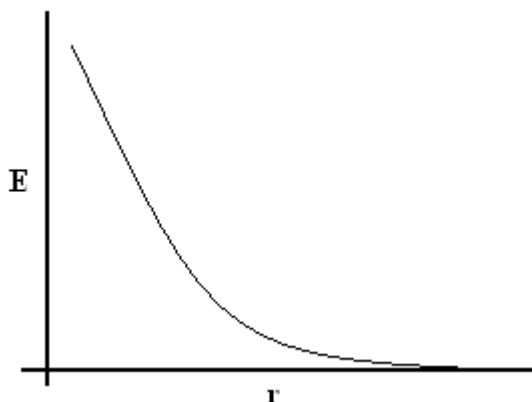


Class XII
Physics
Chapter 1: Electric Charges and Fields

Top Concepts

1. Like charges repel and unlike charges attract.
2. Conductors allow movement of electric charge through them, insulators do not.
3. Quantization of electric charge means that total charge (q) of a body is always an integral multiple of a basic quantum of charge (e) i.e., $q = ne$, where $n = 0, \pm 1, \pm 2, \pm 3, \dots$
4. Additivity of electric charges : Total charge of a system is the algebraic sum of all individual charges in the system.
5. Conservation of electric charges: Total charge of an isolated system remains unchanged with time.
6. Superposition Principle : Property that the forces with which two charges attract or repel each other are not affected by the presence of a third (or more) additional charge(s).
7. The electric field E at a point due to a charge configuration is the force on a small positive test charges q placed at the point divided by a magnitude $|q|$ / $4 \pi \epsilon_0 r^2$; it is radially outwards from q , if q is positive and radially inwards if q is negative.
8. E at a point varies inversely as the square of its distance from Q , the plot of E v/s r will look like the figure given below.



8. Coulomb's Law: The mutual electrostatic force between two point charges q_1 and q_2 is proportional to the product q_1q_2 and inversely proportional to the square of the distance r_{21} separating them.

$$\vec{F}_{21} \text{ (force on } q_2 \text{ due to } q_1) = \frac{k(q_1q_2)}{r_{21}^2} \hat{r}_{21}$$

where \hat{r}_{21} is a unit vector in the direction from q_1 to q_2 and $k = \frac{1}{4\pi\epsilon_0}$

is the constant of proportionality.

9. An electric field line is a curve drawn in such a way that the tangent at each point on the curve gives the direction of electric field at that point.

10. Important properties of field lines are:

(i) Field lines are continuous curves without any breaks.

(ii) Two field lines cannot cross each other.

(iii) Electrostatic field lines start at positive charges and end at negative charges – they cannot form closed loops.

11. The electric flux $\phi = \int d\phi = \int \vec{E} \cdot d\vec{S}$ is a 'dot' product, hence it is scalar.

$\Delta\phi$ is positive for all values of $\theta < \frac{\pi}{2}$

$\Delta\phi$ is negative for all values of $\theta > \frac{\pi}{2}$.

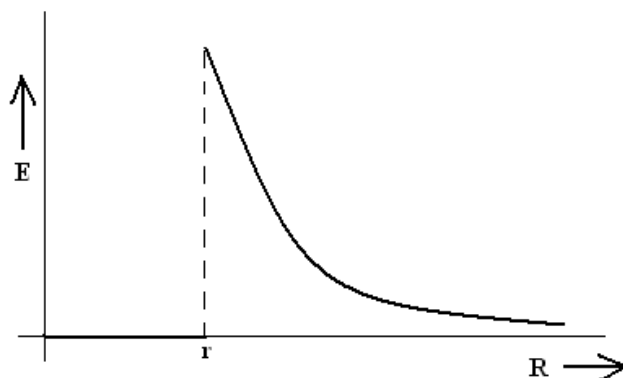
12. Gauss's law: The flux of electric field through any closed surface S is $1/\epsilon_0$ times the total charge enclosed by S .

$$\phi = \int \vec{E} \cdot d\vec{S} = \frac{q}{\epsilon_0}$$

13. Electric field outside the charged shell is as though the total charge is concentrated at the centre. The same result is true for a solid sphere of uniform volume charge density.

The electric field is zero at all points inside a charged shell.

Graphical plot of \vec{E} vs R inside the spherical shell.



Top Formulae

1. Coulomb's Law:

$$\vec{F}_{21} \text{ (force on } q_2 \text{ due to } q_1) = \frac{k(q_1 q_2)}{r_{21}^2} \hat{r}_{21}$$

where \hat{r}_{21} is a unit vector in the direction from q_1 to q_2 and $k = \frac{1}{4\pi\epsilon_0}$

is the constant of proportionality.

2. Electric field at a point due to charge q is given as

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

3. Field due to an electric dipole in its equatorial plane at a distance r from the centre:

$$E = \frac{-p}{4\pi\epsilon_0} \frac{1}{(a^2 + r^2)^{\frac{3}{2}}}$$

$$\cong \frac{-p}{4\pi\epsilon_0 r^3}, \quad \text{for } r \gg a$$

Field due to an electric dipole on the axis at a distance r from the centre:

$$E = \frac{2pr}{4\pi\epsilon_0 (r^2 - a^2)^2}$$

$$\cong \frac{2p}{4\pi\epsilon_0 r^3} \quad \text{for } r \gg a$$

Imp Note: The $1/r^3$ dependence of dipole electric fields should be noted in contrast to the $1/r^2$ dependence of electric field due to a point charge.

4. A dipole placed in uniform electric field E experiences:

Torque $\vec{\tau}$ given by

$$\vec{\tau} = \vec{p} \times \vec{E},$$

Zero Force.

5. The flux $\Delta\phi$ if electric field E through a small area element ΔS is given by

$$\Delta\phi = \vec{E} \cdot \Delta\vec{S}$$

The vector area element ΔS is

$$\Delta\vec{S} = \Delta S \hat{n}$$

Where ΔS is the magnitude of the area element and \hat{n} is normal to the area element, which can be considered planar for sufficiently small ΔS .

6. Electric field E , due to an infinitely long straight wire of uniform linear charge density λ ,

$$E = \frac{\lambda}{2\pi\epsilon_0 r} \hat{n}$$

where r is the perpendicular distance of the point from the wire and \hat{n} is the radial unit vector in the plane normal to the wire passing through the point.

7. Electric field E , due to an infinite thin plane sheet of uniform surface charge density σ ,

$$E = \frac{\sigma}{2\epsilon_0} \hat{n}$$

where \hat{n} is a unit vector normal to the plane, outward on either side.

8. Electric field E , due to thin spherical shell of uniform surface charge density σ

$$E = \frac{q}{4\pi\epsilon_0 r^2} \cdot \hat{r} \quad (r \geq R)$$

$$E = 0 \quad (r < R)$$

where r is the distance of the point from the centre of the shell and R the radius of the shell, q is the total charge of the shell & $q = 4\pi R^2 \sigma$.

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Class XII
Physics
Ch 2: Electrostatic Potential and capacitance
Chapter Notes

Top Concepts

1. Potential at a point is the work done by per unit charge by an external agency, in bringing a charge from infinity to that point.

2. Equipotential surface:

Definition: An equipotential surface is a surface over which potential has a constant value.

Imp:

- a. For a point charge, concentric spheres centered at a location of the charge are equipotential surfaces.
- b. The electric field E at a point is perpendicular to the equipotential surface through the point.
- c. E is in the direction of the steepest decrease of potential.

3. Electric field E along the outward normal to the surface is zero and σ is the surface charge density. Charges in a conductor can reside only at its surface. Potential is constant within and on the surface of a conductor.

In a cavity within a conductor (with no charges), the electric field is zero.

4. Capacitance is determined purely geometrically, by the shapes, sizes, and relative positions of the two conductors.

5. Changes observed when the medium between the plates of a capacitor is filled with an insulating substance (dielectric).

i. polarization of the medium gives rise to a field in the opposite direction.

The net electric field inside the insulating medium is reduced.

ii. potential difference between the plates is thus reduced.

iii. capacitance C increases from its value C_0 when there is no medium (vacuum).

$$C = KC_0$$

where K is the dielectric constant of the insulating substance.

6. A conductor has a cavity with no charge inside the cavity, then $\vec{E} = 0$ inside, no matter what happens outside the conductor.

Therefore, even if there are intense electric fields outside the conductor, the cavity inside has $\vec{E} = 0$, shielding whatever is inside the cavity from whatever is outside the cavity. This is called electrostatic shielding.

Top Formulae

1. Potential due to a charge at a point is given by

$$V(r) = \frac{1}{4\pi\epsilon_0} \frac{Q}{r}$$

2. The electrostatic potential at a point with position vector \vec{r} due to a point dipole of dipole moment \vec{p} placed at the origin is

$$V(r) = \frac{1}{4\pi\epsilon_0} \frac{\vec{p} \cdot \vec{r}}{r^2}$$

The result is true also for a dipole (with charges $-q$ and q separated by $2a$) for $r \gg a$.

3. For a charge configuration q_1, q_2, \dots, q_n with position vectors $\vec{r}_1, \vec{r}_2, \dots, \vec{r}_n$, the potential at a point P is given by the superposition principle

$$V = \frac{1}{4\pi\epsilon_0} \left(\frac{q_1}{r_{1p}} + \frac{q_2}{r_{2p}} + \dots + \frac{q_n}{r_{np}} \right)$$

where r_{1p} is the distance between q_1 and P , and so on.

4. Potential energy stored in a system of charges is the work done (by an external agency) in assembling the charges at their locations. Potential energy of two charges q_1, q_2 , at \vec{r}_1, \vec{r}_2 is given by

$$U = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r_{12}}$$

where r_{12} is distance between q_1 and q_2

5. PE of a charge q in an external potential, $V(r) = qV(r)$.

PE of a dipole of dipole moment p in a uniform electric field $E = -p \cdot E$.

6. Capacitance C of a system of two conductors separated by an insulator is defined by $C = Q/V$

where Q and $-Q$ are the charges on the two conductors

V is the potential difference between them.

7. Capacitance C of a parallel plate capacitor (with vacuum between the plates) is given by

$$C = \epsilon_0 \frac{A}{d}$$

where A is the area of each plate and d the separation between them.

8. For capacitors in the series combination, the total capacitance C is given by:

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots$$

For capacitors in the parallel combination, the total capacitance C is given by:

$$C = C_1 + C_2 + C_3 + \dots$$

where $C_1, C_2, C_3 \dots$ are individual capacitances

9. The energy U stored in a capacitor of capacitance C , with charge Q and voltage V is

$$U = \frac{1}{2} QV = \frac{1}{2} CV^2 = \frac{1}{2} \frac{Q^2}{C}$$

The electric energy density (energy per unit volume) in a region with electric field is $(1/2) \epsilon_0 E^2$

10. The potential difference between the conductor (radius r_0) inside & outside spherical shell (radius R) is

$$\phi(r_0) - \phi(R) = \frac{q}{4\pi\epsilon_0} \left(\frac{1}{r_0} - \frac{1}{R} \right), \text{ which is always positive.}$$

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Class XII: Physics
Ch 3: Current Electricity

Chapter Notes

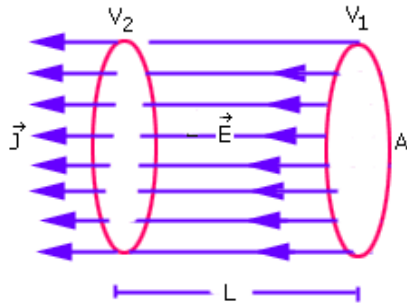
Top Concepts

1. Current through a given area of a conductor is the net charge passing per unit time through the area.
2. The current density vector \vec{J} gives current per unit area flowing through area (ΔA) when it is held normal to the direction of charge flow. Note that the direction of \vec{J} is in the direction of current flow.
3. Drift speed, which is the magnitude of this velocity, is enormously small as compared to the thermal speed, which is not a vector and is much larger.
4. When a conducting substance is brought under the influence of an electric field \vec{E} , free charges (e.g. free electrons in metals) move under the influence of this field in such a manner, that the current density \vec{J} due to their motion is proportional to the applied electric field.

$$\vec{J} = \sigma \vec{E}$$

where σ is a constant of proportionality called electrical conductivity.

This statement is one possible form of Ohm's law.



If we consider a cylindrical chunk of such a material with cross sectional area A and length L through which a current is passing along the length and normal to the area A , then, since \vec{J} and \vec{E} are in the same direction,

$$J = \sigma E$$

$$JAL = \sigma ELA$$

where A is cross sectional area and L is length of the material through which a current is passing along the length, normal to the area A .

But, $JA = I$, the current through the area A and $EL = V_1 - V_2$, the potential difference across the ends of the chunk denoting $V_1 - V_2$ as V , this gives:

$$V = \frac{IL}{\sigma A} = RI$$

where $R = \frac{L}{\sigma A}$

is called resistance of the material.

In this form, **Ohm's law** can be stated as a linear relationship between the potential drop across a substance and the current passing through it.

R is measured in ohm (Ω), where

$$1\Omega = 1V/A$$

5. Emf (Electromotive force) is the name given to a non-electrostatic agency. Typically, it is a battery, in which a chemical process achieves this task of doing work in driving the positive charge from a low potential to a high potential.

The effect of such a source is measured in terms of work done per unit charge in moving a charge once around the circuit. This is denoted by ϵ .

6. Metals have low resistivity: Range of ρ varies from $10^{-8} \Omega \text{ m}$ to $10^{-6} \Omega \text{ m}$.

Insulators like glass and rubber have high resistivity: Range of ρ varies from 10^{22} to 10^{24} times greater than that of metals.

Semiconductors like Si and Ge lie roughly in the middle range of resistivity on a logarithmic scale.

7. Current density j gives the amount of charge flowing per second per unit area normal to the flow.

$$J = nq v_d$$

where n is the number density (number per unit volume) of charge carriers each of charge q and v_d is the drift velocity of the charge carriers. For electrons $q = -e$. If j is normal to a cross – sectional area A and is constant over the area, the magnitude of the current I through the area is $nev_d A$.

8. Ohm's law is obeyed by many substances, but it is not a fundamental law of nature. It fails if
- V depends on I non-linearly. Example is when ρ increases with I (even if temperature is kept fixed).
 - The relation between V and I depends on the sign of V for the same absolute value of V.
 - The relation between V and I is non-unique. For e.g., GaAs

An example of (a) & (b) is of a rectifier

9. When a source of emf ϵ is connected to an external resistance R, the voltage V_{ext} across R is given by

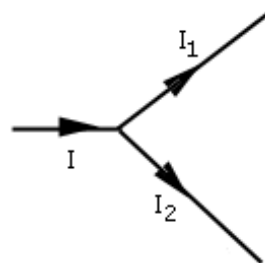
$$V_{\text{ext}} = IR = \frac{\epsilon}{R + r} R$$

where r is the internal resistance of the source.

10. Kirchhoff's Rules –

Kirchhoff's First Rule:

At any junction of several circuit elements, the sum of currents entering the junction must equal the sum of currents leaving it.



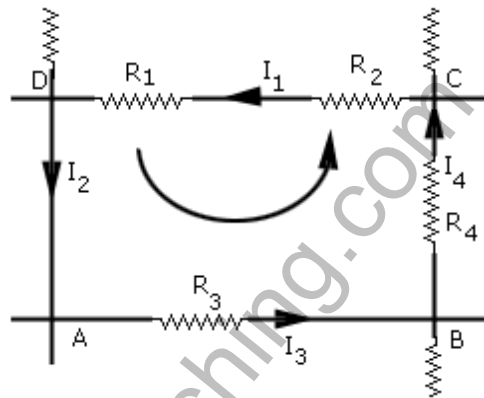
In the above junction, current I enters it and currents I_1 and I_2 leave it.

Then, $I = I_1 + I_2$.

This is a consequence of charge conservation and assumption that currents are steady, that is no charge piles up at the junction.

Kirchhoff's Second Rule:

The algebraic sum of changes in potential around any closed resistor loop must be zero. This is based on the principle that electrostatic forces alone cannot do any work in a closed loop, since this work = Potential difference, which is zero, if we start at one point of the loop and come back to it.



Applied to a loop as above (which could be part of a bigger circuit). This gives:

$$(R_1 + R_2) I_1 + R_3 I_3 + R_4 I_4 = 0$$

11. Points to remember in case of current loops:

(i) Choose any closed loop in the network and designate a direction (in this example counter clockwise) to traverse the loop.

(ii) Go around the loop in the designated direction, adding emf's and potential differences. An emf is counted as **positive** when it is traversed (-) to (+) { ϵ in the above examples} and **negative** in the opposite case i.e., from (+) to (-). {in the above example}

An IR term is counted negative if the resistor is traversed in the same direction of the assumed current, and positive if in the opposite direction.

(iii) Equate the total sum to zero.

12. The Wheatstone bridge is an arrangement of four resistances – R_1 , R_2 , R_3 , R_4 , as shown in the text. The null point condition is given by

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

This is also known as the balance condition. If R_1 , R_2 , R_3 are known, for instance, R_4 can be determined.

$$R_4 = \left(\frac{R_2}{R_1} \right) R_3$$

13. In a balanced condition of the meter bridge,

$$\frac{R}{S} = \frac{P}{Q} = \frac{\sigma \ell_1}{\sigma(100 - \ell_1)} = \frac{\ell_1}{100 - \ell_1}$$

$$\therefore R = \frac{S \ell_1}{(100 - \ell_1)}$$

σ : Resistance per unit length of wire

ℓ_1 : Length of wire from one end where null point is obtained.

14. The potentiometer is a device to compare potential differences. Since the method involves a condition of no current flow, the device can be used to measure potential differences; internal resistance of a cell and compare emf's of two sources.

The potential gradient of the wire in a potentiometer depends on the current in the wire.

If an emf ϵ_1 is balanced against length ℓ_1 ,

$$\epsilon_1 = \rho \ell_1$$

Similarly, if ϵ_2 is balanced against ℓ_2 ,

$\epsilon_2 = \rho \ell_2$, then the comparison of emf's of the two cells is given by

$$\therefore \frac{\epsilon_1}{\epsilon_2} = \frac{\ell_1}{\ell_2}$$

Top Formulae

1. Electrical conductivity is the inverse of specific resistance for a conductor

whereas the specific resistance is the resistance of unit cube of the material of the conductor.

$$\sigma = \frac{1}{\rho} = \frac{ne^2\tau}{m}$$

σ = conductivity

ρ = resistivity

SI unit of conductivity = mhm^{-1}

2. Mobility μ is defined to be the magnitude of drift velocity per unit electric field.

$$\mu = \left(\frac{v_d}{E} \right)$$

Now, $v_d = \frac{q\tau E}{m_q}$ where q is the electric charge of the current carrier and m_q is its mass.

$$\therefore \mu = \left(\frac{q\tau}{m_q} \right)$$

Mobility is a measure of response of a charge carrier to a given external electric field. If the mass of a charge carrier is large, then for

a given field \vec{E} , its acceleration will be small and will contribute very little to the electric current.

3. **Ohm's law** $R = \frac{L}{\sigma A}$

where R is called resistance of the material.

4. Resistivity ρ is defined to be reciprocal of conductivity

$$\rho = \frac{1}{\sigma}$$

It is measured in ohm-metre(Ω m).

5. Resistivity as a function of temperature is given as,

$$\rho_T = \rho_0 [1 + \alpha(T - T_0)]$$

α : Temperature coefficient of resistivity. ρ_0 is the resistivity of the material at some initial reference temperature. ρ_T is the resistivity of the material at temperature T. At low temperatures, its variation is non-linear.

6. (a) Total resistance R of n resistors connected in series is given by

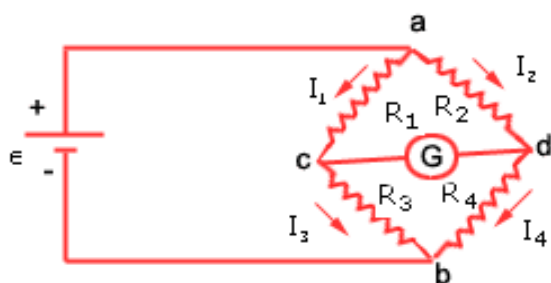
$$R = R_1 + R_2 + \dots + R_n$$

(b) Total resistance R of n resistors connected in parallel is given by

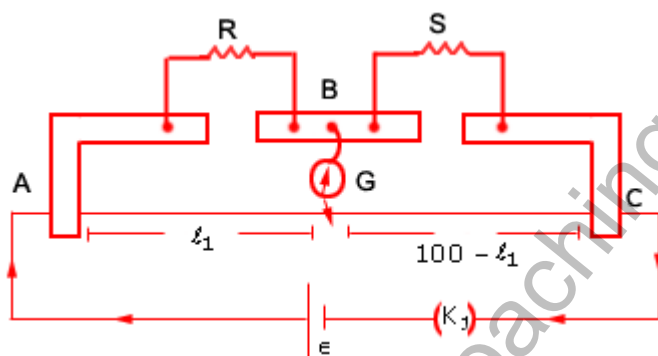
$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_n}$$

Top Diagrams

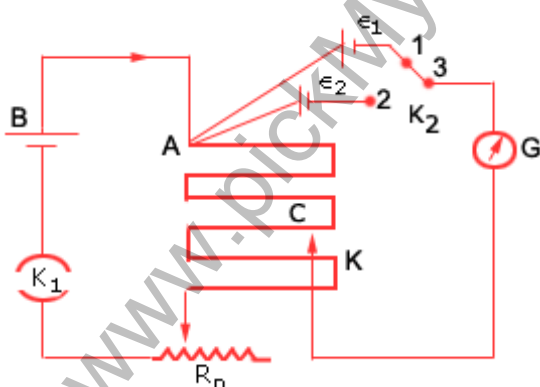
1. Balanced Wheatstone bridge



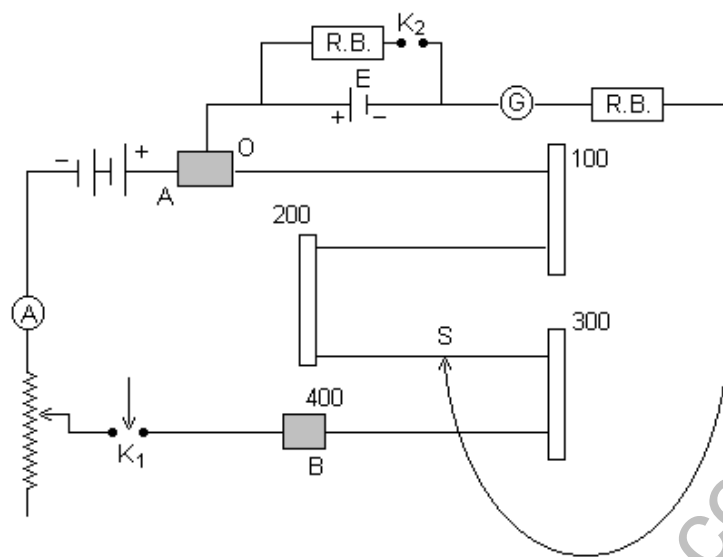
2. Balanced meter bridge



3. Potentiometer: Comparison of emf's of two cells:



4. Potentiometer: Determination of internal resistance of cell:



Class XII: Physics
Ch 4: Moving Charges and Magnetism
Chapter Notes

Top Formulae

1. Lorentz Force : Force on a charge q moving with velocity \vec{v} in the presence of magnetic and electric fields \vec{B} and \vec{E} .

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

The magnetic force $\vec{F}_B = q(\vec{v} \times \vec{B})$ is normal to \vec{v} and work done by it is zero.

2. Force F on a straight conductor of length ℓ and carrying a steady current I placed in a uniform external magnetic field \vec{B} ,

$$\vec{F} = I\vec{\ell} \times \vec{B}$$

3. A charge q executes a circular orbit in a plane normal with frequency called the cyclotron frequency given by:

$$\nu_c = \frac{qB}{2\pi m}$$

This cyclotron frequency is independent of the particle's speed and radius.

4. Biot – Savart law asserts that the magnetic field $d\vec{B}$ due to an element $d\vec{\ell}$ carrying a steady current I at a point P at a distance r from the current element is:

$$d\vec{B} = \frac{\mu_0}{4\pi} I \frac{d\vec{\ell} \times \vec{r}}{r^3}$$

5. Magnetic field due to circular coil of radius R carrying a current I at an axial distance x from the centre is

$$B = \frac{\mu_0 I R^2}{2(x^2 + R^2)^{3/2}}$$

At the centre of the coil,

$$B = \frac{\mu_0 I}{2R}$$

6. Ampere's Circuital Law: For an open surface S bounded by a loop C, then the Ampere's law states that $\oint_C \vec{B} \cdot d\vec{\ell} = \mu_0 I$ where I refers to the current passing through S.

If B is directed along the tangent to every point on the perimeter then

$$BL = \mu_0 I_e$$

where I_e is the net current enclosed by the closed circuit.

7. Magnetic field at a distance R from a long, straight wire carrying a current I is given by:

$$B = \frac{\mu_0 I}{2R}$$

The field lines are circles concentric with the wire.

8. Magnetic field B inside a long Solenoid carrying a current I is

$$B = \mu_0 nI$$

where n is the number of turns per unit length.

For a toroid,

$$B = \frac{\mu_0 NI}{2\pi r}$$

where N is the total numbers of turns and r is the average radius.

9. Magnetic moment \vec{m} of a planar loop carrying a current I, having N closely wound turns, and an area A, is

$$\vec{m} = NI\vec{A}$$

Direction of \vec{m} is given by the right – hand thumb rule: curl and palm of your right hand along the loop with the fingers pointing in the direction of the current. The thumb sticking out gives the direction of \vec{m} (and \vec{A}).

When this loop is placed in a uniform magnetic field B, the force F on it is: $F = 0$

And the torque on it is,

$$\vec{\tau} = \vec{m} \times \vec{B}$$

In a moving coil galvanometer, this torque is balanced by a counter torque due to a spring, yielding.

$$k\Phi = NIAB$$

where Φ is the equilibrium deflection and k the torsion constant of the spring.

10. An electron moving around the central nucleus has a magnetic moment μ_ℓ , given by

$$\mu_\ell = \frac{e}{2m} \ell$$

where ℓ is the magnitude of the angular momentum of the circulating electron about the central nucleus. The smallest value of μ_ℓ is called the Bohr magneton μ_B and it is $\mu_B = 9.27 \times 10^{-24} \text{ J/T}$

Class XII: Physics
Ch5: Magnetism and Matter

Chapter Notes

Key Learnings

1. Magnetic materials tend to point in the north – south direction.
Like magnetic poles repel and unlike ones attract.
Cutting a bar magnet in two leads to two smaller magnets.
Magnetic poles cannot be isolated.
2. When a bar magnet of dipole moment \vec{m} is placed in a uniform magnetic field \vec{B} ,
 - a. The force on it is zero
 - b. The torque on it is $\vec{m} \times \vec{B}$
 - c. Its potential energy is $-\vec{m} \cdot \vec{B}$, where we choose the zero of energy at the orientation when \vec{m} is perpendicular to \vec{B}
3. Consider a bar magnet of size ℓ and magnetic moment \vec{m} , at a distance r from its mid – point, where $r \gg \ell$, the magnetic field \vec{B} due to this bar is,
4. Gauss's law for magnetism states that the net magnet flux through any closed surface is zero

$$\vec{B} = \frac{\mu_0 \vec{m}}{2\pi r^3} \quad (\text{along axis})$$

$$= -\frac{\mu_0 \vec{m}}{4\pi r^3} \quad (\text{along equator})$$

$$\phi_B = \sum_{\text{all area elements } \Delta \vec{S}} \vec{B} \cdot \Delta \vec{S} = 0$$

5. The pole near the geographic north pole of the earth is called the north magnetic pole.

The pole near the geographic south – pole is called the south magnetic pole.

The magnitude of the magnetic field on the earth's surface = 4×10^{-5} T.

6. Three quantities are needed to specify the magnetic field of the earth on its surface – the horizontal component, the magnetic declination, and the magnetic dip.

These are known as the elements of the earth's magnetic field.

7. Consider a material placed in an external magnetic field \vec{B}_0 .

The magnetic intensity is defined as,

$$\vec{H} = \frac{\vec{B}_0}{\mu_0}$$

The magnetization \vec{M} of the material is its dipole moment per unit volume.

The magnetic field \vec{B} in the material is,

$$\vec{B} = \mu_0 (\vec{H} + \vec{M})$$

8. For a linear material $\vec{M} = \chi \vec{H}$. So that $\vec{B} = \mu \vec{H}$ and

χ : Magnetic susceptibility of the material.

μ_r : Relative magnetic permeability

μ the magnetic permeability area, related as follows:

$$\mu = \mu_0 \mu_r$$

$$\mu_r = 1 + \chi$$

9. Magnetic materials are broadly classified as; diamagnetic, paramagnetic and ferromagnetic.

For diamagnetic materials χ is negative and small.

For paramagnetic materials χ is positive and small.

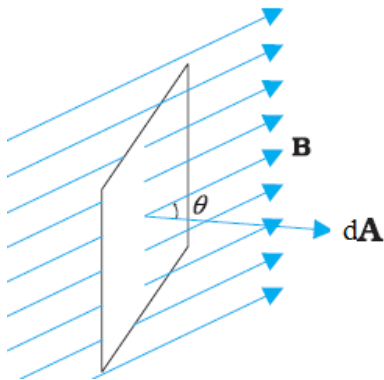
For ferromagnetic materials χ lies between \bar{B} and \bar{H} .

10. Substances, which at room temperature, retain their ferromagnetic property for a long period of time are called permanent magnets.

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Ch: Electromagnetic Induction**Class XII Physics****Chapter Notes****Magnetic Flux**

Magnetic flux through a plane of area dA placed in a uniform magnetic field B



$$\phi = \int \vec{B} \cdot d\vec{A}$$

If the surface is closed, then

$$\phi = \oint \vec{B} \cdot d\vec{A} = 0$$

This is because magnetic lines of force are closed lines and free magnetic poles do not exist.

Electromagnetic Induction: Faraday's Law

- a). First Law: whenever there is a change in the magnetic flux linked with a circuit with time, an induced emf is produced in the circuit which lasts as long as the change in magnetic flux continues.
- b). Second Law:

$$\text{Induced emf, } E \propto \left(\frac{d\phi}{dt} \right)$$

Lenz's Law

The direction of the induced emf or current in the circuit is such that it opposes the cause due to which it is produced, so that,

$$E = -N \left(\frac{d\phi}{dt} \right)$$

$N \rightarrow$ No. of turns in coil

Lenz's law based on energy conservation.

EMF Current and Charge Induced in the Circuit

$$\begin{aligned} \text{a). Induced emf} \quad E &= -N \frac{d\phi}{dt} \\ &= -\frac{N(\phi_2 - \phi_1)}{t} \end{aligned}$$

$$\begin{aligned} \text{b). Induced current} \quad I &= \frac{E}{R} = -\frac{N}{R} \left(\frac{d\phi}{dt} \right) \\ &= -\frac{N(\phi_2 - \phi_1)}{R t} \end{aligned}$$

Charge depends only on net change in flux does not depends on time.

Emf Induced Due to Linear Motion of a Conducting Rod in a Uniform Magnetic Field

$$E = -\vec{\ell} \cdot (\vec{v} \times \vec{B})$$

If \vec{e} , \vec{v} and \vec{B} are perpendicular to each other then

$$E = Bv\ell$$

Induced EMF Due to Rotation of a Conducting Rod in a Uniform Magnetic Field

$$E = \frac{1}{2} B\omega\ell^2 = B\pi n\ell^2 = BAn$$

Where n is the frequency of rotation of the conducting rod

Induced EMF Due to Rotation of a Metallic Disc in a Uniform Magnetic Field

$$E_{OA} = \frac{1}{2} B\omega R^2 = B\pi R^2 n = BAn$$

Induced EMF, Current and Energy Conservation in a Rectangular Loop Moving in a Non – Uniform Magnetic Field with a Constant Velocity

i) Net increase in flux crossing through the coil in time Δt

$$\Delta\phi = (B_2 - B_1) \ell v \Delta t$$

- ii) Emf induced in the coil

$$E = (B_1 - B_2) \ell v$$

- iii) If the resistance of the coil is R, then the current induced in the coil

$$I = \frac{E}{R} = \frac{(B_1 - B_2)}{R} \ell v$$

- iv) Resultant force acting on the coil

$$F = I \ell (B_1 - B_2) \text{ (towards left)}$$

- v) The work done against the resultant force

$$W = (B_1 - B_2)^2 \frac{\ell^2 v^2}{R} \Delta t \text{ joule}$$

Energy supplied in this process appears in the form of heat energy in the circuit.

- vi) Energy supplied due to flow of current I in time Δt

$$H = I^2 R \Delta t$$

$$\text{Or } H = (B_1 - B_2)^2 \frac{\ell^2 v^2}{R} \Delta t \text{ joule}$$

$$\text{Or } H = W$$

Rotation of Rectangular Coil in a Uniform Magnetic Field

- a) Magnetic flux linked with coil

$$\begin{aligned} \phi &= BAN \cos \theta \\ &= BAN \cos \omega t \end{aligned}$$

- b) Emf induced in the coil

$$E = \frac{d\phi}{dt} = BA N \omega \sin \omega t = E_0 \sin \omega t$$

- c) Current induced in the coil

$$\begin{aligned} I &= \frac{E}{R} = \frac{BAN \omega}{R} \sin \omega t \\ &= \frac{E_0}{R} \sin \omega t \end{aligned}$$

- d) Both Emf and current induced in the coil are alternating

Self Induction and Self Inductance (L)

On changing the current in a coil, an induced e.m.f. is produced in the coil then the phenomenon is called self induction

i) $\phi \propto I$ or $\phi = LI$

or $L = \frac{\phi}{I}$

ii) $E = -L \frac{dI}{dt}$

where L is a constant, called self inductance or coefficient of self – induction.

Or $L = \frac{E}{-(dI/dt)}$

iii) Self inductance of a circular coil

$$L = \frac{\mu_0 N^2 \pi R}{2} = \frac{\mu_0 N^2 A}{2R}$$

iv) Self inductance of a solenoid

$$L = \frac{\mu_0 N^2 A}{\ell}$$

v) Two coils of self – inductances L_1 and L_2 , placed far away (i.e., without coupling) from each other.

a For series combination:

$$L = L_1 + L_2 + \dots + L_n$$

b For parallel combination:

$$\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2} + \dots + \frac{1}{L_n}$$

Mutual Induction and Mutual Inductance

a) On changing the current in one coil, if the magnetic flux linked with a second coil changes and induced e.m.f. is produced in that coil, then this phenomenon is called mutual induction.

b) $\phi_2 \propto I_1$ or $\phi_2 = MI_1$

Or $M = \frac{\phi_2}{I_1}$

c) $E_2 = -\frac{d\phi_2}{dt} = -M \frac{dI_1}{dt}$

$$\text{Or } M = \frac{E_2}{-(dI_1 / dt)}$$

d) $M_{12} = M_{21} = M$

e) Mutual inductance two coaxial solenoids

$$M = \frac{\mu_0 N_1 N_2 A}{\ell}$$

f) If two coils of self inductance L_1 and L_2 are wound over each other, the mutual inductance is given by

$$M = K\sqrt{L_1 L_2}$$

Where K is called coupling constant.

g) For two coils wound in same direction and connected in series

$$L = L_1 + L_2 + 2M$$

For two coils wound in opposite direction and connected in series

$$L = L_1 + L_2 - 2M$$

For two coils in parallel

$$L = \frac{L_1 L_2 - M^2}{L_1 + L_2 \pm 2M}$$

Energy Stored in an Inductor

Energy stores in the form of M.F.

$$U_B = \frac{1}{2} L I_{\max}^2$$

Magnetic energy density

$$u_B = \frac{B^2}{2\mu_0}$$

Eddy Current

When a conductor is moved in a magnetic field, induced currents are generated in the whole volume of the conductor. These currents are called eddy currents.

Transformer

- a) It is a device which changes the magnitude of alternating voltage or current.
- b) $\frac{E_s}{E_p} = \frac{n_s}{n_p} = K$
- c) $\frac{I_p}{I_s} = \frac{n_s}{n_p}$ (For ideal transformer)
- d) In an ideal transformer:
 $E_p I_p = E_s I_s$ or $P_{in} = P_{out}$
- e) In step – down transformer:
 $n_s > n_p$ or $K > 1$
 $E_s > E_p$ and $I_s < I_p$
- f) In step – up transformer:
 $n_s < n_p$ or $K < 1$
 $E_s < E_p$ and $I_s > I_p$
- g) Efficiency $\eta = \frac{P_{out}}{P_{in}} \times 100\%$

Generator or Dynamo

It is a device by which mechanical energy is converted into electrical energy. It is based on the principle of E.M.I.

AC Generator

It consists of field magnet, armature, slip rings and brushes.

DC Generator

It consists of field magnet, armature, commutator and brushes.

Motor

It is a device which converts electrical energy into mechanical energy.

Back emf $e \propto \omega$

Current flowing in the coil

$$i_a = \frac{E - e_b}{R}$$

Or $E = e_b + i_a R$

Where R is the resistance of the coil.

Out put Power = $i_a e_b$

Efficiency $\eta = \frac{e_b}{E} \times 100\%$

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Ch: Alternating Current**Phy XII****Chapter Notes****TOP Formulae****Alternating Current (a.c)**

The current whose magnitude changes with time and direction reverses periodically, is called alternating current.

a) Alternating emf E and current I at any time are given by:

$$E = E_0 \sin \omega t, \text{ where } E_0 = NBA \omega$$

$$\text{and } I = I_0 \sin (\omega t - \phi), \text{ here } I_0 = NBA \omega / R$$

$$\omega = 2\pi n = \frac{2\pi}{T}, T \rightarrow \text{Time period}$$

Values of Alternating Current and Voltage

- a) Instantaneous value: It is the value of alternating current and voltage at an instant t .
- b) Peak value: Maximum values of voltage E_0 and current I_0 in a cycle, are called peak values.
- c) Mean value: For complete cycle.

$$\langle E \rangle = \frac{1}{T} \int_0^T E dt = 0$$

$$\langle I \rangle = \frac{1}{T} \int_0^T I dt = 0$$

$$\text{Mean value for half cycle : } E_{\text{mean}} = \frac{2E_0}{\pi}$$

d) Root – mean- square (rms) value:

$$E_{rms} = (\langle E^2 \rangle)^{1/2} = \frac{E_0}{\sqrt{2}} = 0.707E_0 = 70.7\%E_0$$

$$\text{And } I_{rms} (\langle I^2 \rangle)^{1/2} = \frac{I_0}{\sqrt{2}} = 0.707I_0 = 70.7\%I_0$$

RMS values are also called apparent or effective values.

Phase difference Between the EMF (Voltage) and the Current in an AC Circuit

- a) For pure resistance: The voltage and the current are in same phase
i.e. phase difference $\phi = 0$
- b) For pure inductance: The voltage is ahead of current by $\pi/2$ i.e. phase difference $\phi = +\pi/2$.
- c) For pure capacitance: The voltage lags behind the current by $\pi/2$ i.e. phase difference $\phi = -\pi/2$.

Reactance

a) Reactance $X = \frac{E}{I} = \frac{E_0}{I_0} = \frac{E_{rms}}{I_{rms}} \pm \pi/2$

b) Inductive reactance

$$X_L = \omega L = 2\pi nL$$

c) Capacitive reactance

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi nC}$$

Impedance

$$\text{Impedance } Z = \frac{E}{I} = \frac{E_0}{I_0} = \frac{E_{\text{rms}}}{I_{\text{rms}}} \phi$$

Where ϕ is the phase difference of the voltage E relative to the current I .

b) For L – R series circuit:

$$Z_{RL} = \sqrt{R^2 + X_L^2} = \sqrt{R^2 + \omega L^2}$$

$$\text{And } \tan \phi = \left(\frac{\omega L}{R} \right) \quad \text{or} \quad \phi = \tan^{-1} \left(\frac{\omega L}{R} \right)$$

c) For R – C series circuit:

$$Z_{RC} = \sqrt{R^2 + X_C^2} = \sqrt{R^2 + \left(\frac{1}{\omega C} \right)^2}$$

$$\text{And } \tan \phi = \frac{1}{\omega CR}$$

$$\text{Or } \phi = \tan^{-1} \left(\frac{1}{\omega CR} \right)$$

d) For L – C series circuit:

$$Z_{LCR} = \sqrt{R^2 + (X_L - X_C)^2}$$

$$= \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C} \right)^2}$$

$$\text{And } \tan \phi = \frac{\left(\omega L - \frac{1}{\omega C} \right)}{R}$$

$$\text{Or } \phi = \tan^{-1} \left(\frac{\omega L - \frac{1}{\omega C}}{R} \right)$$

Conductance

Reciprocal of resistance is called conductance.

$$\therefore \text{Conductance} \quad G = \frac{1}{R} \text{ mho}$$

Power in and AC Circuit

a) Electric power = (current in circuit) x (voltage in circuit)

$$P = IE$$

b) Instantaneous power:

$$P_{\text{inst}} = E_{\text{inst}} \times I_{\text{inst}}$$

c) Average power:

$$P_{\text{av}} = \frac{1}{2} E_0 I_0 \cos \phi = E_{\text{rms}} I_{\text{rms}} \cos \phi$$

d) Virtual power (apparent power):

$$= \frac{1}{2} E_0 I_0 = E_{\text{rms}} I_{\text{rms}}$$

Power Factor

a) Power factor

$$\cos \phi = \frac{P_{\text{av}}}{P_v} = \frac{R}{Z}$$

b) For pure inductance

$$\text{Power factor, } \cos \phi = 1$$

c) For pure capacitance

$$\text{Power factor, } \cos \phi = 0$$

d) For LCR circuit

$$\text{Power factor, } \cos \phi = \frac{R}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C} \right)^2}}$$

$$X = \left(\omega L - \frac{1}{\omega C} \right)$$

Wattless Current

The component of current differing in phase by $\pi/2$ relative to the voltage, is called wattless current.

rms value of wattless current :

$$= \frac{I_0}{\sqrt{2}} \sin \phi$$

$$= I_{\text{rms}} \sin \phi = \frac{I_0}{\sqrt{2}} \left(\frac{X}{Z} \right)$$

Choke Coil

An inductive coil used for controlling alternating current whose self inductance is high and resistance is negligible, is called choke coil.

The power factor of this coil is approximately zero.

Series Resonant Circuit

- a) when the inductive reactance (X_L) becomes equal to the capacitive reactance (X_C) in the circuit, the total impedance becomes purely resistive ($Z=R$). In this state voltage and current are in same phase ($\phi = 0$), the current and power are maximum and impedance is minimum. This state is called resonance.

- b) At resonance,

$$\omega_r L = \frac{1}{\omega_r C}$$

Hence resonant frequency $f_r = \frac{1}{2\pi\sqrt{LC}}$

- c) In resonance the power factor of the circuit is one.

Half – Power Frequencies

Those frequencies f_1 and f_2 at which the power is half of the maximum power (power at resonance), i.e.,

$$P = \frac{1}{2} P_{\max}$$

$$\text{And } I = \frac{I_{\max}}{\sqrt{2}}$$

f_1 and f_2 are called half – power frequencies

$$P = \frac{P_{\max}}{2}$$

Band – Width

The frequency interval between half – power frequencies is called band – width.

$$\therefore \text{Bandwidth } \Delta f = f_2 - f_1$$

For a series LCR resonant circuit,

$$\Delta f = \frac{1}{2\pi} \frac{R}{L}$$

Quality Factor (Q)

$$Q = 2\pi \times \frac{\text{Maximum energy stored}}{\text{Energy dissipated per cycle}}$$

$$= \frac{2\pi}{T} \times \frac{\text{Maximum energy stored}}{\text{Mean power dissipated}}$$

$$\text{Or } Q = \frac{\omega_r L}{R} = \frac{1}{\omega_r C R} = \frac{f_r}{(f_2 - f_1)} = \frac{f_r}{\Delta f}$$

Ch: Electromagnetic Waves

Class XII Physics

Chapter Notes

Top Concepts

1. Displacement current is due to time-varying electric field and is given by

$$i_d = \epsilon_0 \frac{d\phi_E}{dt}$$

Displacement current acts as a source of magnetic field in exactly the same way as conduction current.

2. Electromagnetic waves are produced only by charges that are accelerating, since acceleration is absolute, and not a relative phenomenon. An electric charge oscillating harmonically with frequency ν , produces electromagnetic waves of the same frequency ν . An electric dipole is a basic source of electromagnetic waves.

3. Electromagnetic waves with wavelength of the order of a few metres were first produced and detected in the laboratory by Hertz in 1887. He thus verified a basic prediction of Maxwell's equations.

4. Electric and magnetic fields oscillate sinusoidally in space and time in an electromagnetic wave. The oscillating electric and magnetic fields, **E** and **B** are perpendicular to each other, and to the direction of propagation of the electromagnetic wave.

5. For a wave of frequency ν , wavelength λ , propagating along z-direction, we have

$$\begin{aligned} E &= E_x(t) = E_0 \sin(kz - \omega t) \\ &= E_0 \sin\left[2\pi\left(\frac{z}{\lambda} - \nu t\right)\right] = E_0 \sin\left[2\pi\left(\frac{z}{\lambda} - \frac{t}{T}\right)\right] \end{aligned}$$

$$\begin{aligned} B &= B_y(t) = B_0 \sin(kz - \omega t) \\ &= B_0 \sin\left[2\pi\left(\frac{z}{\lambda} - \nu t\right)\right] = B_0 \sin\left[2\pi\left(\frac{z}{\lambda} - \frac{t}{T}\right)\right] \end{aligned}$$

They are related by $E_0/B_0 = c$

6. The speed c of electromagnetic wave in vacuum is related to μ_0 and ϵ_0 (the free space permeability and permittivity constants) as follows:

$$c = 1/\sqrt{\mu_0 \epsilon_0}$$

The value of c equals the speed of light obtained from optical measurements. Light is an electromagnetic wave; c is, therefore, also the speed of light. Electromagnetic waves other than light also have the same velocity c in free space.

The speed of light, or of electromagnetic waves in a material medium is given by $v = 1/\sqrt{\mu\epsilon}$

where μ is the permeability of the medium and ϵ its permittivity.

7. Electromagnetic waves carry energy as they travel through space and this energy is shared equally by the electric and magnetic fields.

8. If in a region of space in which there exist electric and magnetic fields \vec{E} and \vec{B} , there exists Energy Density (Energy per unit volume) associated with these fields given by

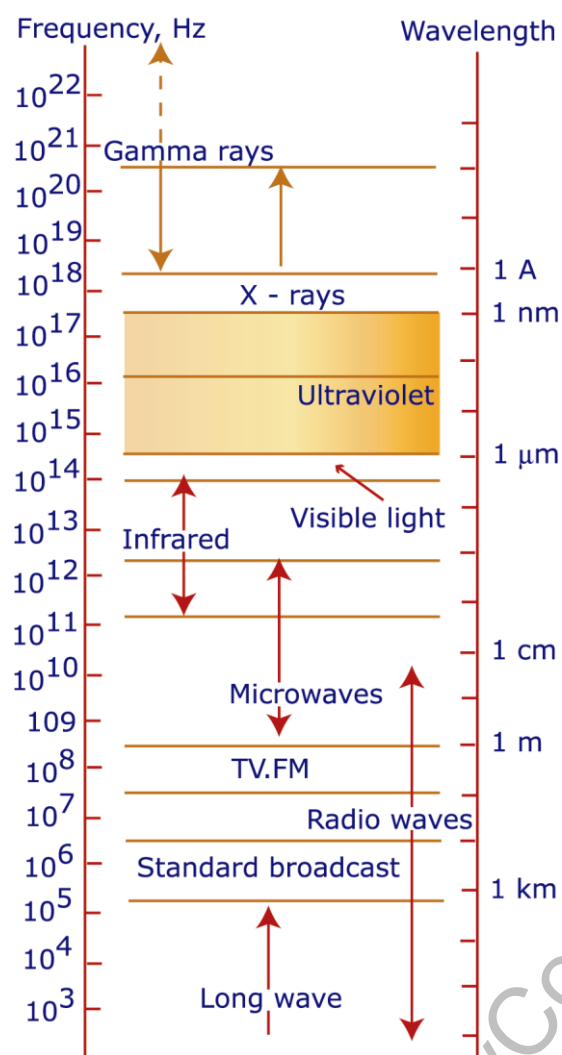
$$U = \frac{\epsilon_0}{2} \vec{E}^2 + \frac{1}{2\mu_0} \vec{B}^2 \quad (0.1)$$

where we are assuming that the concerned space consists of vacuum only.

9. Electromagnetic waves transport momentum as well. When these waves strike a surface, a pressure is exerted on the surface. If total energy transferred to a surface in time t is U , total momentum delivered to this surface is $p = U/c$.

10. The spectrum of electromagnetic waves stretches, in principle, over an infinite range of wavelengths. The classification of electromagnetic waves according to frequency is the electromagnetic spectrum. There is no sharp division between one kind of wave and the next. The classification has more to do with the way these waves are produced and detected.

Different regions are known by different names; γ -rays, X-rays, ultraviolet rays, visible rays, infrared rays, microwaves and radio waves in order of increasing wavelength from 10^{-2} \AA or 10^{-12} m to 10^6 m .



11.

- (a) Radio Waves: Produced by accelerated motion of charges in wires. They are used in radio and television communication systems. They are generally in the frequency range from 500 kHz to about 1000 MHz.
- (b) Microwaves: These are short wavelength radio waves with frequencies in the gigahertz range. Due to their short wavelengths, they are suitable for radar systems used in aircraft navigation. Microwave ovens use them for cooking.
- (c) Infrared Waves: These are produced by hot bodies and molecules. They lie in the low frequency or long wavelength end of the visible spectrum.
- (d) Visible Light: The spectrum runs from about 4×10^{14} Hz to about 7×10^{14} Hz. Our eyes are sensitive to this range of wavelengths.
- (e) Ultraviolet light: It covers wavelengths ranging from 400 nm to 0.6 nm. The sun is an important source of UV rays.
- (f) X-rays: These cover the range 10 nm to about 10^{-4} nm.
- (g) Gamma Rays: These lie in the upper frequency range of the spectrum, and have wavelengths in the range $10^{-10} - 10^{-14}$ m.

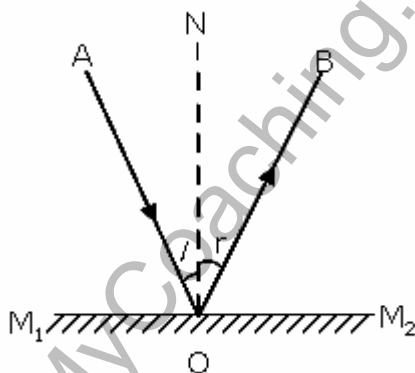
Chapter – 9 XII Physics

Ray optics and Optical Instruments Chapter Notes

Key Concepts

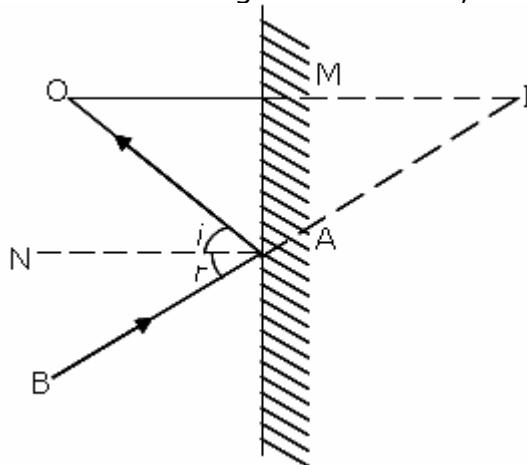
1. Laws of Reflection. The reflection at a plane surface always takes place in accordance with the following two laws:

- (i) The incident ray, the reflected ray and normal to surface at the point of incidence all lie in the same plane.
- (ii) The angle of incidence, i is equal to the angle of reflection r , i. e.,
 $\angle i = \angle r$.



2. Formation of Image by the Plane Mirror. The formation of image of a point object O by a plane mirror is represented in figure. The image formed I has the following characteristics:

- (i) The size of image is equal to the size of object.
- (ii) The object distance = Image distance i.e., $OM = MI$.



- (iii) The image is virtual and erect.
- (iv) When a mirror is rotated through a certain angle, the reflected ray is rotated through twice this angle.

3. Reflection of Light from Spherical Mirror.

A spherical mirror is a part cut from a hollow sphere. They are generally constructed from glass.

The reflection at spherical mirror also takes place in accordance with the laws of reflection.

4. Sign Convention. Following sign conventions are the new cartesian sign convention:

- (i) All distances are measured from the pole of the mirror & direction of the incident light is taken as positive. In other words, the distances measured toward the right of the origin are positive.
- (ii) The distance measured against the direction of the incident light are taken as negative. In other words, the distances measured towards the left of origin are taken as negative.
- (iv) The distance measured in the upward direction, perpendicular to the principal axis of the mirror, are taken as positive & the distances measured in the downward direction are taken as negative.

Note. The focal length of a concave mirror is positive and that of a convex mirror is positive and that of a convex mirror is negative.

5. Focal Length of a Spherical Mirror.

The distance between the focus and the pole of the mirror is called focal length of the mirror and is represented by f .

The focal length of a mirror (concave or convex) is equal to half of the radius of curvature of the mirror, i.e., $f = R / 2$.

The straight line joining the pole and the centre of curvature of spherical mirror extended on both sides is called principal axis of the mirror.

6. Mirror Formula is

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

Where u = distance of the object from the pole of mirror

v = distance of the image from the pole of mirror

f = focal length of the mirror

$$f = \frac{r}{2}, \text{ where } r \text{ is the radius of curvature of the mirror.}$$

7. Magnification. It is defined as the ratio of the size of the image to that of the object

$$\text{Linear magnification } m = \frac{I}{O} = -\frac{v}{u} = \frac{f-v}{f} = \frac{f}{f-u}$$

Where I size of image and O = size of object.

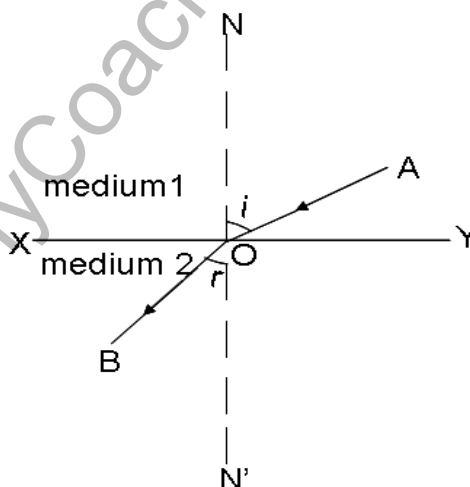
Magnification, m is positive, implies that the image is real and inverted
Magnification, m is negative, implies that the image is virtual and erect.

8. Refraction. When a ray of light falls on the boundary separating the two media, there is a change in direction of ray. This phenomenon is called refraction.

9. Laws of Refraction. (i) The incident ray normal at the point of incidence and refracted ray all lie in one plane.

(ii) For the same pair of media and the same colour of light, the ratio of the sine of the angle of incidence to the sine of the angle of refraction

is constant i.e., $\frac{\sin i}{\sin r} = {}_a\mu_b$



Where ${}_a\mu_b$ is a constant known as **Refractive Index** of the medium b with respect to the medium a ;

i is the angle incidence in medium a and
 r is the angle of refraction in medium b .

10. Principle of Reversibility of Light. As light follows a reversible path,

we have $\frac{\sin r}{\sin i} = {}_b\mu_a$

Multiplying (i) and (ii), we get

$${}_a\mu_b \times {}_b\mu_a = \frac{\sin i}{\sin r} \times \frac{\sin r}{\sin i} = 1$$

$${}_a\mu_b = \frac{1}{{}_b\mu_a}$$

Refractive index of a medium can also be determined from the following:

(i) $\mu = \frac{\text{Velocity of light in air}}{\text{Velocity of light in the medium}}$

(ii) $\mu = \frac{1}{\sin c}$

Where c is the critical angle.

The Critical angle is the angle of incidence in a denser medium corresponding to which the refracted ray just grazes the surface of separation.

11 Apparent Depth of a Liquid. If the object be placed at the bottom of a transparent medium, say water, and viewed from above, it will appear higher than it actually is.

The refractive index μ in this case is given by the relation :

Refractive index of the medium, $\mu = \text{Real depth} / \text{Apparent depth}$

12 Refraction through a Single Surface. If μ_1, μ_2 are refractive indices of first and second media, R the radius of curvature of spherical surface, formula is

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{(\mu_2 - \mu_1)}{R}$$

where u and v are the distances of the object and the image from the centre of the refracting surface of radius of curvature R respectively.

13. Refraction through a Thin Lens. It R_1 and R_2 are radii of curvature of first and second refracting surfaces of a thin lens of focal length f, then lens-makers formula is

$$\frac{1}{f} = \left(\frac{\mu_2 - \mu_1}{\mu_1} \right) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

If the lens is surrounded by air, $\mu_1 = 1$ and $\mu_2 = \mu$ then

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

Thin lens formula is

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

14. Magnification Produced by a Lens

$$m = \frac{I}{O} = \frac{v}{u}$$

Where I is size of image and O is size of object.

15. Power of a Lens. The power of a lens P is its ability to deviate the ray towards axis and is given by

$$P = \frac{1}{f(\text{in metres})} \text{ Diopters}$$

$$= \frac{100}{f(\text{in cm})} \text{ Diopters}$$

The focal length (f) of thin lenses of focal lengths f_1, f_2, f_3, \dots placed in contact of each other is given by

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + \dots$$

16. Refraction Through Prism. When a ray of monochromatic light is refracted by a prism, the deviation δ produced by the prism is given by

$$\delta = i + e - A$$

Where
 i = angle of incidence
 e = angle of emergence
 A = angle of the prism

The angle of deviation δ_m is minimum, when ray passes symmetrically through the prism. The refractive index μ of the prism is

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

17. Dispersion. The splitting of white light into constituent colours is called the dispersion.

A prism causes deviation as well as dispersion.

18 Optical Instruments, Optical instruments are the devices which help human eye in observing highly magnified images of tiny objects, for detailed examination and in observing very far objects whether terrestrial or astronomical.

19. Human Eye, It is the most familiar and complicated optical instrument provided by nature to living beings. In this device, light enters through a curved front surface, called cornea, passes through the pupil – central hole in the iris. The light is focused by the eye lens on the retina. The retina senses light intensity and colour and transmits the electrical signals via optical nerves to the brain. Brain finally processes the information.

20. Microscope, A simple microscope is a short focal length convex lens. The magnifying power of a simple microscope is

$$M = 1 + \frac{D}{f}$$

The magnifying power, M of a compound microscope is

$$M = M_o \times M_e = \frac{v}{u} \left(1 + \frac{D}{f_e} \right)$$

Where, M_o and M_e denote the linear magnifying of the objective and eye lens.

21. Telescope, (a) The magnifying power, M of refracting telescope is

$$M = \frac{f_o}{f_e}$$

and $L = (f_o - f_e)$; L = length of the telescope.

(b) For the final image is formed at the least distance of distant vision, the magnifying power is given as

$$M = \frac{f_o}{f_e} \left(1 + \frac{F_e}{D} \right)$$

(c) The resolving power of a telescope

$$\theta = \frac{1.22\lambda}{d}$$

where, λ = wavelength of light
 d = diameter of the objective of the telescope

θ = angle subtended by the point object at the objective

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Class XII
Physics
Ch: Wave Optics

Chapter Notes

Top Concepts

1. **A wave front** is the locus of points having the same phase of oscillation. Rays are the lines perpendicular to the wavefront, which show the direction of propagation of energy. The time taken for light to travel from one wavefront to another is the same along any ray.

2. **Huygens' Principle.**

According to Huygens'

- (a) Each point on the given wave front (called primary wave front) acts as a fresh source of new disturbance, called secondary wavelet, which travels in all directions with the velocity of light in the medium
 - (b) A surface touching these secondary wavelets, tangentially in the forward direction at any instant gives the new wavefront at that instant. This is called secondary wave front,
3. Huygens' Construction is based on the principle that every point of a wavefront is a source of secondary wavefront. The envelope of these wavefronts i.e., the surface tangent to all the secondary wavefront gives the new wavefront.

4. **Refraction and Reflection of Plane Waves Using Huygens' Principle.**

The law of reflection ($i = r$) and the Snell's law of refraction

$$\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \frac{\mu_2}{\mu_1} = \mu_{21}$$

can be derived using the wave theory. (Here v_1 and v_2 are the speed of light in media 1 and 2 with refractive index μ_1 and μ_2 respectively).

The frequency ν remains the same as light travels from one medium to another. The speed v of a wave is given by

$$v = \frac{\lambda}{T}$$

where λ is the wavelength of the wave and $T (=1/\nu)$ is the period of oscillation.

5. **Doppler effect** is the shift in frequency of light when there is a relative motion between the source and the observer. The effect can be used to measure the speed of an approaching or receding object.

for the source moving away from the observer, $\nu < \nu_0$ and for the source moving towards the observer, $\nu > \nu_0$. The change in frequency is given as

$$\Delta \nu = \nu - \nu_0 \approx -\frac{v}{c} \nu_0$$

where we are using the approximation $v \ll c$.

So, finally,

$$\frac{\Delta \nu}{\nu_0} = -\frac{v}{c}$$

- 6. Coherent and Incoherent Addition of Waves.** Two sources are coherent if they have the same frequency and a stable phase difference. In this case, the total intensity I is not just the sum of individual intensities I_1 and I_2 due to the two sources but includes an interference term:

$$I = I_1 + I_2 + 2k \cdot E_1 \cdot E_2$$

where \mathbf{E}_1 and \mathbf{E}_2 are the electric fields at a point due to the sources.

The interference term averaged over many cycles is zero if

- (a) the sources have different frequencies; or
- (b) the sources have the same frequency but no stable phase difference.

For such coherent sources, $I = I_1 + I_2$.

According to the superposition principle when two or more wave motions traveling through a medium superimpose one another, a new wave is formed in which resultant displacements due to the individual waves at that instant.

The average of the *total* intensity will be

$$\bar{I} = \bar{I}_1 + \bar{I}_2 + 2\sqrt{\bar{I}_1 \bar{I}_2} \cos \Phi$$

where ϕ is the inherent phase difference between the two superimposing waves.

The significance is that the intensity due to two sources of light *is not equal* to the sum of intensities due to each of them. The resultant intensity depends on the relative location of the point from the two sources, since changing it changes the path difference as we go from one point to another. As a result, the resulting intensity will vary between maximum and minimum values, determined by the maximum and minimum values of the cosine function. These will be

$$\bar{I}_{\text{MAX}} = \bar{I}_1 + \bar{I}_2 + 2\sqrt{\bar{I}_1 \bar{I}_2} = (\sqrt{\bar{I}_1} + \sqrt{\bar{I}_2})^2$$

$$\bar{I}_{\text{MIN}} = \bar{I}_1 + \bar{I}_2 - 2\sqrt{\bar{I}_1 \bar{I}_2} = (\sqrt{\bar{I}_1} - \sqrt{\bar{I}_2})^2$$

- 7. Young's experiment,** two parallel and very close slits S_1 and S_2 (illuminated by another narrow slit) behave like two coherent sources and produce on a screen a pattern of dark and bright bands – interference fringes. For a point P on the screen, the path difference

$$S_2P - S_1P = \frac{y_1 d}{D_1}$$

where d is the separation between two slits, D_1 is the distance between the slits and the screen and y_1 is the distance of the point of P from the central fringe.

For constructive interference (bright band), the path difference must be an integer multiple of λ , i.e.,

$$\frac{y_1 d}{D_1} = n\lambda \text{ or } y_1 = n \frac{D_1 \lambda}{d}$$

The separation Δy_1 between adjacent bright (or dark) fringes is.

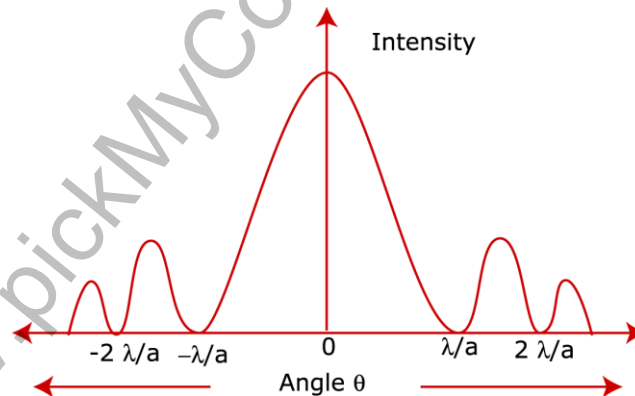
$$\Delta y_1 = \frac{D_1 \lambda}{d}$$

using which λ can be measured.

- 8. Diffraction** refers to light spreading out from narrow holes and slits, and bending around corners and obstacles. The single-slit diffraction pattern shows the central maximum (at $\theta = 0$), zero intensity at angular separation $\theta = \pm (n + \frac{1}{2})\lambda$... ($n \neq 0$).

Different parts of the wavefront at the slit act as secondary sources: diffraction pattern is the result of interference of waves from these sources.

The intensity plot looks as follows, with there being a bright central maximum, followed by smaller intensity *secondary maxima*, with there being points of zero intensity in between, whenever $d \sin \theta = n\lambda$, $n \neq 0$



- 9. Emission, absorption and scattering** are three processes by which matter interacts with radiation.

In emission, an accelerated charge radiates and loses energy.

In absorption, the charge gains energy at the expense of the electromagnetic wave.

In scattering, the charge accelerated by incident electromagnetic wave radiates in all direction.

- 10. Polarization** specifies the manner in which electric field E oscillates in the plane transverse to the direction of propagation of light. If E oscillates back and forth in a straight line, the wave is said to be

linearly polarized. If the direction of E changes irregularly the wave is unpolarized.

When light passes through a single polaroid P_1 light intensity is reduced to half, independent of the orientation of P_1 . When a second Polaroid P_2 is also included, at one specific orientation wrt P_1 , the net transmitted intensity is reduced to zero but is transmitted fully when P_1 is turned 90° from that orientation. This happens because the transmitted polarization by a polaroid is the component of E parallel to its axis.

Unpolarized sunlight scattered by the atmosphere or reflected from a medium gets (partially) polarized.

Linearly Polarized light passing through some substances like sugar solution undergoes a rotation of its direction of polarization, proportional to the length of the medium traversed and the concentration to the substance. This effect is known as optical activity.

- 11.** Brewster's Law: When an incident light is incident at the polarizing angle, the reflected & the refracted rays are perpendicular to each other. The polarizing angle, also called as Brewster's angle, is given by $\tan \theta_p = \mu$ this expression is also called Brewster's law.
- 12.** Polarization by scattering: Light is scattered when it meets a particle of similar size to its own wavelength. For e.g. scattering of sunlight by dust particles. Rayleigh showed that the scattering of light is proportional to the fourth power of the frequency of the light or varies as $\frac{1}{\lambda^4}$ where λ is the wavelength of light incident on the air molecules of size d where $d \ll \lambda$. Hence blue light is scattered more than red. This explains the blue colour of the sky.

TOP Formulae

1. Snell's law of refraction:

$${}_1\mu_2 = \frac{c_1}{c_2} = \frac{\text{speed of light in first medium}}{\text{speed of light in second medium}}$$

2. Relation between phase difference & path difference:

$$\Delta\phi = \frac{2\pi}{\lambda} \cdot \Delta x$$

where $\Delta\phi$ is the phase difference & Δx is the path difference

3. Young's double slit interference experiment:

$$\text{Fringe width: } w = \frac{D\lambda}{d}$$

where D is the distance between the slits & the screen
 d is the distance between the two slits

Constructive interference:

Phase difference : $\Delta\phi = 2\pi n$ where n is an integer

Path difference: $\Delta x = n\lambda$, where n is an integer

Destructive interference:

Phase difference : $\Delta\phi = \left(n + \frac{1}{2}\right)2\pi$ where n is an integer

Path difference: $\Delta x = \left(n + \frac{1}{2}\right)\lambda$, where n is an integer

4. Diffraction due to single slit:

Angular spread of the central maxima = $\frac{2\lambda}{d}$

Width of the central maxima: $\frac{2\lambda D}{d}$

where D is the distance of the slit from the screen
 d is the slit width

Condition for the minima on the either side of the central maxima:
 $d \sin\theta = n\lambda$, where $n = 1, 2, 3, \dots$

5. Intensity of the light due to polarization:

$$I = I_0 \cos^2\theta$$

where I is the intensity of light after polarization

I_0 is the original intensity

θ is the angle between the axis of the analyzer & the polarizer

Brewster's Law:

$\mu = \tan\theta_p$ where θ_p is the polarizing angle, that is, the angle of incidence at which the angle of refraction in the second medium is right angle

Class XII

Physics

Ch : Dual Nature of Radiation and Matter

- 1 **Electric Discharge:** The passage of an electric current through a gas is called electric discharge.
- 2 **Discharge Tube:** A hard glass tube along with the necessary arrangement, which is used to study the passage of electric discharge through gases at low pressure, is called a discharge tube.
- 3 **Cathode Rays.** Cathode rays are the stream of negatively charged particles, electrons which are shot out at a high speed from the cathode of a discharge tube at pressure below 0.01 mm of Hg.
- 4 **Work Function.** The minimum amount of energy required by an electron to just escape from the metal surface is known as work function of the metal.
- 5 **Electron Emission.** The minimum amount of energy required by an electron to just escape from the metal surface is known as work function of the metal.
 - (i) **Thermionic emission.** Here electrons are emitted from the metal surface with the help of thermal energy.
 - (ii) **Field or cold cathode emission.** Electrons are emitted from a metal surface by subjecting it to a very high electric field.
 - (iii) **Photoelectric emission.** Electrons emitted from a metal surface with the help of suitable electromagnetic radiations.
 - (iv) **Secondary emission.** Electrons are ejected from a metal surface by striking over its fast moving electrons.
- 6 **Forces Experienced by an Electron in Electric and Magnetic Fields.**
 - (a) **Electric field:** The force F_E experienced by a electron e in an electric field of strength (intensity) E is given by

$$F_E = eE$$
 - (b) **Magnetic field:** The force experienced by an electron e in a magnetic field of strength B weber/m² is given by

$$F_B = Bev$$

where v is the velocity with which the electron moves in the electric field and the magnetic field, perpendicular to the direction of motion.

If the magnetic field is parallel to the direction of motion of electron, then, $F_B = 0$.
- 7 **Photoelectric Effect:** The phenomenon of emission of electrons from the surface of substances (mainly metals), when exposed to electromagnetic radiations of suitable frequency, is called photoelectric effect and the emitted electrons are called photoelectrons.

8 **Cut Off or Stopping Potential:** The value of the retarding potential at which the photoelectric current becomes zero is called cut off or stopping potential for the given frequency of the incident radiation.

9 **Threshold Frequency:** The minimum value of the frequency of incident radiation below which the photoelectric emission stops altogether is called threshold frequency.

10 **Laws of Photoelectric Effect.**

(i) For a given metal and a radiation of fixed frequency, the number of photoelectrons emitted is proportional to the intensity of incident radiation.

(ii) For every metal, there is a certain minimum frequency below which no photoelectrons are emitted, howsoever high is the intensity of incident radiation. This frequency is called *threshold frequency*.

(iii) For the radiation of frequency higher than the threshold frequency, the maximum kinetic energy of the photoelectrons is directly proportional to the frequency of incident radiation and is independent of the intensity of incident radiation.

(iv) The photoelectric emission is an *instantaneous* process.

11 **Einstein's Theory of Photoelectric Effect.** Einstein explained photoelectric effect with the help of Planck's quantum theory. When a radiation of frequency ν is incident on a metal surface, it is absorbed in the form of discrete packets of energy called quanta or photons.

A part of energy $h\nu$ of the photon is used in removing the electrons from the metal surface and remaining energy is used in giving kinetic energy to the photoelectron.

Einstein's photoelectric equation is

$$KE = \frac{1}{2}mv^2 = h\nu - w_0$$

where w_0 is the work function of the metal.

If ν_0 is the threshold frequency, then $w_0 = h\nu_0$

$$KE = \frac{1}{2}mv^2 = h(\nu - \nu_0)$$

All the experimental observations can be explained on the basis Einstein's photoelectric equation.

12 **Compton Scattering.** It is the phenomenon of increase in the wavelength of X-ray photons which occurs when these radiations are scattered on striking an electron. The difference in the wavelength of scattered and incident photons is called Compton shift, which is given by

$$\Delta\lambda = \frac{h}{m_0c}(1 - \cos\phi)$$

where ϕ is the angle of scattering of the X-ray photon and m_0 is the rest mass of the electron.

13 **$\frac{e}{m}$ of an Electron by Thompson's Method.**

J. J. Thomson devised an experiment to determine the velocity (v) and the ratio of the charge (e) to the mass (m) i.e., $\frac{e}{m}$ of

cathode rays. In this method electric field \vec{E} and magnetic field \vec{B} are applied on the cathode rays.

In the region where they are applied perpendicular to each other and to the direction of motion of cathode rays,

Force due to electric field, F_E = Force due to magnetic field F_B ,

Or
$$eE = Bev \Rightarrow v = \frac{E}{B}$$

Also
$$\frac{e}{m} = \frac{E}{B^2 R} = \frac{V/d}{B^2 R} = \frac{Vx}{B^2 \ell Ld}$$

where

V = Potential difference between the two electrodes (i.e., P and Q)

d = distance between the two electrodes

R = radius of circular arc in the presence of magnetic field B

x = shift of the electron beam on the screen

ℓ = length of the field

L = distance between the centre of the field and the screen.

14 **Milliken's Oil Drop Method.** This determines the charge on the electron. Let ρ be the density of oil, σ is the density of the medium in which oil drop moves and η the coefficient of viscosity of the medium, then the radius r of the drop is

$$r = \sqrt{\frac{9}{2} \frac{\eta v_0}{(\rho - \sigma)g}}$$

where v_0 is the terminal velocity of the drop under the effect of gravity alone. At the terminal velocity v_0 , the force due to viscosity becomes equal to the electric weight of the body. The charge on oil drop is

$$q = \frac{18\pi\eta(v_1 + v_0)}{E} \sqrt{\frac{\eta v_0}{2(\rho - \sigma)g}}$$

where v_1 is the terminal velocity of the drop under the influence of electric field and gravity and E is the applied electric field.

15 **Photocell.** It is an arrangement which converts light energy into electric energy. It works on the principle of photoelectric effect. It is used in cinematography for the reproduction of sound.

16 **Dual Nature of Radiation:** Light has dual nature. It manifests itself as a wave in diffraction, interference, polarization, etc.,

while it shows particle nature in photoelectric effect, Compton scattering, etc.

- 17 **Dual Nature of Matter:** As there is complete equivalence between matter (mass) and radiation (energy) and the principle of symmetry is always obeyed, de Broglie suggested that moving particles like protons, neutrons, electrons, etc., should be associated with waves known as de Broglie waves and their wavelength is called de Broglie wavelength. The de Broglie wavelength of a particle of mass m moving with velocity v is given by

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

where h is Planck's constant.

- 18 **Davison and Germer Experiment.** This experiment confirms the existence of de Broglie waves associated with electrons.
- 19 **de Broglie Wavelength of an Electron.** The wavelength associated with an electron beam accelerated through a potential

$$\lambda = \frac{h}{\sqrt{2meV}} = \frac{12.3}{\sqrt{V}} \text{ \AA}$$

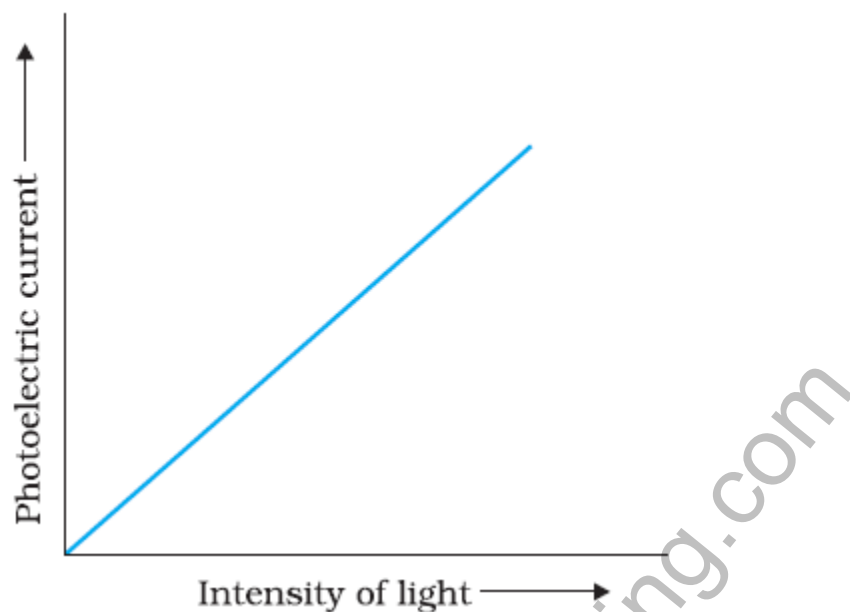
- 20 **Electron Microscope:** It is a device which makes use of accelerated electron beams to study very minute objects like viruses, microbes and the crystal structure of solids. It has a magnification of $\sim 10^5$.

TOP Formulae

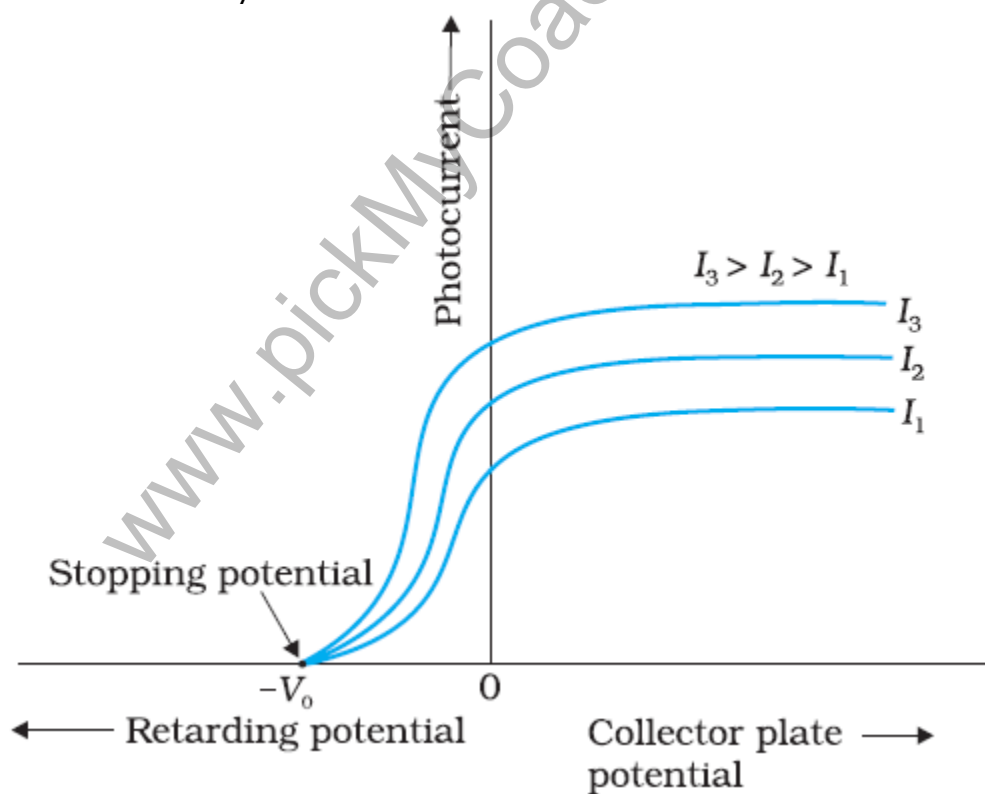
1. Maximum kinetic energy of the photoelectrons emitted from the metal surface: $K_{\max} = eV_o = h\nu - \phi_o$ (Einstein's Photoelectric equation)
2. Work function of a metal surface:
 $w_o = \phi_o = h\nu_o$
3. de Broglie wavelength associated with the particle of momentum p is given as: $\lambda = \frac{h}{p} = \frac{h}{mv}$
 $\lambda = \frac{1.227}{\sqrt{V}} \text{ nm}$, where V is the magnitude of accelerating potential
4. Heisenberg uncertainty principle:
 $\Delta x \cdot \Delta p \approx h/2\pi$, where Δx is uncertainty in position & Δp is uncertainty in momentum

TOP Diagrams & Graphs:

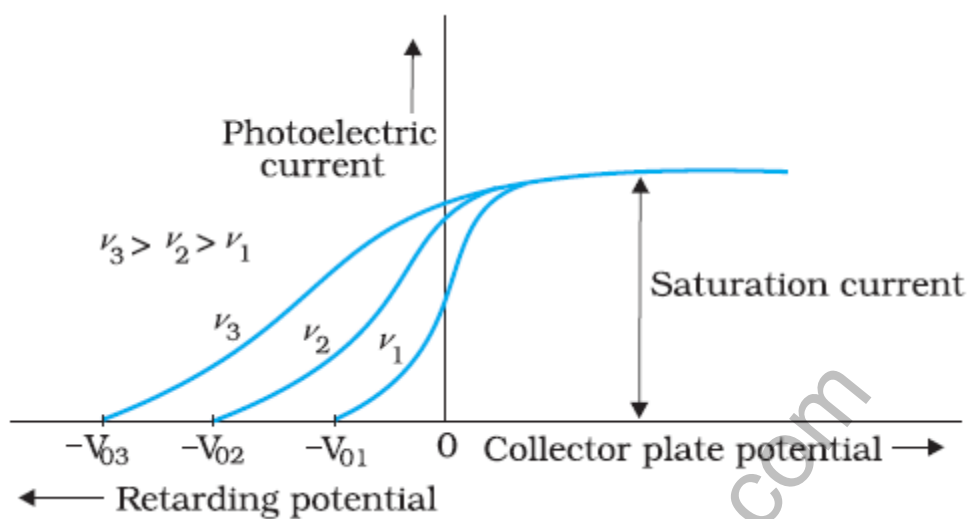
1. Variation of Photoelectron current with intensity of incident light:



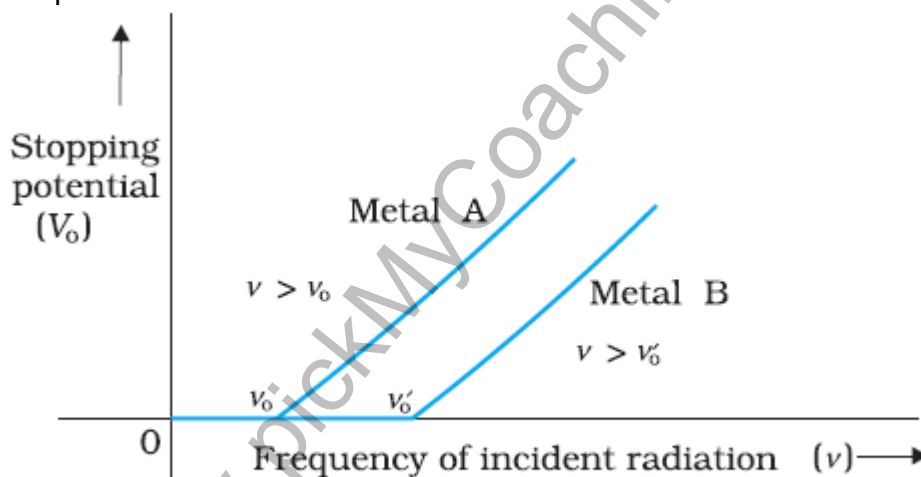
2. Variation of Photoelectron current with collector plate potential for different intensity of incident radiation



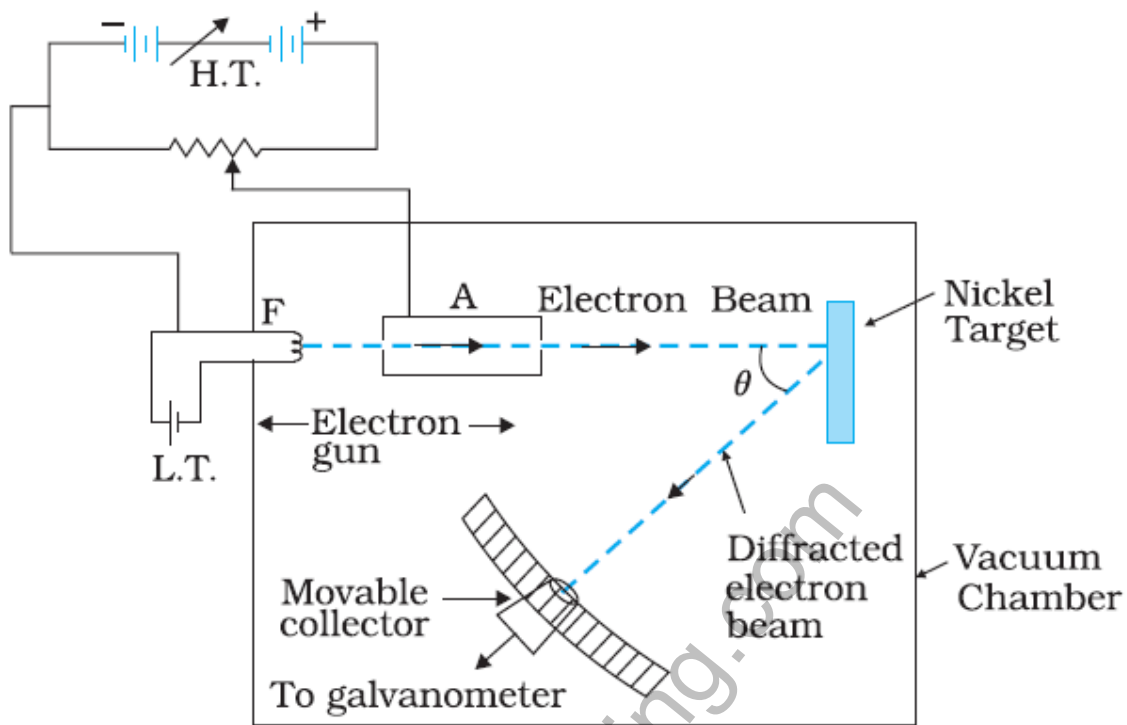
3. Variation of Photoelectron current with collector plate potential for different frequencies of incident radiation



4. Variation of stopping potential V_0 with frequency ν of incident radiation for a given photosensitive material



5. David-Germer electron diffraction arrangement



Class XII
Physics
Ch: Atoms
Chapter Notes

TOP Concepts

1. Thomson's Model of an Atom. An atom consists of positively charged matter in which the negatively charged electrons are uniformly embedded like plums in a pudding. This model could not explain scattering of α -particles through thin foils and hence discarded.

2. Rutherford's Model of an Atom: Geiger and Marsden in their experiment on scattering of α -particles found that most of the α -particles passed undeviated through thin foils but some of them were scattered through very large angles. From the results of these experiments, Rutherford proposed the following model of an atom:

- (i) An atom consists of a small and massive central core in which the entire positive charge and almost the whole mass of the atom are concentrated. This core is called the nucleus.
- (ii) The nucleus occupies a very small space as compared to the size of the atom.
- (iii) The atom is surrounded by a suitable number of electrons so that their total negative charge is equal to the total positive charge on the nucleus and the atom as a whole is electrically neutral.
- (iv) The electrons revolve around the nucleus in various orbits just as planets revolve around the sun. The centripetal force required for their revolution is provided by the electrostatic attraction between the electrons and the nucleus.

This model could not explain in stability of the atom because according to classical electromagnetic theory the electron revolving around the nucleus must continuously radiate energy revolving around the nucleus must continuously radiate energy in the form of electromagnetic radiate energy in the form of electromagnetic radiation and hence it should fall into the nucleus.

3. Distance of Closest Approach. When an α -particle of mass m and velocity v moves directly towards a nucleus of atomic number Z , its initial energy E_i which is just the kinetic energy K gets completely converted into potential energy U at stopping point. This stopping point happens to be at a distance of closest approach d from the nucleus.

$$E = \frac{1}{2}mv^2 = \frac{1}{4\pi\epsilon_0} \frac{2eZe}{d} = \frac{2Ze^2}{4\pi\epsilon_0 d} \quad d = \frac{2Ze^2}{4\pi\epsilon_0 K}$$

hence
$$d = \frac{2Ze^2}{4\pi\epsilon_0 K}$$

4. Impact Parameter. It is defined as the perpendicular distance of the velocity of the α -particle from the central of the nucleus, when it is far away from the atom. The shape of the trajectory of the scattered α -particle depends on the impact parameter b and the nature of the potential field. Rutherford deduced the following relationship between the impact parameter b and the scattering angle θ :

$$b = \frac{1}{4\pi\epsilon_0} \cdot \frac{Ze^2 \cot \frac{\theta}{2}}{E}$$

$$= \frac{1}{4\pi\epsilon_0} \cdot \frac{Ze^2 \cot \frac{\theta}{2}}{\frac{1}{2}mv^2}$$

5. Quantisation or Discretisation. The quantization or discretisation of a physical quantity means that it cannot vary continuously to have any arbitrary value but can change only discontinuously to take certain specific values.

6. Bohr's Model for the Hydrogen Atom.

Basic postulates:

(i) Nuclear concept. An atom consists of a small massive central called nucleus around which planetary electrons revolve. The centripetal force required for their rotation is provided by the electrostatic attraction between the electrons and the nucleus.

(ii) Quantum condition. Of all the possible circular orbits allowed by the classical theory, the electrons are permitted to circulate only in such orbits in which the angular momentum of an electron is an integral multiple of $h/2\pi$, h being Planck's constant.

$$L = mvr = \frac{nh}{2\pi}, n = 1, 2, 3, \dots$$

where n is called principal quantum number.

(iii) Stationary orbits. While revolving in the permissible orbits, an electron does not radiate energy. These non-radiating orbits are called stationary orbits.

(iv) Frequency condition. An atom can emit or absorb radiation in the form of discrete energy photons only, when an electron jumps from a higher to a lower orbit or from a lower to a higher orbit. If E_1 and E_2 are the energies associated with these permitted orbits then the frequency ν of the emitted absorbed radiation is given by

$$h\nu = E_2 - E_1$$

Radius of the orbit of an electron in hydrogen atom is

$$r = \frac{e^2}{4\pi\epsilon_0 mv^2}$$

Kinetic energy K & electrostatic potential energy U of the electron in hydrogen atom:

$$K = \frac{1}{2}mv^2 = \frac{e^2}{8\pi\epsilon_0 r}$$

$$U = -\frac{e^2}{4\pi\epsilon_0 r}$$

Total energy E of the electron in hydrogen atom:

$$E = K + U = -\frac{e^2}{8\pi\epsilon_0 r}$$

Speed of an electron in the nth orbit is given by

$$v = \frac{2\pi ke^2}{nh} = \alpha \cdot \frac{c}{n} = \frac{1}{137} \cdot \frac{c}{n}$$

where $\alpha = \frac{2\pi ke^2}{ch}$ is fine structure constant.

Energy of an electron in nth orbit is given by

$$E_n = \frac{2\pi^2 mk^2 Z^2 e^4}{n^2 h^2} = -\frac{13.6}{n^2} \text{ eV}$$

7. Failure of Bohr's Model: This model is applicable only to hydrogen-like atoms and fails in case of higher atoms. It could not explain the fine structure of the spectral lines in the spectrum of hydrogen atom.

8. Energy Level Diagram. It is a diagram in which the energies of the different stationary states of an atom are represented by parallel horizontal lines, drawn according to some suitable energy scale.

9. Spectral Series of Hydrogen Atom. Whenever an electron in hydrogen atom makes a transition from a higher energy level n_2 to a lower energy level n_1 , the difference of energy appears in the form of a photon of frequency ν given by

$$\nu = \frac{2\pi^2 mk^2 e^2}{h^2} \left[\frac{1}{n_1^2} - \frac{1}{n_2^2} \right]$$

Different spectral series of hydrogen atom are as follows:

- (i) Lyman Series. Here $n_2 = 2, 3, 4, \dots$ and $n_1 = 1$. This series lies in the ultraviolet region.
- (ii) Balmer Series. Here $n_2 = 3, 4, 5, \dots$ and $n_1 = 2$. This series lies in the visible region.
- (iii) Paschen Series. Here $n_2 = 4, 5, 6, \dots$ and $n_1 = 3$. This series lies in the infrared region.
- (iv) Brackett Series. Here $n_2 = 5, 6, 7, \dots$ and $n_1 = 4$. This series lies in the infrared region.
- (v) Pfund Series. Here $n_2 = 6, 7, 8, \dots$ and $n_1 = 5$. This series lies in the infrared region.

10. Excitation Energy. It is defined as the energy required by an electron of an atom to jump from its ground state to any one of its existed state.

11. Ionisation Energy. It is defined as the energy required to remove an electron from an atom, i.e., the energy required to take an electron from its ground state to the outermost orbit ($n = \infty$)

12. Excitation Potential. It is that accelerating potential which gives sufficient energy to a bombarding electron so to excite the target atom by raising one of its electrons from an inner to an outer orbit.

13. Ionisation potential. It is that accelerating potential which gives to a bombarding electron sufficient energy to an outer orbit.

14. de Broglie's hypothesis that electrons have a wavelength $\lambda = h/mv$ gave an explanation for Bohr's quantised orbits by bringing in the wave particle duality. The orbits correspond to circular standing waves in which the circumference of the orbit equals a whole number of wavelengths.

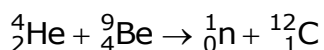
14. MASER. Maser stands for 'Microwaves Amplification by Stimulated Emission of Radiation'. It is simply a device for producing a highly intense, monochromatic coherent and collimated beam of microwaves.

15. LASER. It stands for 'Light Amplification by Stimulated Emission of Radiation'. It is a device used to produce highly intense strong monochromatic coherent and collimated beam of light.

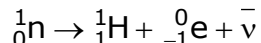
Class XII: Physics
Chapter : Nuclei

TOP Concepts

- 1 **Atomic Number.** The number of protons in the nucleus is called the atomic number. It is denoted by Z .
- 2 **Mass number.** The total number of protons and neutrons present in a nucleus is called the mass number of the element. It is denoted by A .
 Number of protons in an atom = Z
 Number of electrons in an atom = Z
 Number of nucleons in an atom = A
 Number of neutrons in an atom = $N = A - Z$.
- 3 **Nuclear Mass.** The total mass of the protons and neutrons present in a nucleus is called the nuclear mass.
- 4 **Nuclide.** A nuclide is a specific nucleus of an atom characterized by its atomic number Z and mass number A . It is represented as ${}_Z^AX$
 where X = chemical symbol of the element.
 Z = atomic number, and
 A = mass number.
- 5 **Isotopes.** The atoms of an element which have the same atomic number but different mass number are called isotopes. Isotopes have similar chemical properties but different physical properties.
- 6 **Isobars.** The atoms having the same mass number but different atomic number are called isobars.
- 7 **Isotones.** The nuclides having the same number of neutrons are called isotones.
- 8 **Isomers.** These are nuclei with same atomic number and same mass number but in different energy states.
- 9 **Electron Volt:** It is defined as the energy acquired by an electron when it is accelerated through a potential difference of 1 volt and is denoted by eV.
 $1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$
 $1 \text{ MeV} = 10^6 \text{ eV} = 1.602 \times 10^{-13} \text{ J}$
- 10 **Atomic Mass Unit:.** It is $\frac{1}{12}$ th of the actual mass of a carbon atom of isotope ${}_6\text{C}^{12}$. It is denoted by amu or just by u.
 $1 \text{ amu} = 1.660565 \times 10^{-27} \text{ kg}$
 The energy equivalence of 1 amu is
 $1 \text{ amu} = 931 \text{ MeV}$
- 11 **Discovery of Neutrons.** Neutrons were discovered by Chadwick in 1932. When beryllium nuclei are bombarded by α -particles, highly penetrating radiations are emitted, which consists of neutral particles, each having mass nearly that of a proton. These particles were called neutrons.



A free neutron decays spontaneously, with a half life of about 900 s, into a proton, electron and an antineutrino.



- 12 **Size of the Nucleus.** It is found that a nucleus of mass number A has a radius

$$R = R_0 A^{1/3}$$

where $R_0 = 1.2 \times 10^{-15} \text{ m}$.

This implies that the volume of the nucleus, which is proportional to R^3 is proportional A.

Density of nucleus is constant; independent of A, for all nuclei and density of nuclear matter is approximately $2.3 \times 10^{17} \text{ kg m}^{-3}$ which is very large as compared to ordinary matter, say water which is 10^3 kg m^{-3} .

- 13 **Mass-Energy equivalence:** Einstein proved that it is necessary to treat mass as another form of energy. He gave the mass-energy equivalence relation as

$$E = mc^2$$

where m is the mass and c is the velocity of light in vacuum.

- 14 **Mass Defect.** The difference between the rest mass of a nucleus and the sum of the rest masses of its constituent nucleons is called its mass defect. It is given by

$$\Delta m = [Zm_p + (A - Z)m_n] - m$$

- 15 **Binding Energy.** It may be defined as the energy required to break up a nucleus into its constituent protons and neutrons and to separate them to such a large distance that they may not interact with each other.

It may also be defined as the surplus energy which the nucleus gives up by virtue of their attractions which they become bound together to form a nucleus.

The binding energy of a nucleus ${}_Z^AX^A$ is given by

$$\text{B.E.} = [Zm_p + (A - Z)m_n - m]c^2$$

- 16 **Binding Energy per Nucleon.** It is average energy required to extract one nucleon from the nucleus. It is obtained by dividing the binding energy of a nucleus by its mass number.

$$\bar{B} = \frac{\text{B.E.}}{A} = \frac{[Zm_p + (A - Z)m_n - m]c^2}{A}$$

- 17 **Nuclear Forces.** These are the strong in attractive forces which hold protons and neutrons together in a tiny nucleus. These are short range forces which operate over very short distance of about 2 – 3 fm of separation between any two nucleons. The nuclear force does not depend on the charge of the nucleon.

- 18 **Nuclear Density.** The density of a nucleus is independent of the size of the nucleus and is given by

$$\rho_v = \frac{\text{Nuclear mass}}{\text{Nuclear volume}}$$

$$= \frac{m_v}{\frac{4}{3}\pi R^2} = 2.9 \times 10^{17} \text{ kg m}^{-3}.$$

19 **Radioactivity.** It is the phenomenon of spontaneous disintegration of the nucleus of an atom with the emission of one or more radiations like α -particles, β -particles or γ -rays. The substances which spontaneously emit penetrating radiation are called radioactive substances.

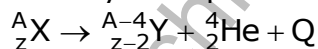
20 **Radioactivity Displacement Law.** It states that

(i) When a radioactive nucleus emits an α -particle, atomic number decreases by 2 and mass number decreases by 4.

(ii) When a radioactive nucleus emits β -particle, its atomic number increases by 1 but mass number remains same.

(iii) The emission of a γ -particle does not change the mass number or the atomic number of the radioactive nucleus. γ -particle emission by a radioactive nucleus lowers its energy state.

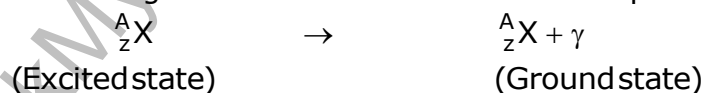
21 **Alpha Decay.** It is the process of emission of an α -particle from a radioactive nucleus. It may be represented as



22 **Beta Decay.** It is the process of emission of an electron from a radioactive nucleus. It may be represented as



23 **Gamma Decay.** It is the process of emission of a γ -ray photon during the radioactive disintegration of a nucleus. It can be represented as



24 **Radioactive Decay Law.** It states that the number of nuclei disintegrated of undecayed radioactive nuclei present at that instant. It may be written as

$$N(t) = N(0)e^{-\lambda t}$$

where $N(0)$ is the number of nuclei at $t = 0$ and λ is disintegration constant.

25 **Decay or disintegration Constant.** It may be defined as the reciprocal or the time interval in which the number of active nuclei in a given radioactive sample reduces to 36.8% $\left(\text{or } \frac{1}{e} \text{ times}\right)$ of its initial value.

26 **Half-life.** The half-life of a radioactive substance is the time in which one-half of its nuclei will disintegrate. It is inversely proportional to the decay constant of the radioactive substance.

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

- 27 **Mean Life.** The mean-life of a radioactive sample is defined as the ratio of the combined age of all the atoms and the total number of atoms in the given sample. It is given by

$$\tau = \frac{T_{1/2}}{0.693} = 1.44T_{1/2}$$

- 28 **Rate of Decay or Activity of a Radioactive Sample.** It is defined as the number of radioactive disintegrations taking place per second in a given sample. It is expressed as

$$R(t) = \left[\frac{dN}{dt} \right] = \lambda N(t) = \lambda N(0)e^{-\lambda t}$$

- 29 **Curie.** It is the SI unit of decay. One curie is the decay rate of 3.7×10^{10} disintegrations per second.

$$1 \text{ Ci (curie)} = 3.70 \times 10^{10} \text{ disintegrations/s}$$

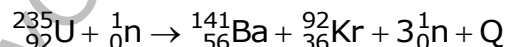
- 30 **Rutherford.** One rutherford is the decay rate of 10^6 disintegrations per second.

- 31 **Natural Radioactivity.** It is the phenomenon of the spontaneous emission of α -, β - or γ -radiations from the nuclei of naturally occurring isotopes.

- 32 **Artificial or Induced Radioactivity.** It is the phenomenon of inducing radioactivity in certain stable nuclei by bombarding them by suitable high energy sub atomic particles.

- 33 **Nuclear Reaction.** It is a reaction which involves the change of stable nuclei of one element into the nucleus of another element.

- 34 **Nuclear Fission.** It is the process in which a heavy nucleus when excited gets split into two smaller nuclei of nearly comparable masses. For example,



- 35 **Nuclear Reactor.** It is a device in which a nuclear chain reaction is initiated, maintained and controlled.

- 36 **Nuclear Fusion.** It is the process of fusion of two smaller nuclei into a heavier nucleus with the liberation of large amount of energy.

- 37 **Critical size and Critical Mass.** The size of the fissionable material for which reproduction factor is unity is called critical size and its mass is called critical mass of the material. The chain reaction in this case remains steady or sustained.

- 38 **Moderator.** Any substance which is used to slow down fast moving neutrons to thermal energies is called a moderator. The commonly used moderators are water, heavy water (D_2O) and graphite.

Class XII: Physics
Chapter: Semiconductor Electronics: Materials, Devices and Simple Circuits

- 1 **Intrinsic Semiconductor:** The pure semiconductors in which the electrical conductivity is totally governed by the electrons excited from the valence band to the conduction band and in which no impurity atoms are added to increase their conductivity are called intrinsic semiconductors and their conductivity is called intrinsic conductivity. Electrical conduction in pure semiconductors occurs by means of electron-hole pairs. In an intrinsic semiconductor,

$$n_e = n_h = n_i$$

where

n_e = the free electron density in conduction band,

n_h = the hole density in valence band, and

n_i = the intrinsic carrier concentration.

- 2 **Extrinsic Semiconductors.** A Semiconductor doped with suitable impurity atoms so as to increase its conductivity is called an extrinsic semiconductor.

Extrinsic semiconductors are of two types:

(i) n-type semiconductors. And (ii) p-type semiconductors.

- 3 **n-type semiconductors.** The pentavalent impurity atoms are called donors because they donate electrons to the host crystal and the semiconductor doped with donors is called n-type semiconductor. In n-type semiconductors, electrons are the majority charge carriers and holes are the minority charge carriers. Thus

$$n_e \cong N_d \gg n_h$$

here N_d = Number density of donor atoms

- 4 **p-type semiconductors.** The trivalent impurity atoms are called acceptors because they create holes which can accept electrons from the nearby bonds. A semiconductor doped with acceptor type impurities is called a p-type semiconductor. In p-type semiconductor, holes are the majority carriers and electrons are the minority charge carriers Thus

$$N_a \cong n_h \gg n_e$$

here N_a = Number density of acceptor atoms

- 5 **Holes.** The vacancy or absence of electron in the bond of a covalently bonded crystal is called a hole. A hole serves as a positive charge carrier.

- 6 **Mobility.** The drift velocity acquired by a charge carrier in a unit electric field is called its electrical mobility and is denoted by μ .

$$\mu = \frac{V_d}{E}$$

The mobility of an electron in the conduction band is greater than that of the hole (or electron) in the valence band.

- 7 **Electrical conductivity of a Semiconductor.** If a potential difference V is applied across a conductor of length L and area of cross-section A , then the total current I through it is given by

$$I = eA (n_e v_e + n_h v_h)$$

where n_e and n_h are the electron and hole densities, and v_e and v_h are their drift velocities, respectively. If μ_e and μ_h are the electron and hole mobilities, then the conductivity of the semiconductor will be

$$\rho = e (n_e \mu_e + n_h \mu_h)$$

and the resistivity will be $\rho = \frac{1}{e(n_e \mu_e + n_h \mu_h)}$

The conductivity of an intrinsic semiconductor increases exponentially with temperature as

$$\sigma = \sigma_0 \exp\left(-\frac{E_g}{2k_B T}\right)$$

- 8 **Forward and Reverse Biasing of a pn-junction.** If the positive terminal of a battery is connected to the p-side and the negative terminal to the n-side, then the pn-junction is said to be forward biased. Both electrons and holes move towards the junction. A current, called forward current, flows across the junction. Thus a pn-junction offers a low resistance when it is forward biased.

If the positive terminal of a battery is connected to the n-side and negative terminal to the p-side, then pn-junction is said to be reverse biased. The majority charge carriers move away from the junction. The potential barrier offers high resistance during the reverse bias. However, due to the minority charge carriers a small current, called reverse or leakage current flows in the opposite direction.

Thus junction diode has almost a unidirectional flow of current.

- 9 **Action of a transistor.** When the emitter-base junction of an npn-transistor is forward biased, the electrons are pushed towards the base. As the base region is very thin and lightly doped, most of the electrons cross over to the reverse biased collector. Since few electrons and holes always recombine in the base region, so the collector current I_c is always slightly less than emitter current I_E .

$$I_E = I_C + I_B$$

where I_B is the base current.

- 10 **Three Configurations of a Transistor.** A transistor can be used in one of the following three configurations:

- (i) Common-base (CB) circuit.
- (ii) Common-emitter (CE) circuit.

- (iii) Common-collector (CC) circuit.
- 11 **Current Gains of a Transistor.** Usually low current gains are defined:

(i) **Common base current amplification factor or ac current gain α .** It is the ratio of the small change in the collector current to the small change in the emitter current when the collector-base voltage is kept constant.

$$\alpha = \left[\frac{\delta I_C}{\delta I_E} \right]_{V_{CB} = \text{constant}}$$

(ii) **Common emitter current amplification factor or ac current gain β .** It is the ratio of the small change in the collector current to the small change in the base current when the collector emitter voltage is kept constant.

$$\beta = \left[\frac{\delta I_C}{\delta I_B} \right]_{V_{CE} = \text{constant}}$$

- 12 **Relations between α and β .** The current gains α and β are related as

$$\alpha = \frac{\beta}{1 + \beta} \text{ and } \beta = \frac{\alpha}{1 + \alpha}$$

- 13 **Transistor as an amplifier.** An amplifier is a circuit which is used for increasing the voltage, current or power of alternating form. A transistor can be used as an amplifier.

ac current gain is defined as:

$$\beta_{ac} \text{ or } A_i = \left[\frac{\delta I_C}{\delta I_B} \right]_{V_{CE} = \text{constant}}$$

dc current gain is defined as

$$\beta_{dc} = \left[\frac{I_C}{I_B} \right]_{V_{CE} = \text{constant}}$$

Voltage gain of an amplifier is defined as

$$A_v = \frac{V_o}{V_i} = \frac{\text{A small change in output voltage}}{\text{A small change in input voltage}} \\ = \frac{\delta V_{CE}}{\delta V_{BE}}$$

Or

$$A_v = \beta_{ac} \cdot \frac{R_{out}}{R_{in}} = A_i \cdot A_r$$

i.e., Voltage gain = Current gain \times Resistance gain

Power gain of an amplifier is defined as

$$A_p = \frac{\text{Output power}}{\text{Input power}} = \text{Current} \times \text{Voltage gain}$$

Or

$$A_p = A_i \cdot A_v = \beta_{ac}^2 \cdot \frac{R_{out}}{R_{in}}$$

14 **Logic Gate.** A logic gate is a digital circuit that has one or more inputs but only one output. It follows a logical relationship between input and output voltage.

15 **Truth Table.** This table shows all possible input combination and the corresponding output for a logic gate.

16 **Boolean Expression.** It is a shorthand method of describing the function of a logic gate in the form of an equation or an expression. It also relates all possible combination of the inputs of a logic gate to the corresponding outputs.

17 **Positive and Negative Logic.** If in a system, the higher voltage level represents 1 and the lower voltage level represent 0, the system is called a positive logic. If the higher voltage represents 0 and the lower voltage level represents 1, then the system is called a negative logic.

18 **OR Gate.** An OR gate can have any number of inputs but only one output. It gives higher output (1) if either input A or B or both are high (1), otherwise the output is low (0).

$$A + B = Y$$

which is read as 'A or B equals Y'.

19 **AND gate.** An AND gate can have any number of inputs but only one output. It gives a high output (1) if inputs A and B are both high (1), or else the output is low (0). It is described by the Boolean expression.

$$A \cdot B = Y$$

which is read as 'A and B equals Y'.

20 **NOT Gate.** A NOT gate is the simplest gate, with one input and one output. It gives as high output (1) if the input A is low (0), and vice versa.

Whatever the input is, the NOT gate inverts it. It is described by the Boolean expression:

$$\bar{A} = Y$$

which is read as 'not A equal Y'.

21 **NAND (NOT+AND) gate.** It is obtained by connecting the output of an AND gate to the input of a NOT gate. Its output is high if both inputs A and B are not high. It is described by the Boolean expression.

$$\overline{A \cdot B} = Y \text{ or } \overline{A} \cdot \overline{B} = Y$$

which is read as 'A and B negated equals Y'.

22 **NOR (NOT+OR) Gate.** It is obtained by connecting the output of an OR gate to the input of a NOT gate. Its output is high if neither input A nor input B is high. It is described by the Boolean expression.

$$\overline{A + B} = Y$$

Which is read as 'A and B negated equals Y'.

- 23 **XOR or Exclusive OR gate.** The XOR gate gives a high output if either input A or B is high but not when both A and B are high or low. It can be obtained by using a combination of two NOT gates, two AND gates and one OR gate. It is described by Boolean expression:

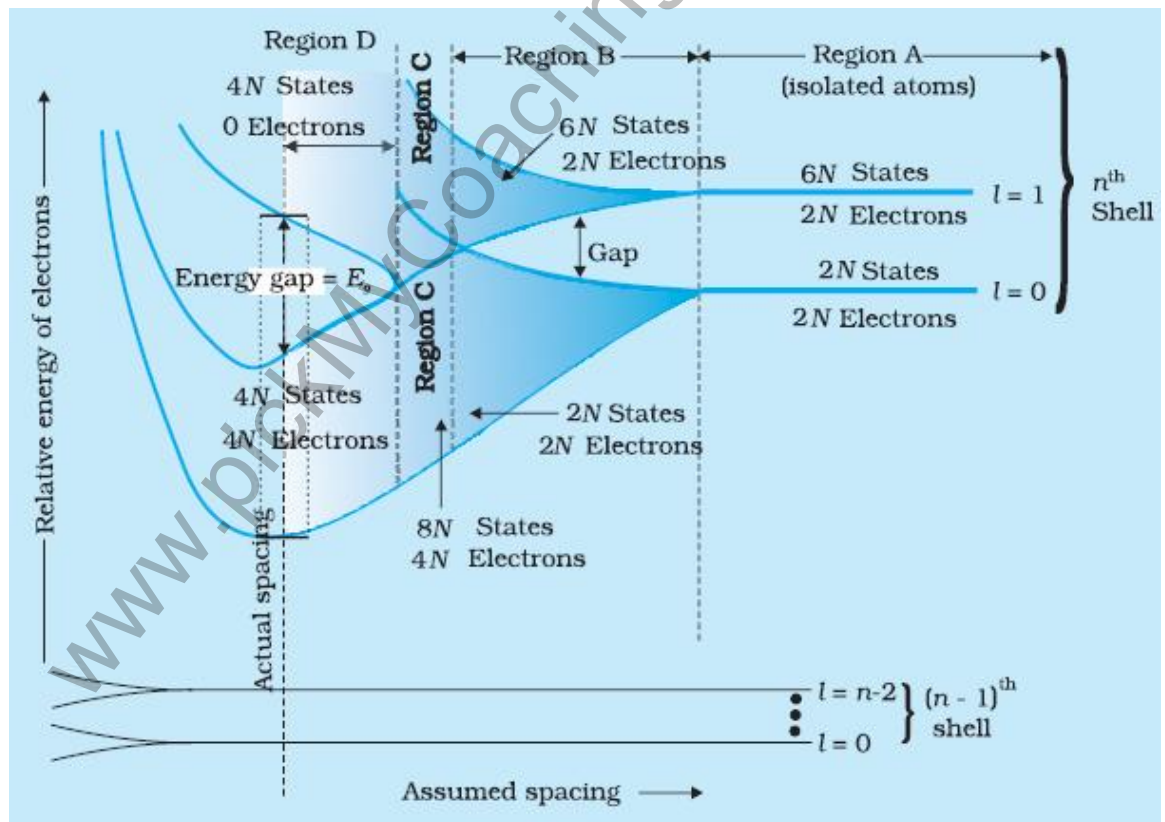
$$Y = \overline{A}B + A\overline{B}$$

The XOR gate is also known as difference gate because its output is high when the inputs are different.

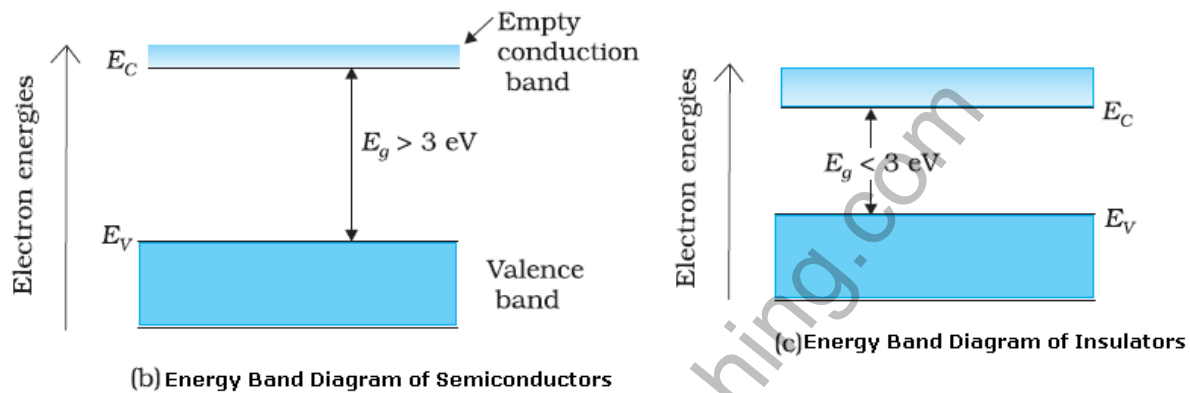
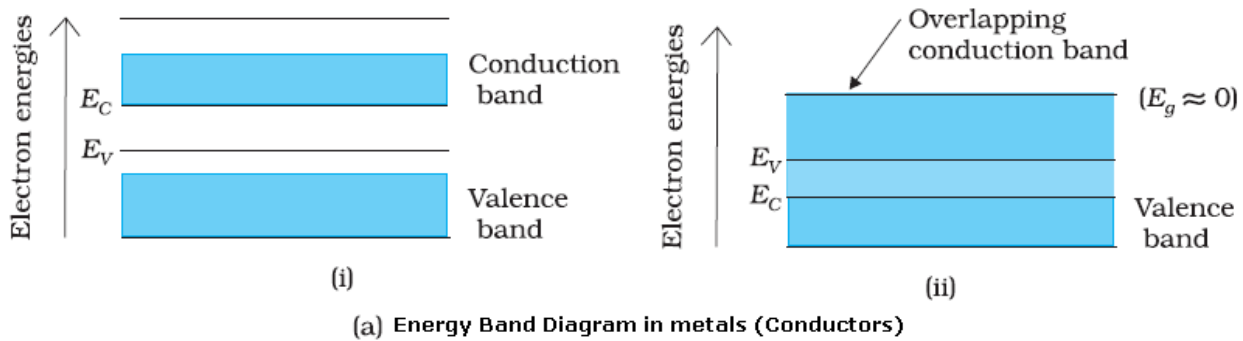
- 24 **Integrated Circuits.** The concept of fabricating an entire circuit (consisting of many passive components like R and C and active devices like diode and transistor) on a small single block (or chip) of a semiconductor has revolutionized the electronics technology. Such a circuit is known as Integrated Circuit (IC).

TOP Diagrams & Circuit Diagrams

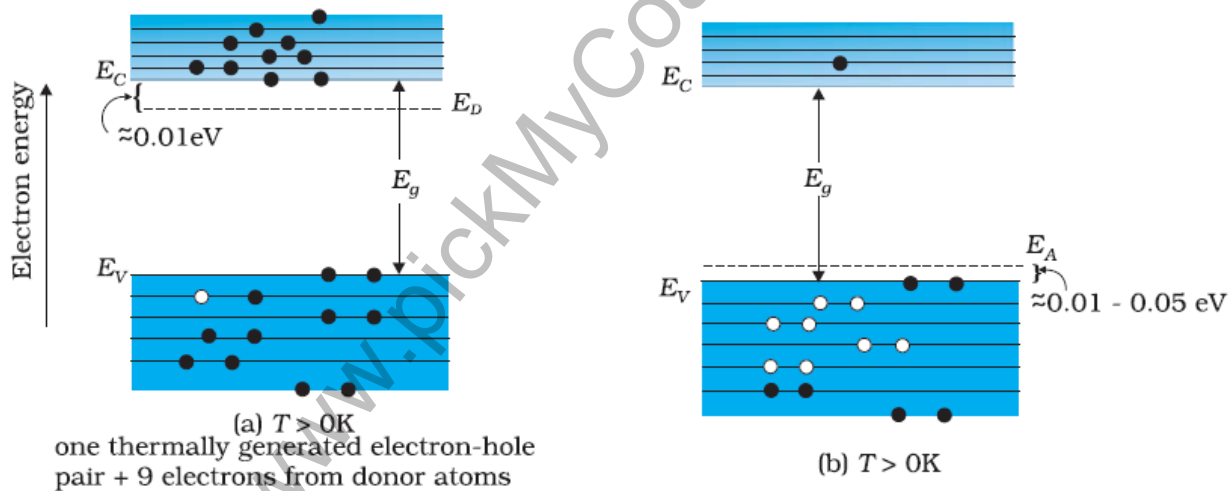
1. Energy Band diagram of solids



2. Energy Band Diagrams of Metals, Semiconductors & Insulators



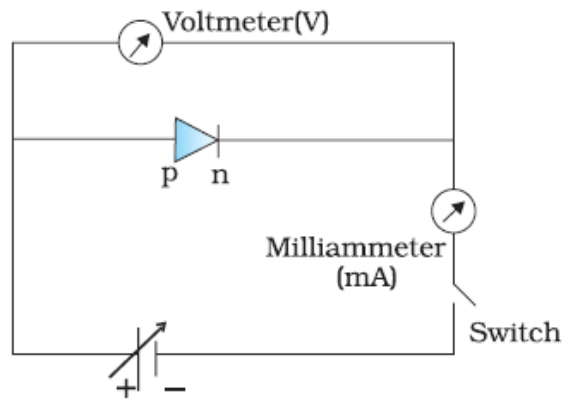
3. Energy Band Diagram of p-type & n-type semiconductors



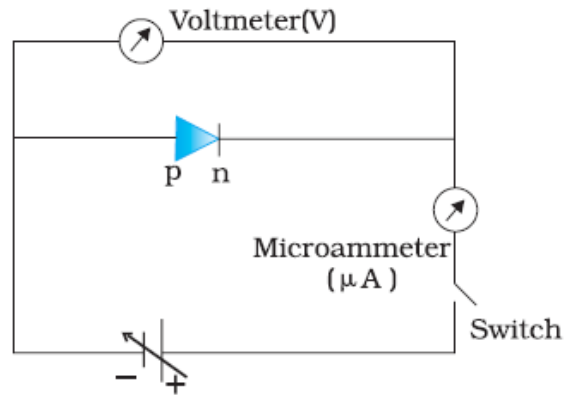
Energy Band Diagram of n-type semiconductor

Energy Band Diagram of p-type semiconductor

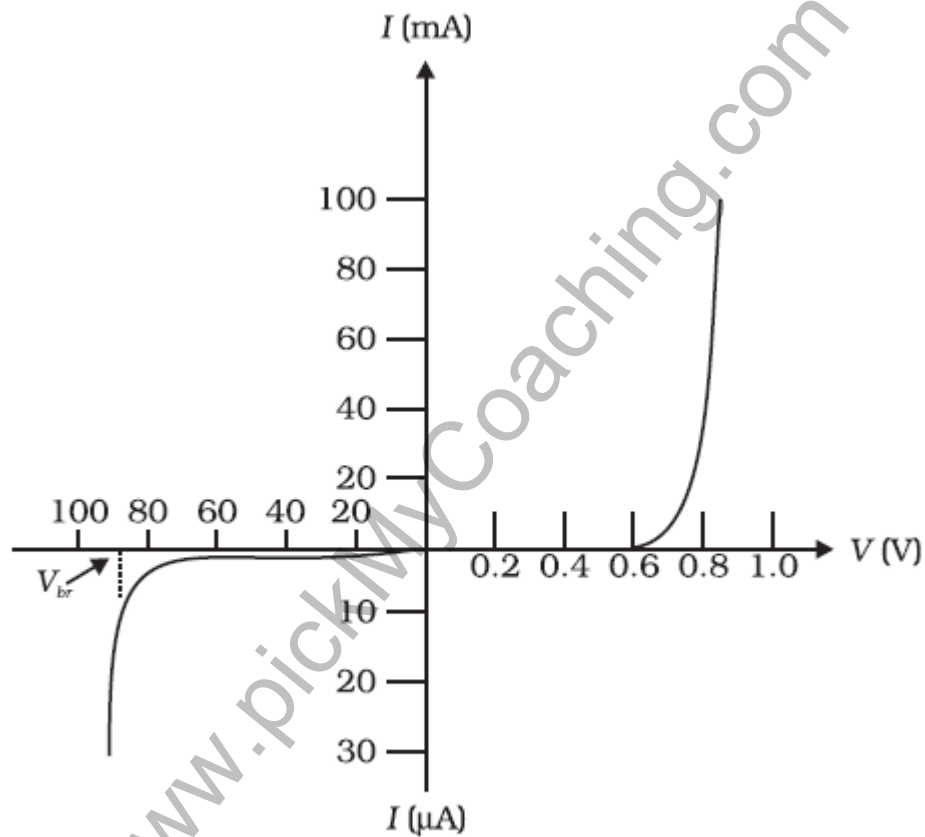
4. VI Characteristics of p-n Junction



(a) Forward Bias: pn Junction

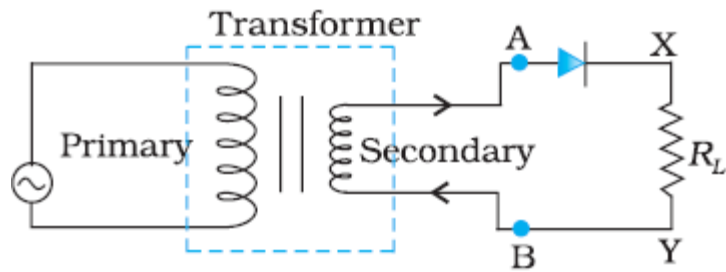


(b) Reverse Bias: pn Junction

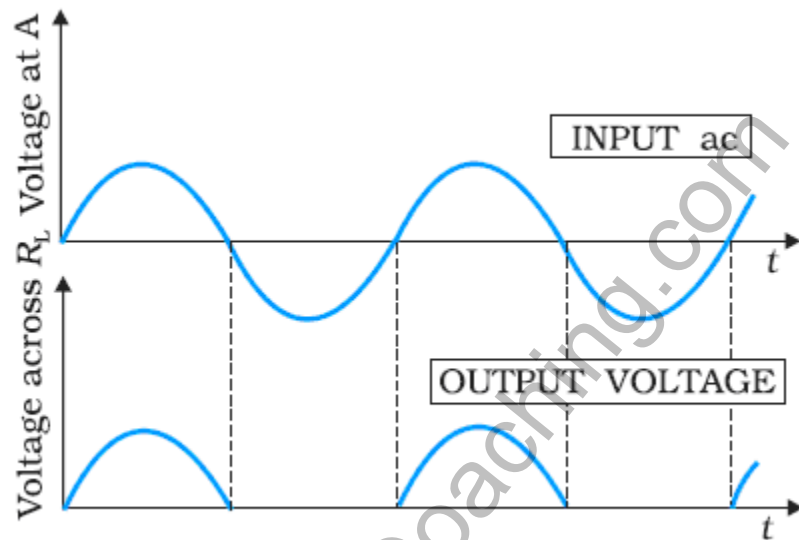


(c) V-I Characteristics of p-n Junction

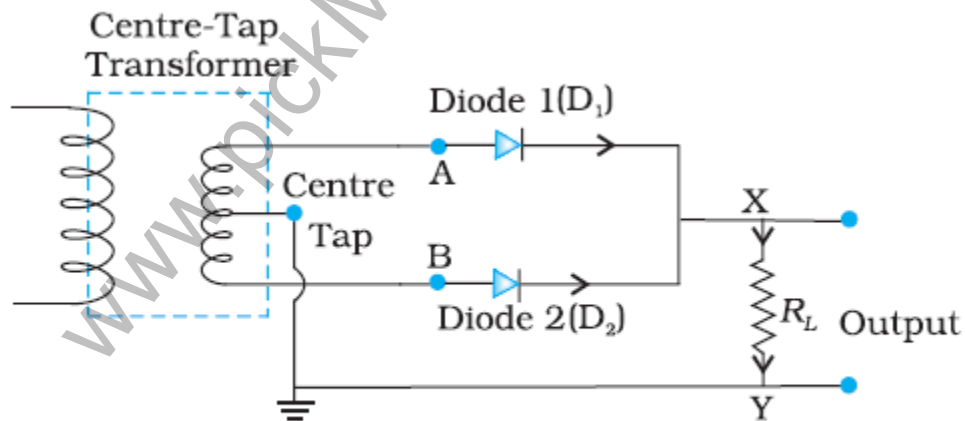
5. p-n Diode as Rectifier



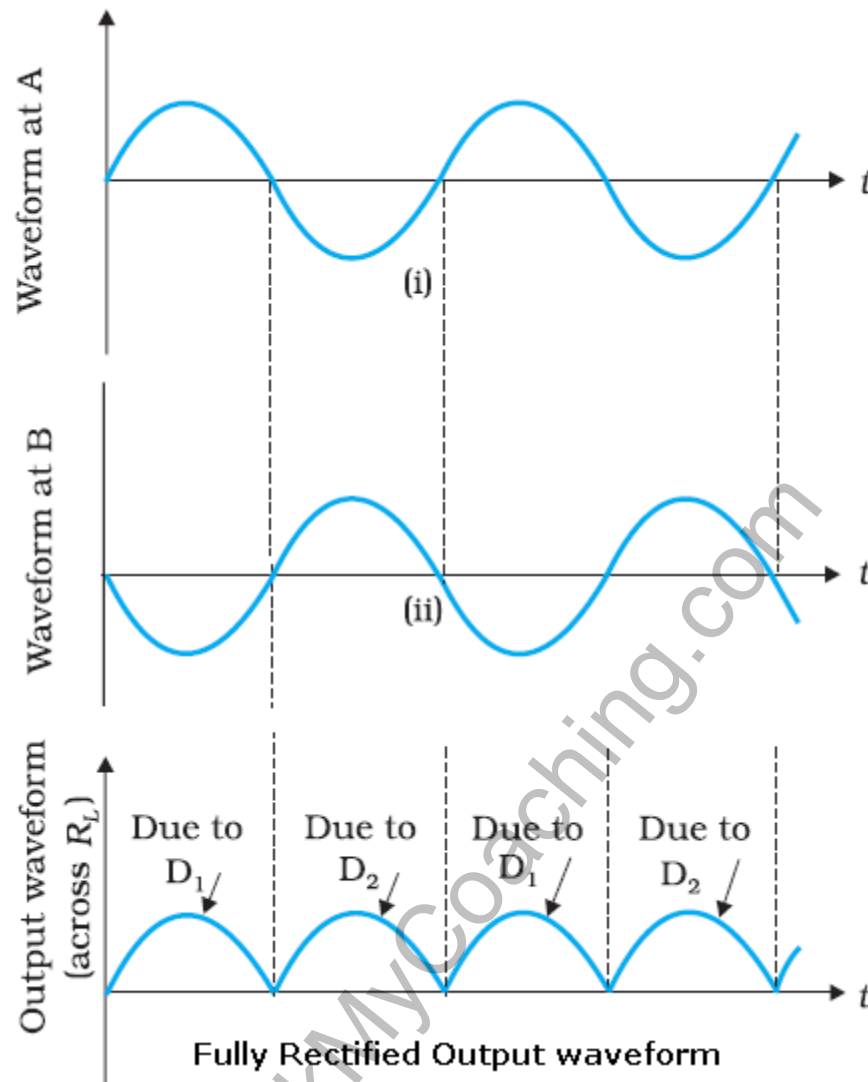
(a) p-n Diode as Half wave Rectifier



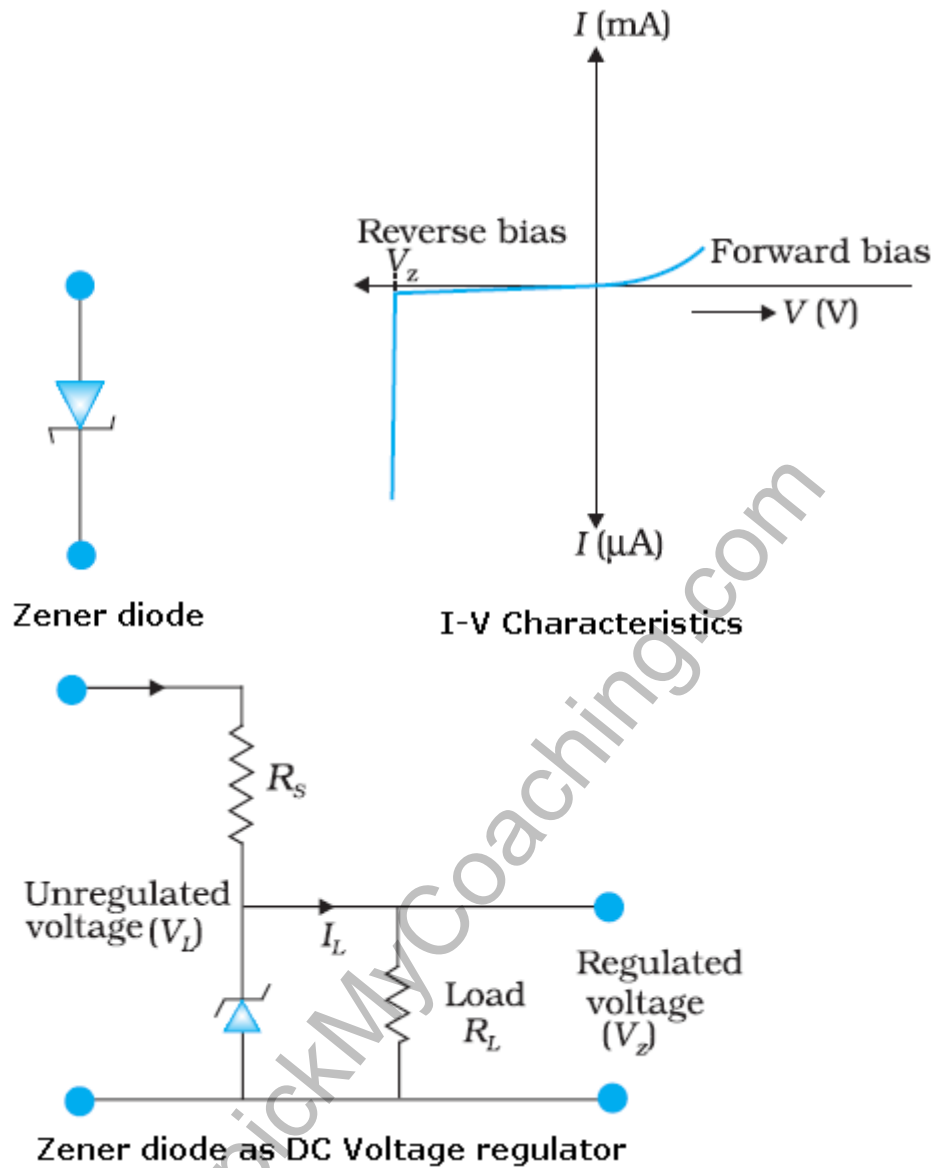
(b) Input & Output Waveform of Half Wave Rectifier

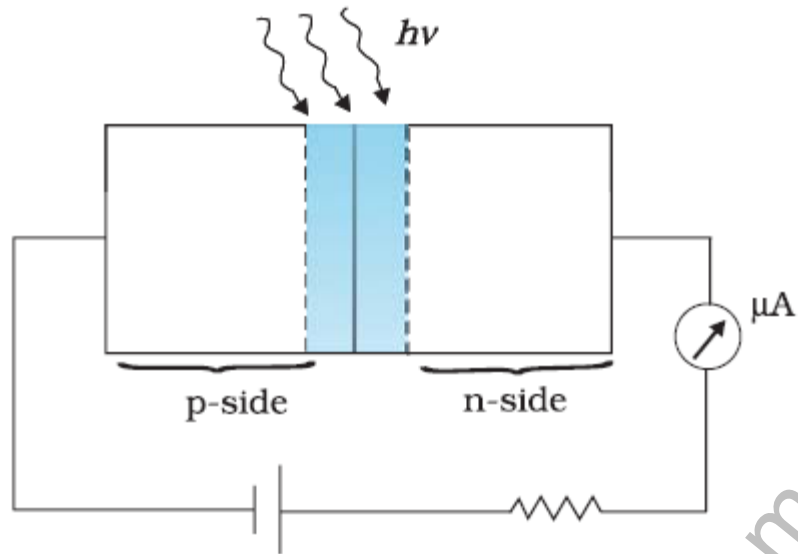


(a) p-n Diode as Full Wave Rectifier

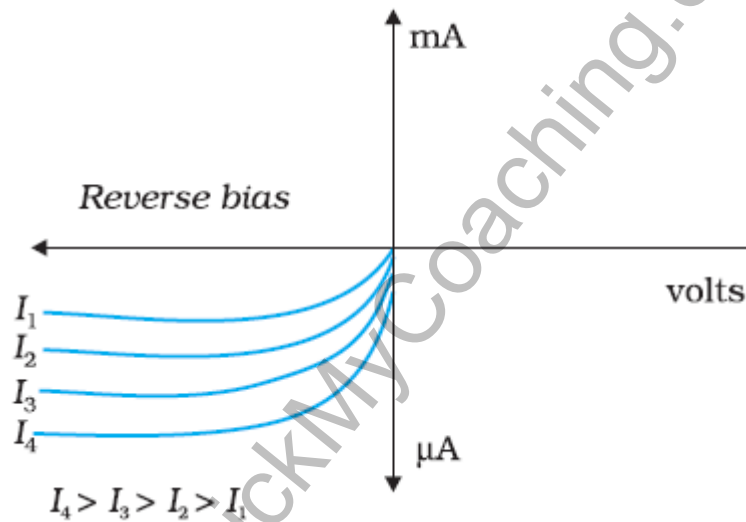


6. Special type p-n Diodes

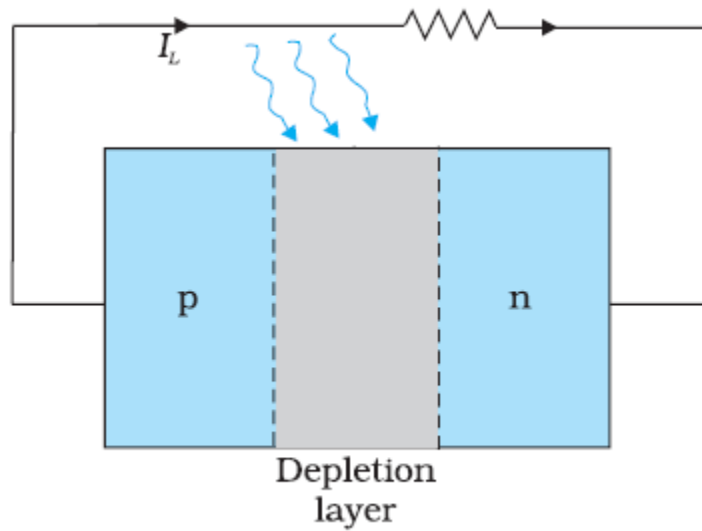




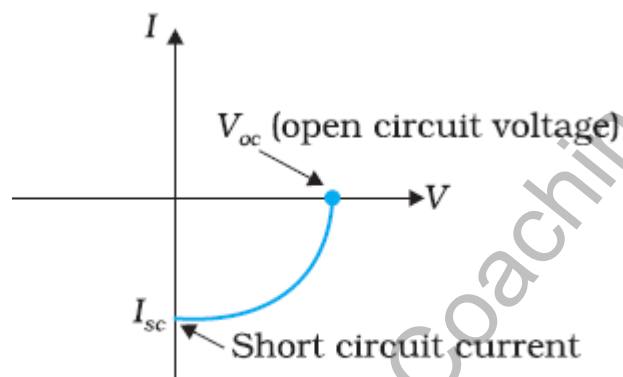
(a) Photodiode



(b) I-V Characteristics of photodiode

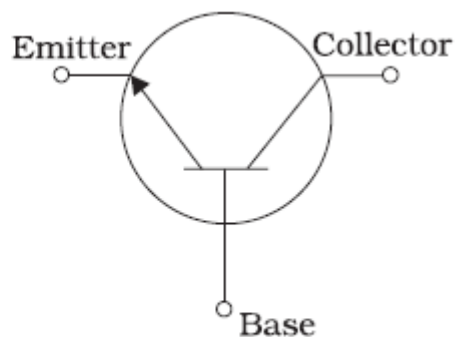
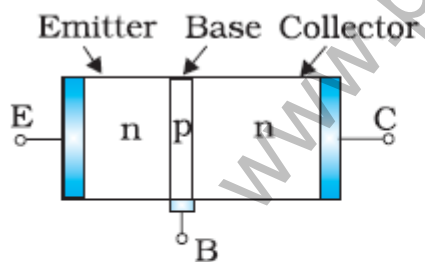


Solar Cell

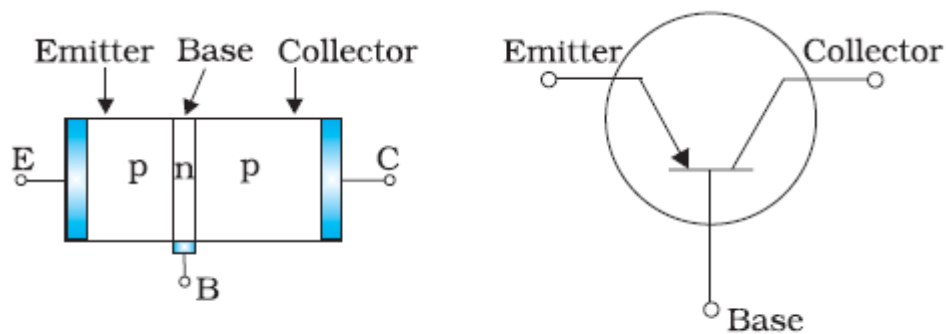


I-V Characteristics of a Solar Cell

7. Symbolic Representations:

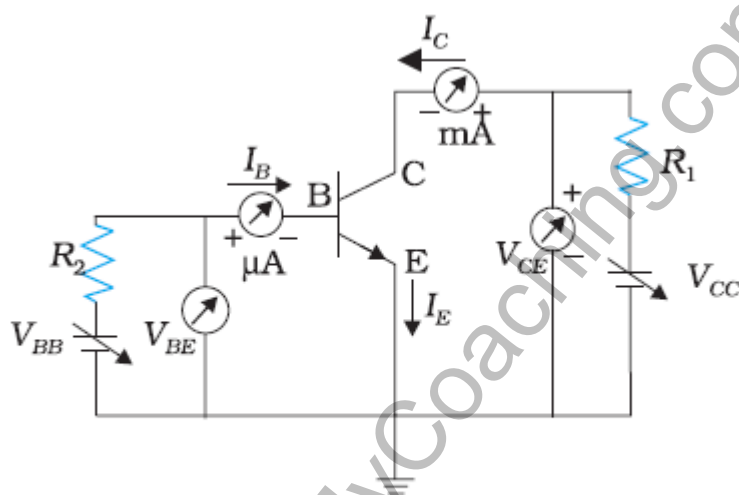


npn Transistor

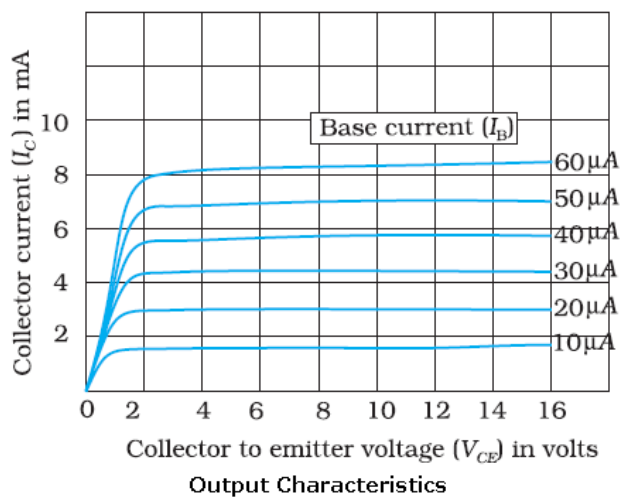
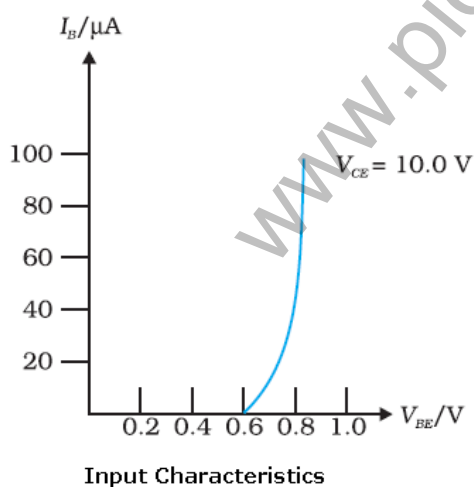


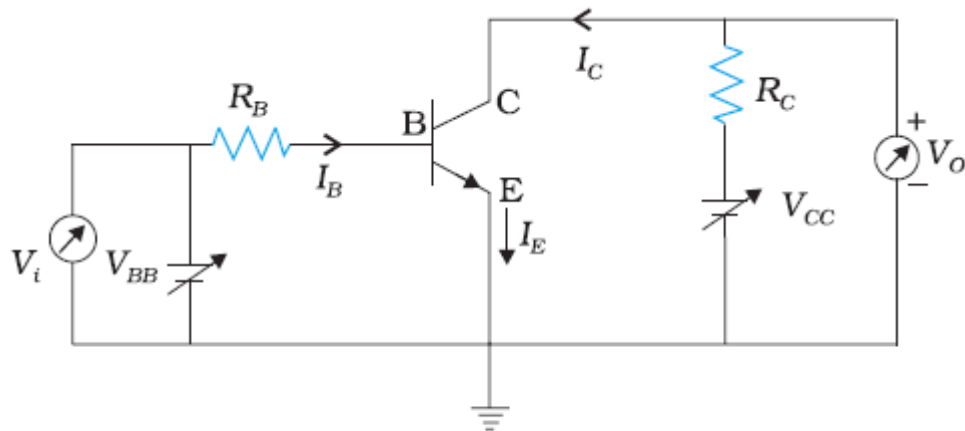
pnp Transistor

8. V-I Characteristics of transistors

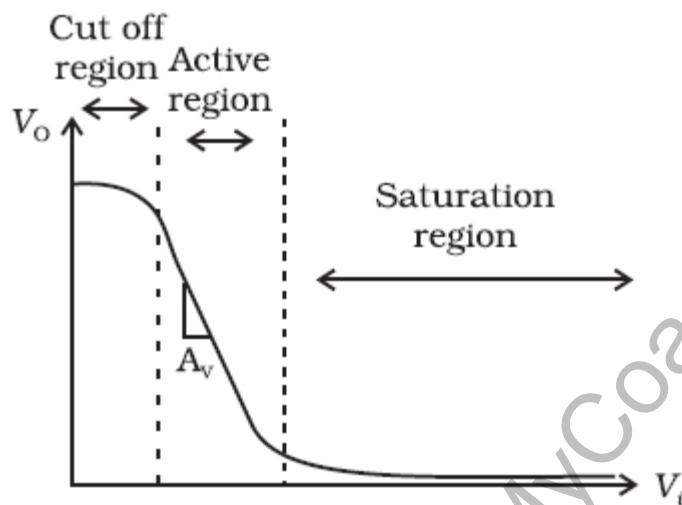


Circuit arrangement:
npn Transistor in CE configuration



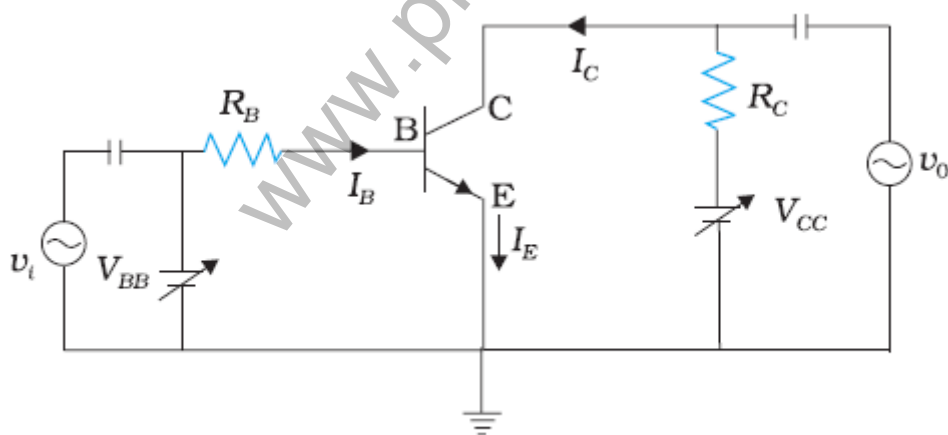


(a) Base Biased transistor in CE configuration



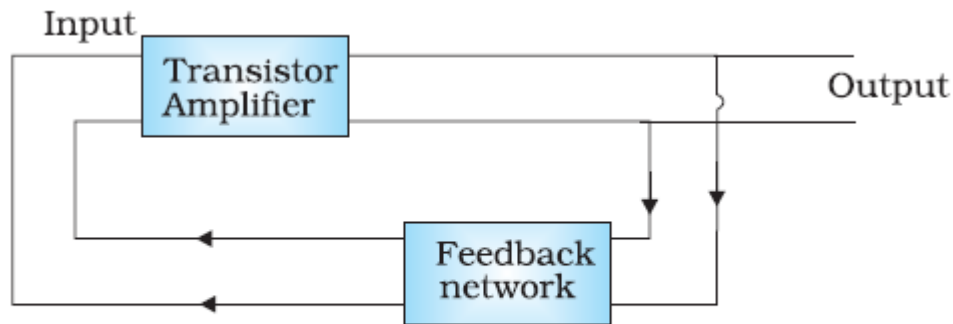
(b) Transfer characteristic

9. Transistor as Amplifier

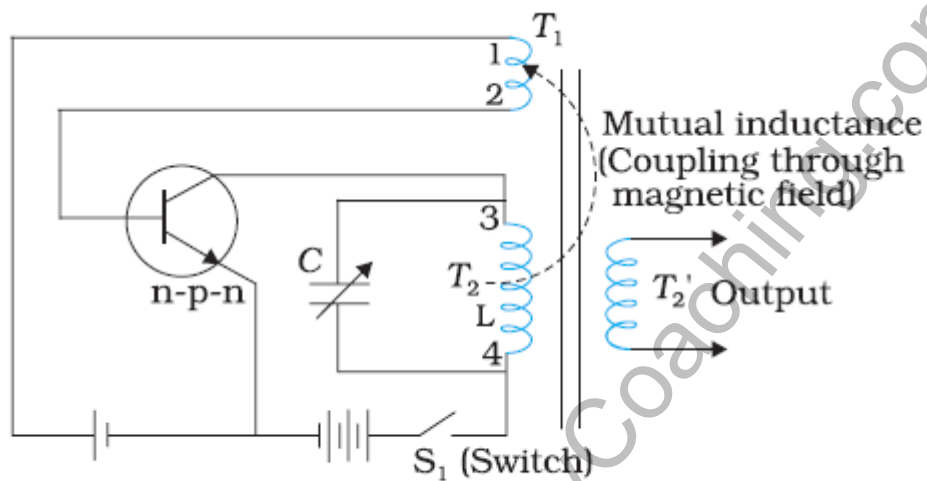


CE Transistor as Amplifier

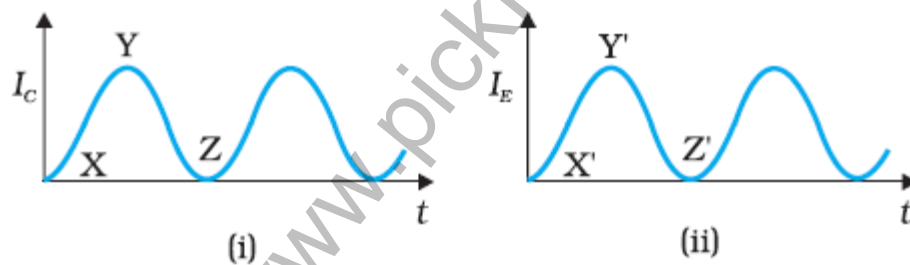
10. Transistor as Oscillator



Transistor with positive feedback working as Oscillator



Tuned Collector Oscillator



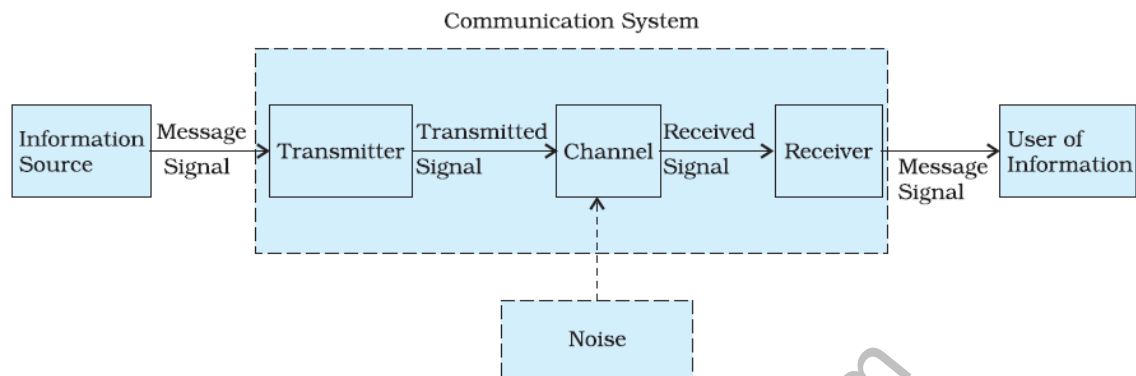
Rise & Fall of I_C & I_E

Class XII: Physics
Chapter: Communication Systems

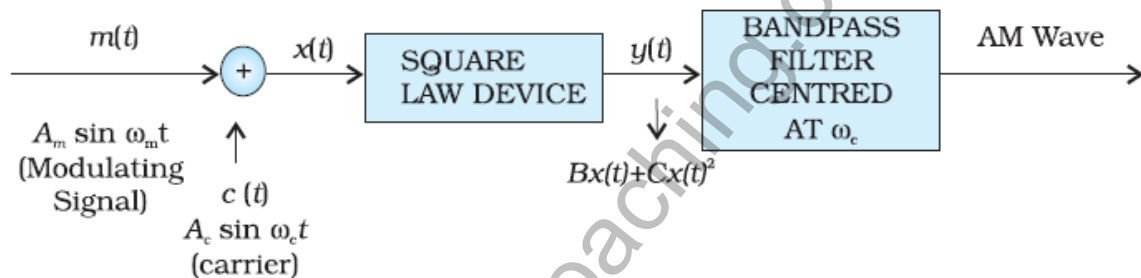
1. **Analog and Digital Mode of Transmission.** An analog message is physical quantity that varies with time usually in a smooth and continuous fashion.
A digital message is an ordered sequence of symbols selected from a finite set of discrete elements
2. **Operational advantages** of digital communication system over analog communication systems are:
 - (i) An improved security message
 - (ii) Increased immunity to noise and external interference.
 - (iii) A common format for encoding different kinds of message signals for the purpose of transmission.
 - (iv) Flexibility in configuration digital communication system.
3. **Attenuation, Distortion,** Interference and Noise are the undesirable effects in the source of signal transmission.
4. **Modulation.** Process of changing some characteristic e.g. amplitude, frequency or phase of a carrier wave in accordance with the intensity of the signal is known as modulation.
5. **Types of Modulation**
 - (i) Amplitude modulation
 - (ii) Frequency modulation
 - (iii) Phase modulation.
6. **Amplitude Modulation.** The amplitude of the carrier wave changes according to the intensity of the signal. The amplitude variation of the carrier wave is at the signal frequency f_s .
7. **Modulation Factor.** The ratio of change of amplitude of carrier wave to the amplitude of normal carrier wave is called modulation factor (m).
8. Pulse modulation could be classified as: Pulse Amplitude Modulation (PAM), Pulse Duration Modulation (PDM) or Pulse Width Modulation (PWM) and Pulse Position Modulation (PPM).
9. **Demodulation.** Demodulation is the process of recovering the signal intelligence from a modulated carrier wave.
10. **FAX.** Facsimiles of FAX means exact reproduction of the documents, a picture, letter, map etc. at receiver end.
11. **MODEM.** The term modem means modulator and demodulator. It converts a series of binary pulses of digital information into an analog signal and transmits across the phone lines.

TOP Block Diagrams

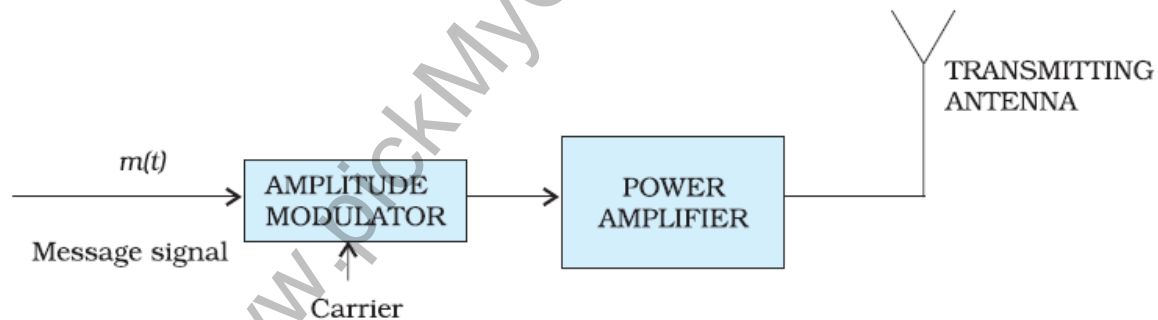
1. Generalized Communication systems



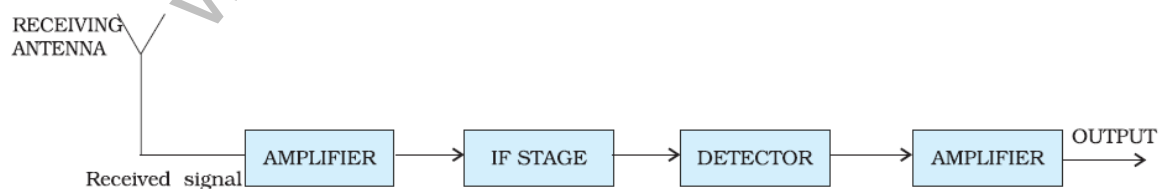
2. Simple Modulator for obtaining AM signal



3. Transmitter



4. Receiver



5. Detection of an AM signal

