}}}$$

$$\boxed{\lambda = \frac{h}{\sqrt{2 V e m_o}}}$$

Where e = charge of electron
m_o = rest mass of electron
h = Planck's constant

The wave length associated with the above equation agreed with the De-Broglie's prediction. Thus it is confirmed that electron has a wave like nature because only a wave has wave length.

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COMPTON'S EFFECT

DEFINITION

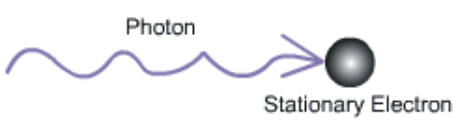
"When a photon strikes a stationary electron, wavelength of photon is increased after collision. This phenomenon is referred to as Compton's effect."

OR

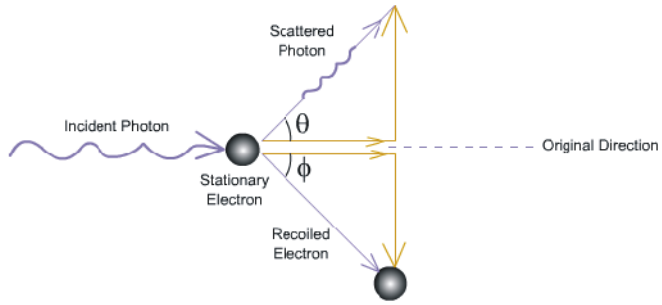
"It is the phenomenon in which a photon of frequency "υ" is scattered by an electron and the scattered photon has a frequency less than that of the incident photon is called Compton's effect."

MATHEMATICAL REPRESENTATION

Consider a photon of frequency υ_1 and wavelength λ_1 strikes a stationary electron of rest mass m_o. After collision the photon is scattered at an angle of θ with its original line of action. While electron moves forward at an angle of ϕ with its original direction.



COLLISION GEOMETRY



ENERGY CONSERVATION

Energy of photon before collision $= E_1 = h\upsilon_1$
Energy of electron before collision $= E_2 = m_oc^2$
Energy of photon after collision $= E1' = h\upsilon_2$
Energy of electron after collision $= E2' = mc^2$
Since the collision between photon and electron is elastic. Therefore energy and momentum will be conserved.

Total energy before collision = Total energy after collision

$$E_1 + E_2 = E_1' + E_2'$$

$$h\upsilon_1 + m_oc^2 = h\upsilon_2 + mc^2$$

$$h\upsilon_1 - h\upsilon_2 = mc^2 - m_oc^2$$

$$h(\upsilon_1 - \upsilon_2) = c^2(m - m_o) \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

MOMENTUM CONSERVATION

Momentum of photon before collision $= h/\lambda_1$
Momentum of electron before collision $= 0$
Momentum of photon after collision $= h/\lambda_2$
Momentum of electron after collision $= mv$

MOMENTUM EQUATION ALONG X-AXIS

$$h/\lambda_1 + 0 = h/\lambda_2 \cos\theta + mv\cos\phi$$

$$h/\lambda_1 = h/\lambda_2 \cos\theta + mv\cos\phi \ldots\ldots\ldots\ldots(2)$$

MOMENTUM EQUATION ALONG Y-AXIS

$$0 + 0 = h/\lambda_2 \sin\theta + (-mv\sin\phi)$$

$$h/\lambda_2 \sin\theta - mv\sin\phi = 0 \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Solving (1) , (2) and (3), we get the following result:

$$1/\upsilon_2 - 1/\upsilon_1 = h/m_oc^2\,(1 - \cos\theta) \ldots\ldots\ldots\ldots(4)$$

$$c(1/\upsilon_2 - 1/\upsilon_1) = hc/m_oc^2\,(1 - \cos\theta)$$

$$c/\upsilon_2 - c/\upsilon_1 = h/m_oc\,(1 - \cos\theta)$$

But $c/\upsilon = \lambda$, therefore,

$$\lambda_2 - \lambda_1 = h/m_oc\,(1 - \cos\theta)$$

where $\lambda_2 - \lambda_1$ = Compton's shift in wavelength
h/m_oc is called Compton's wavelength and its value is 2.426×10^{-12} m.

CONCLUSION

Thus the frequency υ_2 of scattered photon after the collision will be less than the original frequency υ_1.

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LASER

INTRODUCTION

LASER stands for LIGHT AMPLIFICATION BY STIMULATED EMISSION OF RADIATION.
Laser is a device used to produce very intense, highly directional, coherent and monochromatic beam of light.
Laser of different power and application can be produced by using different materials.

CLASSIFICATION OF LASER

Lasers are divided into three main classes depending upon their origin.

- Solid Laser
- Liquid Laser
- Gas Laser

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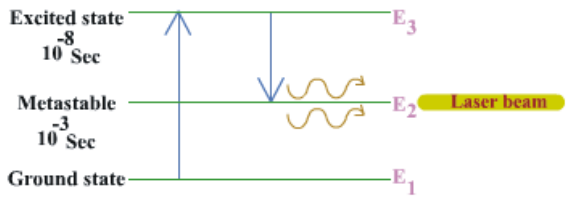
BASIC CONDITIONS TO PRODUCE LASER

- there must be a meta stable state in the system.
- The system must achieve population inversion.
- The photons emitted must be confined in the system for a time to allow them further stimulated emission.

PRINCIPLE OF LASER

The principle of laser production is based on the fact that atoms of a material have a number of energy levels in which at least one is meta stable state.
Consider a three level atomic system having energies E_1, E_2 and E_3 respectively.

Let the atoms are at ground state E_1. If photons interact with an atom in ground state, the atom absorbs the photon and reaches the excited state E_3 . We know that the excited state is an unstable state, therefore, electron must return back to ground state E_1 but such transitions are not allowed and the electron first reach the state E_2. Atoms in the state E_3 which has a life time of about 10^{-8} sec decay spontaneously from state E_3 to state E_2 which is meta stable and has life time of 10^{-3}sec . This means that the atoms reach state E_2 much faster than they leave state E_2. This results in an increase in number of atoms in state E_2, and hence population inversion is achieved.

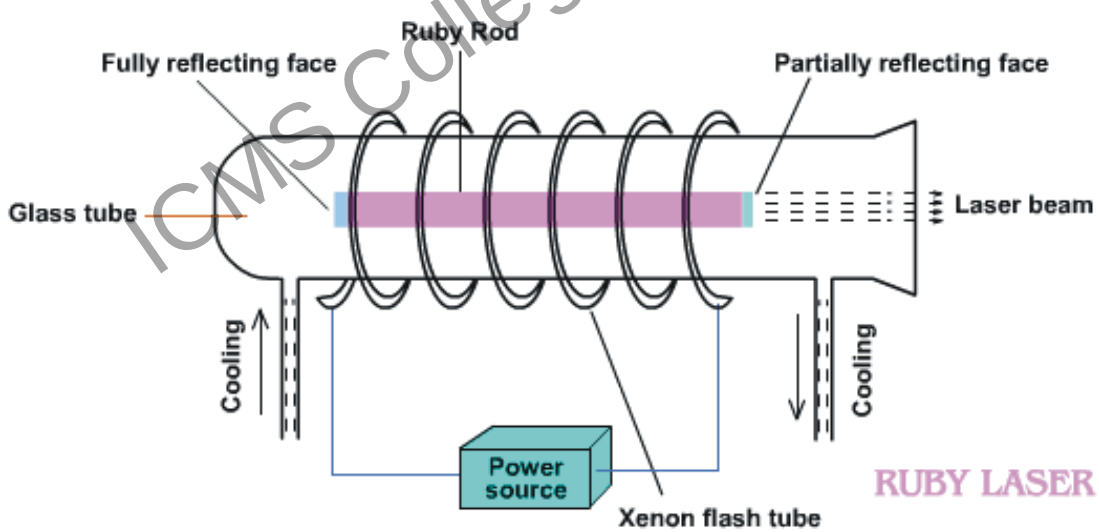


After achieving population inversion it is exposed to a beam of photons which causes induced emission of photons and a beam of laser is produced.

RUBY LASER

CONSTRUCTION

Ruby is a crystal of Al_2O_3, a small number of whose Al atoms are replaced by Cr^{+3} ions. A high intensity helical flash lamp surrounding the ruby rod is used as light source to raise Cr atoms from state E1 to E3.



The ruby laser is a cylindrical rod with parallel, flat reflecting ends. One end is partially reflecting. The flash light is attached with the high voltage.

WORKING

Let the electrons are raised from ground state E1 to Excited state E3 which has a life time 10^{-8} sec. The atoms from the state E3 make transition to state E2. Since E2 is meta-stable state having life time equal to 10^{-3} sec. This means that the atoms reach state E_2 much faster than they leave state E_2. This results in an increase in the number of atoms in state E_2 and hence population inversion is achieved.

In this process few Cr atoms make spontaneous transition from E2 to E1 and emitted photons

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stimulate further transition. In this way we obtain an intense, coherent, monochromatic beam of red laser.

Applications of Laser

The lasers have widespread applications in industry, surgery, entertainment and in a number of other disciplines of life. However, some of them are as under:
Generally speaking, a laser produces a very narrow and intense beam of light that can vaporize any thing which comers in its way.

APPLICATION INDUSTRY

Precision cutting, welding and drilling of tiny holes into hardest materials can be performed by laser beam.

APPLICATION IN MEDIA

A very interesting application is the production of true three dimensional images called "HOLOGRAM".
A hologram records not only the intensity of the light but also the phase difference between two image-beams that cause the interference pattern to reconstruct an image suspended in air like a real object.

APPLICATION IN SURGERY

In surgery, the laser has proved a more delicate and accurate instrument than the finest scalpel. It has been used for bloodlessly removing small humors, cutting and delicate operations. Laser are now widely used in the field of surgery. Laser can also be used to fragment gallstone, stones in kidney and eye-surgery.

APPLICATION AS RANGE FINDER

Laser beam is used as a range finder, lining up equipment accurately in surveying large distances.

APPLICATION IN ELECTRICAL DEVICES

Tiny solid state lasers are widely used in electrical devices. A laser beam replaces the phonographic needle in a compact disk audio system for music reproduction of extremely high fidelity.
A laser can also be used for the photographic recording of output data of computer.

APPLICATION IN ENVIRONMENTAL STUDY

Laser is an important environmental monitoring instrument. Some types of laser can be tuned to a desired frequency. These lasers can be used, as a very sensitive detectors of pollutants in the atmosphere.

APPLICATION IN NUCLEAR FUSION

A high power laser is also a potential source to induce nuclear fusion reaction.

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LAWS OF RADIOACTIVE DECAY

According to law of radioactive decay:
Number of nuclei decay in a certain time is directly proportional to the total number of nuclei present initially.

$$\Delta N \alpha -N \text{ .....(1)}$$

Number of nuclei decay is directly proportional to time interval

$$\Delta N \alpha \Delta t \text{.....(2)}$$

Combining (1) and (2)

$$\Delta N \alpha -N \Delta t$$

OR

$$\Delta N = -\lambda N \Delta t$$

Where N = Number of nuclei initially present
ΔN = Number of nuclei decay
λ = Decay constant

$$\Delta N / N = -\lambda \Delta t$$

Integrating both sides

$$\ln N = -\lambda t + C \text{.....(3)}$$

$$\text{when } t = 0, N = N_o$$

$$\ln No = -\lambda(0) + C$$

$$\ln No = C$$

putting the value of C in (3)

$$\ln N = -\lambda t + \ln No$$

$$\ln N - \ln No = -\lambda t$$

$$\ln (N/No) = -lt$$

$$N/No = e^{-\lambda t}$$

$$\text{If } t = T1/2, N = No/2$$

$$No/2 / No = e^{-\lambda T1/2}$$

$$1/2 = 1/ e^{\lambda T1/2}$$

$$e^{\lambda T1/2} = 2$$

$$\lambda T_{1/2} = \ln 2$$

$$\lambda T_{1/2} = 0.693$$

$$A = \lambda N$$

Where A = activity
and

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N / No = relative activity

Chapter No. 20

WILSON CLOUD CHAMBER

INTRODUCTION

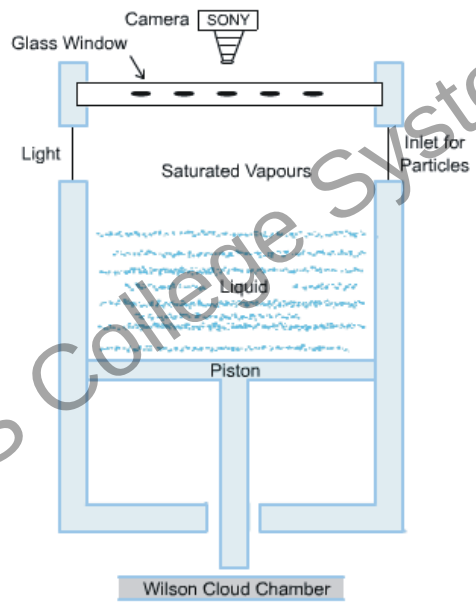
It is an instrument used for the detection and identification of the path of subatomic particles.
In Wilson Cloud Chamber, paths of subatomic particles or ionized particles can be photographed.

WORKING PRINCIPLE

When a particle is passed through the supersaturated vapours, droplets are formed on the line due to ionization along the track and particle is detected.

CONSTRUCTION

It is consist of a closed cylindrical chamber with the transparent glass top, a movable piston at the bottom. On the sides near the top, the cylinder is provided with a glass window. Inside the cylinder a liquid of low boiling point is placed. The piston can be moved up or down. The whole system is air tight. A strong light source is used to illuminate the chamber while the photograph is taken by the camera as shown.



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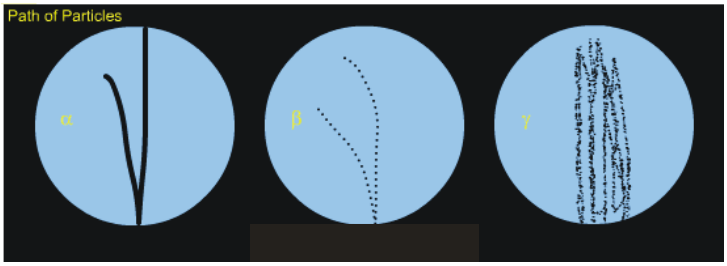
WORKING

Some volatile liquid having low boiling point (methanol CH_3OH or ethanol C_2H_5OH) is poured on the inner surface of the chamber. The piston first is moved slowly up so that the air inside the chamber is cleaned and then it is then moved down, so that the internal pressure is dropped and the air get vapours of the liquid and becomes supersaturated and a fog is observed in the chamber.
At the right moment particles are allowed to enter into the chamber and a powerful and intense beam of light is used to illuminate the track of the particles and photos are taken by the sensitive camera.
If a strong electric or magnetic field is applied to the particles (charged) then their path is altered. By the study of path's length, thickness, continuity or discontinuity and the influence of magnetic field (curve) .i.e. geometry the e/m ratio can be calculated and hence the particle is detected.

PATH DIAGRAM



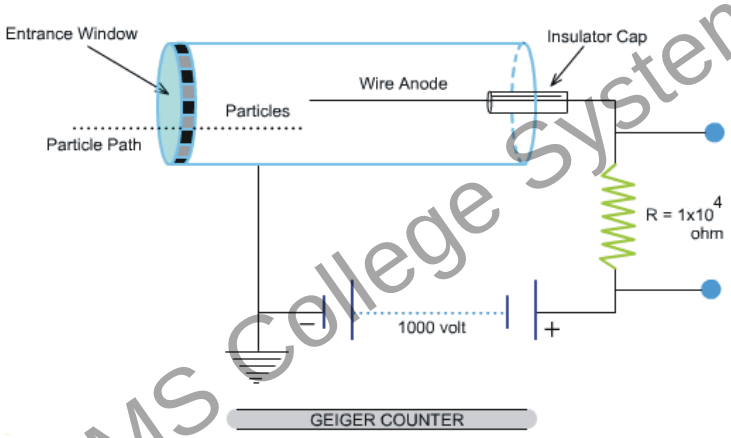
GEIGER COUNTER

INTRODUCTION

Geiger counter is a portable device which is used for the detection and counting of ionized particles and radiation

CONSTRUCTION

It consists of a hollow metallic cylinder, one end of which is closed by an insulating cap. At the center of the cap is fixed a stiff straight wire along the axis of cylinder .A thin mica or glass disc closes the other end which also serves as the entrance window for ionizing particles. The tube contains a special mixture of air, argon, alcohol at a pressure of 50-100 mmHg.



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WORKING

A potential difference of the range of 1000V is maintained between the metal cylinder and the axial wire through a suitable series resistor of 10^9 ohms. When an ionizing particle enters the tube through the window, it ionizes some gas molecules in it. These ions are accelerated by the strong radial electric field producing more ions by collision which produces ionization current so a momentary current flows between the wire and the cylinder and also through the resistor R. The ends of “R” are connected to a loud speaker or an electronic counter.

COUNTING OF PARTICLES

Each time a particle enters the counter and ionization current pulse is created which gives a click in the loud speaker or a count in a counter.

In the case of ionizing radiation, the numbers of counts register by the counter measures the intensity or ionizing power of incident radiation.

ENDED

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