Rapid Revision

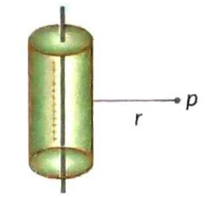
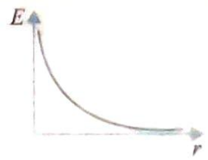
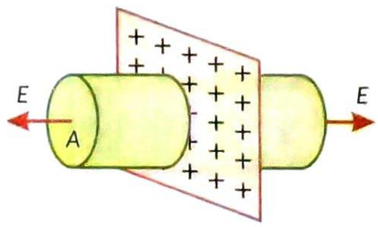
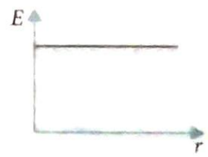
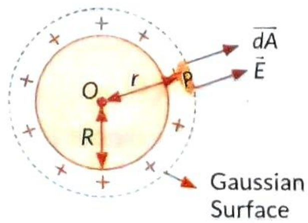
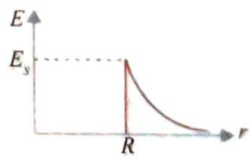
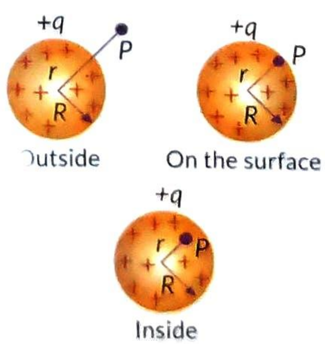
Score 70/70 with Hack sheets

1 Electric Charges and Fields

GAUSS'S LAW AND ITS APPLICATIONS

It states that the total outward electric flux through a closed surface is $1/\varepsilon_0$ times the charge enclosed by the closed surface. $\oint \vec{E}\cdot d\vec{S} = \frac{q}{\varepsilon_0}$, where q is charge enclosed by the closed Gaussian surface.

Gauss's law is used to determine the electric field due to charged symmetrical bodies.

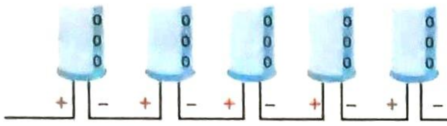
Charge Distribution	Electric Field	Gaussian Surface	Graph
Infinitely long straight uniformly charged wire	$E = \frac{\lambda}{2\pi\varepsilon_0 r}$		
Uniformly charged infinite plane sheet	$E = \frac{\sigma}{2\varepsilon_0}$		
Uniformly charged thin spherical shell	$E_i = 0,\ E_s = \frac{1}{4\pi\varepsilon_0}\cdot\frac{q}{R^2} = \frac{\sigma}{\varepsilon_0}$, $E_o = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2} = \frac{\sigma}{\varepsilon_0}\cdot\frac{R^2}{r^2}$ $i \rightarrow$ inside, $s \rightarrow$ surface, $o \rightarrow$ outside		
Uniformly charged non-conducting sphere	$E_i = \frac{1}{4\pi\varepsilon_0}\frac{qr}{R^3} = \frac{\rho r}{3\varepsilon_0}$ $E_s = \frac{1}{4\pi\varepsilon_0}\frac{q}{R^2} = \frac{\rho R}{3\varepsilon_0}$ $E_o = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2} =$		

2 Electrostatic Potential and Capacitance

CAPACITORS IN SERIES AND IN PARALLEL

Capacitors in Series

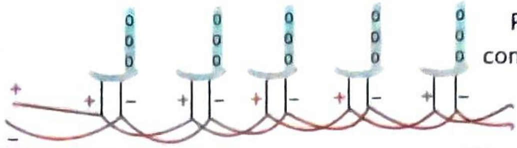
- Same charge flows through each capacitor
- Different potential difference exist across each capacitor if $C_1 \neq C_2 \neq C_3$.
  $V = V_1 + V_2 + V_3$
  $\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$



Series combination

Capacitors in Parallel

- Across each capacitor, potential difference is same.
- Different charges flow through each capacitor if $C_1 \neq C_2 \neq C_3$.
  $q = q_1 + q_2 + q_3 ; C_{eq} = C_1 + C_2 + C_3$



Parallel combination

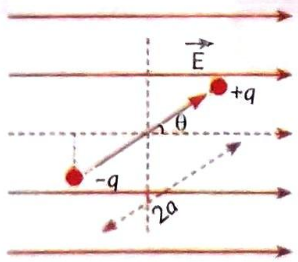
POTENTIAL ENERGY OF A SYSTEM OF CHARGES

- For two point charges, $U = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r_{12}}$
- For three point charges, $U = \frac{1}{2}q_1V_1 + \frac{1}{2}q_2V_2 + \frac{1}{2}q_3V_3$
- For system of n point charges, $U = \frac{1}{2}\sum_{i=1}^{n} q_iV_i$

where, V_i is the potential at the location of the i^{th} charge due to the presence of all other charges in the system.

POTENTIAL ENERGY OF A DIPOLE IN EXTERNAL ELECTRIC FIELD

- $U = -\vec{p}\cdot\vec{E} = -pE\cos\theta$; θ is angle between external electric field and electric dipole moment.
- $W_{\theta_1 \to \theta_2} = U_{\theta_2} - U_{\theta_1} = pE\,(\cos\theta_1 - \cos\theta_2)$
- For $\theta = 0°$, $U = -pE$ (Minimum) so the dipole is in stable equilibrium position.
- For $\theta = 180°$, $U = pE$ (Maximum) so the dipole is in unstable equilibrium position.

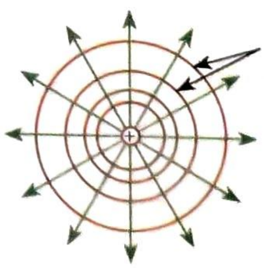


EQUIPOTENTIAL SURFACES

An equipotential surface is a surface with a constant value of potential at all points on the surface. For a single point charge q, the potential is given by

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

V is a constant if r is constant. Thus, equipotential surfaces of a single point charge are concentric spherical surfaces centred at the charge.

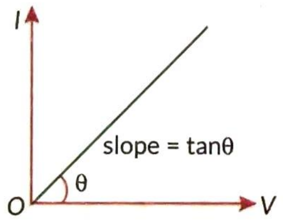


Equipotential surfaces

3 Current Electricity

OHM'S LAW

- **Ohm's law** : It states that the current (I) flowing through a conductor is directly proportional to the potential difference (V) across the ends of the conductor, provided physical conditions of the conductor such as temperature, mechanical strain etc. are kept constant.
  $V \propto I$ or $V = RI$
  where the constant of proportionality R is called resistance of the conductor.
- The graph between potential difference (V) and current (I) through a metallic conductor is a straight line passing through the origin as shown in figure. The reciprocal of slope of line gives resistance.
  $$R = \frac{V}{I} = \frac{1}{\tan\theta\,(\text{slope of } I\text{-}V)}$$



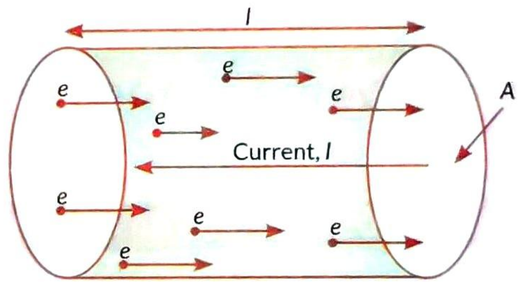
DRIFT OF ELECTRONS

When a potential difference V is applied across a conductor of length l, the drift velocity in terms of V is $v_d = eV\tau/ml$. If the area of cross-section of the conductor is A and the number of electrons per unit volume or the electron density of the conductors is n, then,

$v_d = \frac{I}{enA}$. Also, $I = enA \cdot \frac{eV\tau}{ml}$

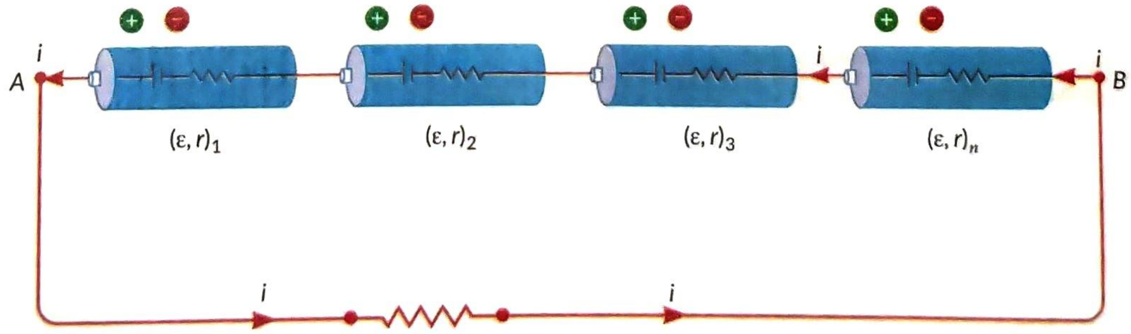
From Ohm's law, V/I = constant = R

Then, $R = ml/ne^2\tau A$



CELLS IN SERIES AND PARALLEL

- For series combination, $\varepsilon_{eq} = \varepsilon_1 + \varepsilon_2$, $r_{eq} = r_1 + r_2$
- For parallel combination. $\varepsilon_{eq} = \frac{\varepsilon_1 r_2 + \varepsilon_2 r_1}{r_1 + r_2}$, $r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$. In general, $\frac{\varepsilon_{eq}}{r_{eq}} = \frac{\varepsilon_1}{r_1} + \frac{\varepsilon_2}{r_2} + ... + \frac{\varepsilon_n}{r_n}$



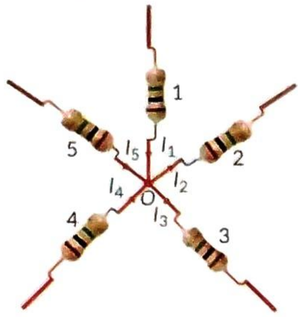
KIRCHHOFF'S RULES

Kirchhoff's rules can be applied to any circuit, even when the resistors are not in series or not in parallel. The two rules are summarized below.

Junction Rule

The sum of the magnitudes of the current directed into a junction equals the sum of the magnitudes of the current directed out of the junction. This is based on conservation of charge.

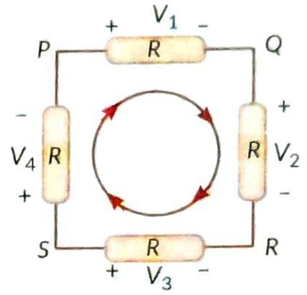
- From the figure, $I_1 - I_2 - I_3 + I_4 + I_5 = 0$
  $I_1 + I_4 + I_5 = I_2 + I_3$



Loop Rule

Around any closed-circuit loop, the sum of the potential drops equals the sum of the potential rises. This is based on the conservation of energy.

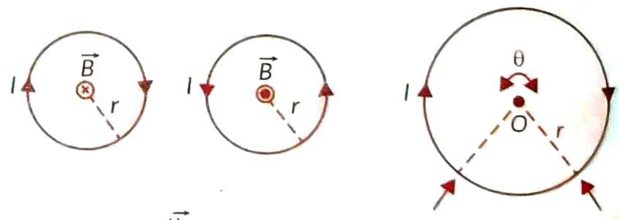
- From the figure, $-V_1 - V_2 + V_3 - V_4 = 0$. Boxes may contain resistor or battery or any other element (linear or nonlinear).

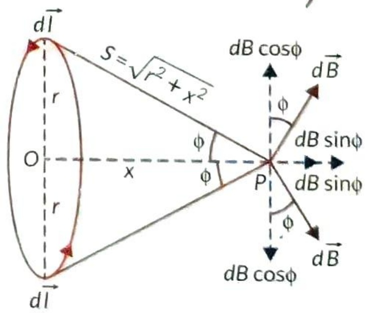


4 Moving Charges and Magnetism

APPLICATIONS OF BIOT-SAVARTS LAW

- Magnetic field strength at any point at centre of circular loop carrying current I and radius r is, $B = \frac{\mu_0 I}{2r}$
- Magnetic field strength at the centre O of circular arc of angle θ carrying current I is, $B = \frac{\mu_0 I\theta}{4\pi r}$
- Magnetic field on the axis of circular loop of radius r carrying current I at distance x is, $B = \frac{\mu_0 I r^2}{2(r^2 + x^2)^{3/2}}$

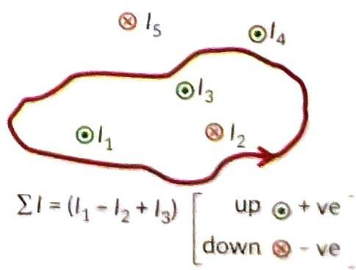




AMPERE'S CIRCUITAL LAW

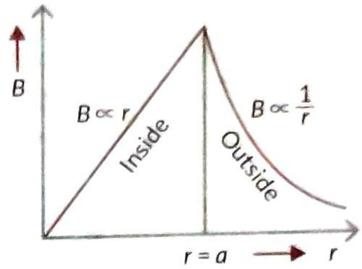
It states that line integral of the magnetic field along any closed path in free space is equal to μ_0 times of net current, crossing through area bounded by the closed path. Mathematically,

$$\oint \vec{B} \cdot d\vec{l} = \mu_0 \Sigma I$$



APPLICATIONS OF AMPERE'S CIRCUITAL LAW

- Magnetic field due to an infinitely long straight solid cylindrical wire of radius a, carrying current I
  - Magnetic field at a point outside the wire *i.e.*, $(r > a)$ is $B = \frac{\mu_0 I}{2\pi r}$
  - Magnetic field at a point inside the wire *i.e.*, $(r < a)$ is $B = \frac{\mu_0 I r}{2\pi a^2}$
  - Magnetic field at a point on the surface of a wire *i.e.*, $(r = a)$ is $B = \frac{\mu_0 I}{2\pi a}$
  - The variation of magnetic field B and the distance r from axis is as shown in the figure.



5 Magnetism and Matter

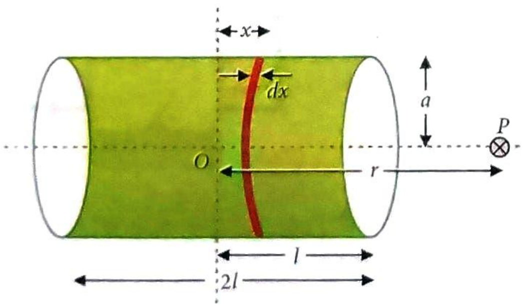
THE BAR MAGNET AND SOLENOID

- Given figure is used for calculation of the axial field of a finite solenoid in order to demonstrate its similarity to that of a bar magnet.
- Magnetic field at point P due to a circular element shown in the figure

$$B = \frac{\mu_0}{4\pi}\frac{2m}{r^3}$$

which is the magnetic field due to a bar magnet at far axial point obtained experimentally.

Hence, a bar magnet and a solenoid produce similar magnetic fields.



MAGNETIC FIELD AT A POINT DUE TO BAR MAGNET

- The magnetic field due to a bar magnet at any point on the axial line (end on position) is $B_{axial} = \frac{\mu_0}{4\pi}\frac{2Mr}{(r^2 - l^2)^2}$

  where r = distance between the centre of the magnet and the given point on the axial line, $2l$ = magnetic length of the magnet and M = magnetic moment of the magnet.

- For short magnet, $l^2 << r^2$, $B_{axial} = \frac{\mu_0 2M}{4\pi r^3}$

  The direction of B_{axial} is along S-N.

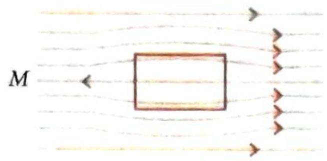
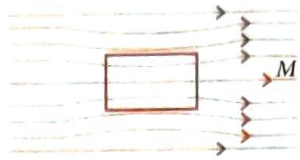
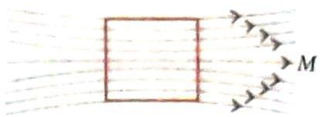
- The magnetic field due to a bar magnet at any point on the equatorial line (broad-side on position) of the bar magnet is

  $$B_{equatorial} = \frac{\mu_0 M}{4\pi(r^2 + l^2)^{3/2}}$$

  For short magnet, $B_{equatorial} = \frac{\mu_0 M}{4\pi r^3}$

  The direction of $B_{equatorial}$ is parallel to N-S.

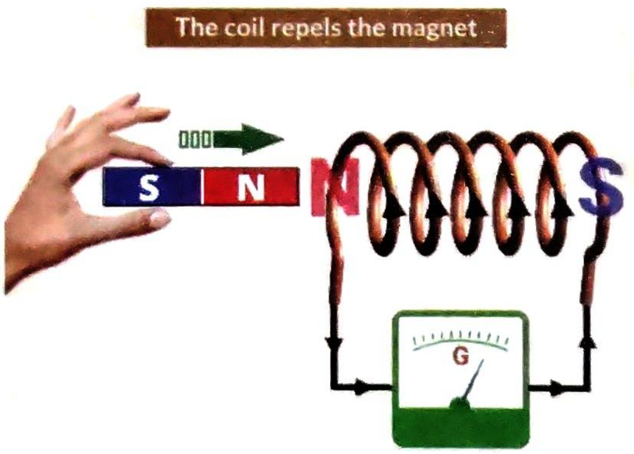
MAGNETIC PROPERTIES OF MATERIALS

Properties	Diamagnetic	Paramagnetic	Ferromagnetic
Cause of magnetism	Orbital motion of electrons	Spin motion of electron	Formation of domains
Substance placed in uniform magnetic field.	Poor magnetisation in opposite direction. Here, $B_m < B_0$ 	Poor magnetisation in same direction. Here, $B_m > B_0$ 	Strong magnetisation in same direction. Here, $B_m >>> B_0$ 
χ_m - T curve	$\chi_m \rightarrow$ Small, negative and temperature independent $\chi_m \propto T^0$	$\chi_m \rightarrow$ Small, positive and varies inversely with temperature $\chi_m \propto \frac{1}{T}$	$\chi_m \rightarrow$ very large, positive and temperature dependent
μ_r	$(\mu < \mu_0)$, $1 > \mu_r > 0$	$(1 + \varepsilon) > \mu_r > 1$, $(\mu > \mu_0)$	$\mu_r >>> 1$, $(\mu >>> \mu_0)$
Magnetic moment of single atom	Atoms do not have any permanent magnetic moment	Atoms have permanent magnetic moment which are randomly oriented. (*i.e.*, in absence of external magnetic field the magnetic moment of whole material is zero)	Atoms have permanent magnetic moment which are organised in domains.

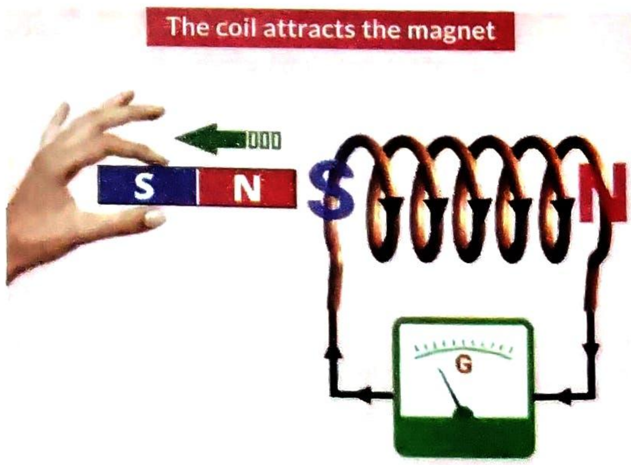
6 Electromagnetic Induction

FARADAY'S AND LENZ'S LAWS

- According to Faraday's law, whenever a conductor is associated with varying magnetic flux, then emf is induced.
- According to Lenz's law, an induced current always flows in a direction such that it opposes the cause that has produced it.



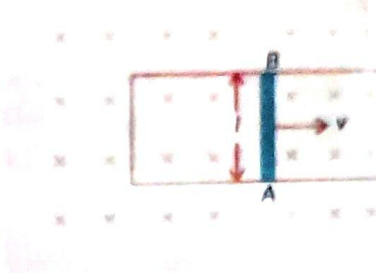
When the "N" Pole of the magnet is moved towards the coil, end of the coil becomes "N" Pole.



When the "N" Poles of the magnet is moved away from the coil, end of the coil becomes "S" Pole.

MOTIONAL EMF

- When a conducting rod of length l, moves with a velocity v perpendicular to a uniform magnetic field B, the induced emf across its ends is $|\varepsilon| = Blv$. This emf is known as motional emf.



- On a rotating conducting wire about one end, $\varepsilon = \frac{B\omega l^2}{2}$

Here, $\vec{B}, \vec{v}$ and $\vec{l}$ are perpendicular to each other.

INDUCTANCE

- Inductance is the tendency of an electrical conductor to oppose a change in electric current flowing through it.
- Inductance depends only on the geometry of the coil and intrinsic material properties. It is the ratio of flux linkage to the current. $L = \frac{N\phi}{I} = \frac{NBA}{I} = \frac{\phi_{total}}{I}$

Self Inductance

- Consider a solenoid of area A, length l, with number of turns. Connect it to a battery E, as shown in figure.
- When current through a coil changes with respect to the time then magnetic flux linked with the coil also changes with respect to time. Due to this an emf and a current is induced in the coil. According to Lenz's law, induced current opposes the change in magnetic flux. This phenomenon is called self induction and a factor by virtue of the coil shows opposition for change in magnetic flux called self inductance of the coil.

Magnetic field due to a solenoid, $B = \frac{\mu_0 NI}{l}$,

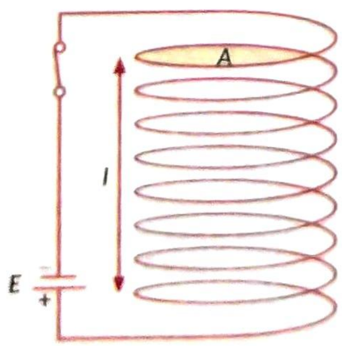
Flux, $\phi_B = \frac{\mu_0 NIA}{l}$

According to Lenz's law, induced e.m.f,

$$\varepsilon = -N\frac{d\phi_B}{dt} = -N\frac{d}{dt}\left(\frac{\mu_0 NIA}{l}\right) = \frac{-\mu_0 N^2 A}{l}\frac{dI}{dt}$$

Also, self induced e.m.f,

$$\varepsilon = -L\frac{dI}{dt}, \text{So, } L = \frac{\mu_0 N^2 A}{l}$$

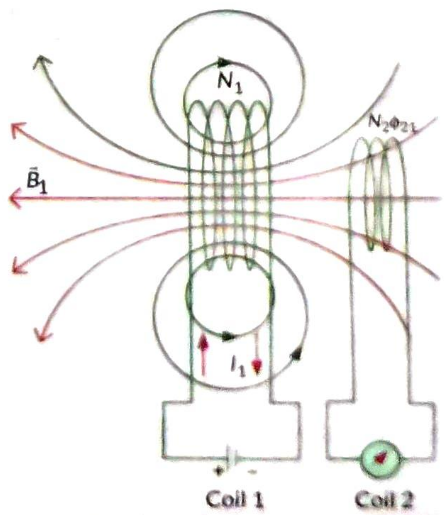


Mutual Inductance

- Mutual induction – Whenever the current passing through a coil or circuit changes, the magnetic flux linked with a neighbouring coil or circuit will also change. Hence an emf will induced in the neighbouring coil or circuit. This phenomenon is known as mutual induction.
- Mutual inductance of coil 2 with respect to coil 1 is

$$M_{21} = \frac{N_2\phi_{21}}{I_1}$$

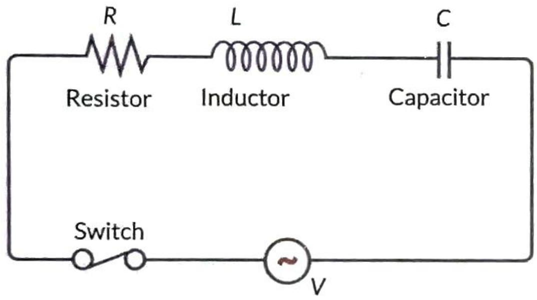
- The emf induced in the secondary coil is given by $\varepsilon_s = -M\frac{dI_1}{dt}$.



7 Alternating Current

AC VOLTAGE APPLIED TO A SERIES *LCR* CIRCUIT

- The alternating e.m.f. leads/lags behind the current by a phase angle ϕ given by $\tan\phi = \frac{\omega L - 1/\omega C}{R}$
- The e.m.f. leads the current, if $\omega L > \frac{1}{\omega C}$ and it lags behind the current, if $\omega L < \frac{1}{\omega C}$
- Impedance of *LCR* circuit, $Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$
- Power factor, $\cos\phi = \frac{R}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}} = \frac{R}{Z}$



TRANSFORMER

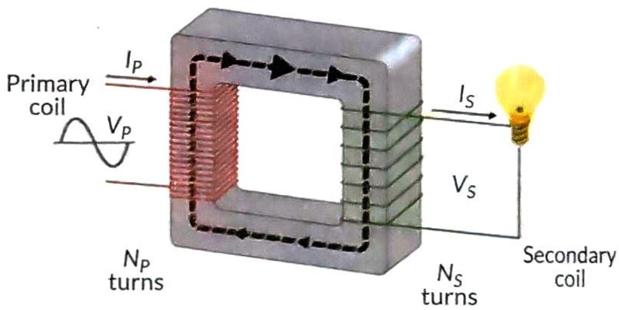
- For ideal transformer, $\frac{V_S}{V_P} = \frac{I_P}{I_S} = \frac{N_S}{N_P} = k$

  where *k* is called transformation ratio.
- For a step-up transformer, $k > 1$.

  i.e., $V_S > V_P$, $I_S < I_P$ and $N_S > N_P$.
- For a step-down transformer, $k < 1$.

  i.e., $V_S < V_P$, $I_S > I_P$ and $N_S < N_P$.
- Efficiency of a transformer,

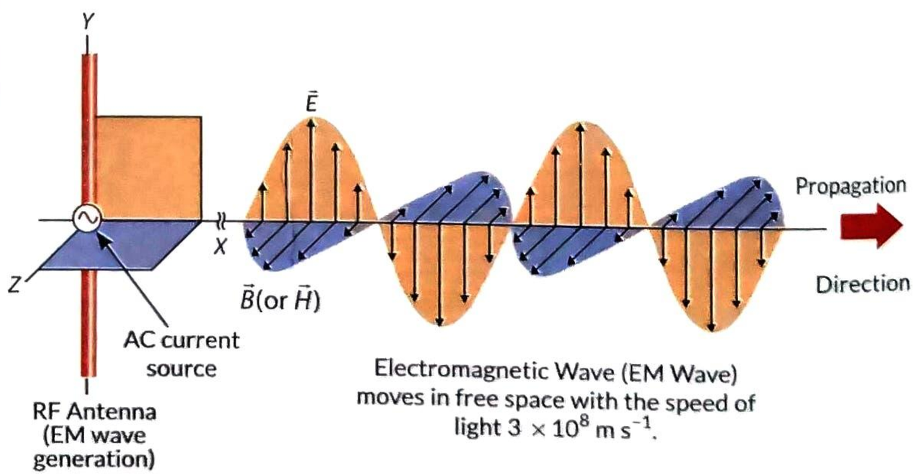
  $$\eta = \frac{\text{Output power}}{\text{Input power}} = \frac{V_S I_S}{V_P I_P}$$



8 Electromagnetic Waves

PRODUCTION AND PROPAGATION OF ELECTROMAGNETIC WAVES

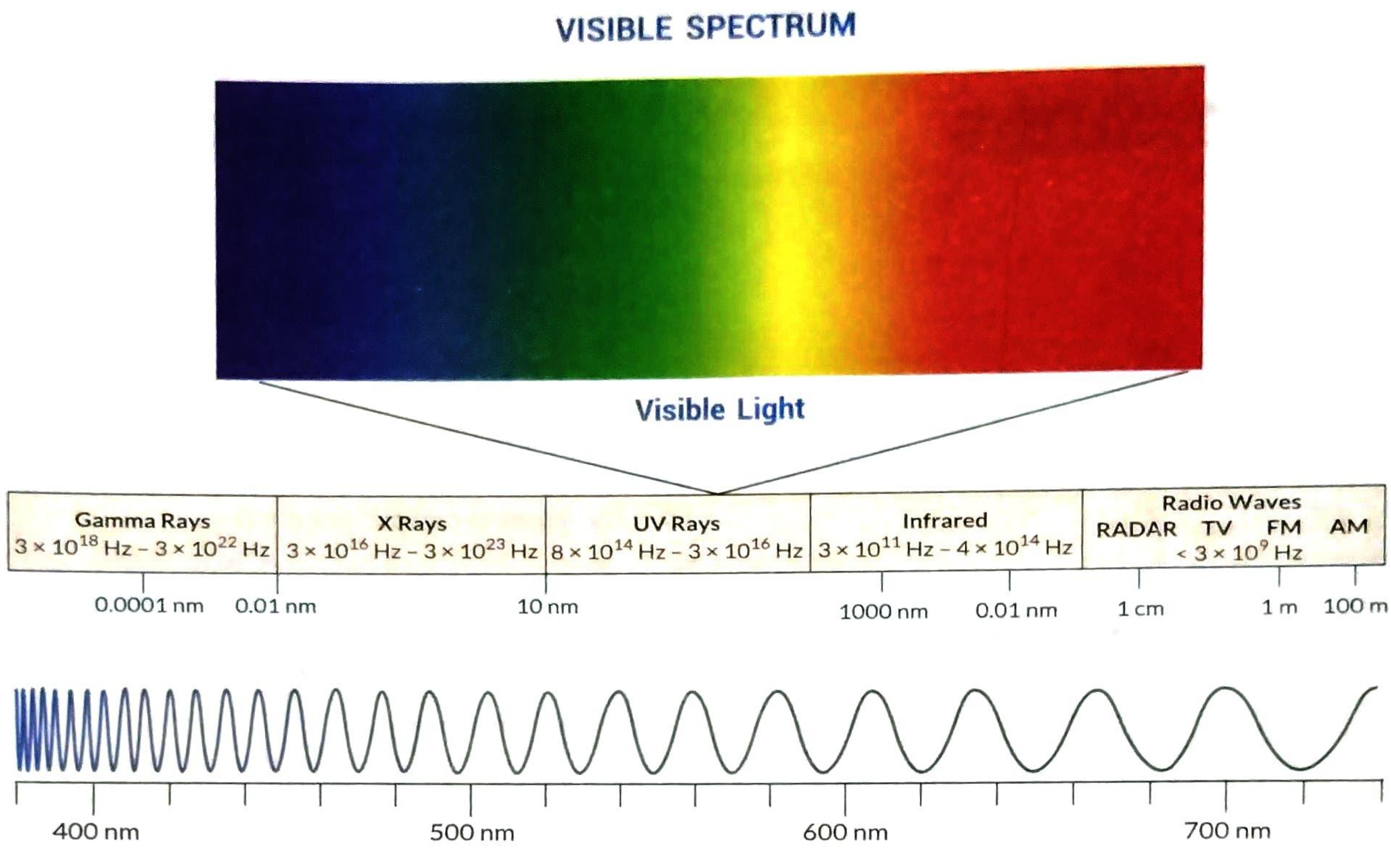
- Electromagnetic waves are produced by oscillating charge or RF antenna.
- Direction of propagation of waves is given by $\hat{k} = \hat{E} \times \hat{H}$
- In electromagnetic wave, the electric and magnetic fields are perpendicular to each other and to the direction of propagation.



Electromagnetic Wave (EM Wave) moves in free space with the speed of light 3×10^8 m s^{-1}.

ELECTROMAGNETIC SPECTRUM

It is the orderly distribution of the EM waves in accordance with their wavelength or frequency into distinct groups having widely differing properties as shown in the figure.

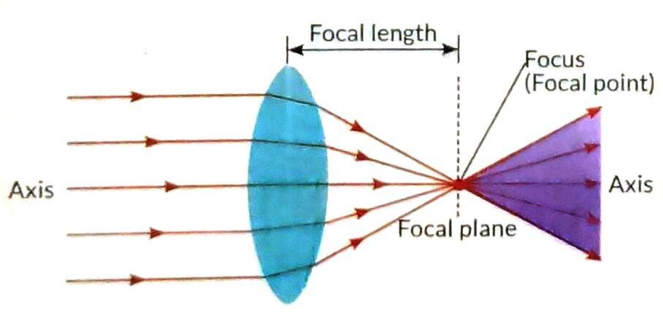


9 Ray Optics and Optical Instruments

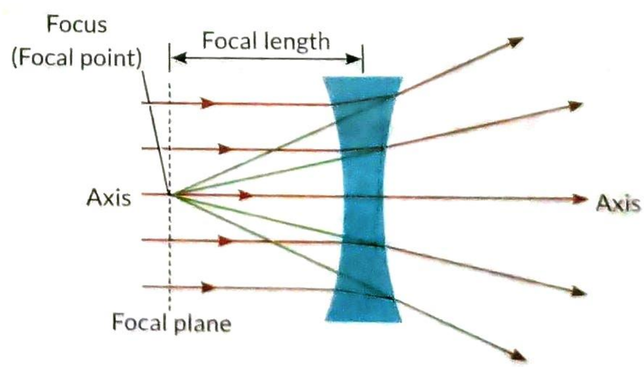
LENS

A lens is a portion of a transparent refracting medium bound by two spherical surfaces or one spherical surface and the other plane surface. Lenses are divided into two classes :

Convex or Converging Lens



Concave or Diverging Lens



Lens Maker's Formula

$$\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Thin Lens Formula

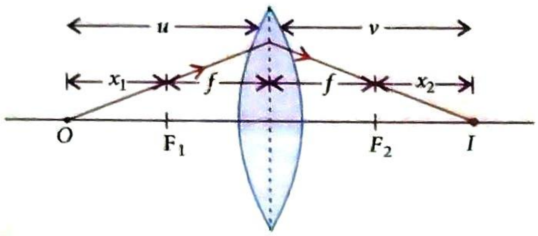
$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$$

Linear Magnification

$$m = \frac{\text{Size of image } (I)}{\text{Size of object } (O)} = \frac{v}{u}.$$

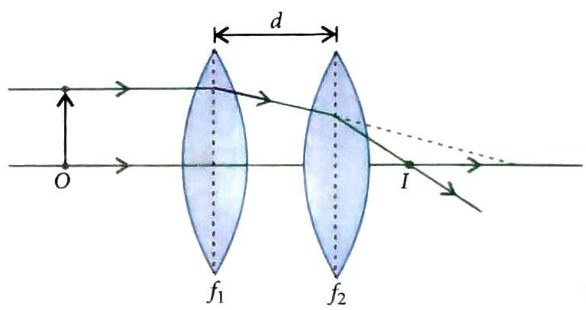
Newton's Formula

$x_1 x_2 = f^2$



Combinations of Thin Lenses

- The total magnification of the combination is given by $m = m_1 \times m_2 \times m_3$ ....
- The focal length of the combination is given by
$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$$
- In terms of power, $P = P_1 + P_2 - dP_1P_2$
- For lenses in contact, put $d = 0$



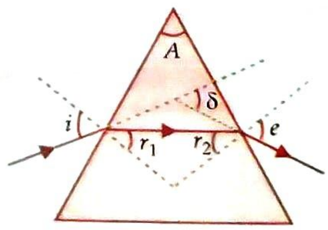
Power of a Lens

- $P = \frac{1}{\text{focal length in metres}}$.
  The SI unit of power of lens is dioptre (D).
  1 D = 1 m^{-1}.
- When focal length (f) of lens is in cm, then
  $P = \frac{100}{f \text{ (in cm)}}$ dioptre.

REFRACTION THROUGH A PRISM

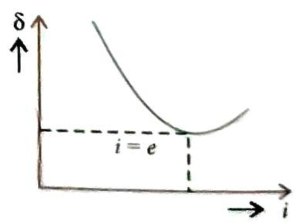
- Prism is a homogeneous, transparent medium enclosed by two plane surfaces inclined at an angle. These surfaces are called the refracting surfaces and angle between them is known as the refracting angle or the angle of prism.

  The angle between the incident ray and the emergent ray is known as the angle of deviation. $\delta = i + e - A$ where, $A = r_1 + r_2$



- The refractive index of the material of the prism is

$$\mu = \frac{\sin\left[\frac{(A+\delta_m)}{2}\right]}{\sin\left(\frac{A}{2}\right)} = \frac{\sin i}{\sin r}$$



This is known as prism formula

If A and δ_m are small then $\delta_m = (\mu - 1)A$.

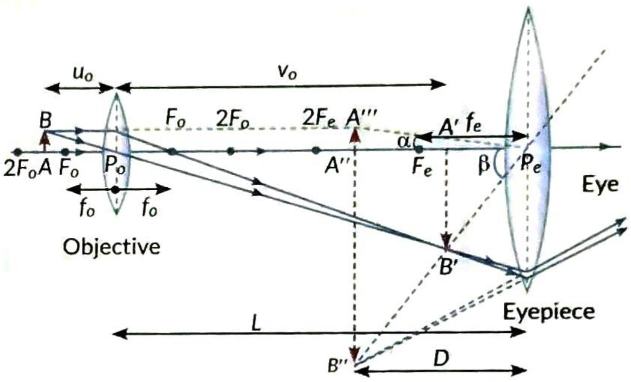
OPTICAL INSTRUMENTS

Simple Microscope

- Magnifying power $M = \dfrac{\text{angle subtended by image at the eye}}{\text{angle subtended by the object at the eye}} = \dfrac{\tan\beta}{\tan\alpha} = \dfrac{\beta}{\alpha}$
- When the image is formed at infinity (far point), $M = \dfrac{D}{f}$
- When the image is formed at the least distance of distinct vision D (near point), $M = 1 + \dfrac{D}{f}$

Compound Microscope

- Magnifying power : $M = m_o \times m_e$
- When the final image is formed at infinity (normal adjustment), $M = \dfrac{v_o}{u_o}\left(\dfrac{D}{f_e}\right)$
  - Length of tube, $L = v_o + f_e$
- When the final image is formed at least distance of distinct vision, $M = \dfrac{v_o}{u_o}\left(1 + \dfrac{D}{f_e}\right)$
  - Length of the tube, $L = v_o + \left(\dfrac{f_e D}{f_e + D}\right)$



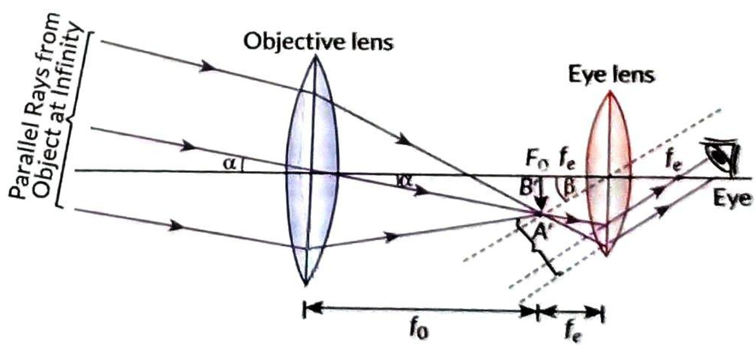
Compound Microscope

Astronomical Telescope (Refracting type)

- When the final image is formed at infinity (normal adjustment),
  $M = \dfrac{f_o}{f_e}$
  - Length of tube, $L = f_o + f_e$
- When the final image is formed at least distance of distinct vision,
  $M = \dfrac{f_o}{f_e}\left(1 + \dfrac{f_e}{D}\right)$
  - Length of tube, $L = f_o + \left(\dfrac{f_e D}{f_e + D}\right)$

Reflecting Type Telescope

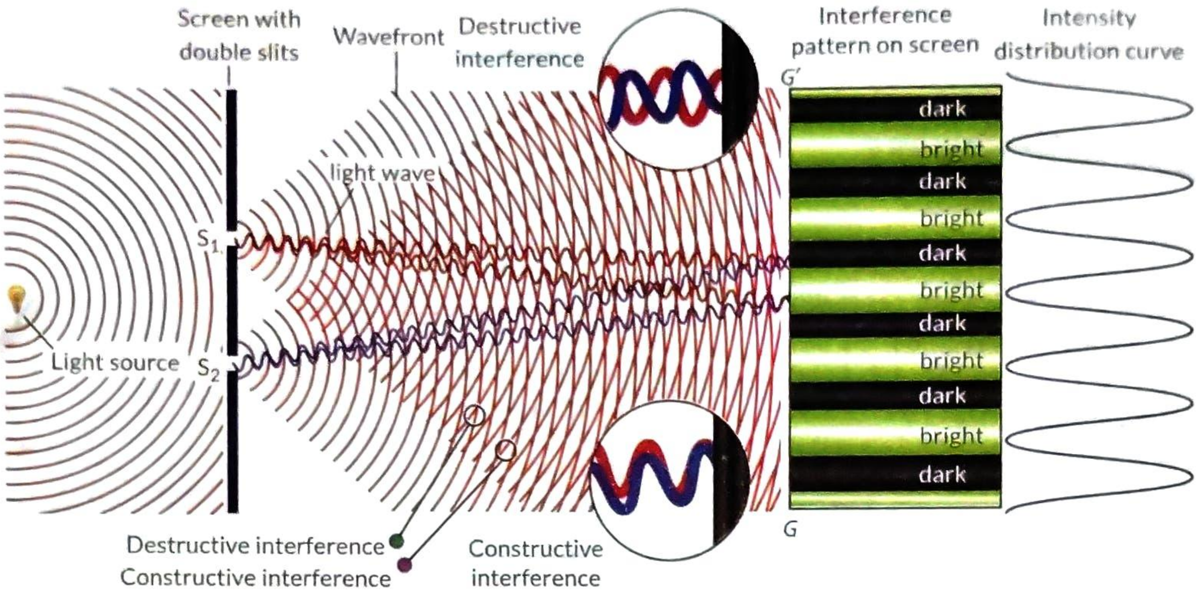
- Magnifying power, $M = \dfrac{f_o}{f_e} = \dfrac{\left(\frac{R}{2}\right)}{f_e}$
- Reflecting type telescope is free from chromatic aberration because light does not undergo refraction.
  By using paraboloidal mirror, spherical aberrations can be eliminated in reflecting type telescope.



10 Wave Optics

YOUNG'S DOUBLE SLIT EXPERIMENT (YDSE)

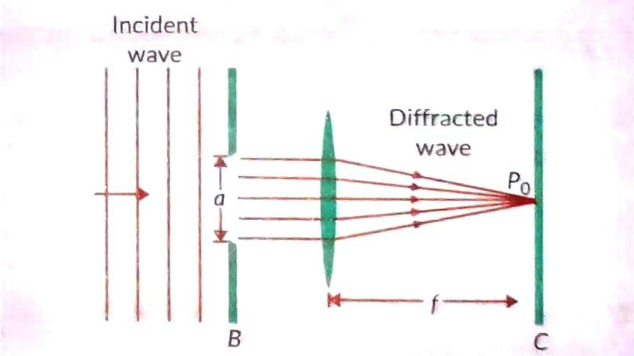
Young used an ingenious technique to lock the phases of waves emanating from coherent sources S_1 and S_2 as shown in figure. Spherical waves emanating from S_1 and S_2 will produce interference fringes on screen GG' as shown in the figure.



DIFFRACTION

- The phenomenon of diffraction involves the spreading out of waves past openings which are on the order of the wavelength of the wave.
- All the rays arriving at P_0 are in phase. Maximum intensity will be produced at point P_0.
- In general, the minima in diffraction pattern occurs at $a \sin\theta = m\lambda;\ m = \pm 1, \pm 2, \pm 3, ...$

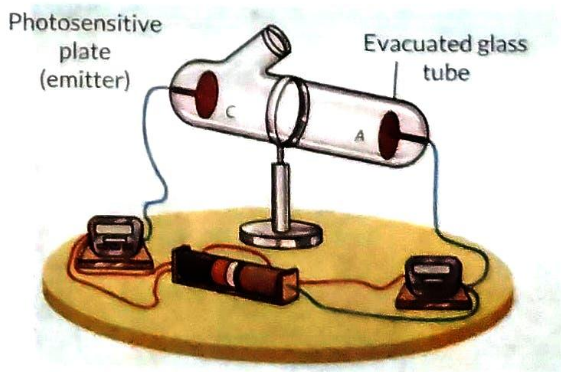
  Secondary maxima occur at $a \sin\theta = \left(m + \frac{1}{2}\right)\lambda$



11 Dual Nature of Radiation and Matter

PHOTOELECTRIC EFFECT

An experimental set-up for photoelectric effect is shown in the figure. An emitting electrode C of a photosensitive material is kept at the negative potential and collecting electrode A is kept at the positive potential in an evacuated tube. When light of sufficiently high frequency falls on emitting electrode, photoelectrons are emitted which travel directly to collecting electrode and hence an electric current called photoelectric current starts flowing in the circuit.



Experimental set-up for photoelectric effect

EINSTEIN'S PHOTOELECTRIC EQUATION

$E = K_{max} + \phi_0$ where ϕ_0 = work function,

E = energy of incident light, K_{max} = maximum K.E. of e^-

$\Rightarrow h\upsilon = \frac{1}{2}mv_{max}^2 + h\upsilon_0$

$\Rightarrow \frac{1}{2}mv_{max}^2 = h(\upsilon - \upsilon_0); eV_0 = k_{max} = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)$

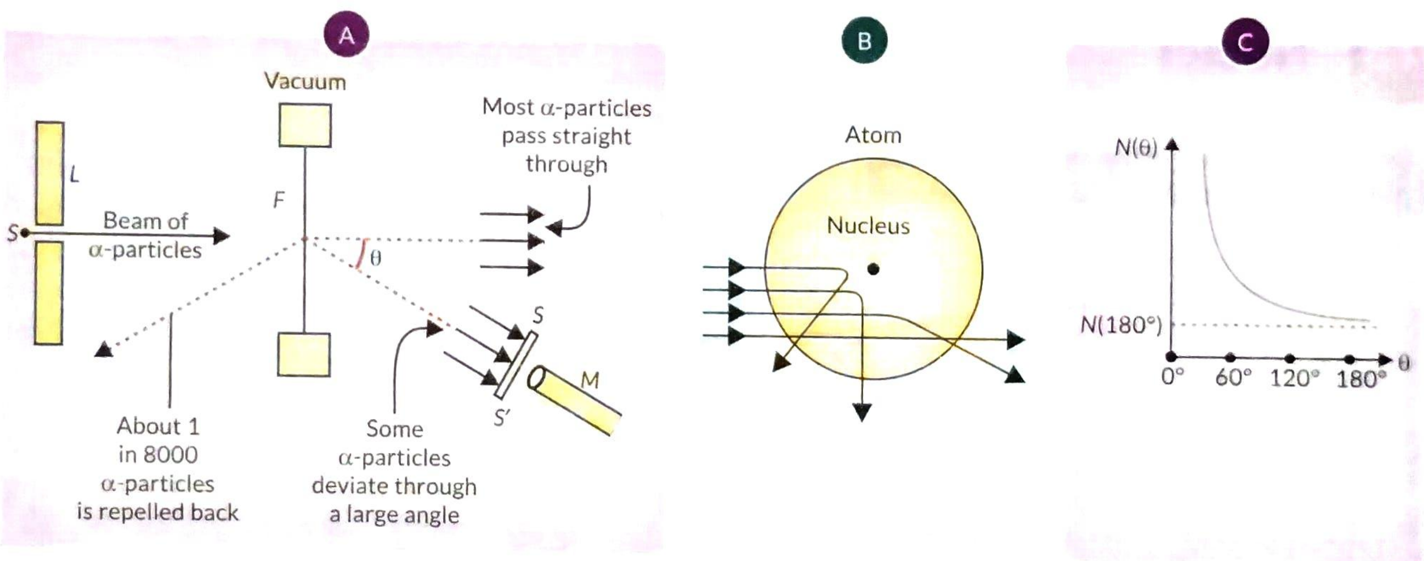
Also, $k_{max} = eV_0$

DE-BROGLIE WAVELENGTH

- $\lambda = \frac{h}{p}$
- For electron having K.E. (K) is
  $\lambda = \frac{h}{\sqrt{2mK}}$, here $p = \sqrt{2mK}$
- For a charged particle accelerated by potential V is
  $\lambda = \frac{h}{\sqrt{2qmV}}$, here $p = \sqrt{2qmV}$

12 Atoms

ALPHA PARTICLE SCATTERING AND RUTHERFORD'S NUCLEAR MODEL OF ATOM



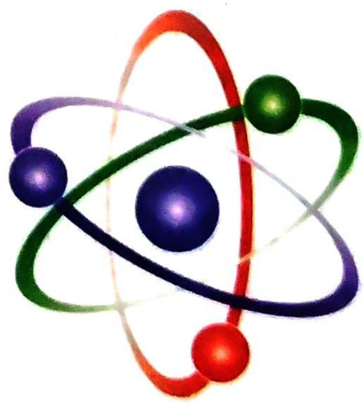
BOHR'S MODEL OF THE HYDROGEN ATOM

Postulates

- An electron in an atom could revolve in certain stable orbit without the emission of radiant energy.
- Electron revolves around the nucleus only in those orbits for which the angular momentum is an integral multiple of $h/2\pi$.
  $L = n(h/2\pi), n = 1, 2, 3, ...$
- An electron might make a transition from one of its specified non-radiating orbits to another of lower energy.

Results :

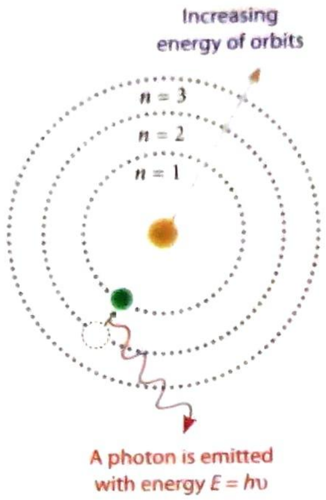
- Velocity : $v_n = \frac{2\pi zke^2}{nh}$
- Radius : $r_n = \frac{n^2h^2}{4\pi^2 kme^2}$
- Angular momentum : $mvr_n = \frac{nh}{2\pi}$



Stability of an atom

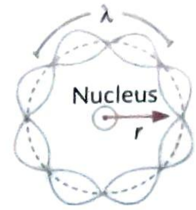
LINE SPECTRA OF THE HYDROGEN ATOM

- While transition between different atomic levels, light radiated in various discrete frequencies are called spectral series of hydrogen atom.
  $h\upsilon = \Delta E = E_i - E_f$
- Each orbit has different energy, and electrons can move to a higher orbit by absorbing energy and drop to a lower orbit by emitting energy.
- The change in energy of the electron when it moves from one orbit to another is
  $\Delta E = E_i - E_f = h\upsilon$
  where $h\upsilon$ is the energy of the observed or emitted photon.



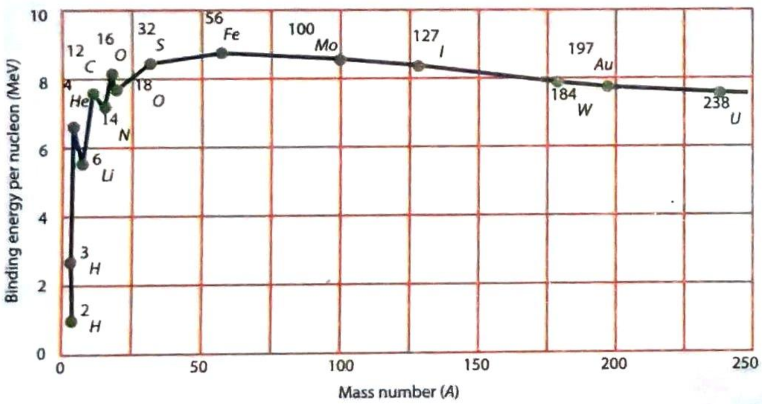
de-Broglie's Explanation of Bohr's Second Postulate of Quantisation

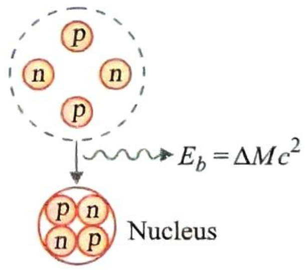
- For electron moving in the n^{th} orbit,
  $2\pi r_n = n\lambda = \frac{nh}{p} = \frac{nh}{mv}$
  $\Rightarrow mvr_n = \frac{nh}{2\pi}$

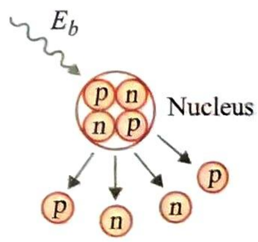


13 Nuclei

BINDING ENERGY PER NUCLEON







Following are the main features of the plot :

- The maximum binding energy per nucleon occurs at around mass number $A = 56$, and corresponds to the most stable nuclei. Iron nucleus Fe^{56} is located close to the peak with a binding energy per nucleon value of approximately 8.75 MeV. It is one of the most stable nuclei that exist.
- Nuclei with very low or very high mass numbers have lesser binding energy per nucleon and are less stable because the lesser the binding energy per nucleon, the easier it is to separate the nucleus into its constituent nucleons.
  Observation from the binding energy per nucleon vs mass number graph. Energy can be liberated in two different ways.

Nuclear fission

A heavy nucleus breaks into two lighter nuclei of comparable masses. BE per nucleon is greater for two lighter fragments than it is for the original nucleus.

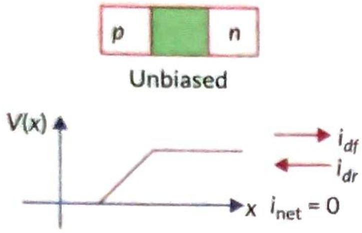
Nuclear fusion

Two lighter nuclei combine to form a heavier nucleus. BE per nucleon is greater in the final nucleus than it is in the two original nuclei.

14 Semiconductor Electronics : Materials, Devices and Simple Circuits

SEMICONDUCTOR DIODE

Formation of *p-n* junction



where,

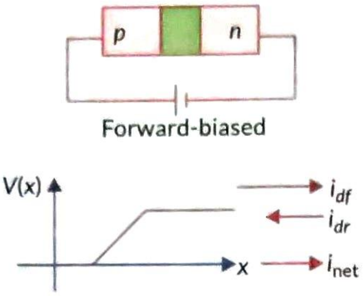
i_{df} = Diffusion Current

i_{dr} = Drift Current

$i_{net} = i_{df} - i_{dr} = 0$

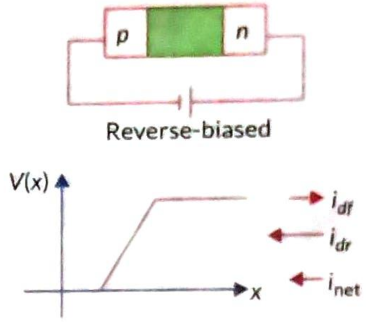
When majority charge carrier moves from *p*-side to *n*-side and *vice-versa*, a depletion region is form. This depletion region forms *p-n* junction.

p-n junction diode under forward bias



- Effective barrier potential decreases.
- Depletion width decreases.
- Low resistance offered at junction.
- High current flows through the circuit.

p-n junction diode under reverse bias



- Effective barrier potential increases.
- Depletion width increases.
- High resistance offered at junction.
- Low current flows though the circuit.

I-V Characteristics

- Current flowing through the diode,

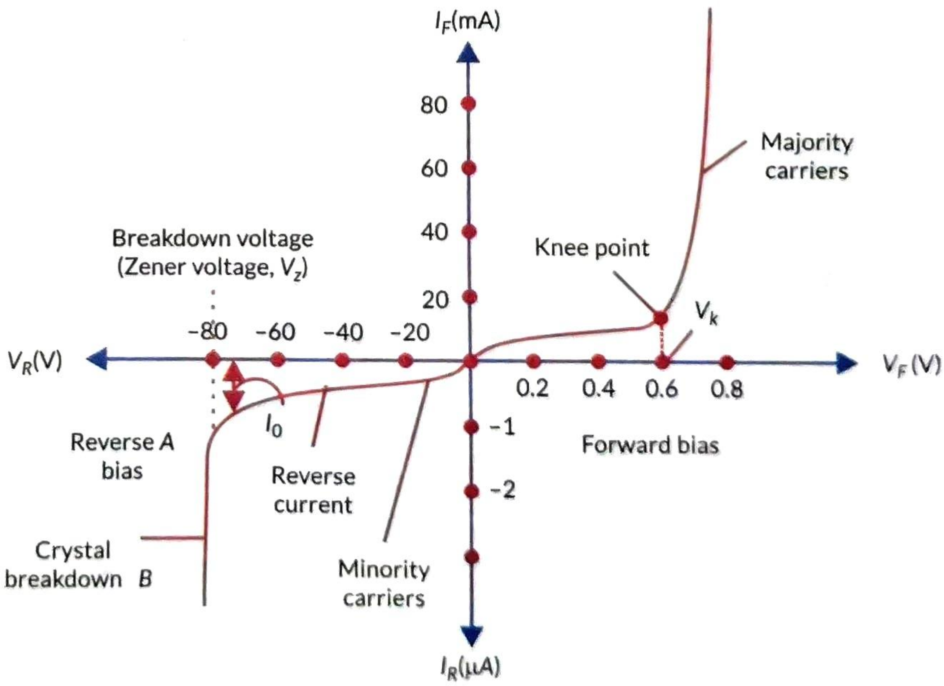
  $I = I_0\left[e^{(eV/nkT)} - 1\right]$

  $n = \text{constant} = \begin{cases} 1 \text{ for Ge} \\ 2 \text{ for Si} \end{cases}$

- Dynamic resistance of *p-n* junction, $r_d = \dfrac{\Delta V}{\Delta I}$

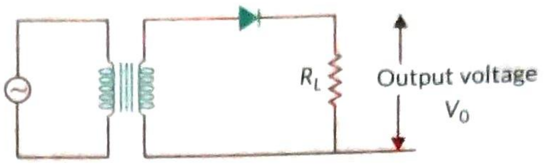
- Static or dc resistance,

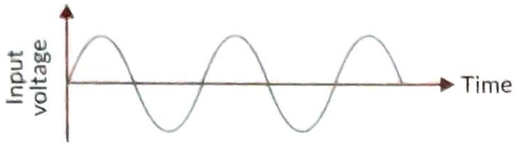
  $r_{dc} = \dfrac{V}{I}$



APPLICATION OF JUNCTION DIODE AS A RECTIFIER

Half Wave Rectifier

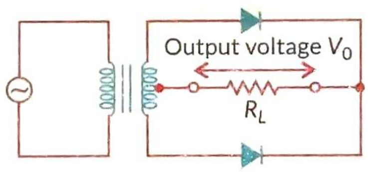


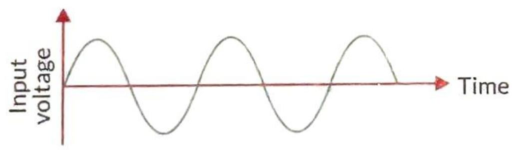


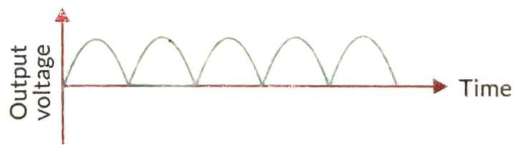
Output frequency = Input frequency

- Rectifier converts ac voltage to dc voltage
- Peak value of current is $I_m = \frac{V_m}{r_f + R_L}$
- rms value of current is $I_{rms} = \frac{I_m}{2}$
- dc value of current is $I_{dc} = \frac{I_m}{\pi}$
- Peak inverse voltage is $P.I.V = V_m$

Full Wave Rectifier







Output frequency = 2 × Input frequency

- dc value of voltage is $V_{dc} = I_{dc} R_L = \frac{I_m}{\pi} R_L$
- Peak value of current is $I_m = \frac{V_m}{r_f + R_L}$
- dc value of current is $I_{dc} = \frac{2I_m}{\pi}$
- **Ripple factor**

  $r = \frac{\text{rms value of the components of wave}}{\text{average or dc value}}$; $r = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}$
- rms value of current is $I_{rms} = \frac{I_m}{\sqrt{2}}$
- Peak inverse voltage is $P.I.V = 2V_m$
- dc value of voltage is

  $V_{dc} = I_{dc} R_L = \frac{2I_m}{\pi} R_L$