1. UNITS AND DIMENSIONS

QUANTITIES AND UNITS:

- Physics is a science based upon study of properties of matter and exact measurement. For measurement of any 'physical quantity', we require some 'reference standard'. This reference standard of measurement is called a unit.
- The magnitude of a quantity is the product of the **unit** (u) used to measure it and the number (n) of times that unit is contained in the given quantity.
- **Characteristics of a Physical quantity are**:
  1) The unit should be well defined.
  2) The unit should neither be too small not too large in comparison with the physical quantity to be measured.
  3) The unit should neither change with time or with change in physical conditions like pressure, temperature, etc.
  4) The unit should be easily reproducible.
- Quantities and Units can be classified in to two categories:- (1) Fundamental quantities and units and (2) Derived quantities and units.

- **Fundamental quantity** is a quantity, which cannot be expressed in terms of any other physical quantity. The units in which these quantities are measured are called fundamental units. Fundamental quantities and units cannot be further resolved into other simpler form. In mechanics the quantities **length**, **mass** and **time** are chosen as fundamental quantities.

- **Derived quantities are** quantities, which can be expressed in terms of any other physical quantities. The units in which these quantities are measured are called derived units. The derived units are derived from fundamental units. The units of speed, acceleration, moment of inertia, resistance etc. are called derived units.

SYSTEM OF UNITS

- The following systems of units have been in use-
  - The French system or C.G.S system.
  - The British system or F.P.S system.
  - The M.K.S system.
  - International system of units or S.I system.

- **The French system or C.G.S system:** This system deals with only three mechanical quantities **mass, length** and **time**. In this system '**C**' stands for centimeter, '**G**' stands for gram, and '**S**' stands for second.
- **The British system or F.P.S system**. This system also deals with only three mechanical quantities **mass, length** and **time**. In this system '**F**' stands for foot, '**P**' stands for pound, and '**S**' stands for second.
- **MKS system:** This system also deals with the basic units of **length, mass** and **time,** where '**M**' stands for meter, '**k**' stands for kilogram, and '**S**' stands for second.
- **SI system (International System of Units):** This system is the improved and extended version of the MKS system of units.

SI system (International System of Units):

Sr. No	Physical quantity	Units	Abbreviation
1.	Length	Meter	m
2.	Mass	Kilogram	kg
3.	Time	Second	s
4.	Electric current	Ampere	A
5.	Luminous intensity	Candela	cd
6.	Thermodynamic temperature…etc.	Kelvin	K
7.	Amount of substance	Mole	mol
	Supplementary units		
1.	Plane angle	Radian	rad
2.	Solid angle	Steradian	Sr

DIMENSIONS:

- Dimension of a physical quantity simply indicates the physical quantities, which appear in that quantity and give absolutely no idea about the magnitude of the quantity.
- If a quantity does not depend upon any of the fundamental units the quantity is said to have the **zero dimension**.
- The dimensions of a derived unit are the powers to which the fundamental unit of mass, length and time must be raised to represent it. The dimension of quantity is represent as $[M^a\ L^b\ T^c]$ or $[M^a][L^b][T^c]$. For example the speed $= \dfrac{\text{distance}}{\text{time}} = \dfrac{[L]}{[T]} = \left[M^0LT^{-1}\right]$.
- It is clear the speed is said to possess zero dimension in mass, one dimension in length and –1 dimension in time. The dimensional formula of speed is$[M^0LT^{-1}]$.
- **Dimensional formula** is an expression which shows how and which of the fundamental units are required to represent the unit of a physical quantity.

Conversion of a physical quantity from one system of units to another

- Let us consider a physical quantity whose dimensional formula is $[M^a L^b T^c]$.
- Let n_1 be the numerical value in a system of fundamental units M_1, L_1 and T_1. Then the magnitude of the physical quantity in this system is $n_1\left[M_1^a\ L_1^b\ T_1^c\right]$.
- Let n_2 be the numerical value in another system of fundamental units M_2, L_2 and T_2. The magnitude of the physical quantity in this system is $n_2\left[M_2^a\ L_2^b\ T_2^c\right]$.
- Since the value of the physical quantity is the same in all systems

$$\therefore n_2\left[M_2^a\ L_2^b\ T_2^c\right] = n_1\left[M_1^a\ L_1^b\ T_1^c\right]$$

$$\text{Or} \quad n_2 = n_1\left[\frac{M_1}{M_2}\right]^a\left[\frac{L_1}{L_2}\right]^b\left[\frac{T_1}{T_2}\right]^c$$

- Above equation can be applied only after expressing the physical quantity in absolute units.
- We can check the accuracy of any relation connecting various physical quantities by using the fact that the dimension of the quantities on the left hand side must be same as that of the

dimension of the quantities on the right hand side of the dimension equation. (Principle of homogeneity of dimensions).

- We can also find a possible relationship between different physical quantities using the concept of the homogeneity of dimensions.

Ex. 1. Conversion of a physical quantity "Force" from MKS system of units to CGS system of unit.

As we know that **Force = (mass) x (acceleration)**

Now, dimension formula for force in MKS system is

$$\mathbf{1\ Newton} = \frac{\mathbf{(Kg.)\ x\ (m)}}{\mathbf{sec^2}} = \frac{\mathbf{M\,L}}{\mathbf{T^2}} = \left[\mathbf{M\,LT^{-2}}\right] \quad \text{------------------} \quad (1)$$

And dimension formula for force in CGS system is

$$\mathbf{1\ dyne} = \frac{\mathbf{(gm)\ x\ (cm)}}{\mathbf{sec^2}} = \frac{\mathbf{M\,L}}{\mathbf{T^2}} = \left[\mathbf{M\,LT^{-2}}\right] \quad \text{------------------} \quad (2)$$

Now, we know **1 Kg** in MKS = **10^3gm** in CGS and **1 m** in MKS = **10^2 cm** in CGS

$$\therefore\ \mathbf{1\ Newton} = \frac{\mathbf{(Kg.)\ x\ (m)}}{\mathbf{sec^2}}$$

$$\left[\mathbf{M\,LT^{-2}}\right] = \frac{\mathbf{(10^3\,gm)\ x\ (10^2\ cm)}}{\mathbf{sec^2}}$$

$$= \mathbf{10^5}\,\frac{\mathbf{(gm)\ x\ (cm)}}{\mathbf{sec^2}}$$

$$= \mathbf{10^5\ dyne}$$

$$= \mathbf{10^5}\left[\mathbf{M\,LT^{-2}}\right] \quad \text{-----------------} \quad \mathbf{(3)}$$

Here, $\mathbf{1\left[M\,L\,T^{-2}\right] = 10^5\left[M\,L\,T^{-2}\right]}$ $\qquad$ $\therefore$ **1 Newton = 10^5 Dyne**

Ex. 2. Check the accuracy of the relation $T = 2\pi\sqrt{\frac{l}{g}}$,

Where **T** = time period of a pendulum,

l = length of the pendulum and

g = acceleration due to gravitational.

Dimension of **L.H.S** of equation = T = **$M^0L^0T^1$** **------------------ (1)**

Now, R.H.S of equation $= \mathbf{2\pi\sqrt{\frac{l}{g}}}$

$$= \sqrt{\frac{\mathbf{m}}{\mathbf{m/sec^2}}}$$

$$= \sqrt{\mathbf{sec^2}}$$

$$= \mathbf{Second}$$

$$= \mathbf{M^0L^0T^1} \quad \text{----------------------} \quad \mathbf{(2)}$$

From equation (1) and (2) we get, L.H.S. = R.H.S., therefore given relation of the equation is true.

ERRORS IN MEASUREMENT

- The uncertainty in a measurement is called '**error**'. It is the difference between the measured and the true value of a physical quantity. Errors can be classified into many categories, some of which are given below:
  - **Instrumental errors**
  - **Personal errors**
  - **Random errors**

- **Instrumental errors:** We do all measurements with the help of instruments. These errors in the construction of the apparatus itself and the measuring instrument itself. If an instrument is faulty or inaccurate, then the errors will presence in the measurement. Either the change of the instrument with a similar one or the use of different methods to measure the same quantity can be of some help in minimizing instrumental errors.
- **Personal errors:** Sometimes the errors that are introduced in the measurement are due to the individual qualities of the experimenter person. These errors may arise due to the lack of attentiveness, poor eyesight, improper setting of the instrument and other peculiarities associated with the experimenter. In order to eliminate or reduce personal errors, different observers should repeat the measurements.
- **Random errors:** It is a common experience that the repeated measurements of a quantity give values, which are slightly different from each other. These errors have no set pattern. These take place in a random manner and are therefore, called random errors. There errors depend on the error in the measuring process and also on the individual measuring person. Random errors can be minimize by repeating the measurements many times and taking the arithmetic mean of all measurements as the correct value of the measured quantity.
- There are three ways to express an error:
  - **Absolute error**
  - **Relative error**
  - **Percentage error**
  - Let 'X' be the actual measured value and let 'X_0' be the true or correct value of the physical quantity then "$\Delta X = X - X_0$" is defined as the absolute error.
  - If we take the arithmetic mean of all absolute errors, we get the final absolute error ΔX_{mean} where $\Delta X_{mean} = \dfrac{|\Delta X_1| + |\Delta X_2| + ... + |\Delta X_n|}{n}$
  - Relative error is defined as the ratio of mean absolute error and the value of the quantity being measured. $\textbf{Relative error} = \dfrac{X - X_0}{X}$

$$\textbf{Percentage error} = \frac{X - X_0}{X} \times 100$$

COMBINATION OF ERRORS:

Addition and Subtraction:

- Suppose two quantities x and y have measured values $x \pm \Delta x$, $y \pm \Delta y$ respectively where Δx and Δy are their absolute error. We wish to find the error Δz in the sum,

$$Z = x + y$$

- We have by addition

$$\begin{aligned} Z \pm \Delta Z &= (x \pm \Delta x) + (y \pm \Delta y) \\ &= x + y \pm \Delta x \pm \Delta y \\ &= x + y \pm (\Delta x + \Delta y) \\ &= x + y \pm \Delta Z \end{aligned}$$

The maximum possible error in $Z = \Delta Z = (\Delta x + \Delta y)$

- Now We find the error Δz in the subtraction,

$$Z = x - y$$

- We have by subtraction

$$\begin{aligned} Z \pm \Delta Z &= (x \pm \Delta x) - (y \pm \Delta y) \\ &= x - y \pm \Delta x \pm \Delta y \\ &= x - y \pm (\Delta x + \Delta y) \\ &= x - y \pm \Delta Z \end{aligned}$$

  The maximum possible error in $Z = \Delta Z = (\Delta x + \Delta y)$

- Thus when two quantities are added or subtracted, the absolute error in the final result is the **sum** of the absolute errors in the quantities.

➢ Multiplication and Division:

- **Multiplication**
- If two quantities x and y are multiplied together, the fractional error in the product is the sum of the two fractional error in x and y.
- Let Δx and Δy be the absolute errors in x and y. We find the error Δz in the multiplication,

$$Z = x\,y$$

$$Z \pm \Delta Z = (x \pm \Delta x) (y \pm \Delta y)$$

Where ΔZ is the maximum possible error in Z

- The maximum possible error ΔZ in the product will be in the range:

$$\begin{aligned} \Delta Z &= (Z \pm \Delta Z) - Z \\ &= (x \pm \Delta x) (y \pm \Delta y) - xy \\ &= xy \pm y\Delta x \pm x\Delta y \pm \Delta x\, \Delta y - xy \\ &= \pm y\Delta x \pm x\Delta y \end{aligned}$$

(By neglecting $\Delta x\, \Delta y$, as it is small in comparisons of $y\Delta x$ and $x\Delta y$)

Dividing L.H.S by Z and R.H.S by xy.

$$\frac{\Delta Z}{Z} = \pm \frac{\Delta x}{x} \pm \frac{\Delta y}{y}$$

The fractional error in xy will be

$$\frac{\Delta Z}{Z} = \pm \left(\frac{\Delta x}{x} + \frac{\Delta y}{y} \right)$$

Hence the maximum error in Z is $\dfrac{\Delta Z}{Z} = \dfrac{\Delta x}{x} + \dfrac{\Delta y}{y}$

- **Division**
- If two quantities x and y are divided together, the fractional error in the product is the sum of the two fractional error in x and y. Let Δx and Δy be the absolute errors in x and y.
- We find the error Δz in the multiplication,

$$Z = \frac{x}{y}$$

$$Z \pm \Delta Z = \frac{x \pm \Delta x}{y \pm \Delta y}$$

Where ΔZ is the maximum possible error in Z

- The maximum possible error ΔZ in the division will be in the range:

$$\Delta Z = (Z \pm \Delta Z) - Z$$

$$= \left(\frac{x \pm \Delta x}{y \pm \Delta y} - \frac{x}{y} \right)$$

$$= \frac{xy \pm y\,\Delta x - xy \pm x\,\Delta y}{y(y \pm \Delta y)}$$

$$= \frac{\pm y\,\Delta x \pm x\,\Delta y}{y(y \pm \Delta y)}$$

(By neglecting Δy, as it is small in comparisons of y)

$$= \frac{\pm y\,\Delta x \pm x\,\Delta y}{y(y)}$$

Dividing L.H.S by Z and R.H.S by $\frac{x}{y}$.

$$\frac{\Delta Z}{Z} = \frac{\pm y\,\Delta x \pm x\,\Delta y}{y(y)} \times \frac{y}{x}$$

$$\frac{\Delta Z}{Z} = \frac{\pm y\,\Delta x \pm x\,\Delta y}{xy}$$

$$\frac{\Delta Z}{Z} = \pm \frac{\Delta x}{x} \pm \frac{\Delta y}{y}$$

The fractional error in $\frac{x}{y}$ will be

$$\frac{\Delta Z}{Z} = \pm \left(\frac{\Delta x}{x} + \frac{\Delta y}{y} \right)$$

Hence the maximum error in Z is $\frac{\Delta Z}{Z} = \frac{\Delta x}{x} + \frac{\Delta y}{y}$

Ex. 3: In an experiment of a simple pendulum, the observation of the period is 2.63s, 2.56s, 2.42s, 2.71s and 2.80s. Calculate the percentage error. (Here the accuracy of two digits after decimal point has been consider)

Mean period $\overline{\mathbf{T}} = \frac{\mathbf{2.63 + 2.56 + 2.42 + 2.71 + 2.80}}{\mathbf{5}} = 2.62$ s

Therefore the absolute error for each observation,

X - $\overline{\mathbf{X}}$ = ΔX

2.63 – 2.62 = 0.01 s

2.56 – 2.62 = -0.06 s

2.42 – 2.62 = -0.20 s

2.71 – 2.62 = 0.09 s

2.80 – 2.62 = 0.18 s

So, the mean of the absolute errors is $= \mathbf{T} = \dfrac{|0.01| + |-0.06| + |-0.20| + |0.09| + |0.18|}{5}$

$$= \frac{0.54}{5} = 0.11\text{s}$$

Hence the period of simple pendulum should be written as **2.62 ± 0.11s**

Now, **Relative error** $= \dfrac{\textbf{Average absolute error}}{\textbf{Mean value}}$

$$= \frac{0.11}{2.62} = 0.0419$$

∴ **Percentage error** = 0.0419 x 100 = 4.19 %

Ex. 4 A physical quantity p is related to four observable in a, b, c and d as follows: . $P = \dfrac{a^3 . b^2}{\sqrt{c.d}}$ **The percentage errors of measurement in a, b, c and d are 1%, 3%, 4% and 2% respectively. What is the percentage error in the quantity P?**

Relative error in **P** is given as $\dfrac{\Delta P}{P} = 3\dfrac{\Delta a}{a} + 2\dfrac{\Delta b}{b} + \dfrac{1}{2}\dfrac{\Delta C}{C} + \dfrac{\Delta d}{d}$

And the percentage error is given as,

$$\frac{\Delta P}{P} \times 100 = 3\left(\frac{\Delta a}{a} \times 100\right) + 2\left(\frac{\Delta b}{b} \times 100\right) + \frac{1}{2}\left(\frac{\Delta C}{C} \times 100\right) + \left(\frac{\Delta d}{d} \times 100\right)$$

Where, $\left(\dfrac{\Delta a}{a} \times 100\right) = 1\%$, $\left(\dfrac{\Delta b}{b} \times 100\right) = 3\%$, $\left(\dfrac{\Delta C}{C} \times 100\right) = 4\%$ & $\left(\dfrac{\Delta d}{d} \times 100\right) = 2\%$

$$\therefore \frac{\Delta P}{P} \times 100 = 3 \text{ x } 1\% + 2 \text{ x } 3\% + ½ \text{ x } 4\% + 2\%$$

$$= 3\% + 6\% + 2\% + 2\% = 13\%$$

Therefore **percentage error** in the quantity **P = 13** %

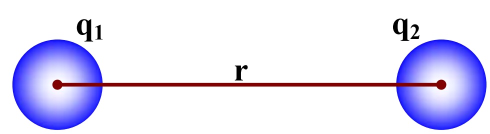
2. STATIC ELECTRICITY

Electric Charge

- When a glass rod is rubbed with silk, glass rod acquiring the property of attracting light objects like feather of birds, small bit of paper etc. Similarly an ebonite rod acquiring the attractive property on being rubbed with flannel, and if we comb dry hair with a rubber comb, the comb acquires the property of attracting small bit of paper etc.
- The electricity developed on bodies, when they are rubbed with each other is called **frictional electricity**. It is also called **static electricity**, as the charges so developed cannot flow from one point to some other point.
- There are two types of charges. (1) Positive charge and (2) Negative charge. The like charges repel each other and unlike charges attract each other.
- The modern concept of electrification is based on the fact that under normal conditions matter contains equal number of positive and negative charge. When two bodies are rubbed together some amount of charge is transferred from one body to another and this results in changing the electrical neutrality of both bodies. This is because a charge transfer takes place. The body, which loses electrons, becomes positively charged while the body, which receives electrons, becomes negatively charged.

Coulomb's Law

- According Coulomb's Inverse Square law, the force of attraction or repulsion between two point charges is directly proportional to the product of magnitude of charges and inversely proportional to the square of the distance between them.
- Let $\mathbf{q_1}$ and $\mathbf{q_2}$ are the two stationary charges separated by distance **'r',** and then the electrostatic force between them is given by



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

$$\therefore F = k\frac{q_1 q_2}{r^2}$$

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

- Where $K(air) = \frac{1}{4\pi\varepsilon_0\varepsilon_r} = 9 \times 10^9$ **N-m²/C²** is the constant of proportionality. It value depends on the nature of the medium in which two charges are located and the system of units adopted to measure.
- In above equation, $\boldsymbol{\varepsilon = \varepsilon_0\varepsilon_r}$ is known as permittivity constant.

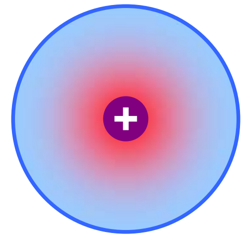
  ε_0 = Absolute permittivity of air or vacuum = $\mathbf{8.854 \times 10^{-12}\ C^2/N\text{-}m^2}$

  ε_r = Dielectric constant or relative permittivity of the medium.

  $\boldsymbol{\varepsilon_r = 1}$ for air or vacuum.

- If we take $q_1 = q_2 = 1$coulomb, $\boldsymbol{\varepsilon_r = 1}$ for air and r = 1meter, Then $F = K = 9 \times 10^9$ N.
- Thus one coulomb is that quantity of charge which will repel an equal and similar charge with a force of 9×10^9 N, when placed in vacuum (or air) at a distance of one meter from it.

Electric Field



- An electric field is defined as the space surrounding an electric charge where its effect such as attraction or repulsion is experienced by other charge.

Intensity of Electric Field(E)

- The **strength** or **intensity** of electric field at any point is defined as the force experienced by a unit positive charge, placed at that point
- Let **F** be the force experience by a charge $\mathbf{q_1}$ coulomb placed at given point in electric field of charge **q**, than the intensity due to a charge **q** at a distance '**r**' is given by

$$\mathbf{E} = \frac{\mathbf{F}}{\mathbf{q_1}} \qquad \text{------------------------(1)}$$

- Now from Coulomb's law, the force between charge **q** and $\mathbf{q_1}$ at a distance **r** is given by

$$\mathbf{F} = \frac{\mathbf{q_1 q}}{\mathbf{4\pi\,\varepsilon_0 \varepsilon_r\, r^2}} \qquad \text{-----------------(2)}$$

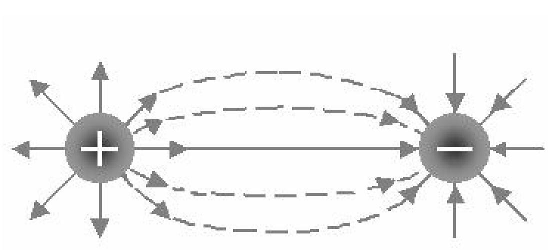
From equation (1) and (2), we get

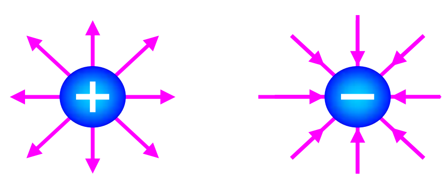
$$\mathbf{E} = \frac{\mathbf{q}}{\mathbf{4\pi\,\varepsilon_0 \varepsilon_r r^2}}$$

- The electric intensity (**E**) is a vector quantity that has magnitude and direction. The direction of **E** is along the direction of the force.
- The unit of intensity of electric field is **Newton/coulomb** or **coulomb/m^2.**

Electric Lines of Force

- Electric field is represented with the help of electric lines of force. Electric line of force is defined as the path along which a unit positive would tend to move when free to do so in an in an electric field.





Properties of electric lines of force:

1. The electric lines of force originate from a positive charge and terminate at a negative charge.
2. The tangent to the line of force indicates the direction of the electric force.
3. No two electric lines of force can intersect each other.
4. When two electric lines of force proceeding in the same direction, repel each other and while proceeding in the opposite direction, attract each other.
5. The electric lines of force are always normal to the surface while starting or ending on it.

Electric Flux (Φ) and Flux density (D) :

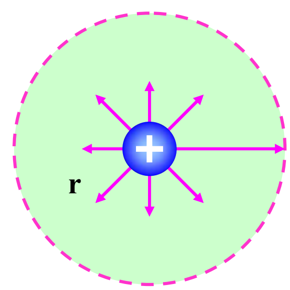
- The total number of lines of force coming out from a positive charge or the total number of lines of force terminating on a negative charge is called **electric flux**. It is denoted by **Φ** and its unit is **coulomb**.
- The total number of electric lines of force, crossing unit surface area normally is known as electric flux density (D).
- Flux density **D** = Electric flux per unit area = **Φ/A**. and its unit is **coulomb/m²**.
- The flux density '**D**' at a given point is proportional to the intensity of electric field '**E**'.

i.e.: $D \propto E$

$$D = \varepsilon E$$

$$D = \varepsilon_0 \varepsilon_r E.$$

Electric flux due to a point charge



- Consider the sphere of a radius '**r**' surrounding a positive charge of **+q** coulomb charge with the charge at placed the center.
- Now as we know,

Electric flux = flux density x Area of sphere

$$\Phi = D \times A$$

$$\Phi = \varepsilon_0 \varepsilon_r E \times 4\pi r^2$$

$$\Phi = \varepsilon_0 \varepsilon_r \frac{1}{4\pi\varepsilon_0 \varepsilon_r} \frac{q}{r^2} (4\pi r^2)$$

$$\Phi = q$$

- Electric flux due to a point charge is equal to strength of charge '**q**' coulomb.

ELECTRIC POTENTIAL

Absolute Electric Potential:

- Absolute Electric Potential at a point is the amount of work done to move a unit positive charge from infinity to that point in the electric field. **Or,**
- The potential at any point in an electric field is defined as the amount of work done in bringing a unit positive charge from infinity to that point against the electric field.
- It is scalar quantity and is denoted by '**V**'

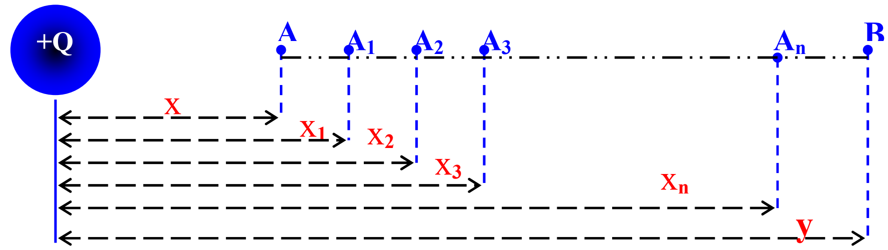
Potential difference (p.d.):

- The potential difference between any two points is the amount of work done in moving a unit positive charge from one point to the other in the electric field.
- Electric Potential difference = (Work done in joule)/(unit positive charge in coulomb)

$$V = W/q \quad \text{volt}$$

- If the work done in moving a unit charge (1C) between the two points is one joule, then the potential difference between the two points is said to be **one volt** (V).
- The S. I. unit of potential is **Joule/coulomb** or **volt**.

Potential Difference due to a point charge



- Consider a point positive charge **Q**. Consider two points **A** and **B** in the electric field of charge **+Q** at a distance **x** and **y** respectively from the charge.
- To calculate the potential difference between points **A** and **B**, the total distance between them is divided in to a number of small segments. **A_1, A_2, A_3,…..A_n** are the points selected between **A** and **B**. Their distances are shown in the figure above.
- Select a pair of points **A** and **A_1**. Intensity of electric field at point **A** is given by

$$E_A = \frac{1}{4\pi\varepsilon_0\,\varepsilon_r}\frac{Q}{x^2}$$

- Intensity of electric field at point A_1 is given by

$$E_{A1} = \frac{1}{4\pi\varepsilon_0\,\varepsilon_r}\frac{Q}{x_1^2}$$

- Since electric intensity decreases in geometric progression as the distance increases, hence the average electric field intensity between the points **A** and **A_1** is given by the geometrical means of **E_A** and **E_{A1}**. i.e.:

$$E_{AA1} = \sqrt{E_A E_{A1}}$$

$$\therefore E_{AA1} = \frac{1}{4\pi\varepsilon_0\,\varepsilon_r}\frac{Q}{x\,x_1}$$

Now, Potential difference $= \dfrac{\text{Work done}}{\text{Unit positive charge}} = \dfrac{\text{(Electric force) x (Distance)}}{\text{Unit positive charge}}$

$= \text{(F/Q) x Distance}$

$= \text{(Electric field) x (Distance)}$

$\therefore$ Potential diff. Between A & A_1 is written as **$V_{AA1} = E_{AA1}$ x D**

$$= \frac{1}{4\pi\varepsilon_0\,\varepsilon_r}\frac{Q}{x\,x_1}(x_1 - x)$$

$$= \frac{Q}{4\pi\varepsilon_0\,\varepsilon_r}\left(\frac{1}{x} - \frac{1}{x_1}\right)$$

- Similarly, the potential differences between different pairs of points can be written as

$$V_{A1A2} = \frac{Q}{4\pi\,\varepsilon_0\varepsilon_r}\left[\frac{1}{x_1} - \frac{1}{x_2}\right] \qquad V_{A2A3} = \frac{Q}{4\pi\,\varepsilon_0\varepsilon_r}\left[\frac{1}{x_2} - \frac{1}{x_3}\right] \qquad V_{AnB} = \frac{Q}{4\pi\,\varepsilon_0\varepsilon_r}\left[\frac{1}{x_n} - \frac{1}{y}\right]$$

By adding the potential differences between the pairs of points, we get the potential difference between points A and B.

$$\therefore V_{AB} = V_{AA1} + V_{A1A2} + V_{A2A3} + \ldots\ldots + V_{AnB}$$

$$\therefore V_{AB} = \frac{Q}{4\pi\varepsilon_0\varepsilon_r}\left[\left(\frac{1}{x}-\frac{1}{x_1}\right)+\left(\frac{1}{x_1}-\frac{1}{x_2}\right)+\left(\frac{1}{x_2}-\frac{1}{x_3}\right)+\ldots+\left(\frac{1}{x_n}-\frac{1}{y}\right)\right]$$

$$\therefore V_{AB} = \frac{Q}{4\pi\varepsilon_0\varepsilon_r}\left[\frac{1}{x}-\frac{1}{y}\right]$$

- The absolute potential at point **A** can be determined by substituting **y = ∞** in above equation.
- In general, potential difference at any point at a distance **r** from a charge **q** is given by

$$\therefore V_A = \frac{1}{4\pi\varepsilon_0\varepsilon_r}\frac{Q}{x}$$

$$V = \frac{1}{4\pi\varepsilon_0\varepsilon_r}\frac{q}{r}$$

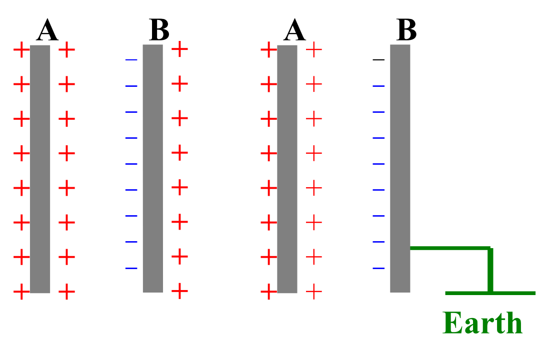
CAPACITANCE

- If we give charge to any conductor, the potential of the conductor also increases as the charge on the conductor gradually increases.
- Let at any instant the charge given to the conductor is **Q** and **V** is the potential, then

$$Q \propto V \quad \text{or} \quad \frac{Q}{V} = C(\text{constant})$$

- The constant (**C**) of proportionality is known as the **capacity** or the **capacitance** of the conductor. Its value depends on the nature of the conductor and other surrounding conditions.
- Now, the capacitance of a conductor is defined as the ratio of the electric charge to the potential due to it.
- Let V=1, then C = Q; Hence the capacity of the conductor is equal to the charge required to raise the potential of the conductor by a one volt. The unit of capacity is **farad**.
- $1\,\text{farad} = \dfrac{1\,\text{coulomb}}{1\,\text{volt}}$

Princpal of capacitor:

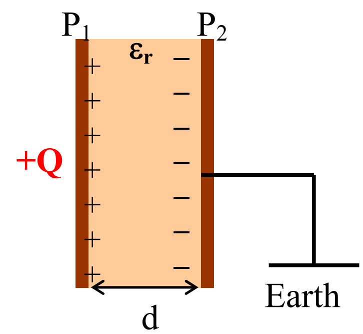


- Capacitor is an arrangement made by which large amount of charge can be stored at a small potential making it suitable and safe for use.
- Consider a conducting metal plate '**A**', which is charged to a potential **+V**.
- If a second conducting plate **B** is brought near to it, then electrostatic induction takes place. As a result of which the nearer side of the metal plate **B** gets equal negative charge whereas the farther side of the plate **B** gets equal positive charge.
- Now if the metal plate **B** is connected to the earth then the free positive charges escape to the earth. Hence the potential of the plate **B** becomes zero.
- Since all positive charges have been removed, the negative charges on metal plate **B** reduce the potential of the metal plate **A** considerable and as a result, the capacity of metal plate **A** is

considerably increased. This arrangement stores the charges and is called as capacitor or condenser.

Capacitance of a parallel plate capacitor:

- The parallel plate capacitor consists of two parallel metal plates of some conducting material, separated from each other by insulated dielectric material or medium. One of the plates is given positive charge and other is earthed.
- Let the parallel plate capacitor consists of two plane plates $\mathbf{P_1}$ and $\mathbf{P_2}$ placed parallel to each other and separated from each other by distance '**d**', containing dielectric material having dielectric constant 'ε_r'.



- Let, **Q** = charge on each plate, **A** = area of each plate, and **d** = distance between two plates.
- Now, Electric flux density is given by $D = \Phi/A = Q/A$

  We have $D = \varepsilon_0 \varepsilon_r E$

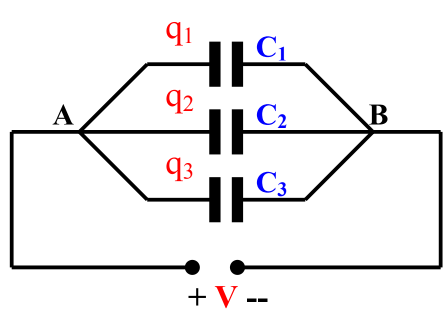
  $\therefore E = D/\varepsilon_0 \varepsilon_r = Q / \varepsilon_0 \varepsilon_r A$ ------------(1)
- Now, Potential difference between the plates is

  $V = E \times d = Q\, d / \varepsilon_0 \varepsilon_r A$ -------------(2)
- According to the definition of capacitance

$$C = Q/V \quad \mathbf{C} = \frac{\mathbf{Q}}{\left(\frac{\mathbf{Qd}}{\boldsymbol{\varepsilon_0 \varepsilon_r A}}\right)} = \frac{\boldsymbol{\varepsilon_0 \varepsilon_r A}}{\mathbf{d}}$$

Condensers in parallel

- In parallel arrangement of condensers, the positive plate of each condenser is connected to a common point; say **A** and the negative plate of each condenser is connected to another common point **B** which is earthed.



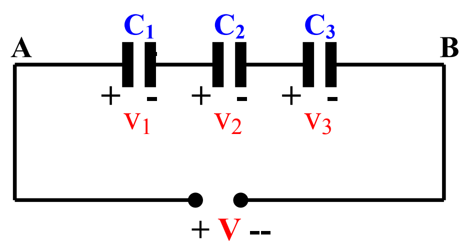
- The point **A** is given some charge, which is shared by all the capacitors depending upon their capacitance. The potential difference across the plates of each condenser is the same as that between the common points.
- Since charges are distributed, so that $\mathbf{q = q_1+q_2+q_3}$ ………………..(1)
- Now we know $C = \dfrac{q}{V}$ $\therefore CV = q$ **,** $C_1V = q_1,$ $C_2V = q_2$, $C_3V = q_3$
- putting these values in (1), We get,

$$\mathbf{Q = q_1+q_2+q_3}$$
$$C_PV = C_1V + C_2V + C_3V = [C_1 + C_2 + C_3]\, V$$
$$\mathbf{C_P = [C_1 + C_2 + C_3]}$$

- Where C_P is the effective capacitance, which is equal to sum of the capacitance of condensers connected in parallel.

Condensers in series

- In series the negative plate of the first condenser is connected to the positive plate of the second condenser and so on.
- In this arrangement each condenser receives the same charge. But the potential difference across the plates of each condenser is different. The total potential difference between ends of the combination is equal to the sum of the potential differences across each condenser.



- Total potential difference, $\mathbf{V = V_1 + V_2 + V_3}$ ………………(1)
- We have $C = \frac{q}{V}$, hence $V = \frac{q}{C}$

  $\therefore$ We can also write $V_1 = \frac{q}{C_1}$, $V_2 = \frac{q}{C_2}$ and $V_3 = \frac{q}{C_3}$
- Putting these values in (1) we get

$$\mathbf{V = V_1 + V_2 + V_3}$$

$$\therefore \frac{\mathbf{q}}{\mathbf{C_S}} = \frac{\mathbf{q}}{\mathbf{C_1}} + \frac{\mathbf{q}}{\mathbf{C_2}} + \frac{\mathbf{q}}{\mathbf{C_3}}$$

$$\frac{\mathbf{1}}{\mathbf{C_S}} = \frac{\mathbf{1}}{\mathbf{C_1}} + \frac{\mathbf{1}}{\mathbf{C_2}} + \frac{\mathbf{1}}{\mathbf{C_3}}$$

3.CURRENT ELECTRICITY AND MAGNETISM

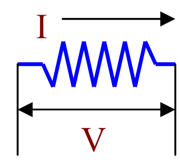
Electric current

- An electric current is the flow of charge from higher potential to the lower potential in metallic conductor. The current flow through any conductor is the rate of flow of charge through any cross section of it. i.e: $\mathbf{I = q/t}$ ampere.

Electromotive force: (e.m.f.): The e.m.f. of the cell is equal to the potential difference between the terminals of the cell on an open circuit.

Ohm's Law:

- Ohm's law gives the relation between potential difference across the ends of a conductor and the current flowing through it. The law states that: "**Under similar physical conditions of the conductor, the current flowing through it is directly proportional to the potential difference across its ends".**
- Let **V** be the potential difference across the ends of a conductor and **I** be the current in ampere flowing through it.
- Then according to Ohm's law $\mathbf{V \alpha I}$



$$\therefore \mathbf{V = RI = IR}, \qquad \text{or} \qquad \therefore \mathbf{R} = \frac{\mathbf{V}}{\mathbf{I}}$$

Where **R** is constant, which is called the **resistance** of the given conductor.

- **K=1/R is called the conductance of the given conductor.**
- Resistance is defined as the property of a conductor due to which it resists the flow of current. The unit of resistance is ohm (**Ω**). Ohm is represented symbolically by **Ω**.
- One **ohm** is defined as the resistance in which a current of one ampere flows through it when a potential difference is maintained between its ends.

$$1 \text{ ohm} = \frac{1 \text{ volt}}{1 \text{ ampere}}$$

Specific resistance <u>or</u> Resistivity

- At the constant temperature, the resistance of a conductor is
    1. Directly proportional to its length, $\mathbf{R \propto L}$
    2. Inversely proportional to its cross sectional area, $\mathbf{R} \propto \mathbf{1/A}$
    3. Depends upon the material of the conductor
- From the above relations it is clear that $\mathbf{R} \propto \frac{\mathbf{L}}{\mathbf{A}}$

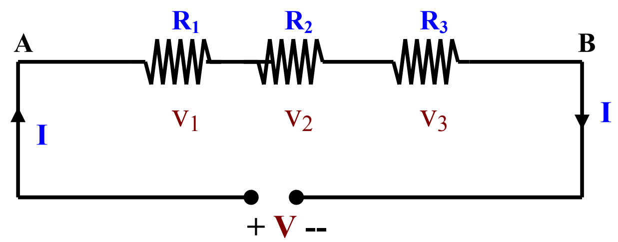
$$\therefore \mathbf{R} = \frac{\boldsymbol{\rho}\mathbf{L}}{\mathbf{A}} \qquad \therefore \boldsymbol{\rho} = \frac{\mathbf{RA}}{\mathbf{L}}$$

- Where ρ is a constant, known as specific resistance (Resistivity) of the material of the conductor, and its value depends upon the nature of the material.
- When L = 1, A = 1

$$\mathbf{R} = \frac{\boldsymbol{\rho}\mathbf{L}}{\mathbf{A}} = \frac{\boldsymbol{\rho} \times \mathbf{1}}{\mathbf{1}} = \boldsymbol{\rho} \qquad \therefore \mathbf{R} = \boldsymbol{\rho}$$

- The specific resistance (Resistivity) of a material is defined as the resistance of unit length of conductor having unit cross sectional area. The unit of specific resistance is **ohm-meter** is MKS and **ohm-cm** in CGS.

Resistance in series



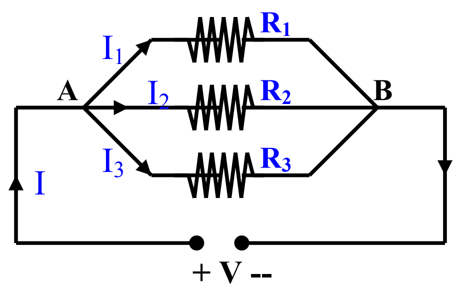
- In series the connection, the resistors are connected as shown in figure.
- In the series arrangement current flows through each resistance is same.
- The potential difference across each resistance is different.
- The total potential difference between the two ends of the combination is equal to the sum of the potential differences across each resistance. i.e; $V = V_1+V_2+V_3$.

  According to Ohm's law; $V=IR_S$, $V_1 = IR_1$, $V_2 = IR_2$ and $V_3 = IR_3$,

$$\therefore V = V_1+V_2+V_3$$
$$IR_S = IR_1+ IR_2 + IR_3$$
$$IR_S = I(R_1+ R_2 + R_3)$$
$$R_S = R_1+ R_2 + R_3$$

- The effective resistance of the series combination R_S is equal to the sum of the resistances in the series combination.

Resistances in parallel



- In parallel combination of the resistor, one end of each resistance is connected to a common point. Similarly the other end is connected to another common point. These common points are connected to a source of current.
- The potential difference across each resistance is the same but the current flowing through each resistance is different. The total current is equal to the sum of the current passing through each resistance. i.e; $I=I_1+I_2+I_3$
- According to Ohm's law; $V=I_1R_P$, $V = I_1R_1$, $V = I_2R_2$ and $V = I_3R_3$

  $\therefore$ We can also write; $I = \dfrac{V}{R_P}$ $I_1 = \dfrac{V}{R_1}$, $I_2 = \dfrac{V}{R_2}$ and $I_3 = \dfrac{V}{R_3}$

$$\therefore I = I_1 +I_2+I_3$$
$$\therefore \frac{V}{R_P} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$
$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

- Thus the reciprocal of the effective resistance of the parallel combination is equal to the sum of the reciprocals of resistances in the parallel combination.

Effect of temperature on resistance

- In general the electrical resistance of a material will vary with temperature. For conductors (metallic), over reasonable ranges of temperature, the resistance increases with increase in temperature.
- Let,

  Resistance at temperature $\mathbf{t_1}$ ^{0}**C** = $\mathbf{R_1}$ ohm.
  Resistance at temperature $\mathbf{t_2}$ ^{0}**C** = $\mathbf{R_2}$ ohm.

- Now change in value of resistance (**R_2 - R_1**) is directly proportional to:
    1. The original resistance of conductor **R_1** at **t_1** ^{0}C.
    2. Change in temperature, **(t_2 - t_1).**

$$\therefore (R_2 - R_1) \propto R_1 (t_2 - t_1).$$
$$\therefore (R_2 - R_1) = \alpha R_1 (t_2 - t_1) \text{- ---------------------------------(1).}$$
$$\therefore R_2 = \alpha R_1 (t_2 - t_1) + R_1.$$
$$\therefore R_2 = R_1 [1+\alpha (t_2 - t_1)] \text{- ---------------------------------(2).}$$

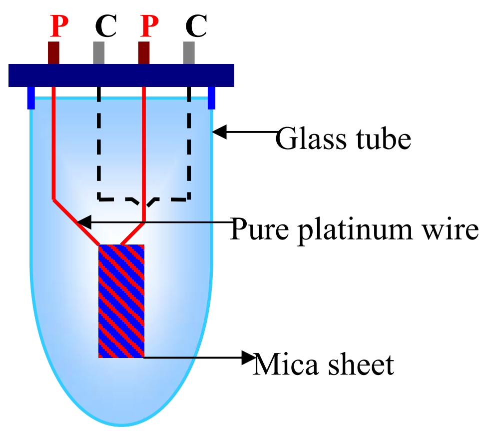
- Now from equation (1)

$$\therefore (R_2 - R_1) = \alpha R_1 (t_2 - t_1)$$
$$\alpha = \frac{(R2 - R1)}{R1\,(t2 - t1)} \text{ ---------------------------------------(3)}$$

- Here "α" is constant and called the temperature co-efficient of resistance (TCR). It is define as increase in resistance per unit original resistance per unit degree rise in temperature. Unit of "α" is 1/^{0}C.

Platinum Resistance Thermometer:

Principle:



- The resistance of pure metallic wire increases with increases in temperature.

Let, **R_{100}** = Resistance at **100** ^{0}C.
R_0 = Resistance at **0** **^{0}C.**
R_t = Resistance at t **^{0}C**

Then, we can have,

$$\alpha = \frac{(R_t - R_0)}{R_0\,(t - 0)} = \frac{(R_{100} - R_0)}{R_0\,(100 - 0)}$$

$$\therefore \quad t = \frac{(R_t - R_0) \times 100}{(R_{100} - R_0)}$$

Construction:

- The platinum resistance thermometer consists of a pure platinum wire wound on a thin mica sheet. A platinum wire is double on itself to avoid induction effect. These are connected to the terminals P-P.
- An exactly similar pair of leads is connected to terminal C-C, to compensate for the resistance of platinum lead. This arrangement is enclosed in ahard glass tube and sealed at the top.

Procedure:

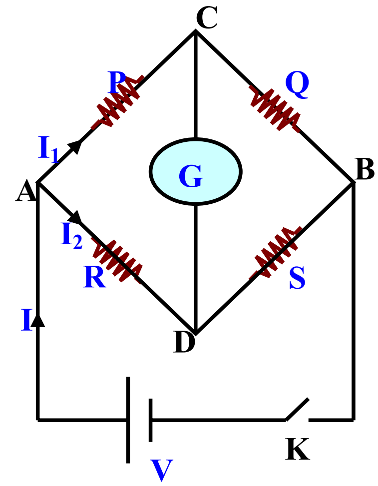
- Resistance of platinum wire is measured by wheatstone bridge, by placing arrangement in the liquid bath at **0** **^{0}C** and **100** **^{0}C** respectively. After that arrangement is placed in a bath of unknown temperature **t** **^{0}C**, and the resistance of platinum wire **R_t** is measured by wheatstone bridge.
- Now the unknown high temperature of the bath can be calculated by using formula

$$t = \frac{(R_t - R_0) \times 100}{(R_{100} - R_0)}$$

- This thermometer is suitable to use over a wide range of temperature i.e: from –200 ^{0}C to 1300 ^{0}C, but it is not suitable for measuring unsteady and rapidly varying temperature.

➢ WHEATSTONE NETWORK

Principle:



- Wheatstone network is an arrangement to determine unknown resistance.
- Two resistances P and Q are joined in series. Other two resistances R and S are joined in series. These combinations are connected in parallel to each other as shown in figure.
- The common points A and B are connected to a battery. A galvanometer G is connected between points C and D.
- Now the resistances are so adjusted that there is no current through galvanometer, i.e: null deflection point is obtained. This is possible only when points C and D are at the same potential.
- Therefore,
  Potential difference across resistance **P** = Potential difference across resistance **R**

$$I_1P = I_2R \quad \text{-------------------(1)}$$

Potential difference across resistance **Q** = Potential difference across resistance **S**

$$I_1Q = I_2S \quad \text{----------------------(2)}$$

Dividing equation (1) by (2),

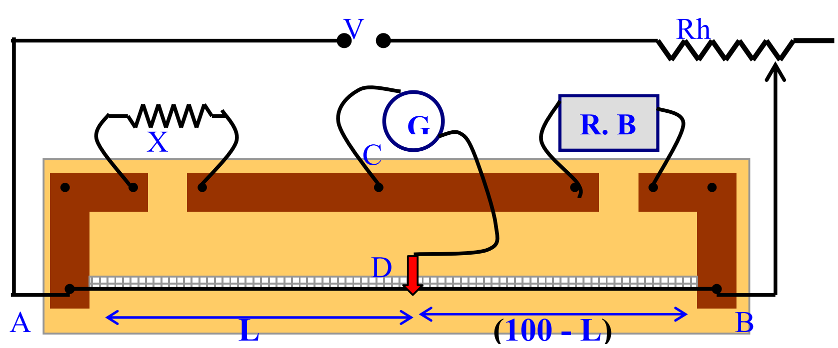
$$(I_1P)/(I_1Q) = (I_2R)/(I_2S)$$

$$\therefore P/Q = R/S$$

- This is called principle of wheatstone network

Meter-Bridge or Wheatstone bridge:

- Meter-bridge is practical application of wheatstone network. It consists of a resistance wire **AB** having one-meter length and uniform cross sectional area. Unknown resistance **X** and the resistance box **R.B** are connected at two gaps as shown in figure.



Procedure:

- Certain value of resistance is introduced with the help of resistance box **R**.
- The pencil jockey is moved over the wire **AB** and the point is found such that there is no deflection in the galvanometer. This point is called null point.
- By applying the principal of wheatstone network, we can have

$$\frac{\mathbf{X}}{\mathbf{R}} = \frac{\textbf{Resistance of wire of length L}}{\textbf{Resistance of wire of length (100 - L)}}$$

$$\frac{\mathbf{X}}{\mathbf{R}} = \frac{\textbf{\{Length of wire L\} x (Resistance per unit length)}}{\textbf{\{Length of wire (100 - L)\} x (Resistance per unit length)}} = \frac{\mathbf{L \times r}}{\mathbf{(100 - L) \times r}}$$

$$\mathbf{X = R \times \frac{L}{(100 - L)}}$$

Fall of potential along the length of a wire, (Principle of Potentiometer):

- Consider a wire of length **L**, having a uniform cross sectional area **A**. let **R** be the resistance and ρ be the specific resistance. If **I** be the current flowing through the wire, the potential difference between its ends **V**, then from Ohm's law

$$\mathbf{V = IR}$$

$$\mathbf{V} = \frac{\mathbf{I\rho}}{\mathbf{A}} \cdot \mathbf{L} \qquad \text{as we know that } \mathbf{R} = \frac{\mathbf{\rho L}}{\mathbf{A}}$$

- Here the current flowing through the wire **I** is constant. Similarly, ρ and **A** are also constant. Therefore the term **Iρ/A** is constant.
- By replacing the term **Iρ/A** by **K = Iρ/A = constant**. we now get

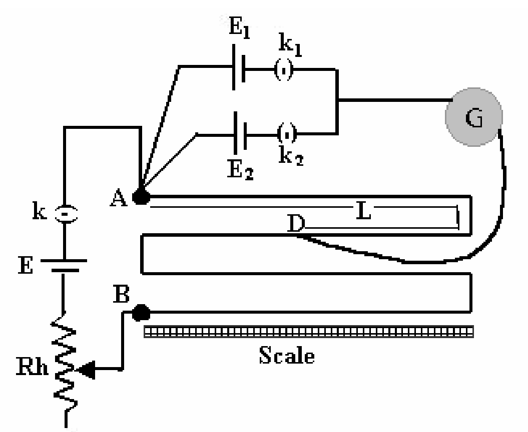
$$\mathbf{V=KL} \quad \text{or} \quad \mathbf{V \propto L}$$

- Thus we see that the potential difference along the length of a wire is directly proportional to its length. This is also called **Principle of Potentiometer**.

POTENTIOMETER:

Comparison of e.m.f.'s of two cells.

- Consider a resistance wire **AB** of uniform cross sectional area. Its ends are connected to the terminals of a standard cell of **E**. The potential difference between points **A** and **B** is equal to the e.m.f. of this cell.
- The fall of the potential across resistance wire **AB** is proportional to the length of the wire.
- To compare the emf's of two cells all the connections are made as shown in circuit diagram. The positive terminal of two cells whose emf's are $\mathbf{E_1}$ and $\mathbf{E_2}$, are connected to point **A** and the negative terminal is connected to a pencil jockey through a galvanometer.



- To start with the experiment the key $\mathbf{K_1}$ is inserted and key $\mathbf{K_2}$ is removed so that the cell of emf's $\mathbf{E_1}$ is in circuit. The key **K** is inserted and the jockey is moved on the potentiometer wire till there is no deflection in the galvanometer. Let the balancing length of the wire be $\mathbf{L_1}$, then according to principle of potentiometer,

$$\mathbf{E_1 \propto L_1}$$

$$\mathbf{E_1 = K\,L_1} \quad \text{----------------------(1)}$$

- Similar part is repeated for the cell of emf's $\mathbf{E_2}$ by inserting the key $\mathbf{K_2}$ and removing key $\mathbf{K_1}$. In this case

$$\mathbf{E_2 \propto L_2}$$

$$\mathbf{E_2 = K\,L_2} \quad \text{-----------------------(2)}$$

- Dividing equation (1) by equation (2), we get,

$$\frac{E_1}{E_2} = \frac{L_1}{L_2} \quad \text{----------------------(3)}$$

- The emf's of the two cells can be compared using this relation. The emf's of the standard cell should be greater than the emf's of the cells to be compared.

HEATING EFFECT OF ELECTRIC CURRENT:

In 1841 scientist joule observed that when electric current is passed through any conductor then the conductor is heated. This effect is called as heating effect of the electric current. The heating effects of electric current have been used in many electrical devices like electric bulb, electric iron, electric heater etc.

Joule's law:

- According to joule's law if a current (**I**) passes through the conductor of resistance (**R**) for '**t**' seconds then the amount of heat (**H**) produce in a given conductor is directly proportional to:
    1. Square of the electric current (**I**) passing through it,
    2. The resistance (**R**) of the conductor, and
    3. The time '**t**' for which current passing.

$$\therefore \mathbf{H} \propto \mathbf{I^2 R\, t} \qquad \therefore\ \mathbf{H} = \frac{\mathbf{I^2 RT}}{\mathbf{J}} = \frac{\mathbf{VIT}}{\mathbf{J}}$$

- Where 'J' is a joule's constant and known as mechanical equivalent of heat. Its value is 4.186 joule/cal.

Electrical power (P)

- It is a time rate of doing electrical work.
- As we know that ' electrical work done to move a unit positive charge = **V** (Potential difference)
- Now total work done to move 'q' charges (**W) = Vq = VIt** joules
- Now electric power **(p) = W/t = VI watt**.

Electrical energy (E)

- It is the capacity to do electrical work.
- Electrical energy = Power (**P**) x Time (**t**) = **VIt** watt-hour or Kilowatt-hour (**KWH**).
- Electricity consumed for domestic/commercial purpose is "**1Unit = 1Kilowatt-hour**"

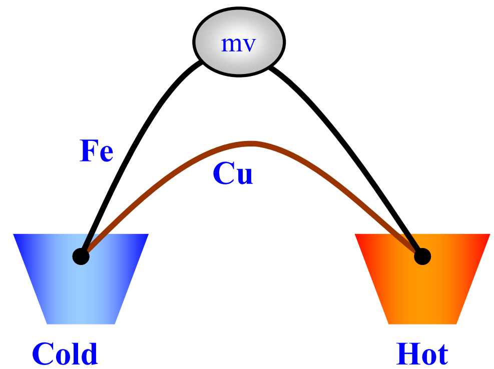
Calculation of electric energy bills:

- Energy consumed by electrical appliances in KWH if calculated by following equation.

$$\text{Unit consumed} = \frac{\text{nwhd}}{1000}$$

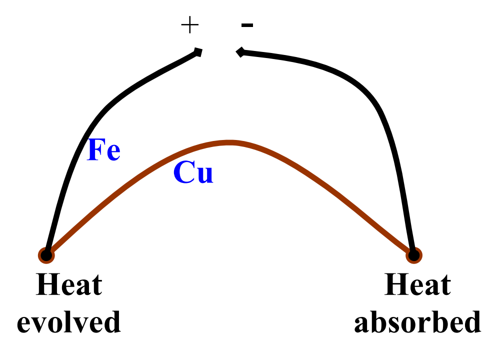
Where **n** = number of electrical appliances.,
w = wattage of electrical appliances.
h = daily hours of use.
d = number of days

Seeback Effect:



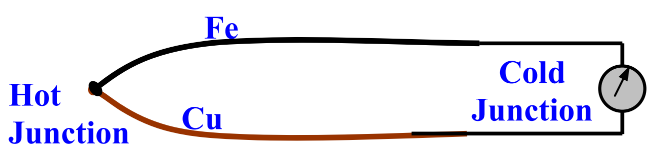
- Seeback discover that if a circuit consists of two dissimilar metals such as iron (Fe) and copper (Cu), an emf's produced in it when junctions of metals are maintained at different temperatures.
- This effect is known as seeback effect.
- The current so produce is called thermo-electric current and The emf's so produce is called thermo-electric emf's and the phenomenon is called as thermo-electricity

Peltier Effect



- Peltier discover that when a current is passing through circuit consist of two dissimilar metals such as iron (Fe) and copper (Cu), heat is evolved (produce) at one junction and heat is absorbed at another junction.
- This effect is known as peltier effect.
- Peltier effect is reversible effect, because if the direction of current is reversed than the hot junction become cold and the cold junction becomes hot.

Thermocouple:



- It is based on the principle of seeback effect. The thermocouple consists of two wires of different material welded at one end, which acts as hot end junction.
- The hot junction is kept in contact with the body whose temperature is to be measured. The galvanometer, which is calibrated in terms of ^{0}C, directly gives the temperature difference between hot and cold junction.
- Advantages:
  1. It has a wide range up to 3000 ^{0}C.
  2. Rapidly changing temperatures can record.
  3. It is cheap and easy to construct.
  4. It can measure temperature at a point.
- Disadvantages:
  1. It is not accurate over wide range.
  2. Different thermocouples are required in the different range of temperature.
  3. For each thermocouple, galvanometer requires fresh calibration.

- Thermoelectric Series:

  Antimony, Nichrome, Iron, Zinc, Copper, Gold, Silver, Lead, Aluminum, Mercury, Platinum, Rhodium, Nickel, Constantan, Bismuth.

  Large distance between two metal, greater is the e.m.f., i.e. largest e.m.f. is obtained with an Antimony-Bismuth.

ELECTROMAGNETISM

Magnet:

- A substance that attracts small pieces of iron and shows approximately north-south direction when suspended freely is called a magnet. Every magnet has two poles. The unit for measurement of pole strength is Weber or ampere-meter.

Magnetic Field:

- The space surrounding the magnet where its effects are felt (observed) is called magnetic field.

Magnetic Force:

- The magnetic force between two magnetic poles of strength $\mathbf{m_1}$ and $\mathbf{m_2}$ placed distance $\mathbf{r}$ apart is given by the relation

$$\mathbf{F = \frac{1}{4\pi\mu_0\mu_r}\frac{m_1 m_2}{r^2}}$$

Where μ_0 = permeability of vacuum
μ_r = relative permeability of the medium,
μ_r = 1 for air

Magnetic Field strength:

- The strength or intensity of magnetic field at a point is defined as the force acting on a unit North Pole placed at that point.
- The intensity of magnetic field at a point at a distance $\mathbf{r}$ from the pole of strength $\mathbf{m}$ is given by

$$\mathbf{H = \frac{1}{4\pi\mu_0\mu_r}\frac{m}{r^2}}$$

- The units of its intensity are (Newton)/(Weber) or ampere -turn/meter.

Magnetic lines of force:

- The curve along which a unit North Pole moves when placed in a magnetic field is called magnetic line of force.
- Outside the magnet, the lines of force start from a North Pole and terminate on a South Pole. Inside a magnet, the direction of lines of force is from South Pole to North Pole.
- The lines of force do not intersect each other.

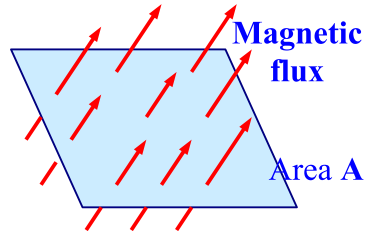
Lines of induction:

- The magnetic lines of force inside a magnetic material are called lines of induction.

Magnetic flux (Φ):

- The number of magnetic lines of induction starting from the magnetic pole is called the magnetic flux. The magnetic flux is equal to the pole strength. Its unit is same as that of pole strength: Weber.

Magnetic induction (B)



- The number of lines of induction crossing unit surface normally is called flux density or more commonly magnetic induction (**B**).
- Let **Φ** be the number of lines of induction crossing an area **A**, normally. The magnetic induction is then given by

$$\mathbf{B} = \frac{\mathbf{\Phi}}{\mathbf{A}}$$

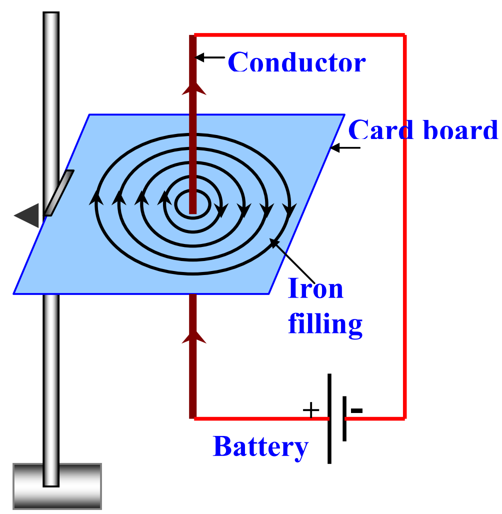
- The units of magnetic induction are weber/m^2 or Newton/amp-m
- The relation between magnetic induction and the intensity of magnetic field is

$$\mathbf{B} = \mu_0\mu\mathbf{H}$$

Putting the value of H we get $\mathbf{B} = \mu_0\mu \frac{1}{4\pi\,\mu_0\mu}\frac{m}{r^2}$

$$\therefore \mathbf{B} = \frac{m}{4\pi\, r^2}$$

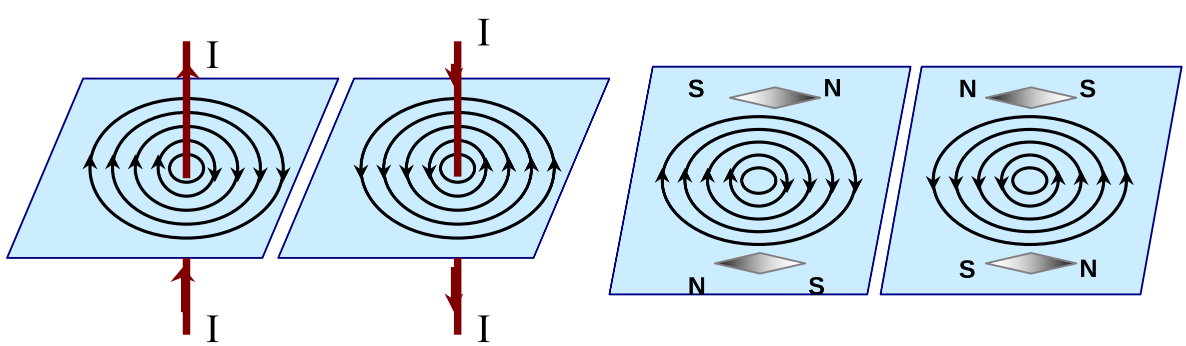
Magnetic effect of electric current:

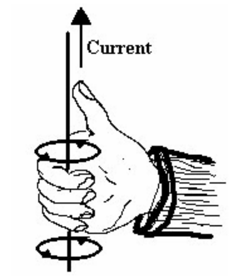


- When electric current is passed through a conductor, a magnetic field is developed in the space surrounding it. This is called the magnetic effect of electric current.
- As shown in figure, take a smooth cardboard sheet with a hole in its center and hold it horizontally.
- Now pass straight copper wire through the hole and sprinkle some iron filing upon the cardboard.
- Pass the electric current through the copper wire. It will found that iron filings are arranging themselves in concentric circles round the wire.
- This clearly indicates that there exists a magnetic field around the conductor carrying current.

Direction of magnetic field and current:

- The direction of the current flowing in a conductor and the direction of the associated field are inter-related.

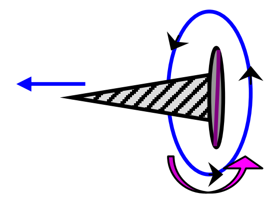




Ampere's rule (Right-hand palm rule):

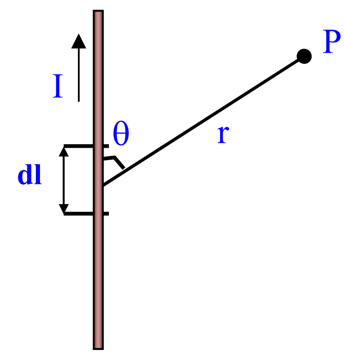
- If a current carrying conductor is grasped in the right hand with the fingers coiled around it and with the extended thumb in the direction of the current.
- Then the tips of the folded fingers give the direction of the lines of force, as shown in figure.

Right-hand crock screw rule:



- If a right hand screw is turned to advance along the conductor in the direction of current, the direction of rotation of the screw gives the direction of the lines of force as shown in figure.

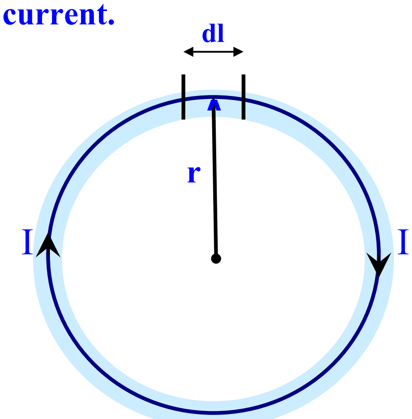
Biot-Savart's law:



- Biot-Savart's law gives the intensity of the magnetic field at a point due to passage of a current through a conductor.
- Consider an element of length **dl** of a conductor through which current of **I** ampere is flowing.
- Take any point **P** at a distance **r** from the center of this element.
- Let θ be the angle between the direction of current and the line joining the mid-point of the element the point **P**. then the intensity of the of magnetic field at point **P** is given by

$$dH = \frac{I\,dl\sin\theta}{4\pi r^2}$$

Magnetic induction at the center of circular coil carrying current.



- Consider a circular coil of radius **r** and carrying current **I** ampere. The length of the conductor is **l = 2πr**.
- Due to passage of current through the conductor, magnetic field is developed in the space surrounding it.
- To find the magnetic induction at the center of the circle, the length of the conductor is divided into number of elements each of length **dl**. Therefore total length of the conductor **l** = ∑**dl**.
- Consider one such element **dl** at point **A** on circular coil. Its distance from the center of the circle is equal to **r**.
- The angle between the line joining the center of the circle and the midpoint of the element **dl** is, θ = 90°.
- The Intensity of magnetic field at the center of the circular coil due to current passing through the element **A** can be given from Biot-Savart's law as

$$dH = \frac{Idl\sin 90}{4\pi\ r^2} = \frac{Idl}{4\pi\ r^2} \quad \text{as} \sin 90 = 1$$

- For all the elements of the conductor, **r** is the same and θ = **90°,** therefore Intensity of magnetic field due to entire length of the conductor is

$$\mathbf{H} = \Sigma d\mathbf{H} = \sum \frac{\mathbf{I}dl}{4\pi r^2}$$

$$\therefore \ \mathbf{H} = \frac{\mathbf{I}}{4\pi r^2}\sum dl = \frac{\mathbf{I}}{4\pi r^2}\cdot l = \frac{\mathbf{I}\times 2\pi r}{4\pi r^2}$$

$$\therefore \ \mathbf{H} = \frac{\mathbf{I}}{2r}$$

We have $\mathbf{B} = \mu_0\mu_r\mathbf{H}$

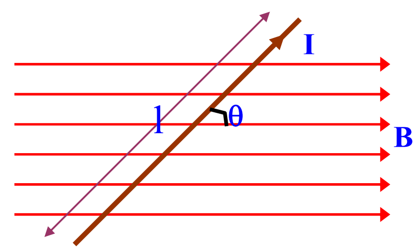
$$\therefore \ \mathbf{B} = \frac{\mu_0\mu_r\mathbf{I}}{2r}$$

- If the coil consists of **n** turns, the total magnetic induction at the center of the coil will be

$$\therefore \ \mathbf{B} = \frac{\mu_0\mu_r\, n\,\mathbf{I}}{2r}$$

Force acting on current carrying conductor placed in a magnetic field.

- If a current carrying conductor is placed in the magnetic field it experiences a force.
- The tendency of this force is such that it tends to move the conductor at right angle to the direction of field and the current.
- Let a conductor of length **l**, carrying current **I** lying in a uniform magnetic field of strength **H** and flux density **B** Wb/m^2, make an angle **θ** with the direction of the field as shown in figure.



- The force experienced by the conductor is directly proportional to:
  1. Length of the conductor (**l**),
  2. Current in the conductor **(I**),
  3. Flux density of the field (**B**).

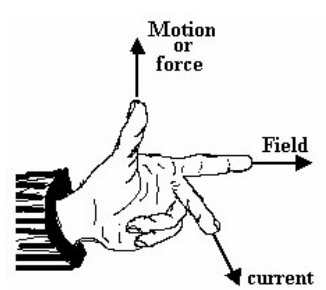
$\therefore$Force experienced by the conductor in the magnetic field is $\mathbf{F} = \mathbf{B}\lambda\mathbf{I}\sin\theta$

If the conductor is at 90^0 to the direction of the field, the force on conductor,

$$\mathbf{F} = \mathbf{B}\mathbf{I}\lambda.$$

Fleming's Left Hand Rule:

- The direction of the induce e.m.f. of the induce current may be found by Fleming's left hand rule.
- Stretch the forefinger. Second finger and thumb of the left hand mutually at right angles.
- If the forefinger points in the direction of field and the second finger in the direction of current, the thumb will point in the direction of motion.



Electromagnetic Induction:

- In 1831, Faraday found that whenever a bar magnet is moved towards or away from a stationary closed coil, electrical current flows through the coil. The electrical current also produces, if magnet is stationary and the coil is moved towards or away from the magnet.
- In other ward, whenever there is relative motion between the coil and the magnet, electric current is produced. This phenomenon is called **electromagnetic induction.**
- Therefore, **electromagnetic induction** is the phenomenon of production of electric current in close coil, when magnetic flux linked with the coil is changed.

FARADAY'S EXPERIMENTS:

The following experiments performed by faraday led to the discovery of the phenomenon of electromagnetic induction.

Experiment 1.

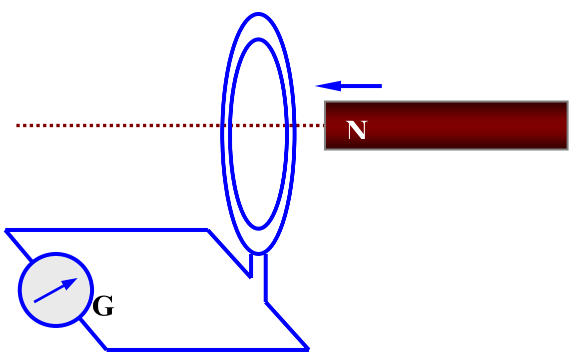
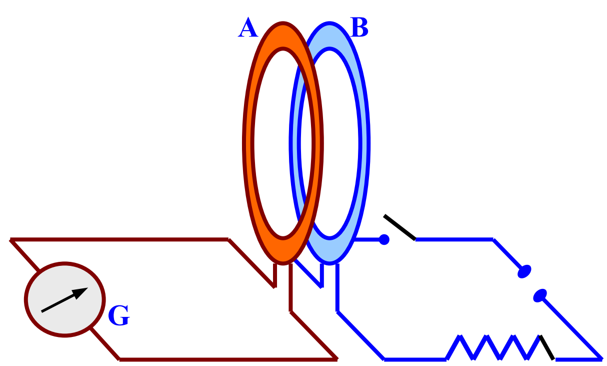


Figure shows a circular loop of wire connected to a sensitive galvanometer. A magnet NS is placed along the axis of the loop of the wire. Faraday found that:

1. Whenever a bar magnet is moved towards the loop of wire, the galvanometer in the circuit shows a sudden deflection.
2. The galvanometer shows deflection only for the time for which the magnet remains in motion.
3. The deflection in the galvanometer becomes large, if the magnet is removed quickly.
4. The deflection in the galvanometer changes direction, when magnet is moved away from the loop of the wire or when the polarity of the magnet is reversed.

The similar results were observed, when the loop of wire is moved and magnet is kept fixed. It is clearly indicated that, the phenomenon of **electromagnetic induction** is connected with the relative motion between the coil and the magnet.

Experiment 2.



In this experimental arrangement, the magnet is replace by a current loop through which current can be switch on of off with the help of a tapping key. Faraday observed following facts:

1. Whenever the tapping key is pressed so that current in loop **B** starts growing from zero to maximum, the galvanometer connected to loop **A** shows deflection.
2. The galvanometer shows deflection only for the time for which the current in the loop **B** is changing.
3. The galvanometer shows deflection in opposite direction, as the current in loop **B** is decreased from maximum to zero by releasing tapping key.

4. The deflection in the galvanometer becomes large, if the tapping key is pressed or released quickly.

The current loop **B** in the setup acts as the magnet **N-S**. It is because; a current loop is equivalent to a magnetic dipole or magnet.

Faraday's laws of electromagnetic induction:

- On the basis of the experiments, Faraday gave the following laws:
  1. Whenever magnetic flux linked with a circuit changes, induced e.m.f. is produced.
  2. The induced e.m.f. lasts as long as the change in magnetic flux continues.
  3. The magnitude of the induced e.m.f. is directly proportional to the rate of change of the magnetic flux.
- Let us consider a coil of **N** turns. Let it be kinked with initial flux Φ_1 and then in time seconds it is linked with a final flux Φ_2 webers. I.e.; flux changes in the coil from Φ_1 to Φ_2 in time t seconds.

Change in flux per conductor = $(\Phi_2 - \Phi_1)$ Wb.

Rate of change in flux per conductor $= \frac{d\Phi}{dt} = \frac{(\Phi 2 - \Phi 1)}{t}$ Wb/sec.

If **E** is the induce e.m.f. produced, then

$$E \,\alpha \left(\frac{d\Phi}{dt} = \frac{(\Phi 2 - \Phi 1)}{t} \right)$$

$$E = -k\left(\frac{d\Phi}{dt} = \frac{(\Phi 2 - \Phi 1)}{t} \right)$$

$$E = -k\frac{d\Phi}{dt} = -k\frac{(\Phi 2 - \Phi 1)}{t}$$

Hence induced e.m.f. in **N** conductors = $E = -kN\frac{d\Phi}{dt} = -kN\frac{(\Phi 2 - \Phi 1)}{t}$

Here, k is constant of proportionality, k=1 in SI system and the negative sign indicates the opposing nature of induced e.m.f.

Lenz's law

- It stat that the direction of the induced e.m.f. is such that it tends to oppose the change in flux which induces it.

4. ELEMENTARY ELECTRONICS

Energy levels in a solid

- Combination of atoms of a material or element and its behavior in an electric or magnetic field depends upon their atomic structure. In the atomic structure, the atomic number is equal to the number of electrons, which is equal to the number of proton as the atom is electrically neutral.
- The orbits (shells) fill up from the center by electrons, until a number of electrons equal to the number of protons are reached. Each orbit (shell) of the atom, hold electrons in the following manner.

Orbit n	Symbol Of shell	Sub-shells	Maximum number of electron hold by orbit = ($2n^2$)	Maximum number of electrons accommodated in each sub-shell				Representation of Electronics configuration
				s	p	d	f	
1	K	S	2	2				$1s^2$
2	L	S, p	8	2	6			$1s^2$, $2s^2$,$2p^6$
3	M	S, p, d	18	2	6	10		$1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^6$, $3d^{10}$
4	N	S, p, d, f	32	2	6	10	14	$1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^6$, $3d^{10}$, $4s^2$,$4p^6$, $4d^{10}$, $4f^{14}$

- For example consider atomic structure of germanium atom. Its atomic number is **32**. The nucleus consists of 32 protons and 32 electrons. The four orbits contain **32** electrons in the following manner:

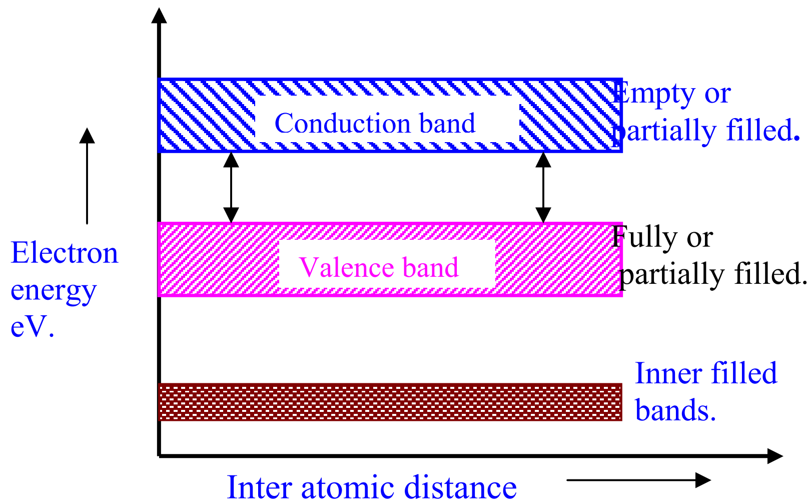
  1^{st} Orbit: **2** Electros (Full)
  2^{nd} Orbit: **8** Electros (Full)
  3^{rd} Orbit: **18** Electros (Full)
  4^{th} Orbit: **4** Electros (Can hold 32 electrons)

  Electronics configuration: $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^6$, $3d^{10}$, $\mathbf{4s^2}$, $\mathbf{4p^2}$

- The forth shell which could hold 32 electrons has only 4 electrons in it. This outer shell often called the valence shell, determines how the atom will bond or react with other atoms. The outermost $\mathbf{4s^2}$, $\mathbf{4p^2}$ electrons are called valence electrons or the electrons in the outermost shell are called valence electrons. The valence energy band is formed by the valence electrons in crystal.

Valence band

- The lower energy band formed by a series of energy levels containing the valence electrons is known as valence band. The valence band may also be defined as **band, which is occupied, by the valence electrons** or **a band having highest occupied band energy.**

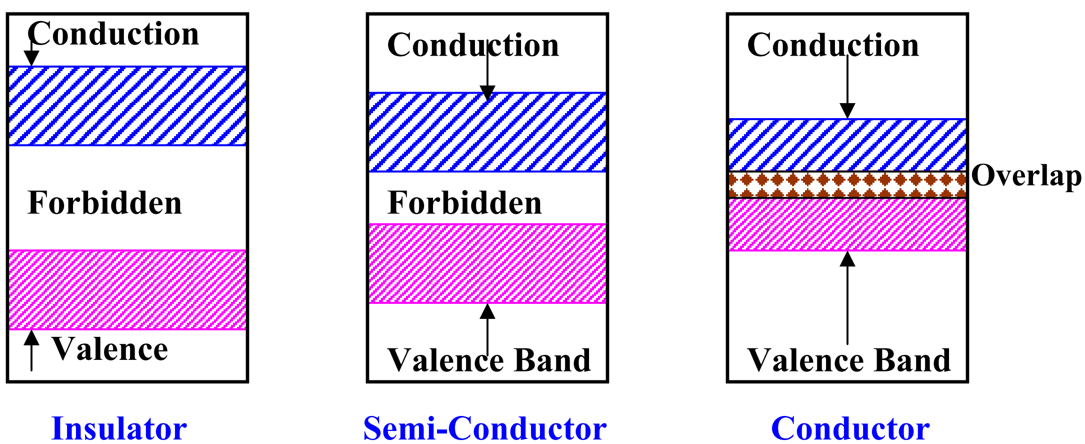


Conduction band

- The next higher permitted energy band formed by empty levels is called the **conduction band.** The electrons occupying this band are known as conduction electrons. The conduction band may also be defined as **the lowest unfilled energy band in the solid**. This may be empty or partially filled by the conduction electrons, which are free to move in the solid.

Forbidden band or band gap

- The valence band and conduction band are separated by a energy gap known as forbidden band or energy band gap. No electron can exist in this band. When an electron in the valence band absorbs enough energy, it jumps the forbidden gap and enters the conduction band.



- On the basis of forbidden gap, the insulator, semiconductor and conductors are described as **Insulators, Semiconductor and Conductors.**

Insulators:

In case of insulators, the forbidden energy gap is very wide and therefore the electrons cannot jump from valence band to conduction band. In insulators valence electrons are bound very tightly to their parent atoms. When a very large energy is supplied (by increasing temperature), an electron may be able to jump across the forbidden gap and thus certain insulators become conductors at high temperature. The resistivity of insulators is of the order of10^7 ohm-metre.

Semiconductor:

In semiconductor, the forbidden energy gap is very small. Semiconductors material is one whose electrical properties lie between insulator and conductors. At **0^oK**, there are no electrons in conduction band and the valence band is completely filled. When a small amount of energy is supplied, the electrons can easily jump from valence band to conduction band.

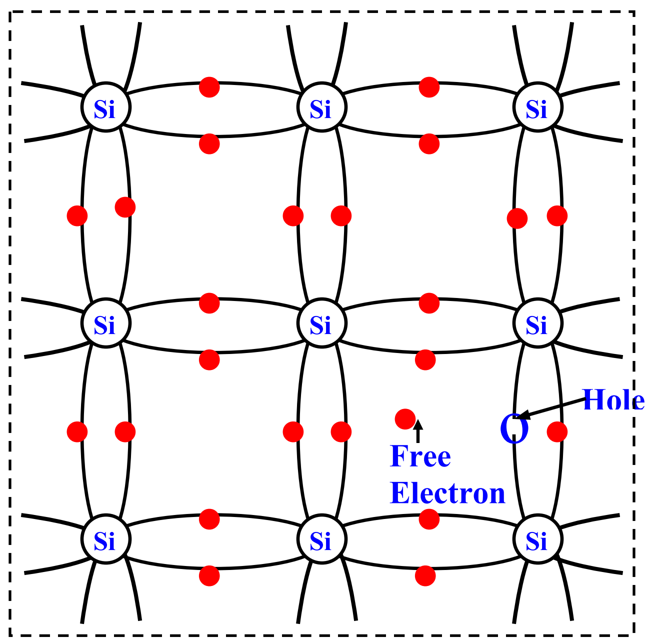
Conductors:

In case of conductors, there is no existence of forbidden band, whereas Conduction band and Valence band overlaps with each other. Here plenty of free electrons are available for electric conduction. The electrons from the valence band freely enter in the conduction band.

INTRINSIC AND EXTRINSIC SEMICONDUCTORS

Intrinsic Semiconductors

- Pure semiconductor material behaves as an insulator at low temperatures.
- Due to the thermal agitation of the crystal structure, electrons from a few covalent bonds come out. The bonds from which electrons are freed, a vacancy is created. This vacancy of electron is called hole.
- Some other electron in a covalent bond can fill this hole. As the electron from a covalent bond moves to fill the hole, the hole is created in the covalent bond from which the electron has moved.
- Thus, at room temperature, a pure semiconductor will have electrons and holes wandering in random directions. This electrons and holes are called **intrinsic carriers** and such a semiconductor is called **intrinsic semiconductor**.



- In intrinsic semiconductor number of electrons and holes are equal. For example highly pure crystal of Ge, Si etc.

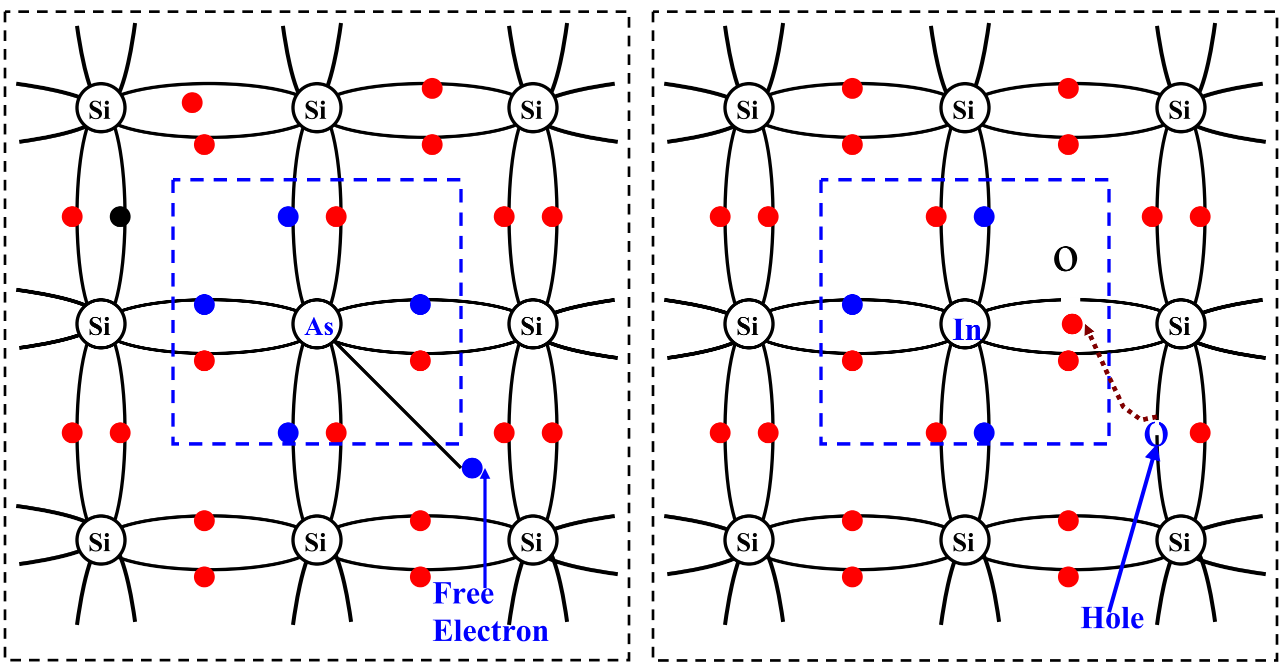
Extrinsic Semiconductors

- Pure semiconductor at room temperature possesses free electrons and holes but their number is small therefore conductivity offered by pure semiconductor cannot be made of any practical use.

- By the addition of impurities, the conductivities of pure semiconductor can be remarkably improved. The process of adding impurity to pure semiconductors is called **doping**.
- The impurity atoms are two types: **(1) Pentavalent impurity atoms, (2) Trivalent impurity atoms**
  - **(1)** **Pentavalent impurity atoms** having 5 valence electrons such as Antimony (**Sb**) or Arsenic (**As**). Such atoms, when added to a pure semiconductor, will create excess of free electrons.
  - **(2)** **Trivalent impurity atoms** having 3 valence electrons such as Indium (**In**) or Gallium (**Gu**). Such atoms, when added to a pure semiconductor, will make the crystal deficient in electrons and holes will be produced.
- Hence addition of pentavalent or trivalent impurity can increase the electrical conductivity of pure semiconductor material. Such types of semiconductors are called **extrinsic semi-conductors**.

N – type semiconductor and P – type semiconductor

Figure shows the effect of adding pentavalent impurity arsenic (As) and trivalent impurity indium (In) to silicon crystal. When impurity is added to the silicon crystal, its atoms replace the silicon atoms.



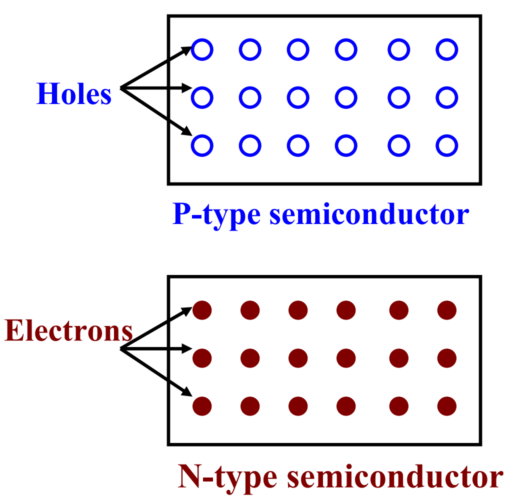
N-Type Semiconductor P-Type Semiconductor

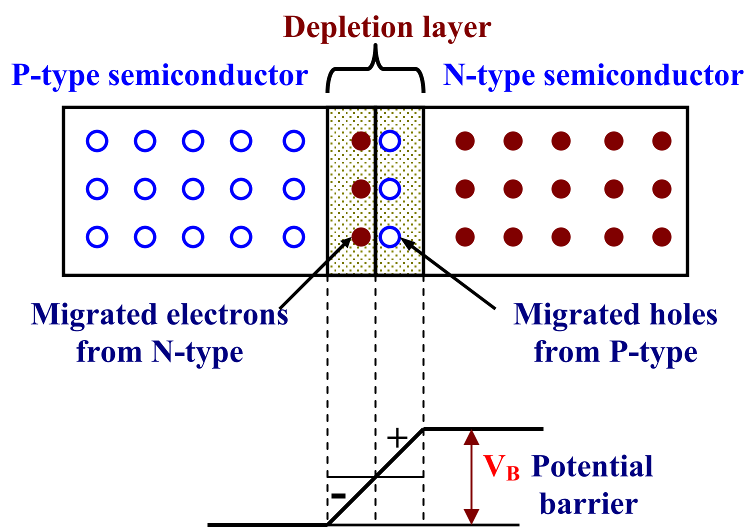
- For arsenic (As) impurity, the four electrons out of the five valence electrons of As-atom take part in covalent bonding with four silicon atoms surrounding it. The fifth electron is set free.
- The extra free electrons created in the crystal will be equal to the number of impurity atoms added. This type of impurity is called **donor impurity**. These free electrons in the silicon crystal are called extrinsic carrier and the Si crystal is called **N-type extrinsic semiconductor**.
- For indium (In) impurity, the four silicon atoms surrounding Indium atom, can share one electron each with the Indium atom, which has got three valence electrons.

- In an attempt to have 8 electrons in valence shell, the Indium atom robs one electron from one of the nearby covalent bond. Thus a hole is created in the covalent bond from which electron has been robbed.
- The extra holes created in the crystal will be equal to the number of impurity atoms added. This type of impurity is called **accepter impurity**. These holes in the silicon crystal are called extrinsic carrier and Si crystal is called **P-type extrinsic semiconductor.**

P-N JUNCTION DIODE:

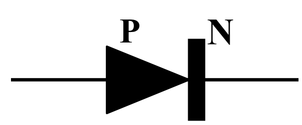
- When a **P-type** crystal is kept in contact with **N-type** crystal so as to form one piece, the assembly so obtained is called **P-N junction** or **junction diode**. In the p-section, holes are the majority carriers: while in the n-section, the majority carriers are electrons.
- Due to the high concentration of different types of charge carriers in the two sections, holes from P-region diffuse into N-region and electrons from N-region diffuse into P-region. In both cases when an electron meets a hole, they cancel the effect of each other and as a result, a thin layer forms at the junction, called **depletion layer**. The thickness of the depletion layer is of the order of 10^{-6}m.
- The potential difference developed across the junction due to migration of majority charge carriers is called **potential barrier**. It opposes the further migration of charge carriers. The value of potential barrier depends on the amount of doping of the semiconductor crystal.



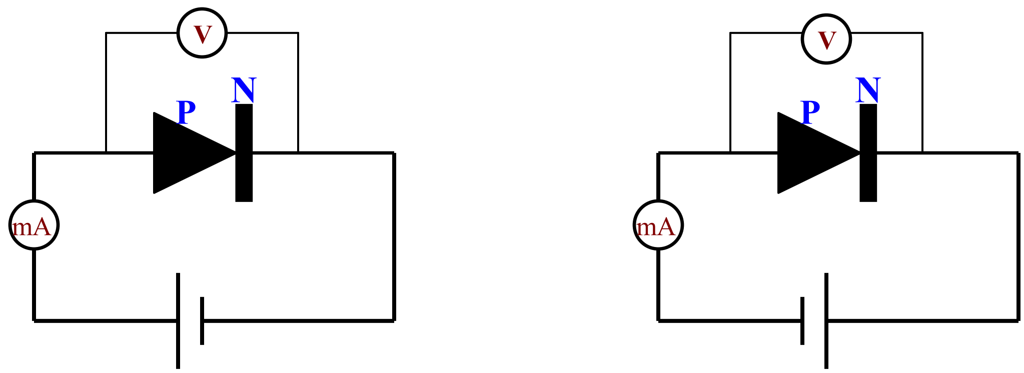


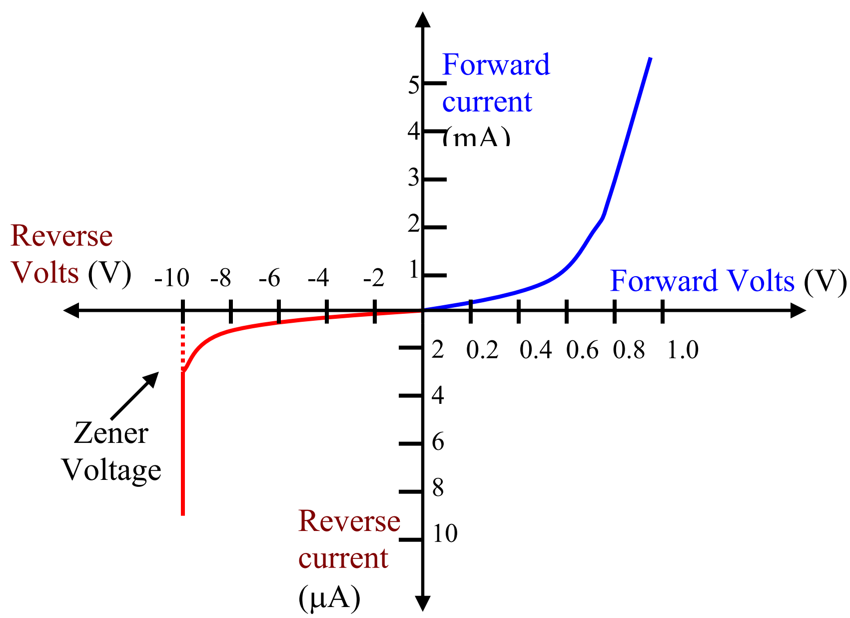
SYMBOLIC REPRESENTATION OF JUNCTION DIODE.

The arrowhead represents the p-section of the junction diode points in the direction in which the holes current, when junction diode is forward biased. The electron current will flow in opposite direction.



CHARACTERISTICS OF A P-N JUNCTION DIODE.





Forward bias:

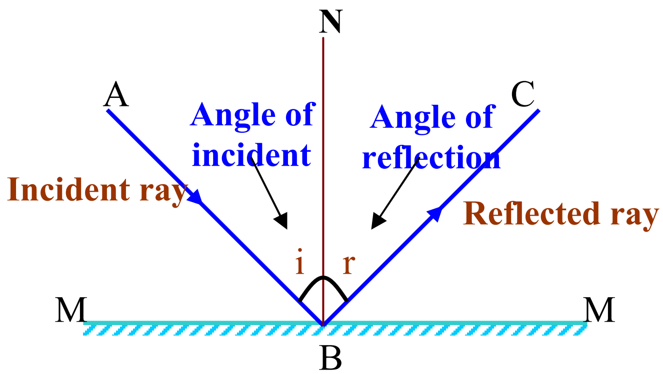
- When the battery is connected to the diode with P-section connected to positive pole and N-section to the negative pole, the junction diode is said **forward biased**.
- If the forward bias is greater than the potential barrier, the majority carriers move towards the junction and cross it.
- During the forward bias, due to motion of the majority carriers towards the junction, the depletion layer becomes thin and hence the junction diode offers a low resistance to the flow of current.
- Characteristic graph of forward bias shows a minimum few voltage (of about 0.3 to 0.7 V) is needed to overcome the potential barrier at the junction. With the further increase of forward bias from this value, the current in the external circuit increases rapidly and for a voltage as little as 1V or so, the current reached a value of about 8 to 10 miliAmperes.

Reverse bias:

- When the battery is connected to the diode with P-section connected to negative pole and N-section to the positive pole, the junction diode is said to be **reverse biased**.
- When reverse bias is applied, the majority carriers are pulled away from the junction so that the depletion region becomes thick. The resistance of junction diode becomes very high. The majority carriers do not cross the junction. However, a little amount of current flows due to the motion of minority carriers. This current is called reverse current.
- If the reverse bias is made very high, the covalent bonds near the junction break down and a large number of electron-hole pairs liberated and the reverse current increases abruptly to a relatively high value.
- The maximum reverse potential difference, which a diode can tolerate without break down, is called reverse **break down voltage** or **zener voltage**. Its value depends upon the density of impurity atoms.

5. LIGHT

LAWS OF REFLECTION:



MM→ **Smooth polished surface**
NB→ **Normal to the surface MM**
AB→ **Incident ray**
BC→ **Reflected ray**
∠ABN→ **Incident angle = i**
∠NBC→ **Reflected angle = r**

- When a ray of light falls on a smooth polished surface, it is reflected from the surface as shown in figure. Following are the **laws of reflection**:
    1. The incident ray, the reflected ray and the normal all lie in the same plane.
    2. The angle of incidence ($\angle$i) is equal to the angle of reflection ($\angle$ r).
- If the angle of incidence i =0 i.e. the incident ray follows the path of the normal than the angle of reflection is zero.

Real and virtual image:

- **Real image**: If the rays, after reflection, actually converge to a point, then the image is said to be a real image. It can always be formed on a screen suitably placed.
- **Virtual image**: If the rays diverging from a point source, after reflection appear to diverge from a point then the image is said to be virtual image. It cannot be formed on the screen.

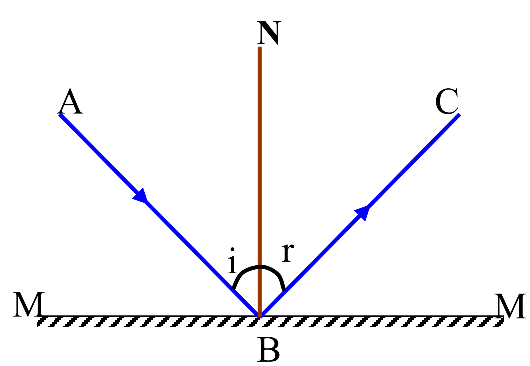
Properties of image formed by plane mirror:

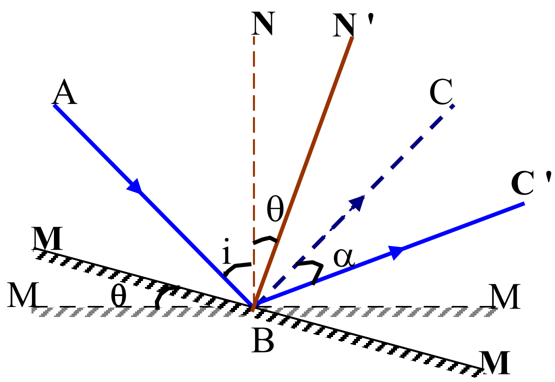
- Following are the properties of the image formed by plane mirror.

1. The image formed by a plane mirror is virtual and erect.
2. The image is laterally reversed.
3. The image and the object are of equal size.
4. The image is as far behind the mirror as the source is in front of it.
5. When the plane mirror is rotated through a certain angle, the reflected ray turns through double the angle.

Effect of rotation of a plane mirror:

- **Before rotation,**
  AB is the incident ray on mirror **MM**,
  BN is the normal,
  BC is the reflected ray,
  According to laws of reflection
  $\angle ABN = i = \angle NBC = r$
  $\therefore \angle ABC = \angle ABN + \angle NBC = 2i$





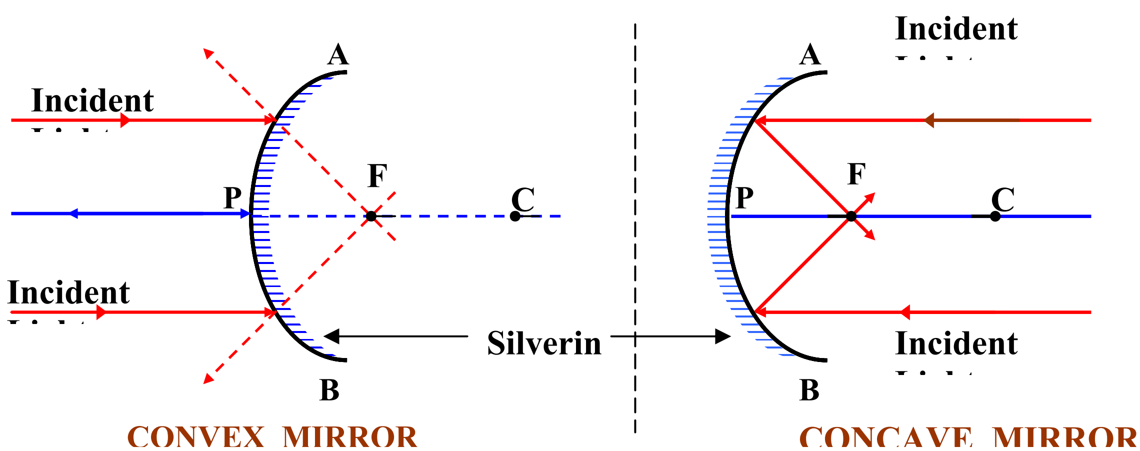
➢ **After rotation through angle θ,**
M'M' is new position of mirror,
BN' is new position of normal,
BC' is new position of reflected ray,
According to laws of reflection
$\angle AB N' = \angle N'B C' = (i + \theta)$
$\therefore \angle ABC' = \angle ABN' + \angle N'BC' = 2(i + \theta)$

➢ Due to the rotation of the mirror, the reflected light moves through an angle CBC' which is given by

$$\angle CBC' = \alpha = \angle ABC' - \angle ABC$$
$$\alpha = (2i + 2\theta) - 2i$$
$$\alpha = \mathbf{2\theta}$$

➢ Thus, If a ray of light falls on a plane mirror and the mirror is rotated through an angle θ, then the reflected ray gets rotated through double the angle i.e. 2θ.
➢ When the mirror rotates through a certain angle, the reflected ray moves double the angle

SPHERICAL MIRRORS:



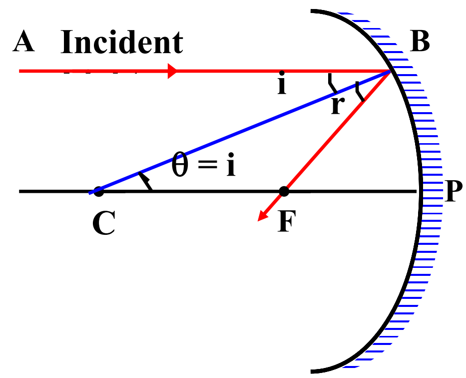
➢ The spherical mirror is a reflecting surface, which forms a part of the sphere.
➢ When a reflection takes place from the inner surface, the mirror is known as a **concave mirror**.
➢ When reflection takes place from the outer surface, the mirror is known as **convex mirror**.

Some definitions regarding the spherical mirror:

➢ **Centre of curvature**: It is the centre of the sphere of which the mirror is a part. In the figure **C** is the centre of curvature.
➢ **Radius of curvature**: It is the radius of the sphere of which the mirror is a part. In figure **PC** is the radius of curvature.
➢ **Pole**: The middle point **P** of the mirror is termed as pole of the mirror.

- **Principle axis**: The straight line joining the centre of curvature to the pole is called the principal axis of the mirror.
- **Principal focus**: When a narrow beam of light, parallel to the principal axis and close to it, is incident on the surface of a concave mirror (Convex mirror) the reflected beam is found to converge to (diverge from) the point on the axis. The point **F** is called principal focus.
- **Focal length**: The distance between the pole **P** and the principal focus **F** of the mirror is called focal length. This is denoted by **f**.

Relation between R and f:



- In the figure,

  AB = Incident ray,
  BF = Reflected Ray,
  BC = Normal to the mirror surface,
  According to the laws of reflection,
  $\angle i = \angle r$
  From the geometry, In ΔBCF
  $\angle BCF = \angle\theta = \angle i = \angle r$
  $\therefore CF = FB$ (side opposite of equal angle)

- If the aperture of mirror is small FB can be taken as PF, That is **FB ≅ PF**

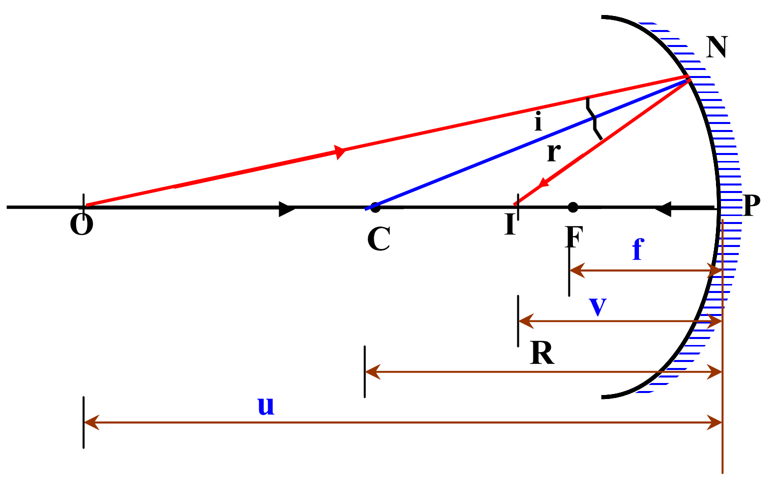
$$\therefore \mathbf{CF = PF} = f$$

$$\text{Now, } PC = CF + PF$$

$$PC = PF + PF$$

$$\mathbf{R = 2f}$$

Relation between 'u', 'v', and 'f' for concave mirror:



- Consider an object **O** placed on the axis of a concave mirror of small aperture.
- **ON**= incident ray, **NC** = normal and **NI** = reflected ray; **i** = angle of incidence, **r** = angle of reflection.
- The second ray **OP** that is incident normally is reflected back along the same path.
- The two rays actually intersect at **I** and therefore **I** is the real image of the object **O**.
- **PC** = **R,** is the radius of curvature and **PF** = **f**, the focal length of the concave mirror.
- Let, **u** is the object distance from the pole and **v** is the image distance from the pole.

- As NC is the internal bisector of the angle ∠ONI of ΔONI, hence

$$\frac{NI}{NO} = \frac{IC}{CO} = \frac{PC - PI}{PO - PC}$$

- If the aperture of mirror is small, $NI \cong PI$ and $NO \cong PO$,

$$\frac{PI}{PO} = \frac{PC - PI}{PO - PC}$$

$$\therefore \frac{v}{u} = \frac{r - v}{u - r}$$

$$\therefore vu - vr = ur - uv$$

$$\therefore vr + ur = 2\,uv$$

By dividing above equation, both sides by uvr,

$$\frac{1}{u} + \frac{1}{v} = \frac{2}{r}$$

$$\mathbf{\frac{1}{u} + \frac{1}{v} = \frac{1}{f}} \qquad \text{or} \qquad \mathbf{\frac{1}{f} = \frac{1}{u} + \frac{1}{v}}$$

Magnification:

- The linear magnification 'm' for a mirror is given by

$$\mathbf{m = \frac{size\ of\ the\ image}{size\ of\ the\ object} = \frac{Image\ distance}{Object\ distance} = \frac{v}{u}}$$

- In case of mirror, we have

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

$$\text{or} \quad \frac{v}{u} + \frac{v}{v} = \frac{v}{f}$$

$$\text{or} \quad \frac{v}{u} = \frac{v}{f} - 1$$

$$\text{or} \quad \frac{v}{u} = \frac{v - f}{f}$$

Again,

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

$$\text{or} \quad \frac{u}{u} + \frac{u}{v} = \frac{u}{f}$$

$$\text{or} \quad \frac{u}{v} = \frac{u}{f} - 1$$

$$\text{or} \quad \frac{u}{v} = \frac{u - f}{f}$$

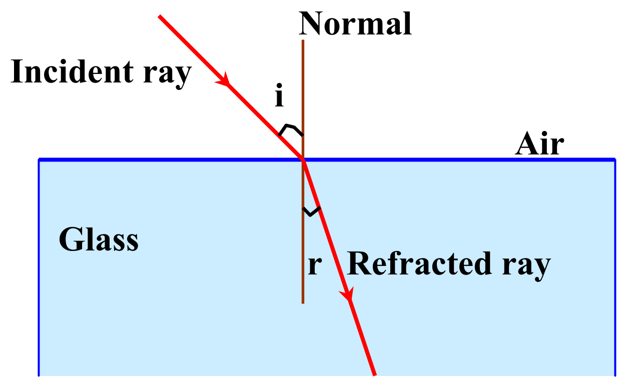
$$\text{or} \quad \frac{v}{u} = \frac{f}{u - f}$$

- In this way magnification $\mathbf{m = \frac{v}{u} = \frac{v - f}{f} = \frac{f}{u - f}}$

REFRACTION:

In a homogeneous medium, a ray of light travels in a straight line. But when a ray of light is incident on a plane transparent medium such as glass, it is observed that the ray of light deviates from the original path in the second medium. This bending of light is called refraction.

Laws of refraction

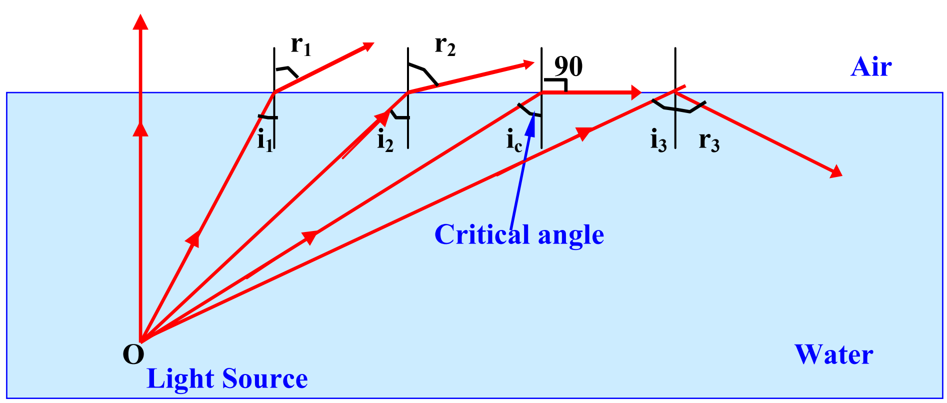


1. The incident ray, the refracted ray and the normal to the surface of separation of two mediums lie one plane.
2. When a ray of light traverse from optically rarer medium to the optically denser medium the refracted ray will bend towards the normal. And if it traverses from optically denser medium to the optically rarer the refracted ray will bend away from the normal.
3. **Snell's law:** For any two mediums, the ratio of the sine of angle of incidence (sin i) to the sine of the angle of refraction (sin r) is a **constant** for a light beam of a particular wavelength (colour). Thus; $$\frac{\sin i}{\sin r} = \text{const} = {}^{a}\mu_{g}$$

This constant is called the refractive index of the second medium (glass) with respect to the first medium (air). The refractive index may also be defined in terms of velocity of light.

$$\textbf{Refractive index of medium w.r.t air } ({}^{a}\mu_{m}) = \frac{\textbf{velocity of light in vaccum / Air}}{\textbf{velocity of light in the medium}}$$

Total internal refraction:



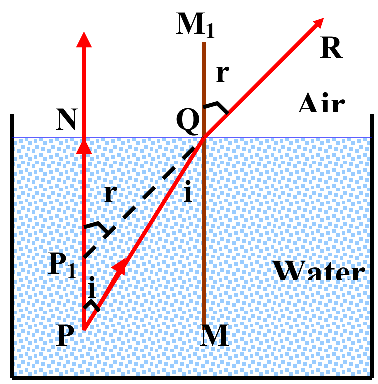
- We know that when a ray of light passes from an optically denser to a rarer medium, the refracted ray is bent away from the normal i.e. the angle of refraction is greater than the angle of incidence.
- As the angle of incidence increases the angle of refraction also increases, till for a particular value of angle of incidence, the refracted ray emerges along the surface of separation. This particular angle of incidence is known as **critical angle.**

- If any ray is incident at an angle greater than the critical angle i_c, no refraction occurs and the incident ray is reflected back in the same medium. This phenomenon is known as **total internal reflection.**
- Figure shows a source of light placed in a medium of higher refractive index and emitting light in all direction. When $i = i_c$, $r = 90°$

$$\therefore \textbf{Refractive index of water w.r.t. air } {}^a\mu_w = \frac{\sin 90}{\sin i_c}$$

$$\therefore \sin i_c = \frac{1}{{}^a\mu_w} \quad \text{OR} \quad \therefore i_c = \sin^{-1}\left(\frac{1}{{}^a\mu_w}\right)$$

Real and apparent depth:



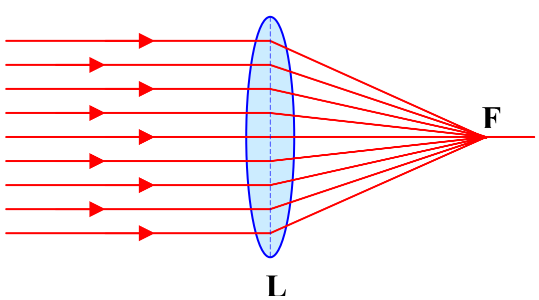
- Consider an object **P** kept in denser medium say water. It is observed from the rarer medium.
- **PN** is an normally incident ray which passes in to second medium without any deviation.
- **PQ** is an incident ray at angle **i**.
- **QR** is a refracted ray with an angle **r.** it appear to come from $\mathbf{P_1}$, which is virtual image of **P**.
- Refractive index of water w.r.t. air is given by

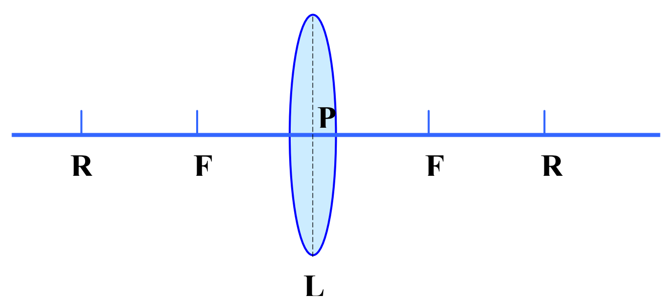
$$ {}^a\mu_w = \frac{\sin\angle r}{\sin\angle i} = \frac{\sin\angle RQM_1}{\sin\angle PQM} = \frac{\sin\angle QP_1N}{\sin\angle QPN}$$

$$ {}^a\mu_w = \frac{(QN/QP_1)}{(QN/QP)} = \frac{QP}{QP_1} = \frac{PN}{P_1N} = \frac{\text{Real depth}}{\text{Apparent depth}}$$

By Assuming **Q** to be very near to N, therefore QP = PN and $QP_1 = P_1N$,

LENS

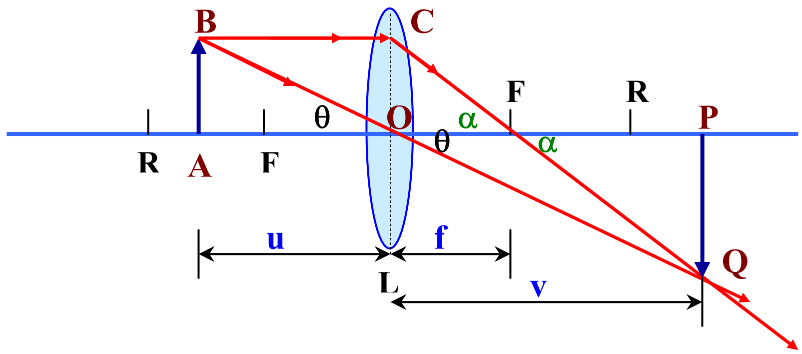




Some definitions

- **Principal axis:** the line joining the centers of curvature of two spherical surfaces is known as the principal axis.
- **Principal focus:** when a parallel is incident on a convex lens, the beam converges to the point F on the principal axis known as principal focus.
- **Focal length:** the distance between the optical centre and the principal focus of the lens is called as focal length.

Relation between u, v, and f for the convex lens



- Let **L** be a convex lens with optical centre **O** as shown in figure. **AB** is an object placed beyond **F** on the principal axis.
- A ray **BC** parallel to the principal axis strikes the lens at **C** and passes through principal focus **F** of the lens. The second ray **BO** passes through the lens, which is undeviated. The two rays intersect at **Q** and hence **PQ** is the image of the object **AB**. This image is real and inverted.
- In the figure, Δ**ABO** and Δ**PQO** are similar triangles. Thus according to properties of similar triangle, we have

$$\frac{PQ}{AB} = \frac{OP}{OA} ----------(1)$$

- Similarly Δ**FOC** and Δ**FPQ** are similar, thus

$$\frac{PQ}{CO} = \frac{FP}{FO} ----------(2)$$

As AB = CO and from equation (1) & (2), we can write

$$\frac{OP}{OA} = \frac{FP}{FO}$$

$$\therefore \quad \frac{OP}{OA} = \frac{OP - OF}{FO} = \frac{v - f}{f}$$

$$\therefore \quad \frac{v}{u} = \frac{v - f}{f}$$

$$\therefore vf = vu - uf \quad \text{Or} \quad uv = vf + uf ----------(3)$$

By dividing both sides by uvf,

$$\frac{\mathbf{1}}{\mathbf{v}} + \frac{\mathbf{1}}{\mathbf{u}} = \frac{\mathbf{1}}{\mathbf{f}} \text{ or } \frac{\mathbf{1}}{\mathbf{f}} = \frac{\mathbf{1}}{\mathbf{u}} + \frac{\mathbf{1}}{\mathbf{v}} \quad --------------(4)$$

This relation is called the lens formula.

Refraction through a prism and prism formula:

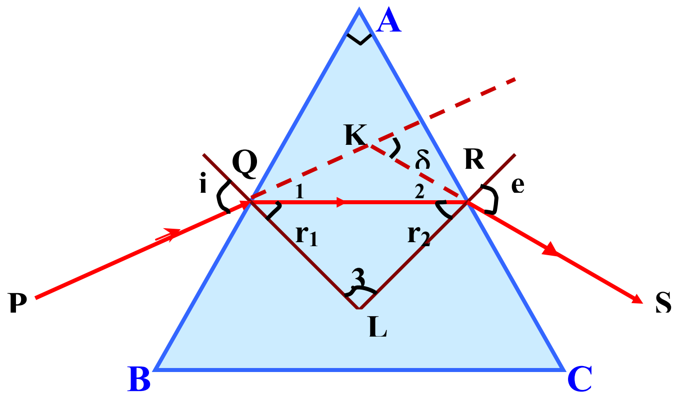


Figure shows the prism **ABC** with.

PQ = incident ray,
QR = refracted ray,
RS = emergent ray,
$\angle$**i** = angle of incidence,
$\angle$**e** = angle of emergence
$\angle\delta$ = angle of deviation
$\angle$**A** = angle of prism

- **ABC** represents a prism. The angle $\angle$**A** included between two refracting surface is called **angle of prism**.
- A ray of light **PQ** is incident on the face **AB** at an angle of incidence $\angle$**i**. It is refracted and travels along **QR**. At point **R** the ray is once again refracted and emerges from the surface **AC** along **RS** marking angle $\angle$**e** with the normal to the surface **AC**. The ray along **RS** is called emergent ray and the angle $\angle$**e** is called the angle of emergence.
- The angle through which the incident ray gets deviated on passing through prism is called **angle of deviation $\angle\delta$.**
- When a ray of light passes symmetrically through the prism, angle of deviation becomes minimum. It is called angle of minimum deviation $\angle\delta_m$.
- When angle of deviation is minimum, the angle of incidence is equal to the angle of emergence (i = e) and the refracted ray is parallel to the base of the prism.

Derivation of the prism formula

From the figure, we can write

$$\angle i = \angle 1 + \angle r_1 \quad \text{and} \quad \angle e = \angle 2 + \angle r_2$$

$$\therefore \angle i + \angle e = \angle 1 + \angle r_1 + \angle 2 + \angle r_2 \text{ ----------------------------(1)}$$

Now in ΔQKR, the angle of deviation $\angle\delta$ is the exterior angles of the triangle.

$$\therefore \angle 1 + \angle 2 = \angle\delta \text{ ------------------------------------ (2)}$$

In quadrilateral AQLR,

$$\angle A + \angle AQL + \angle 3 + \angle LRA = 360^\circ$$

$$\therefore A + 90^\circ + \angle 3 + 90^\circ = 360^\circ$$

$$\therefore A + \angle 3 = 180^\circ \text{----------------------------------(3)}$$

Also in ΔQLR,

$$\angle r_1 + \angle r_2 + \angle 3 = 180^\circ \text{---------------------------------------(4)}$$

Comparing (3) and (4) we get

$$\angle r_1 + \angle r_2 = \angle A \text{ ---(5)}$$

From equation (1),(2) and (5),

$$\angle i + \angle e = \angle A + \angle\delta \text{--(6)}$$

In the minimum deviation condition,

$i = e$, $\delta = \delta_m$ and $r_1 = r_2 = r$

$$\therefore\ i + e = A + \delta_m$$

$$\therefore\ 2i = A + \delta_m$$

$$\therefore\ \mathbf{i} = \frac{\mathbf{A} + \boldsymbol{\delta}_\mathbf{m}}{\mathbf{2}}$$

Now we have $r_1 + r_2 = A$

$$\therefore\ r_1 + r_2 = A = 2r$$

$$\therefore\ r = A/2$$

As the refractive index (μ) is given by,

$$\mu = \frac{\sin i}{\sin r}$$

$$\therefore\ \boldsymbol{\mu} = \frac{\mathbf{sin}\left(\frac{\mathbf{A} + \boldsymbol{\delta}_\mathbf{m}}{\mathbf{2}}\right)}{\mathbf{sin}\left(\frac{\mathbf{A}}{\mathbf{2}}\right)}$$

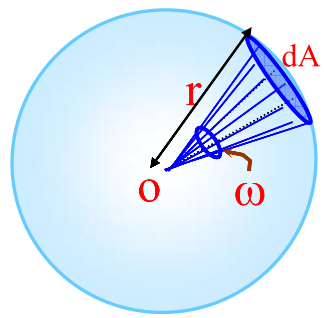
6. Photometry

As light is a form of energy, it is a measurable quantity. The branch of optics, which deals with the measurement of light, is known as photometry (Photo + metry = Light + measurement). Light (visible) is either reflected by the object or is emitted by it. Thus objects are of two types: (1) Non luminous objects and (2) Self-luminous objects.

Non-luminous objects: The objects which do not give light of their own are called non-luminous objects e.g. trees, Moon, planets etc. When non-luminous objects are illuminated by a source of light, they scatter a part of light, which reaches our eye and the object becomes visible

Self-luminous objects: The objects which give light of their own are called self-luminous objects e.g. Sun, burning candle, lighted lamp etc.

Solid Angle:



- Imagine a sphere of radius **r** . Consider a small area **dA** on the surface of the sphere. If the points on the boundary of this area are joined on the center **O**, the lines enclose an angle known as solid angle **dω** subtended by the area **dA** at **O**.
- Solid angle subtended by the area **dA** at a distance **r** from it is given by

$$d\omega = \frac{dA}{r^2}$$ Its unit is steradian.

- The solid angle subtended at the centre of a sphere by the whole surface area of a sphere is

$$\omega = \frac{\text{Area of sphere}}{r^2}$$

$$= \frac{4\pi r^2}{r^2}$$

$$= 4\pi \quad \text{Steradian.}$$

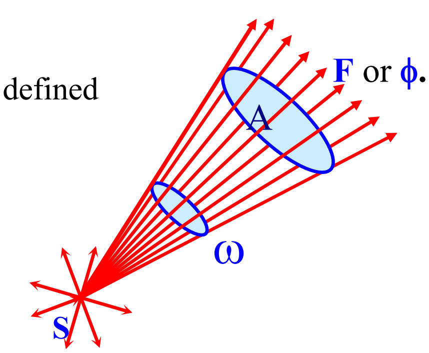
Luminous flux:

- The total amount of light which flows from a source (or an illuminating surface) per second is known as luminous flux. Since it is the rate of flow of energy, it is a sort of power. It is expressed by **F** or **ϕ.** Its unit is **lumen**.
- Lumen is a luminous flux radiated by a uniform point source of 1 candlepower through unit solid angle.

Luminous intensity or Illuminating power:

- The illuminating power of a point source in any direction is defined as the luminous flux per solid angle emitted in that direction.
- If **F** is the luminous flux radiated by a source within a solid angle ω in any particular direction, then (luminous intensity) illuminating power is given by

$$I = \frac{F}{\omega}$$



- For whole sphere, $\omega = 4\pi$, Therefore $\mathbf{I} = \dfrac{\mathbf{F}}{4\pi}$
- If **F** is measured in lumens and ω in steradians, then

$$\mathbf{I} = \frac{\textbf{lumens}}{\textbf{steradians}} = \textbf{Candela}$$

- **Candela** is defined as 1/60th of the luminous intensity per square centimeter of the standard light source when light source is at the temperature of solidifying platinum.

Intensity of illumination of a surface:

- The intensity of illumination at a point on a surface is defined as the luminous flux received on a unit area of the surface surrounding the point.
- If **F** is the total flux falling over an area **A** the intensity of illumination

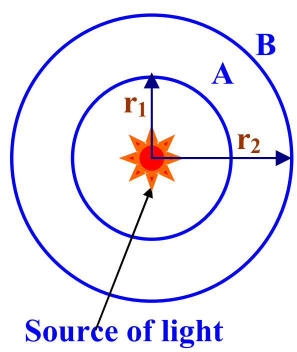
$$\mathbf{E} = \frac{\textbf{Luminous Flux}}{\textbf{Area of Sphere}} = \frac{\mathbf{F}}{\mathbf{A}}\ \frac{\textbf{lumens}}{\mathbf{m}^2}$$

$$\mathbf{E} = \frac{\mathbf{F}}{4\pi \mathbf{r}^2} = \frac{\mathbf{F}}{4\pi} \times \frac{1}{\mathbf{r}^2}$$

$$\mathbf{E} = \frac{\mathbf{I}}{\mathbf{r}^2}$$

Inverse Square Law: -

- Consider a point source **S** emitting light in all directions.
- Let **F** be the luminous flux of the source.
- Also consider two spherical surfaces **A** and **B** of radii $\mathbf{r_1}$ and $\mathbf{r_2}$ with **S** as the centre.
- The intensity of illumination $\mathbf{E_1}$ at a point on the surface **A** is given by



$$\mathbf{E_1} = \frac{\textbf{Luminous Flux}}{\textbf{Area of Sphere}} = \frac{\mathbf{F}}{4\pi \mathbf{r_1}^2} = \frac{\mathbf{I}}{\mathbf{r_1}^2} \quad \text{-------------(1).}$$

- Similarly the intensity of illumination $\mathbf{E_2}$ on surface **B** is

$$\mathbf{E_2} = \frac{\textbf{Luminous Flux}}{\textbf{Area of Sphere}} = \frac{\mathbf{F}}{4\pi \mathbf{r_2}^2} = \frac{\mathbf{I}}{\mathbf{r_2}^2} \quad \text{--------------(2).}$$

From equations (1) and (2),

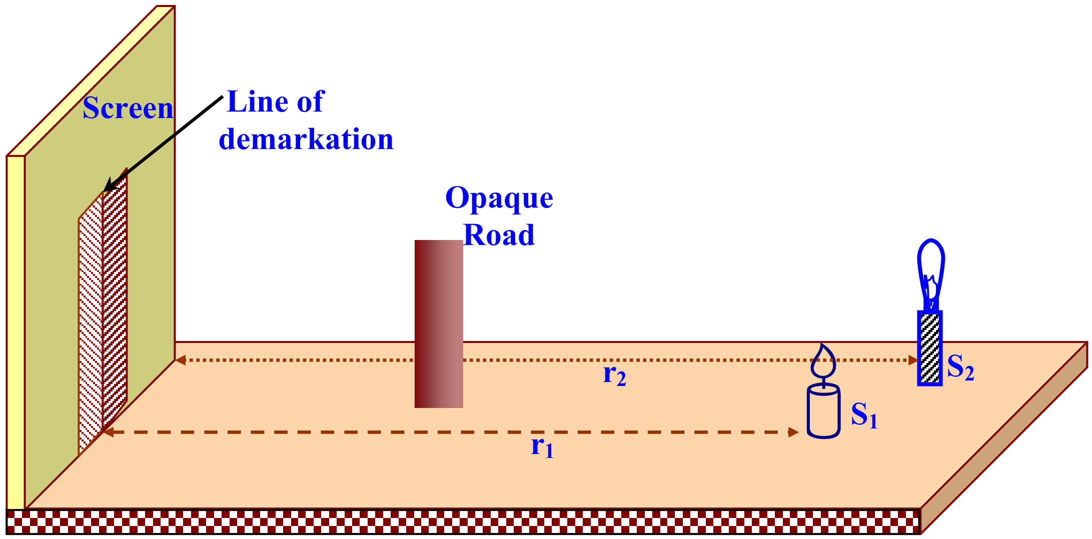
$$\mathbf{E_1 / E_2 = r_2^2 / r_1^2}$$

$$\text{or } \mathbf{E \propto 1 / r^2}$$

- **Intensity of illumination** of a surface is inversely proportional to the distance of the surface from the source. This law is known as inverse square law.

PHOTOMETERS:

(1) Rumford's shadow photometer



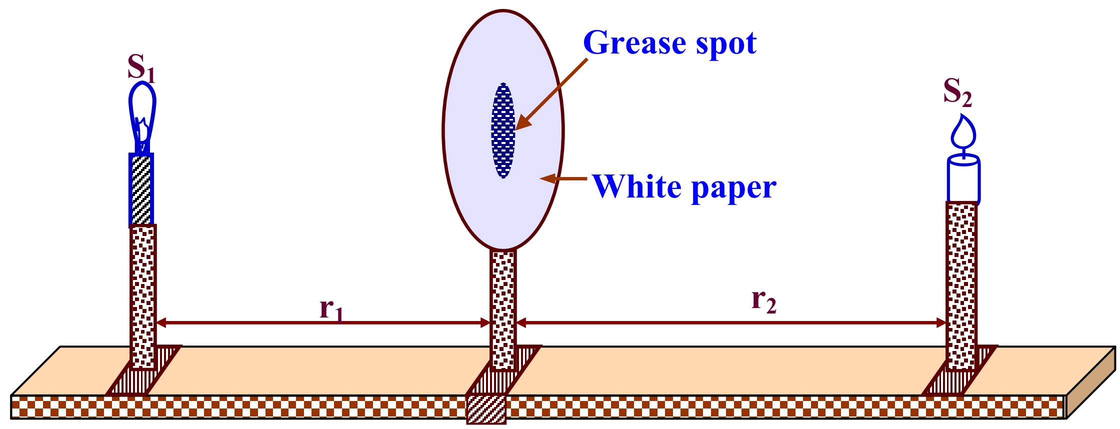
- Rumford's photometer consists of a wooden base and a perpendicular screen as shown in figure.
- An opaque rod is fixed vertically on a wooden base in front of a screen.
- Two sources of light S_1 and S_2, the illuminating powers of which are to be compared are placed in front of the rod.
- Two shadows of a rod are formed on the screen due to two sources of light.
- The distances of r_1 and r_2 from the screen are adjusted in such a way that the line of demarkation between the two shadows disappears. Therefore both the shadows have equal intensity of illumination.
- Let I_1 and I_2 be the illuminating powers of sources S_1 and S_2 and r_1 and r_2 be the distances of the two sources from the screen.
- Since both the shadows are equally illuminated, the intensity of illumination is

$$E = I_1 / r_1^2 = I_2 / r_2^2$$

Therefore $$I_1 / I_2 = r_1^2 / r_2^2$$

- Therefore illuminating powers of two sources can be compared or if one of them is known, another can be calculated.

(2) Bunsen's Grease-spot photometer



- The apparatus consists of a simple optical bench. The screen is made up of the thick piece of unglazed white paper. This paper is mounted inside a metal frame and it is kept on the middle of the optical bench.
- A circular spot is made on the screen with the help of grease or oil. The spot appears brighter in the transmitted light.
- Two sources of light $\mathbf{S_1}$ and $\mathbf{S_2}$ are placed on the opposite sides of the screen. The positions of $\mathbf{S_1}$ and $\mathbf{S_2}$ are adjusted such that the image of spot cannot be distinguished from rest of the paper when observed from any of the sides. This is possible when intensities of illumination on both the portions of a screen are same.
- Let
  - $\mathbf{I_1}$ and $\mathbf{I_2}$ are the illuminating powers of the sources $\mathbf{S_1}$ and $\mathbf{S_2}$.
  - $\mathbf{r_1}$ and $\mathbf{r_2}$ be the distances of the sources from the screen.
  - **a** = the fraction of light reflected from paper
  - **b** = the fraction of light reflected from grease spot.
  - **(1- a)** = fraction of light transmitted from paper
  - **(1- b)** = fraction of light transmitted from grease spot.
  - $\mathbf{E_1}$ and $\mathbf{E_2}$ are the intensities of illuminations due to $\mathbf{S_1}$ and $\mathbf{S_2}$.
- Let the light be observed from the side of source $\mathbf{S_1}$.

  Then, the light received from the paper is $= \mathbf{E_1\, a + E_2\, (1\text{-}a)}$ and

  The light received from the grease spot is $= \mathbf{E_1\, b + E_2\, (1\text{-}b)}$
- Since the intensities on both the portions of a screen are same,

$$\mathbf{E_1\, a + E_2\, (1-a) = E_1\, b + E_2\, (1-b)}$$

$$\therefore \mathbf{E_1\, (a-b) = E_2\, (a-b)}$$

$$\therefore \mathbf{E_1 = E_2}$$

$$\therefore \mathbf{I_1 / r_1^2 = I_2 / r_2^2}$$

$$\mathbf{OR} \quad \therefore \mathbf{I_1 / I_2 = r_1^2 / r_2^2}$$

APPLIED PHYSICS DEPARTMENT, POLYTECHNIC, M.S.UNI. OF BARODA.

NUMERICALS FOR F. S. F.Y.D (C.M.E. & P.C.T.) 2005-2006

1) Convert two-dyne force in to Newton.
2) In Ohm's experiment, Values of the unknown resistances, are 4.12 Ω, 4.08 Ω, 4.,22 Ω, 4.27 Ω and 4.14 Ω. Calculate absolute error, relative error and percentage error in these observations.
3) If the value of G in MKS system is 6.67×10^{-11} Nm^2/kg^2, what will be its value in CGS system?
4) Check the dimensional validity of the following equations:
   (a) $d = v_0t + ½ at^2$, Where d = displacement, v_o = initial velocity, t = time and a = acceleration
   (b) Kinetic energy $K=1/2\ mv^2$, Where m = mass of and object and v = velocity of the object
   (c) $T = 2\pi\sqrt{\frac{l}{g}}$, Where T = Time period, l = length and g = Gravitational acceleration.
   (d) $F = \frac{mad}{t}$, where F = force, m = mass of and object and a = acceleration
5) If the formula for a Physical quantity W is : $W=\frac{\mathbf{a^4b^3}}{\mathbf{c^{1/3}d^{1/2}}}$ and if the percentage errors in the measurements of a, b, c and d are 1 %, 2 %, 3 % and 4 % respectively, calculate % error in W.
6) Two charges of 4 μC and 16 μC are placed 40 cm apart in air. Calculate the force between them.
7) Two like charges placed in air at a distance of 0.1m repel each other with a force of 1 N. Find the force between them when placed 5cm apart in a medium of dielectric constant 2.5.
8) Two identical spheres carrying charges of $7x10^{-5}$ coulomb and $–5x10^{-5}$ coulomb are brought in contact with each other and then separated by a distance of 20 cm in a medium of dielectric constant 2.5. Calculate the force between them.
9) Calculate the intensity of electric field at a point 0.4m from a charge of 1.6 μC when placed in air.
10) Two-point charges 9 coulomb And 25 coulomb are placed 2m apart in free space. Find the position of a point between them where intensity due to charges will be equal.
11) A charge of 2.75×10^{-9} coulomb is placed in a medium of dielectric constant 2.2. Calculate the potential at a point 15cm from it.
12) Two electric charges 25 coulomb and – 40 coulomb are separated by 1.3 m. Determine the position of a point in between them where the resultant potential is zero.
13) A parallel plate capacitor has rectangular plates of $400cm^2$ and separated by 2mm with air as a medium. What charge will appear on the plates if a 200-volt potential difference is applied?
14) Two capacitors of capacitance 0.8 microfarad and 1.2 microfarad are connected in parallel and a potential difference of 110 volt is applied to the combination. How much charge is taken from the source and how is it shared?
15) Three capacitors of 6, 12 and 16 microfarad are connected in series. A potential difference of 220V is applied to the combination. How much charge will be drawn?
16) Two condensers have an equivalent capacitance of 12 microfarad when connected in parallel and 2.25 microfarad when connected in series. Calculate their individual capacitance?
17) The effective resistance of two resistances is 32 ohm when connected in series and 6 ohm when connected in parallel. Find the value of each resistance.
18) When two resistors are connected in series, their equivalent resistance is 20 ohm and when they are connected in parallel, the resistance is 3.2 ohm. What is the value of each resistance?
19) How would you combine four resistances of one ohm each to produce an effective resistance of 0.25 ohm?

20) Three capacitors C_1 =4, C_2 =6 and C_3 =2 microfarad are connected in series. The potential difference across C_2 is 50V. What is the potential difference across C_1 and C_3?
21) At what temperature, would the resistance of a copper conductor be double its resistance at 0° C? Temp. Coefficient = 3.9×10^{-3} /^{0}C.
22) Resistance of a silver wire is 2.1 ohm at 27^0 C and 2.7 ohm at 100^0C. Find its temperature coefficient of resistance.
23) A 220 V 100W bulb is connected to 110V supply. Calculate the power consumed.
24) What is the resistance of 100W 240V bulb?
25) A person uses five 60W bulbs, two 100W fans, one 80W TV, three 18W CFL tubes, one 160W fridge. On an average these are used for 5 hours a day. Calculate the bill for the month of 30 days at the rate of Rs.5.75 per unit.
26) What length of conductor of resistivity 100E-8 ohm-m, area of cross-section 2.5×10^{-7} m^2 would be needed to make a resistor of 57.6 ohms?
27) If a copper wire is stretched to increase its length by 1 %, what will be the percentage change in its resistance?
28) A wire of given diameter, length and material has a resistance of 5 ohm. It is then stretched to twice its length, the volume of wire remaining constant. What is the new resistance?
29) A resistance wire having a diameter of 1mm and specific resistance 44E-6 ohm-met is bent into a circle of radius 3cm. Calculate the total resistance.
30) A wire has a resistance of $1/\pi$ ohm/met. A circle of radius 1m is made from this wire. What is the total resistance?
31) A coil of 6 ohm and a coil of 12 ohm are connected in parallel and this combination is then connected in series with another coil of 2 ohm and a battery of 18 volt. What is the current in each of these three coils?
32) In the Wheatstone bridge network, the values of resistances P, Q, R and S are 3, 2, 6 and 4 ohm respectively. Galvanometer resistance is 50 ohm and battery connected is of emf 5V.Calculate the current drawn from the battery.
33) A straight conductor of 1m length and carrying a current of 20 amp is placed at right angles to uniform magnetic field of 1.5 web/m^2. Find the force acting on a conductor.
34) Find the current passing through a wire of length 0.2m when kept in a magnetic field of 4.5×10^{-2} weber/m^2 at an angle of 30^0 which experiences a force of 2.25×10^{-2} N.
35) A circular coil has 20 turns each of radius 10cm. If it carries a current of 1 amp. Find the magnetic induction at its center. Given $\mu_0 = 4\pi$ E-7 web/amp-m.
36) Magnetic flux associated with a coil of 100 turns changes from 64×10^{-5} web to 4×10^{-5} web in 0.02 sec. Calculate the induced emf.
37) An object is placed 20cm from a concave mirror whose focal length is 10cm. Find where the image is?
38) Using a certain concave mirror, the magnification is found to be 4 times as great when the object was 25 cm from the mirror, as it was with the object at 40 cm from the mirror. Find the focal length of the mirror.
39) An object 1cm high is placed at a distance of 10cm from a concave mirror of 5cm focal length. Find the nature, position and the size of the image.
40) A concave mirror of focal length 10cm is placed at a distance of 35cm from a wall. How far from the wall should an object be placed to get its real image on the wall?
41) Find the position of an object placed in front of a concave mirror of 15cm focal length so as to get its image magnified three times.

42) It is required to throw upon a wall a real image of a candle flame which stands 10cm from wall and the image is to be 4 times the size of the flame. What sort of mirror is required and where should it be placed?
43) An object is placed in front of a convex lens and the distance between it and its image is 54cm. If the magnification produced is 2, calculate the focal length of a lens.
44) In an equilateral prism, the angle of incidence is 49^0 when the prism is placed for minimum deviation position. Find the angle of minimum deviation and the refractive index of prism.
45) The angle of minimum deviation for a prism of refracting angle 60^0 is 42^0. Find the refractive index of prism.
46) For a 60^0 prism, the angle of incidence and angle of emergence both are equal to 49^0. Calculate the refractive index of the prism.
47) Calculate the angle of minimum deviation for a prism of refractive index 1.732 and having refracting angle of 60^0.
48) A ray of light is incident at an angle of 60^0 on one face of a prism, which has an angle of 30^0. The ray emerging out of the prism makes an angle of 30^0 with incident ray. Show that the emergent ray is perpendicular to the face through which it emerges and calculate the refractive index of the material of prism.
49) A light bulb is on the bottom of a swimming pool 2 m below the water surface. A person on the diving board above the pool sees a circle of light. What is the diameter of this circle?
50) Two lamps 32c.p. and 8 c.p. are placed 2 m apart. Where should a screen be placed in order that the lamps may equally illuminate it?
51) A 72 candela lamp is placed at 12m from screen. How far from the screen and on the same side an additional 36 candela lamp be placed in order that the intensity of illumination on the screen is doubled?
52) A monochromatic parallel beam of light is incident at an angle of 50° on one of the refracting faces of the prism. It is deviated through the prism in the minimum deviation position. The angle of prism is 60°. Find the refractive index of the prism for this beam.
53) A rectangular tank 6 m deep is full of water. By how much does the water appear to be raised, given that the refractive index of water is 1.33?
54) The illuminating power of two sources of light A and B which are 10 m apart are as 4: 9. Find at what points on the line joining them, the intensity of illumination is the same.
55) A 50 C.P. lamp A and 36 C.P. lamp B are placed in a straight link at 10 cm and 6 cm respectively on the same side of the grease spot. Where should be a 96 C.P. be placed in order to make the spot disappear?