ITC 100 Inspiring Years

classmate

BECAUSE YOU ARE ONE OF A KIND

Modern physics

{Theory}

Steep volcanoes surround **Lake Atitlán** in Guatemala, Central America

Notebook

Scanned by CamScanner

Photoelectric Effect and wave-particle duality

Photon theory of light

* photon ⇒ A particle representing a quantum of light or other electromagnetic radiation.

* Conversions and results regarding photons:

a) A photon always travels at a speed $c = 299,792,458\ m/s \approx 3.0 \times 10^8\ m/s$ in vacuum. This is true for any frame of reference used to observe the photon.

b) The mass of a photon is not defined in the sense of newtonian mechanics. We shall ignore this concept. We simply state that the rest mass of a photon is zero.

c) Each photon has a definite energy and a definite linear momentum.

d) Let E and P be the energy and linear momentum of a photon of light, and f and λ be the frequency and wavelength of the same light when it behaves as a wave.

$$E = hf \quad \left\{ h = \text{Planck constant} \right.$$
$$P = h/\lambda \quad \left\{ h = 6.625 \times 10^{-34}\ J\text{-}S \right.$$

Scanned by CamScanner

e) A photon may collide with a material particle. The total energy and the total momentum remain conserved in such a collision. The photon may get absorbed and/or a new photon may be emitted. Thus, the number of photons may not be conserved.

f) If the intensity of light of a given wavelength is increased, there is an increase in the number of photons crossing a given area in a given time. The energy of each photon remains the same.

g) For a given wavelength, λ, the energy of light is an ~~integer~~ integer times hc/λ. Thus, the photon theory is, therefore, also called the quantum theory of light.

Photoelectric Effect

* Photoelectric Effect ⇒ When a light of sufficiently small wavelength is incident on a metal surface, electrons are ejected from the metal. This phenomenon is called photoelectric effect.

Scanned by CamScanner

* Photoelectrons ⇒ The electrons ejected from the metal are called photoelectron.

* Work function (φ) ⇒ ~~Wave~~ Work function is the minimum energy that must be given to an electron to liberate it from the surface of a particular substance.

* When light is incident on a metal surface, the photons collide with the free electrons. In a particular collision, the photon may give all of its energy to the free electron

→ If this energy is more than the work function {φ}, the electron may come out of the metal.

→ The electron after receiving the energy, may lose energy to the metal in course of collisions with the atoms of the metal.

→ Only if an electron near the surface gets the extra energy and heads towards the outside, it is able to come out.

Scanned by CamScanner

→ $\boxed{K_{max} = E - \Phi}$

K_{max} = Maximum kinetic energy of electron
E = Energy supplied by photon to individual electron
Φ = work function

→ The above mentioned equation is called <u>Einstein's photoelectric equation.</u>

→ <u>Threshold wavelength and frequency</u>

* <u>Threshold wavelength</u> $\{\lambda_0\}$ ⇒ Threshold wavelength is the maximum wavelength of light that should be subjected to the surface of metal to just make electron escape.

$$\boxed{\lambda_0 = hc/\Phi}$$

* <u>Threshold frequency</u> $\{f_0\}$ ⇒ Threshold frequency is the minimum frequency of light that should be subjected to the surface of metal to just make electron escape.

$$\boxed{f_0 = \Phi/h}$$

Scanned by CamScanner

→ Results on Experimental Arrangement

1) When light of sufficiently small wavelength falls on a metal surface, the metal emits electrons. The emission is almost instantaneous.

2) The kinetic energies of the photoelectrons vary from zero to a maximum of K_{max}.

$$\boxed{K_{max} = hf - \phi}$$

3) The photocurrent may be stopped by applying a negative potential to the anode with respect to the cathod. The minimum magnitude of the potential needed to stop the photocurrent is called the stopping potential. It is proportional to the maximum kinetic energy of the photoelectrons.

$$\boxed{V = \frac{hf - \phi}{e}} \quad \{V - \text{Stopping potential}\}$$

4) The stopping potential does not depend on the intensity of the incident light. This means that the kinetic energy of the photoelectrons is independent of intensity of light.

Scanned by CamScanner

5) The stopping potential depends on the wavelength of the incident light.

6) The photocurrent increases if the intensity of the incident light is increased.

Matter wave

→ Louis victor de broglie in his PhD thesis suggested that every matter can have both wave and particle nature.

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

λ = de broglie wavelength of matter wave

h = Planks constant

p = momentum of matter

Scanned by CamScanner

2

Bohr's model and physics of atom

⇒ Earlier Construction of atomic models :-

① Democritus study
In 15th century BC, the Greek philosopher democritus proposed that all matter consists of very small indivisible particles called atomos.

② Thomson's study
Thomson suggested in 1898 that the atom is a positively charged solid sphere and electrons are embedded in it in sufficient number so as to make the atom electrically neutral.

③ Lenard's study
Lenard suggested in 1903 that the atom must have a lot of empty space in it. He proposed that the atom is made of electrons and similar tiny particles carrying positive charge.

④ Rutherford's study

// Ernest rutherford suggested structure of atom by doing a series of experiments from 1906 to 1911 on alpha particle scattering :-

Scanned by CamScanner

-> According to this model, the atom contains a positively charged tiny particle at its centre called the nucleus of the atom.

-> This nucleus contains almost all the mass of the atom.

-> Outside this nucleus, there are electrons which move around it at some separation.

-> The space between the nucleus and the electrons is empty and determines the size of the atom.

-> The amount of the positive charge on the nucleus is exactly equal to the total amount of negative charges on all the electrons of the atom.

Scanned by CamScanner

⇒ Hydrogen spectra

→ When a material body is heated, it emits electromagnetic radiation.

→ If hydrogen gas enclosed is a sealed tube is heated to high temperatures, it emits radiation.

→ If this radiation is passed through a prism components of different wavelengths are deviated by different amounts and thus we get the hydrogen spectrum.

→ The most striking feature in this spectrum is that only some sharply defined, discrete wavelengths emit in the emitted radiation.

* Rydberg formula

When electron jump from higher energy orbital to lower energy orbital, they radiate energy in the form of light.

$$f = 109677 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) cm^{-1} \quad \left\{ R = \frac{me^4}{8\varepsilon_0^2 h^3 c} \right\}$$

*	Lyman Series	Balmer Series	Paschen Series
	Ultraviolet	Visible	Infrared

Scanned by CamScanner

⇒ Bohr's model

* Bohr's postulates

ⓐ The electron revolves round the nucleus in circular orbit.

ⓑ The orbit of the electron around the nucleus can take only some special values of radius. In these orbits of special radii, the electron does not radiate energy as expected from Maxwell's Laws. These orbits are called stationary orbits.

ⓒ The energy of the atom has a definite value in a given stationary orbit. The electron can jump from one stationary orbit to other.

→ If electrons jump from higher energy orbits to lower energy orbit, it emits a photon of radiation.

→ The electron can also absorb energy from some source and jump from lower energy orbit to a higher energy orbit.

Scanned by CamScanner

(d) In stationary orbits, the angular momentum l of the electron about the nucleus is an integral multiple of plank constant h divided by 2π.

$$\boxed{l = n\frac{h}{2\pi}}$$ Can be derived from De-Broglie and Einstein-Plank equation

→ This assumption is called bohrs quantization rule.

* Explaining hydrogen atom and H-like atom ions

→ Hydrogen-like atom ⇒ containing only one electron.

Eg → He^{+}, Li^{++}, Be^{+++} etc.

→ Let us assume that the nucleus has a positive charge Ze and an electron moving with a constant speed v along a circle of radius r with the centre at the nucleus.

// Balancing Coulomb and centrifugal force :-

$$\frac{KZe^2}{r^2} = \frac{mv^2}{r} \Rightarrow r = \frac{KZe^2}{mv^2} \quad (1)$$

Scanned by CamScanner

// Using bohr's quantization order :-

$$mvr = n\frac{h}{2\pi} \quad \text{--- (II)}$$

// Using Eq (I) and (II) we get :-

$$\boxed{v = \frac{2\pi k e^2 Z}{nh}}$$

$$\boxed{r = \frac{n^2 h^2}{4\pi^2 k m e^2 Z}}$$

$$\boxed{E_{(n)} = \frac{1.24 \times 10^{-6}}{\lambda} eV}$$

$$E = KE + U$$

$$E = \frac{1}{2}mv^2 - \frac{kZe^2}{r}$$

$$\boxed{E = -k^2 \frac{2\pi m e^4}{n^2 h^2}}$$

$$\boxed{E = -\frac{13.6}{n^2} eV}$$

* Series structure {Hydrogen spectra}

→ Lyman Series {Ultraviolet region}

All the transitions of electrons from higher energy orbit to, n=1 corresponds to wavelength grouped between 121.6 nm to 91.2 nm.

These line constitute lyman series.

Scanned by CamScanner

→ Balmer series {Visible region}
All the transition of electron from higher energy orbit to, n=2 corresponds to wavelength groupped between 656.3 nm to 365.0 nm. These line constitute Balmer series.

→ Paschen series {Infrared region}
All the transition of electron from higher energy orbit to n=3 corresponds to wavelength groupped between 1875 nm to 822 nm. These line constitute Paschen series.

* Some terms associated

→ Ionization energy ⇒ Ionization energy of an atom or molecule describes the minimum amount of energy required to remove an electron (to infinity) from an atom or molecule in the gaseous state.

$$X + \text{energy} \longrightarrow X^+ + e^-$$

★ Quantum mechanical model of atom

3
Photometry

→ Photometry is the science of the measurement of light, in terms of its ~~per~~ perceived brightness to the human eye.

⇒ Total Radiant flux ⇒ The total energy of radiation emitted by a source per unit time is called its total radiant flux.

→ The SI unit of total radiant flux of a source is watt.

⇒ Luminosity of Radiant flux

→ The luminosity of radiant flux measures the capacity to produce brightness sensation in eye.

→ Radiation is "visible" if its luminosity is not zero.

→ Luminosity is maximum for wavelength around 555 nm.

→ Its SI unit is lumen.

→ The luminous flux of a source of 1/683 W emitting monochromatic light of wavelength 555 nm is called one lumen.

Scanned by CamScanner

⇒ Luminous flux : Relative luminosity

→ Relative luminosity of a wavelength refers to the fraction :-

$$= \frac{\text{luminous flux of a source of given wavelength}}{\text{luminous flux of a 555 nm source of same power.}}$$

→ For radiation having a range of wavelengths, the luminous flux gets contribution from each wavelength.

⇒ Luminous Efficiency

Total luminous flux per unit radiant flux is called luminous efficiency.

$$* \text{ Luminous Efficiency} = \frac{\text{Total luminous flux}}{\text{Total radiant flux}}$$

$$* \text{ Overall luminous efficiency} \Rightarrow \frac{\text{Luminous flux emitted}}{\text{Power input to the source}}$$

Scanned by CamScanner

⇒ Luminous Intensity or Illuminating power

The luminous intensity of a source in a given direction is defined as:-

$$I = \frac{dF}{d\omega} \quad \begin{cases} dF = \text{luminous flux of the radiation emitted.} \\ d\omega = \text{solid angle} \end{cases}$$

⇒ The SI unit of luminous intensity is lumens/steradian.

⇒ This is called a candela written in short as "cd".

⇒ Luminous intensity is also called illuminating power.

⇒ Illuminance

Illuminance is the total luminous flux incident on a surface per unit area.

$$E = \frac{dF}{dA}$$

⇒ The SI unit of illuminance is lumen/m^2 and is also called lux.

Scanned by CamScanner

⇒ Inverse Square law

$$E = \frac{I \cos\theta}{r^2}$$

I = luminous intensity of source

θ = angle between area vector and line of sight (or source).

r = separation

⇒ Lambert's Cosine law

Lambert's cosine law states that for a small plane surface light source, intensity of light in different direction is given by:-

$$I = I_0 \cos\theta$$

I_0 = luminous intensity along normal

θ = angle between normal to that of the direction.

→ The surface which radiate according to the Lambert's cosine law are called perfectly diffused.

Scanned by CamScanner

⇒ Photometers

* Photometer is an instrument for measuring light intensity.

Mechanism

→ Two screen are placed side by side.

→ One screen is illuminated by the source S_1 only and the other screen by the source S_2 only.

→ Light falls on the two screen at equal angles.

→ The distances d_1 and d_2 of the sources from the screens are so adjusted that the two screens look equally bright.

→ If I_1 and I_2 be the intensities of the two sources

$$\frac{I_1}{d_1^2} = \frac{I_2}{d_2^2} \Rightarrow \boxed{\frac{I_1}{I_2} = \frac{d_1^2}{d_2^2}}$$

Scanned by CamScanner

4

Semiconductors & Semiconductor devices

⇌ Introduction

→ These solids do conduct electricity when an electric field is applied, but the conductivity is very small as compared to the usual metallic conductors.

{ Silicon's Conductivity is about 10^{11} times smaller than that of copper & is about 10^{13} times larger than that of fused quarts
└→ {glass containig of silica} }

→ Semiconductor's conductivity increases with increase in temperature.

Scanned by CamScanner

⇒ Energy bands in solid

$Na \Rightarrow 1s^2\ 2s^2\ 2p^6\ 3s^1$

Completely filled — Vacant

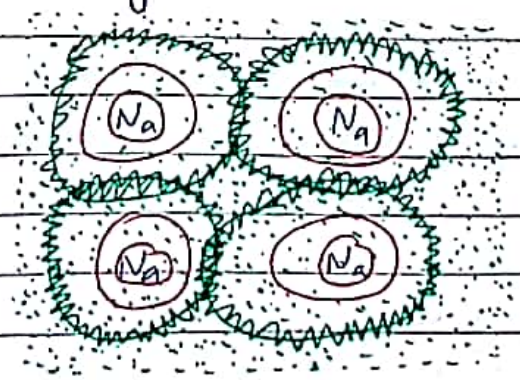
⇒ Let us consider a group of N Sodium atom, Separated from each other by large distances.

⇒ Total No of electron = 11N

$1s \Rightarrow 2N \quad 2s \Rightarrow 2N$

$2P \Rightarrow 6N \quad 3S \Rightarrow N$

⇒ Now Suppose, the atoms are drawn closer to one another to the extent that the outer 3S electrons of one atom starts interacting with the 3S electrons of the neighbouring atoms



Scanned by CamScanner

⇒ Due to these interection the energy of 3s states will change.

⇒ It turns out that the changes in energy in all the 2N states of 3s level are not identical.

* Some of the states are shifted up in energy and some are pushed down.

⇒ The magnitude of change is also different for different states of 3s level.

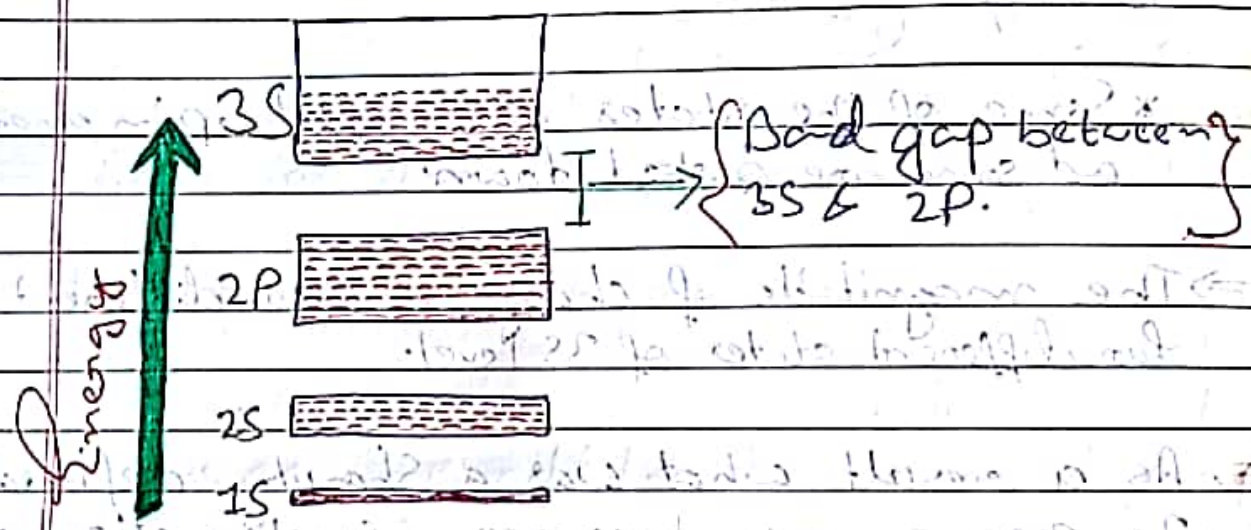
⇒ As a result what was a sharply defined 3s energy, now becomes a combination of several closely spaced energies.

⇒ We say that these 2N states have formed an energy band.

The inner electron interact weakly with each other so that this splitting of sharp energy levels into bands is less for inner electrons.

Scanned by CamScanner

* **Band gap** → The difference between the highest energy in a band and the lowest energy in the next higher band is called the band gap between the two band.



→ At zero Kelvin, the energy is the lowest and the electrons fill the bands from the bottom according to the Pauli exclusion principle till all the electrons are accommodated.

→ As the temperature is raised, the electrons may collide with each other and with ions to exchange energy.

* At absolute temperature T, the order of energy exchanged is KT.

Scanned by CamScanner

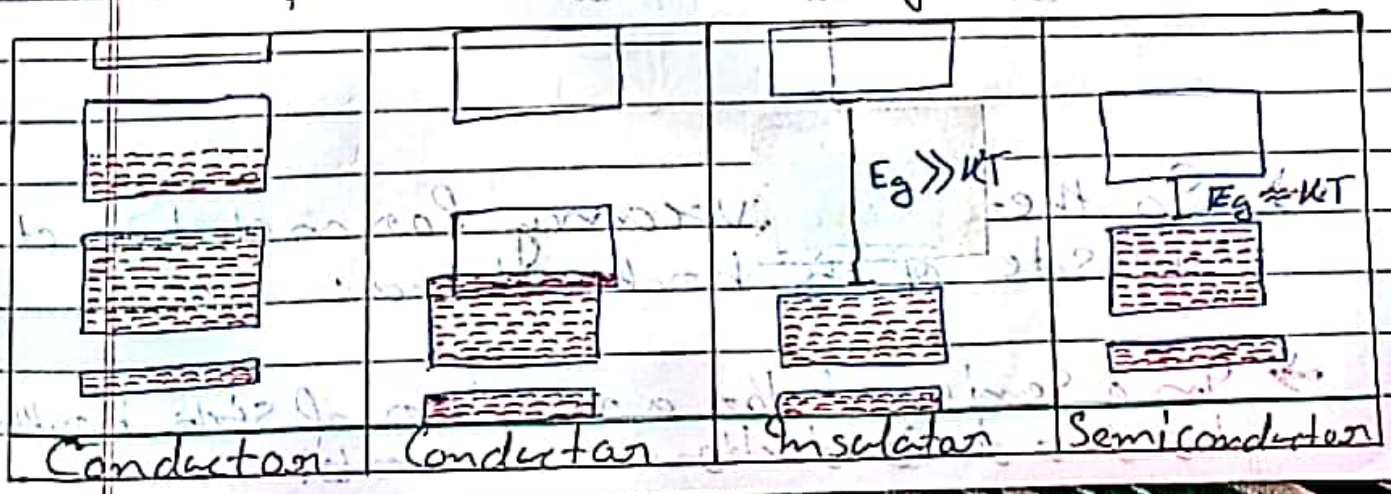
→ The outermost electrons which are in the highest occupied energy band, may take up this energy ≈ KT if empty state are available in the same band.

→ Similar is the scenario when an electric field is applied.

* The electric field in general, can supply only a small amount of energy to the electrons. Only the electrons in the highest occupied band can accept this energy.

→ These electrons can acquire kinetic energy and move according to the electric field. This results in electric current.

* The energy band structure in solide may be classified in four broad types :-



Scanned by CamScanner

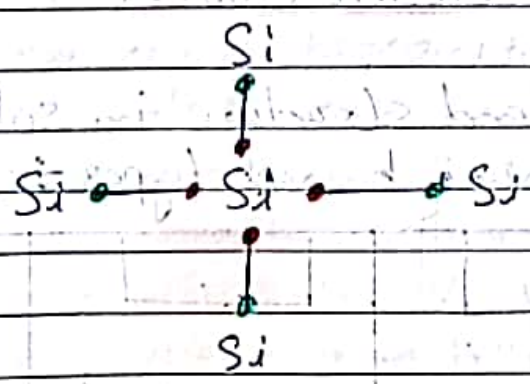
* Valance bands ⇒ The energy bands which are completly filled at zero Kelvin are called Valance band.

* Conduction bands ⇒ The energy bands which are partialy filled an empty at zero Kelvin are called Conduction bands.

⇒ The Semiconductor

Si ⇒ $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$

→ Due to heat, one of these valence electrons may acquire additional energy and jump to conduction band.



→ So, there is a vacancy for an electron at the site of the broken bond.

→ In a semiconductor a number of such broken bond and conduction electron exist.

Scanned by CamScanner

→ Vacancies are also called holes.

→ It is customary in semiconductor physics to treat a vacancy in valence bond as a particle having positive charge +e.

→ Thus in a pure semiconductor, the number of conduction electrons equal to the number of holes.

→ When an electric field is applied, conduction electrons drift opposite to the field and holes drift along the field.

* Intrinsic semiconductors ⇒ also called i-type semiconductors is a name for pure semiconductors.

Scanned by CamScanner

⇒ P-Type & N-Type Semiconductors

→ In an Intrinsic semiconductor only a small fraction of the valence electrons are able to reach the conduction band.

→ The conduction properties of a Semiconductor can be drastically changed by diffusing a small amount of impurity in it.

★ Doping ⇒ The process of diffusing an impurity is known as doping.

ⓐ N-Type semiconductor

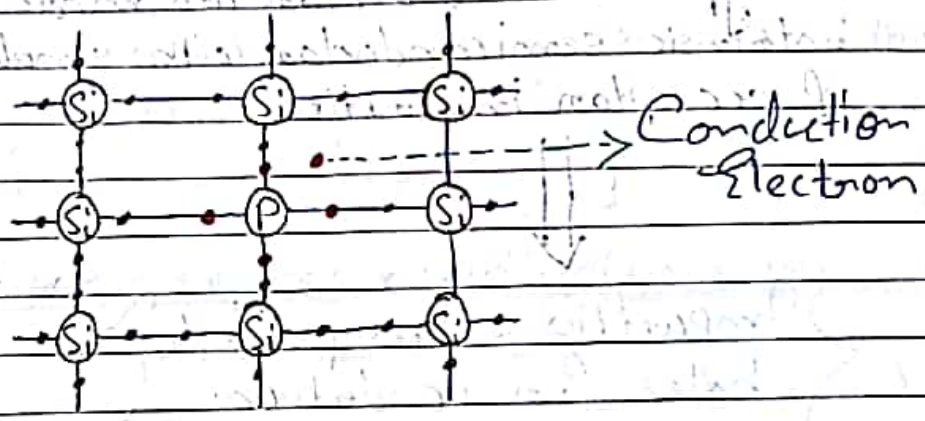
"N-Type semiconductor are made by doping intrinsic semiconductors with small amount of donar impurities.

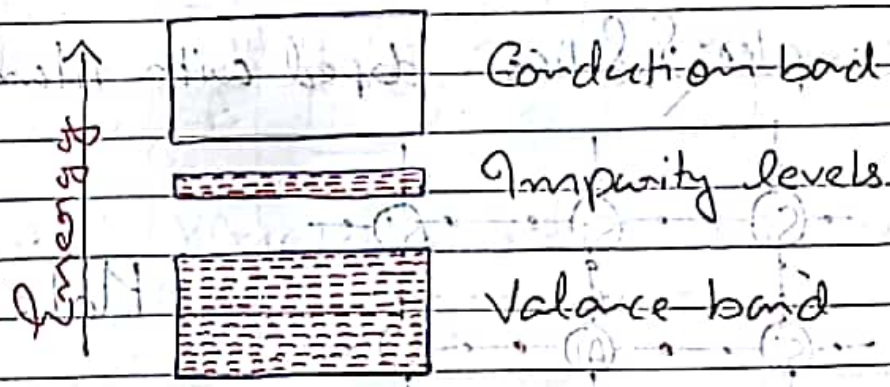
⇓

{Impurities which provides Electron for Conduction.}

Scanned by CamScanner

Example: {Silicon doped with phosphorus}





→ No of Negative charge carriers is much larger than number of positive charge carriers.

Scanned by CamScanner

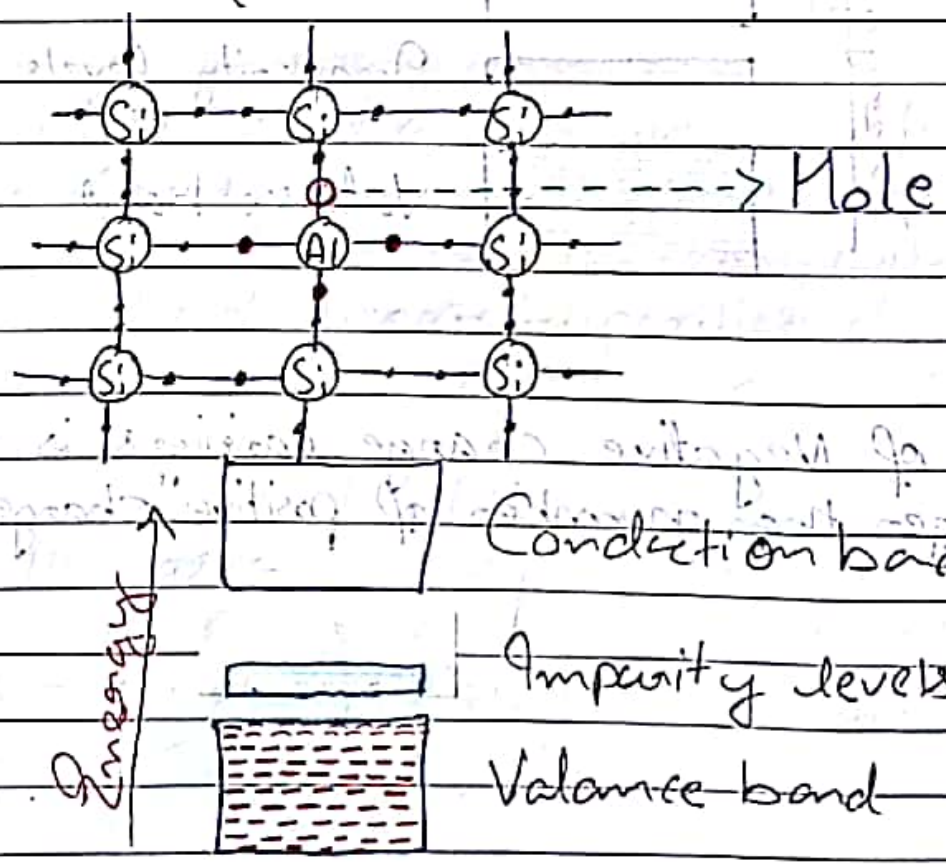
(b) P-Type Semiconductor

"P-Type Semiconductor are made by doping intrinsic semiconductor with small amount of acceptor impurities"

⇓

{Impurities which provide holes for conduction.}

Examples: {Silicon doped with Aluminium}

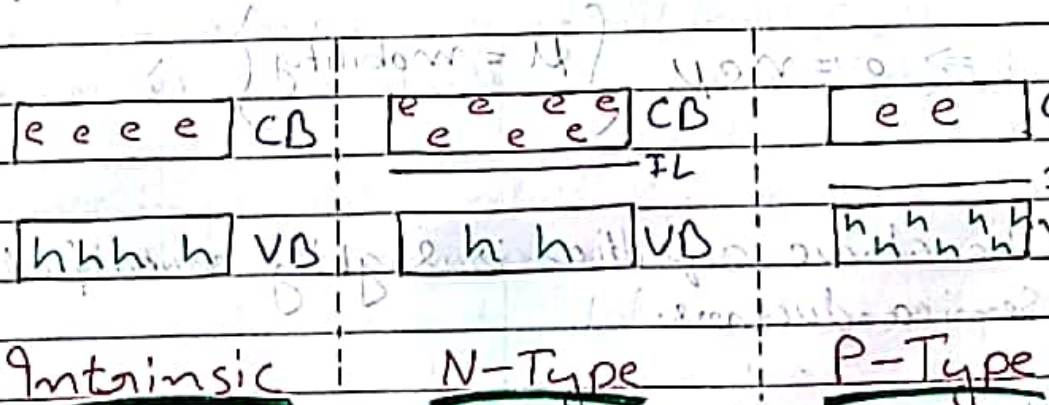


Scanned by CamScanner

→ No of holes are much larger than the number of negative charge carriers.

★ Extrinsic semiconductor ⇒ Semiconductors with an impurity doped into it are called extrinsic semiconductor.

★ Schematic representation of intrinsic & extrinsic Semiconductors



⇒ Density of charge carriers and Conductivity

⇒ The conductivity of a metal is given by :-

$$\sigma = \frac{J}{E} = ne\left(\frac{v}{E}\right) \quad \left\{\begin{array}{l} v = \text{drift speed} \\ n = \text{Conduction electron density} \end{array}\right\}$$

⇒ The quantity $\left(\frac{v}{E}\right)$ is known as mobility of the electrons.

$$\Rightarrow \sigma = ne\mu \quad \{\mu = \text{mobility}\}$$

⇒ The above equation is slightly modified for Semiconductors.

⇒ In Semiconductors conductions is due to the conduction electrons as well as holes.

⇒ The conductivity of a semiconductor is therefore written as :-

$$\boxed{\sigma = n_e e \mu_e + n_h e \mu_h}$$

$\left\{\begin{array}{l} n_e, n_h = \text{density of conduction electron and hole} \\ \mu_e, \mu_h = \text{Mobility of conduction electron and hole.} \end{array}\right\}$

Scanned by CamScanner

* Temperature dependence of conductivity of a Semiconductor

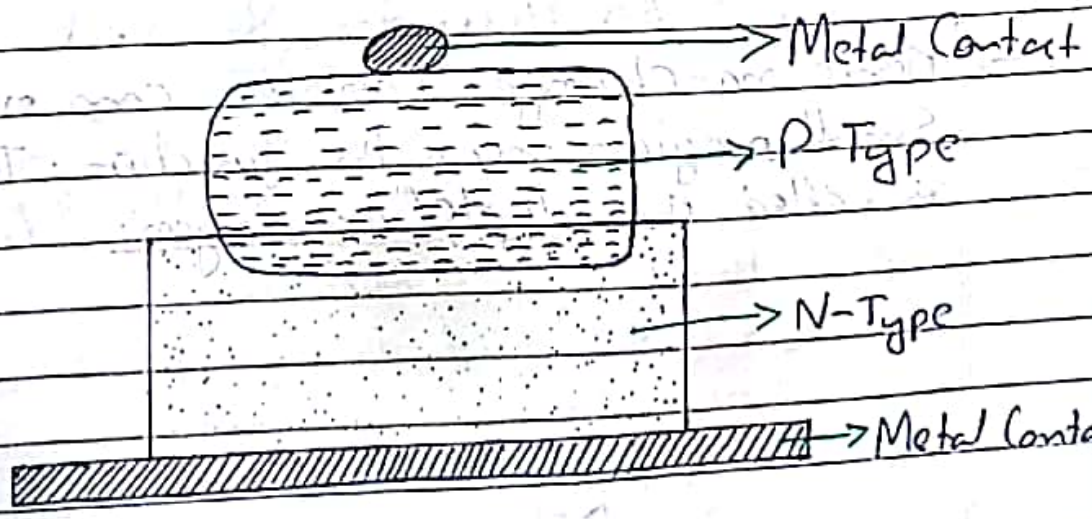
(i) With increase in temperature electron-hole pair increases and hence conductivity increases.

(ii) With increase in temperature drift speed and hence mobility decreases and hence conductivity decreases.

⇒ However, the effect of increasing charge carriers is much more prominent than the effect of the decreases in drift speed.

⇒ Hence in general conductivity increases with increase in temperature.

⇒ P-N Junction



Scanned by CamScanner

* Schematic representation

h h h h	e e e e
h h h h	e e e e
h e h h	e h e e
h h h h	e e e e
↓	↓
P-Type	N-Type

⇒ The above setup cannot be at Equilibrium, as there is a large concentration of holes in the left half and a small concentration of it in the right side.

⇒ So at the junction, some holes will be occupied by electrons, creating a net electric field near the junction from right to left.

⇒ Hence no charge carrier can remain in a small region near the junction. This region is called the <u>depletion layer</u>.

Scanned by CamScanner

* Diffusion current ⇒ Diffusion current is a current in a semiconductor caused by the diffusion of charge carriers {holes/electrons}.

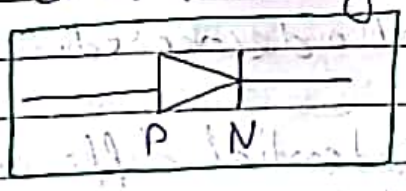
* Drift Current ⇒ Electric current due to applied electric field.

⇒ In steady state, the diffusion current equal the drift current in magnitude and there is no net transfer of charge at any cross-section.

⇒ P-N Junction diode

* Diode ⇒ Any device which freely allows electric current in one direction but dose not allow it in the opposite direction is called a diode.

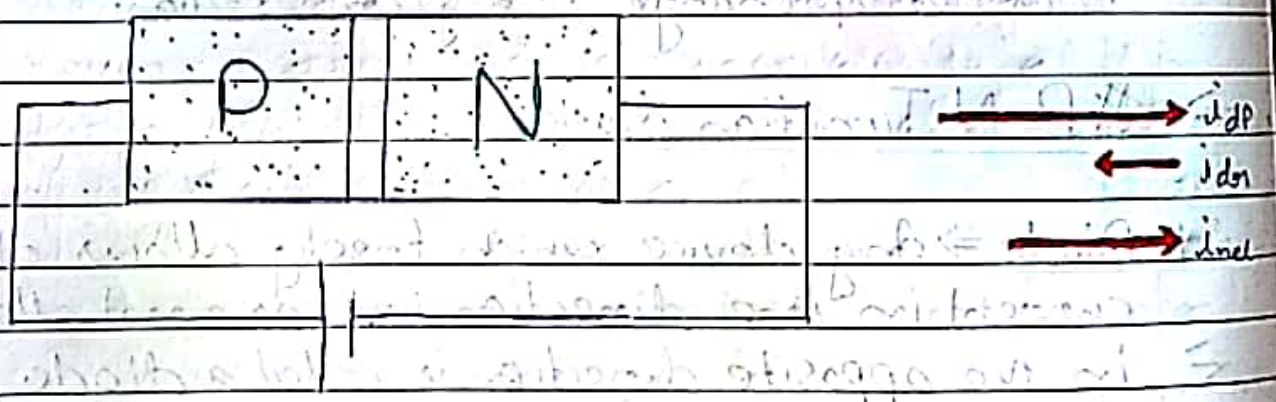
⇒ The diode is Symbolised as :-



Scanned by CamScanner

(a) Case 1: Battery is connected with its positive terminal connected to the p-side and the negative terminal connected to the n-side.

⇒ If positive terminal of the battery is connected to the p-side and the negative terminal to the n-side, we say that the junction is **Forward-biased**.



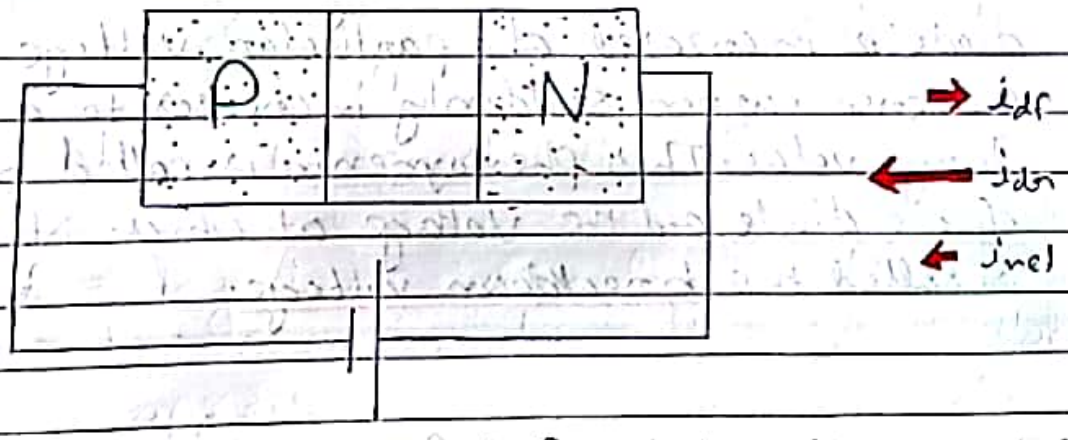
⇒ The diffusion increases as the applied potential difference is increases and barrier height is also decreased.

⇒ When the applied potential difference is so high that the potential barrier is reduced to zero or is reversed, the diffusion increases very rapidly.

{A P-N Junction dosenot obey Ohm's Law}

(b) Case 2: Battery is connected with its positive terminal connected to the n-side and the negative terminal connected to the P-side.

⇒ If the P-side of the junction is connected to the negative terminal and the n-side to the positive terminal of a battery, the junction is said to be **reverse-biased**.



⇒ There is a net current from n-side to the p-side but ~~a net~~ the current ~~from the n-side to the~~ is small as the drift current itself is small {typically in microamperes}.

* Dynamic Resistance, $R = \frac{\Delta V}{\Delta i}$

Scanned by CamScanner

* Photo diode ⇒ A photodiode is a type of photodetector capible of converting light into either current or voltage.

* Light-emitting diode (LED) ⇒ LED is a semiconductor light source.

⇒ Zener diode

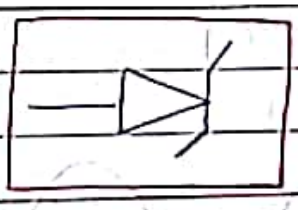
⇒ If the reverse-bias voltage across a P-n junction diode is increased, at a particular voltage the reverse current suddenly increases to a large value. This phenomenon is called breakdown of the diode and the voltage at which it occures is called the breakdown voltage.

* Zener breakdown ⇒ Breakdown in which the electric field enables tunneling of electrons from the valence to the conduction band of a semiconductor, leading to a large number of free minority carriers which suddenly increases the reverse current.

Scanned by CamScanner

* Avalanche breakdown ⇒ If the minority carriers acquire sufficient kinetic energy from the electric field and collide with a valance electron, the bond will be broken and the valence electron will be taken to the conduction band. Thus a hole-electron pair will be created.

⇒ Once the breakdown occurs, the potential difference across the diode does not increase even if the applied battery potential is increased.



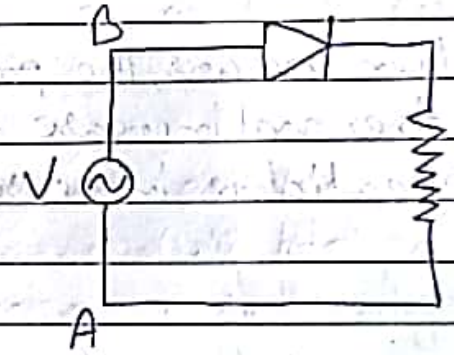
"Representation of zener diode"

Scanned by CamScanner

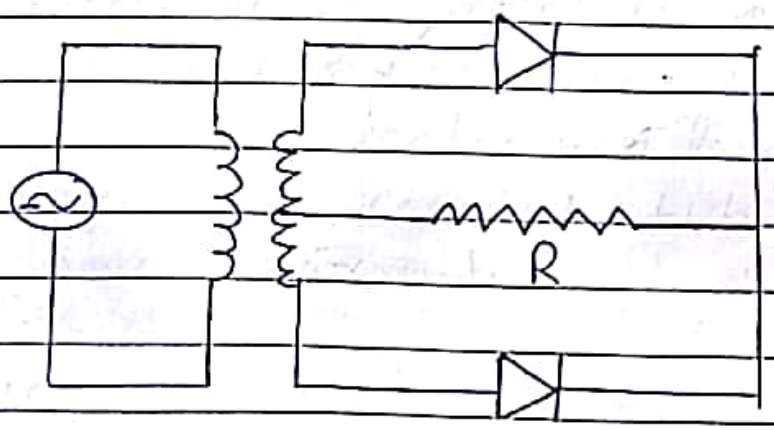
P-N Junction as a rectifier

* **Rectifier** ⇒ A rectifier is a device which converts an alternating current into a direct current.

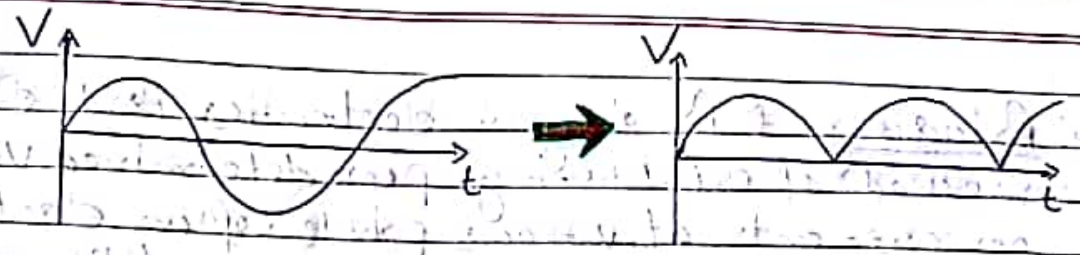
(I) Half wave Rectifier



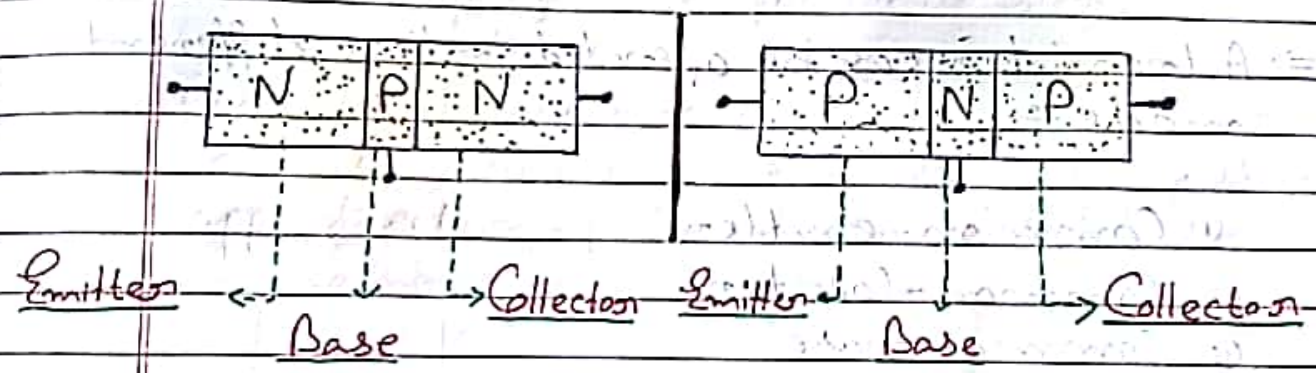
(II) full wave Rectifier



Scanned by CamScanner



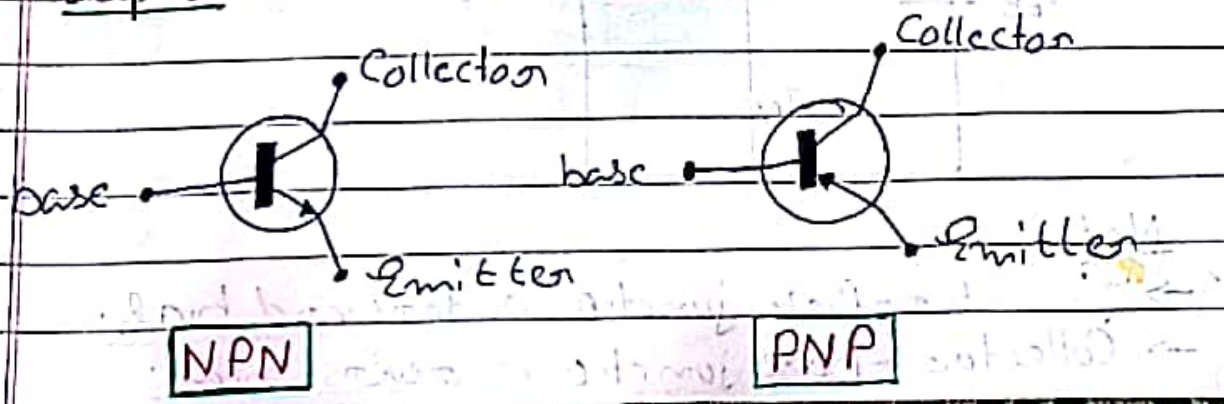
⇒ Junction Transistors



* Base ⇒ The middle layer is called the base and is very lightly doped with impurity.

* Emitter ⇒ One of the outer layers is heavily doped and is called Emitter.

* Collector ⇒ The other layer is moderately doped and is called Collector.



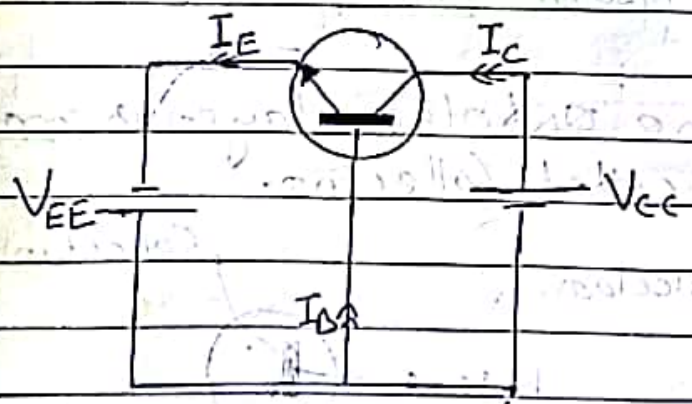
* **Biasing** ⇒ Biasing in electronics is the method of establishing predetermined voltages or currents at various points of an electronic circuit for proper operating conditions in electronic components.

⇒ A transistor can be operated in three different mode :-

(i) Common-emitter
(ii) Common-Collector
(iii) Common-base

* **Working of Transistor**

Let us consider an n-p-n transistor connected to the proper biasing batteries.



Note

→ Emmiter-Base junction is forward bias.
→ Collector-Base junction is reverse bias.

Scanned by CamScanner

⇒ The thickness of the base region is so small that most of the electrons diffusing into the base region cross over into the collector region.

⇒ The reverse bias of the base-collector junction helps this process, because, as the electrons appears near this junction they are attracted by the collector.

⇒ These electrons go through the batteries V_{CC} and V_{EE} and are then back to the emitter.

* Emitter current ⇒ The electrons going from the battery V_{EE} to the emitter constitute the $\boxed{\text{Emitter current } I_E}$

* Collector current ⇒ The electrons going from the collector to the battery V_{CC} constitute the $\boxed{\text{Collector current } I_C}$

* Base current ⇒ Current through wire connecting base is $\boxed{\text{base current } I_B}$.

$$\boxed{I_E = I_B + I_C} \quad (1) \left\{ \text{using Kirchhoff's Law} \right\}$$

Scanned by CamScanner

* α and β - Parameters

$$\alpha = \frac{I_C}{I_E} \quad \text{—(ii)} \quad \{\text{Defination}\}$$

$$\beta = \frac{I_C}{I_B} \quad \text{—(iii)} \quad \{\text{Defination}\}$$

⇒ Using Eq (ii) & (iii) we get :-

$$\boxed{\beta = \frac{\alpha}{1-\alpha}}$$

* Common emitter transistor Characteristics

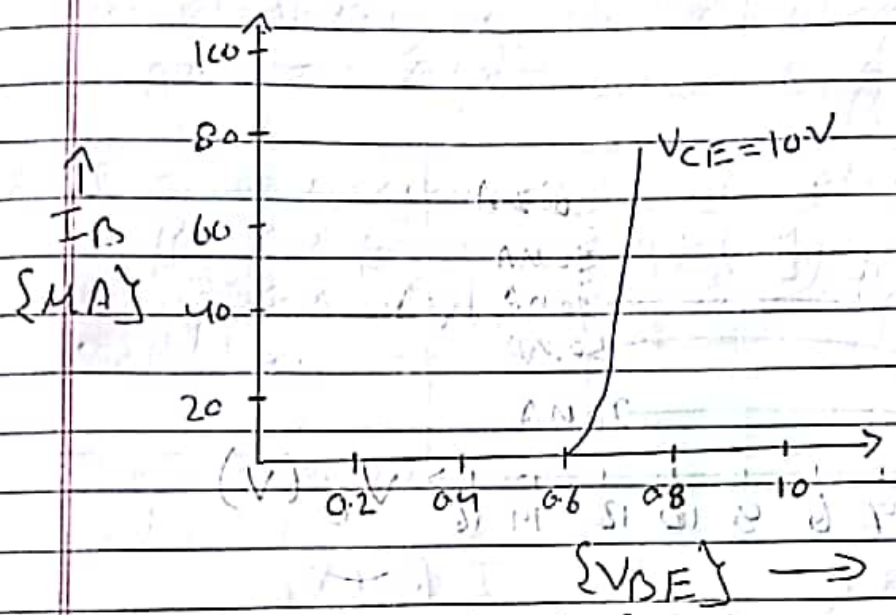
When a transistor is used in CE Configuration, the input is between the base and the emitter and output is between the collector and the emitter.

⇒ Input Characteristics ⇒ The variation of the base Current I_B with the base-emitter Voltage V_{BE} is called the input Characteristics

⇒ Output Characteristics ⇒ The variation of the Collector current I_C with the Collector-emitter Voltage V_{CE} is called the output Characteristics.

Scanned by CamScanner

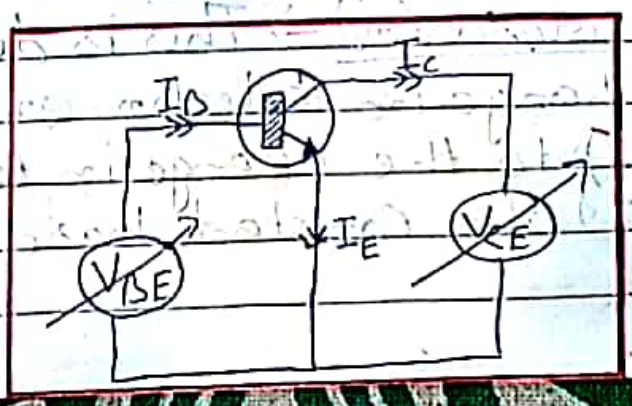
// Input Characteristics.



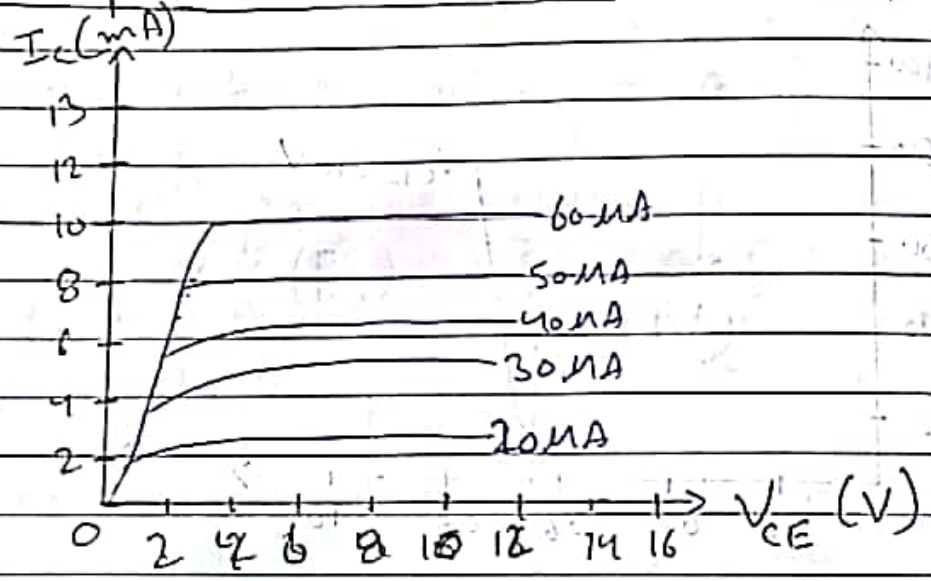
Note

⇒ Collector-emitter voltage V_{CE} is kept large enough to make the base collector junction reverse biase.

⇒ For Si-transistor V_{BE} is 0.6 to 0.7V



Output Characteristic



(i) Input resistance (r_i) ⇒ This is defined as the ratio of change in base-emitter Voltage (ΔV_{BE}) to the resulting change in base current (ΔI_B) at Constant Collector-emitter Voltage (V_{CE}).

$$r_i = \left(\frac{\Delta V_{BE}}{\Delta I_B}\right)_{V_{CE}}$$

(ii) Output resistance (r_o) ⇒ This is defined as the ratio of change in collector-emitter Voltage (ΔV_{CE}) to the change in collector current (ΔI_C) at a Constant base current I_B.

Scanned by CamScanner

$$r_o = \left(\frac{\Delta V_{CE}}{\Delta I_C}\right)_{I_B}$$

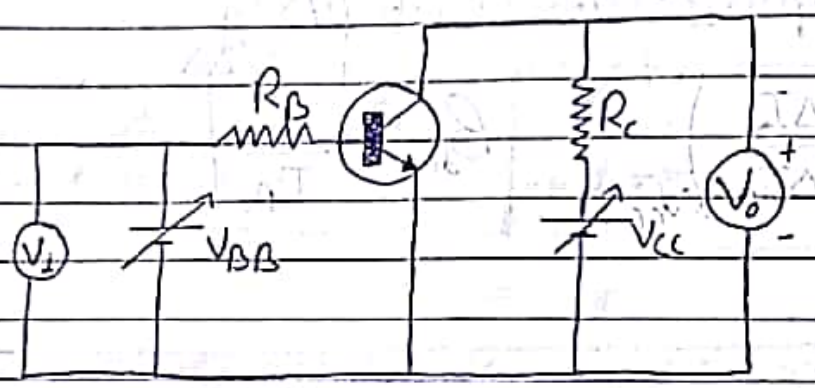
(iii) Current amplification factor (β)

$$\beta_{ac} = \left(\frac{\Delta I_C}{\Delta I_B}\right)_{V_{CE}} \qquad \beta_{dc} = \frac{I_C}{I_B}$$

Scanned by CamScanner

⇒ Transistor as device

① Transistor as switch



⇒ $V_{BB} = I_B R_B + V_{BE}$ & $V_{CC} = I_C R_C + V_{CE}$

{using Kirchhoff's Law}

⇒ $V_i = I_B R_B + V_{BE}$

$V_o = V_{CC} - I_C R_C$

{using above equations & Kirchhoff's Law}

⇒ Let us see how V_o changes as V_i increases from zero onward in case of Si-transistor.

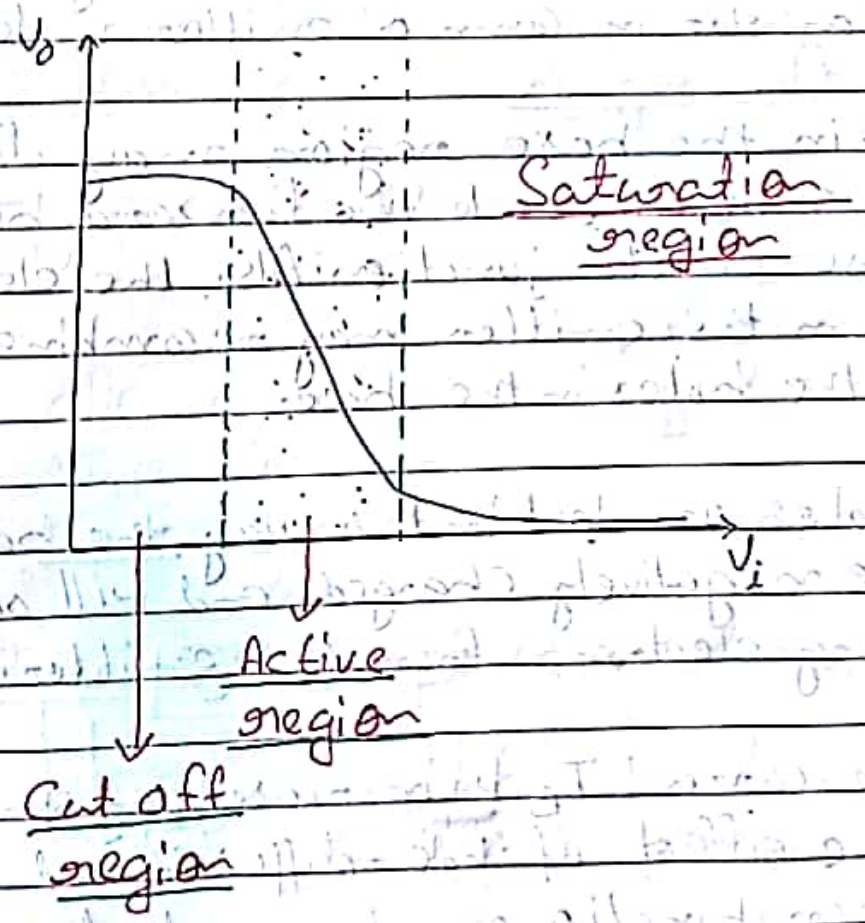
★ As long as input V_i is less than 0.6 V, the transistor will be in cut off state and current I_C will be zero.

Hence $V_o = V_{CC}$

Scanned by CamScanner

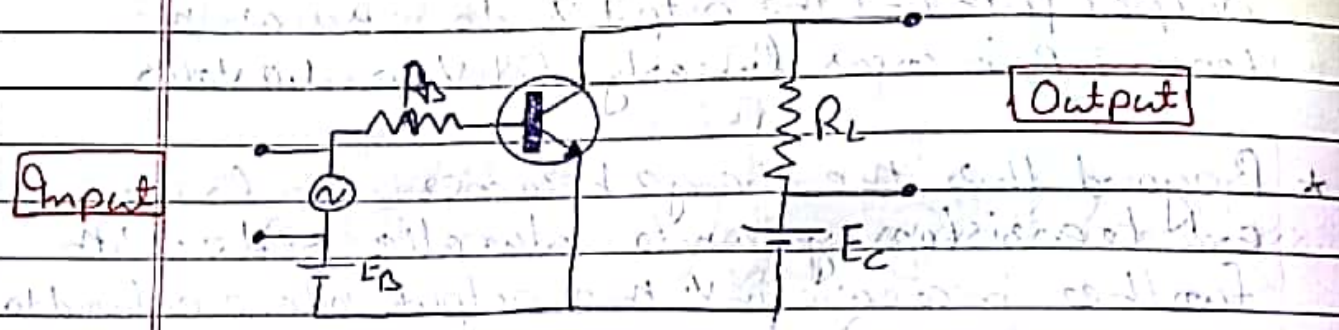
★ When V_i become greater than 0.6V, the transistor is in active state with some current I_c in the output path and the output V_o decreases as the term I_cR_c increas linearly, till V_i is 1.0 Volt.

★ Beyond this, the change becomes non linear and transistor goes into saturation state. With further increase in V_i the output voltage is found to decrease further towards zero through it may never become zero.



Scanned by CamScanner

② Transistor as Amplifier



"Figure shows an amplifier circuit using an n-p-n transistor in common emitter mode"

⇒ The holes in the base region may diffuse into the emitter due to the forward biasing of the base-emitter junction. Also, the electrons coming from the emitter may recombine with some of the holes in the base.

⇒ If the holes are lost in this way, the base will become negatively charged and will obstruct the incoming electrons from the emitter.

⇒ If the base current I_B is increased by small amount, the effect of hole-diffusion and hole-electron recombination may be neutralised and the collector current will be increased.

Scanned by CamScanner

⇒ Thus, a small change in the current I_B in the base circuit controls the larger current I_C in the collector circuit.

⇒ This is the basis of amplification with the help of a transistor.

Note

→ The current gain defined as $\Delta I_C / \Delta I_B$, is typically of the order of 50.

* Voltage gain, Current gain, Power gain

→ Voltage gain ⇒ The ratio V_o/V_i is called the voltage gain of the amplifier.

$$\Delta I_B = \frac{V_i}{R_{BE}} \quad \text{—(1)}$$

⇒ The collector current I_C and I_B is related as :-

$$I_C = \beta I_B \Rightarrow \Delta I_C = \beta \Delta I_B$$

$$\Rightarrow \Delta I_C = \frac{\beta V_i}{R_{BE}} \quad \{\text{from eq (1)}\}$$

$$\Rightarrow V_o = \Delta I_C R_L = \frac{\beta V_i R_L}{R_{BE}}$$

Scanned by CamScanner

Hence, Voltage gain $\boxed{\frac{V_o}{V_i} = \beta \frac{R_L}{R_{BE}}}$

→ Current gain, $\boxed{\frac{\Delta I_C}{\Delta I_B} = \beta}$

→ Power gain = Voltage gain * Current gain

$$\Rightarrow \boxed{\frac{\beta^2 R_L}{R_{BE}}}$$

* Transfer Conductance

"Transfer Conductance is defined as :-"

$$\boxed{g_m = \frac{\Delta I_C}{\Delta V_{BE}}}$$

* Transistor used in an Oscillator circuit

⇒ The function of an oscillator circuit is to produce an alternating voltage of desired frequency when only DC batteries are available.

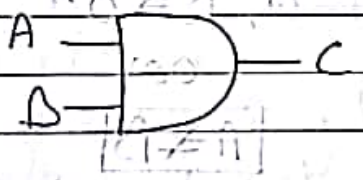
$$\boxed{f = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}}$$

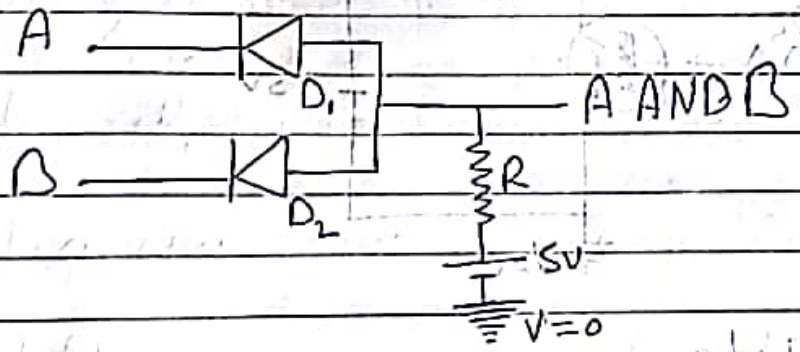
Scanned by CamScanner

⇒ LOGIC GATES

① AND Gate

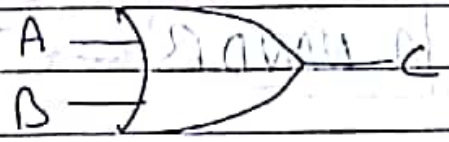
"C=1 if A and B are 1"

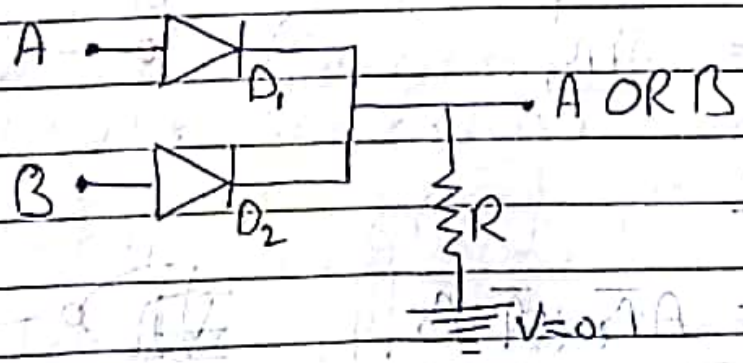




② OR Gate

"C=1 if A or B is 1"





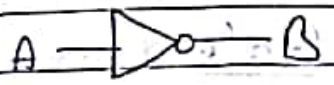
Scanned by CamScanner

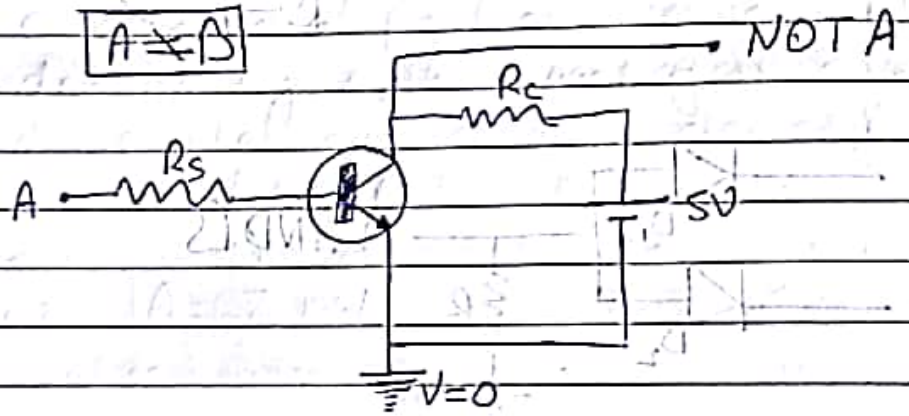
③ Not gate

"If $A=1, B\neq 1$ and if $A=0, B\neq 0$"

or

$\boxed{A \neq B}$



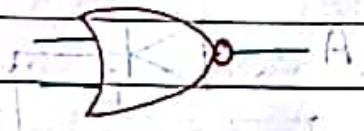


④ NAND gata

$\boxed{A \text{ NAND } B = \overline{AB}}$

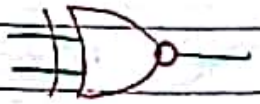
⑤ NOR Gate

$\boxed{A \cdot \text{NOR } B = \overline{A+B}}$



⑥ XOR Gate

$\boxed{A \text{ XOR } B = A\overline{B} + \overline{A}B}$



Scanned by CamScanner

5
The NUCLEUS

⇒ Properties of Nucleus

① Nuclear Constituents

⇒ Nucleus is made of proton and neutrons.

$m_p = 1.672 \times 10^{-27}$ Kg

$m_n = 1.674 \times 10^{-27}$ Kg

⇒ It is customary in nuclear physics and high energy physics to represent mass in energy units according to the conversion formula $E = mc^2$. (Matter can be viewed as a condensed form of energy).

Thus, $m_p = 938.27$ MeV/c^2

$m_n = 939.56$ MeV/c^2

* Rest mass energy ⇒ The energy corresponding to the mass of the particle when it is at rest is called its rest mass energy.

* Fermions ⇒ Any particle that obey pauli exclusion principle are called fermions.

* Pauli exclusion principle ⇒ No two identicle particle can occupy same quantum state.

Scanned by CamScanner

→ Proton and neutrons are fermions.

* Nucleons ⇒ Protons and neutrons are collectively called nucleons.

⇒ The number of protons in a nucleus {Atomic number} is denoted by Z, the number of neutrons by N and the total number of nucleons {Mass number} is denoted by A.

Thus, $\boxed{A = Z + N}$

⇒ A nucleus is symbolically expressed as ${}^{A}_{Z}X$.

* isotopes ⇒ The nuclei having the same number of protons but different number of neutrons are called isotopes.

* isotones ⇒ The nuclei having the same number of neutrons but different number of protons are called isotones.

* isobars ⇒ The nuclei with same mass number.

* nuclide ⇒ All the nuclei with given Z & N are collectively called nuclide.

Scanned by CamScanner

classmate
Date
Page

② Nuclear stability

for stable nuclie
(i) $\frac{p}{n} \approx 1$ {light nuclie}
(ii) $\frac{p}{n} \approx \frac{1}{1.5}$ {heavy nuclie}

⇒ More than 1000 nuclides have been identified but not all are stable.

⇒ An unstable nucleus emits some kind of particle and changes its constitution {called radioactive nuclide}.

⇒ A stable nucleus maintains its constitution at the time.

③ Nuclear radius

⇒ Experiments show that the average radius R of a nucleus may be written as :-

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

$R_0 = 1.1$ fm
A = mass number

④ Nuclear spin

⇒ The protons and neutrons inside a nucleus move in well-defined quantum states and thus have orbital angular momentum.

⇒ Apart from this, protons and neutrons also have internal spin angular momentum. $m_s = +\frac{1}{2}$ or $-\frac{1}{2}$.

Scanned by CamScanner

⇒ The total angular momentum of the nucleus is the resultant of all the spin and orbital angular momentum of the individual nucleons.

* Spin ⇒ The total angular momentum of a nucleus is called the nuclear spin.

⇒ Nuclear force

ⓐ Nuclear forces are short-ranged. They are most effective only upto a distance of the order of a femtometer or less.

ⓑ Nuclear forces are, on an average, much stronger than electromagnetic force (50-60 times stronger) in the nuclear range.

ⓒ Nuclear forces are independent of charge.

ⓓ An important property of nuclear force is that it is not a central force. The force between a pair of nucleons is not solely determined by the distance between the nucleons.

ⓔ The force is stronger if the spins of the nucleons are parallel and weaker in not parallel.

Scanned by CamScanner

⇒ Binding Energy

"Binding Energy is the energy required to disassemble a whole entity into separate parts"

⇒ Thus, the rest mass energy of a nucleus is smaller than the rest mass energy of its constituent nucleons in free state.

→ The difference of the two energies is the binding energy.

$$\boxed{B = (Zm_p + Nm_n - M)c^2}$$

⇒ Binding Energy can be expressed in terms of the following :-

ⓐ Volume energy

⇒ Each nucleons interact with its surrounding nucleons. Hence energy associated with it is proportional to number of nucleons.

$$b_v = a_1 A \quad \text{—①}$$

Scanned by CamScanner

classmate
Date
Page

ⓑ Surface energy

⇒ Nucleons at the surface does not ~~interact~~ interact with nucleons through all side, that it decreases binding energy proportional to surface area.

$$b_s = -a_2 A^{2/3} \quad \text{—ⓘⓘ}$$

ⓒ Coulombs repulsion energy

⇒ The coulomb potential energy is proportional to $Z(Z-1)/r$ and is inversly proportional to the nuclear radius R.

$$b_c = -a_3 Z(Z-1)/A^{1/3}$$

$$\Rightarrow \boxed{\frac{B}{A} = a_1 - \frac{a_2}{A^{1/3}} - a_3 \frac{Z(Z-1)}{A^{4/3}}}$$

* Mass Excess ⇒ (Actual mass) − (Calculated mass)

Scanned by CamScanner

⇒ Radioactive decay

⇒ The two main processes by which an unstable nucleus decays are alpha decay and beta decay.

★ Alpha decay

⇒ In alpha decay, the unstable nucleus emits an alpha particle reducing its proton number Z as well as its neutron number N by 2.

→ The alpha decay process may be represented as :-

$$\boxed{{}^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He}$$

Parent nucleus ← → daughter nucleus

⇒ Alpha decay occurs in all nuclei with mass number, $A > 210$.

* Q-Value ⇒ The difference between the rest mass energy of the initial constituents and that of the final products is called the Q-value of the process.

Scanned by CamScanner

$$\boxed{Q = U_i - U_f}$$

* alpha ray ⇒ A stream of alpha particles coming from a bulk material is called alpha ray.

★ Beta decay

"Beta decay is a process in which either a neutron is converted into a proton or a proton is converted into a neutron"

→ Such transformations takes place because of weak forces operating within a neutron or a proton.

→ Case 1: neutron converted into proton.

⇒ When a neutron is converted into a proton, an electron and a new particle named antineutrino are created and emitted from the nucleus.

$$n \longrightarrow P + e + \bar{\nu}$$

⇒ The electron emitted from the nucleus is called a beta particle (β^-).

Scanned by CamScanner

* beta ray ⇒ A stream of beta particle coming from a bulk of unstable nuclei is called beta ray.

⇒ The beta decay process may be represented by:-

$$\boxed{{}^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}Y + \beta^{-} + \bar{\nu}}$$

$$\boxed{Q = \left[m\left({}^{A}_{Z}X\right) - m\left({}^{A}_{Z+1}Y\right)\right]c^2}$$

⇒ Case 2: Proton converted into neutron.

⇒ When a proton is converted into neutron, an ~~electron~~ positron and neutrino are created and emitted from the nucleus.

$$p \rightarrow n + e^{+} + \nu$$

⇒ The positron so emitted is called a beta plus decay.

Note

→ When an electron and positron collids, both the particles are distroyed and energy is made available.

Scanned by CamScanner

⇒ The beta plus decay process may be represented as:

$$^{A}_{Z}X \longrightarrow ^{A}_{Z-1}Y + \beta^{+} + \nu$$

$$Q = \left[m(^{A}_{Z}X) - m(^{A}_{Z-1}Y) - 2m_e\right]c^2$$

⇒ An isolated proton does not beta^{+} decay to neutron as mass of neutron is greater than proton.

⇒ <u>Electron capture</u>

⇒ In this process proton capture an electron and convert itself to neutron and neutrino.

$$p + e \rightarrow n + \nu$$

⇒ Process may be represented as:

$$^{A}_{Z}X + e \longrightarrow ^{A}_{Z-1}Y + \nu$$

$$Q = \left[m(^{A}_{Z}X) - m(^{A}_{Z-1}Y)\right]c^2$$

⇒ When an atomic electrons are captured, X-rays are emitted.

Scanned by CamScanner

★ Gamma decay

"nucleons in higher energy quantum state goes to lower quantum state by emitting Y-rays is known as gamma decay".

* radioactive decay ⇒ α, β & Y decay are collectively called radioactive decay.

* radioactive material ⇒ The material capable of undergoing radioactive decay are called radioactive material.

* Nuclear radiation ⇒ The α-, β and Y-rays are collectively called Nuclear radiation.

Scanned by CamScanner

⇒ Law of Radioactive decay

Strange behaviour

⇒ Suppose several identical active nuclei are prepared at the same instant and are kept in identical environment. They will, in general not decay simultaneously. Some will decay quite early and some will live longer.

⇒ No rule in physics predicts the time at which it will decay. Only when it decays we know that it has done so.

⇒ Radioactive decay cannot be described by classical physics. One has to use quantum mechanics to understand it.

⇒ In quantum mechanics, the equations of physics do not predict the exact future of a system in terms of the present condition. The equations only give the probability of a particular particle behaving in a particular fashion.

Scanned by CamScanner

⇒ Suppose there are N active nuclei at an instant t. The number of nuclei that will decay is proportional to small time gap dt and number of active nuclei N :-

$$\boxed{dN = -\lambda N dt} \quad \{\lambda = \text{decay constant}\}$$

$$\Rightarrow \boxed{N = N_0 e^{-\lambda t}} \quad \{N_0 = \text{number of active nuclei at } t=0\}$$

$$\Rightarrow -\frac{dN}{dt} = \lambda N$$

→ The quantity $\left(-\frac{dN}{dt}\right)$ gives the number of decay per unit time and is called the activity of the sample.

Thus,

$$\boxed{A = A_0 e^{-\lambda t}} \quad \{[A] = \text{disintegration/s or Curie (Ci)}\}$$

* Specific activity ⇒ The activity per unit mass is called specific activity.

Scanned by CamScanner

★ Half-life

"The time elapsed before half the active nuclei decay is called half-life and is denoted by $t_{1/2}$"

$$\Rightarrow \frac{N_0}{2} = N_0 e^{-\lambda t_{1/2}} \qquad \boxed{t_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda}}$$

⇒ As activity is proportional to N, the activity also reduces to half its value in one half-life.

$$N = N_0 e^{-\frac{\ln 2\, t}{t_{1/2}}} = \frac{N_0}{(e^{\ln 2})^{t/t_{1/2}}}$$

$$\Rightarrow \boxed{N = \frac{N_0}{2^{t/t_{1/2}}}}, \text{ Similarly } \boxed{A = \frac{A_0}{2^{t/t_{1/2}}}}$$

★ Average life

⇒ The number of nuclei which decay between the time t and t+dt is $\lambda N dt$.

⇒ The life of these nuclei is approximately t each.

⇒ The sum of the lives of these dN nuclei is $t\lambda N dt$.

Scanned by CamScanner

⇒ The sum of all the lives of all the N nuclei that were active at t=0 will be :-

$$S = \int_0^\infty t\lambda N\,dt = \lambda N_0 \int_0^\infty t e^{-\lambda t}\,dt$$

$$\Rightarrow \frac{\lambda N_0}{\lambda^2} = \frac{N_0}{\lambda}$$

$$\Rightarrow \boxed{t_{av} = \frac{S}{N_0} = \frac{1}{\lambda} = \frac{t_{1/2}}{\ln 2}}$$

⇒ Properties and use of nuclear radiation

★ Alpha ray

⇒ Its penetrating power is low. Even in air its intensity falls down to very small values within a few centimeters.

⇒ Alpha rays coming from radioactive materials travels at large speeds of the order of 10^6 m/s.

⇒ All the alpha particles coming from a particular decay scheme have the same energy.

Scanned by CamScanner

⇒ Alpha ray produces scintillation when it strikes certain fluorescent materials such as barium platinocyanide.

⇒ It causes ionization of gas.

★ Beta ray

⇒ Its penetrating power is greater than that of alpha ray. Tipically, it can travel several metres in air before its intensity drop to small values.

⇒ The ionization power is less than that of alpha rays.

⇒ Beta ray also produces scintillation in fluorescent materials, but the scintillation is weak.

⇒ The energy of the beta particle coming from the same decay scheme are not equal.

★ Beta-plus ray

Beta-plus ray has all the properties of beta rays exept that it made of positively charged particle.

Scanned by CamScanner

★ Gamma ray

⇒ It has the least ionizing power and the largest penetrating power among different types of nuclear radiation.

⇒ All the photons coming from a particular gamma decay scheme have the same energy.

⇒ Being an electromagnetic wave, gamma ray travels in vacuum with the velocity c.

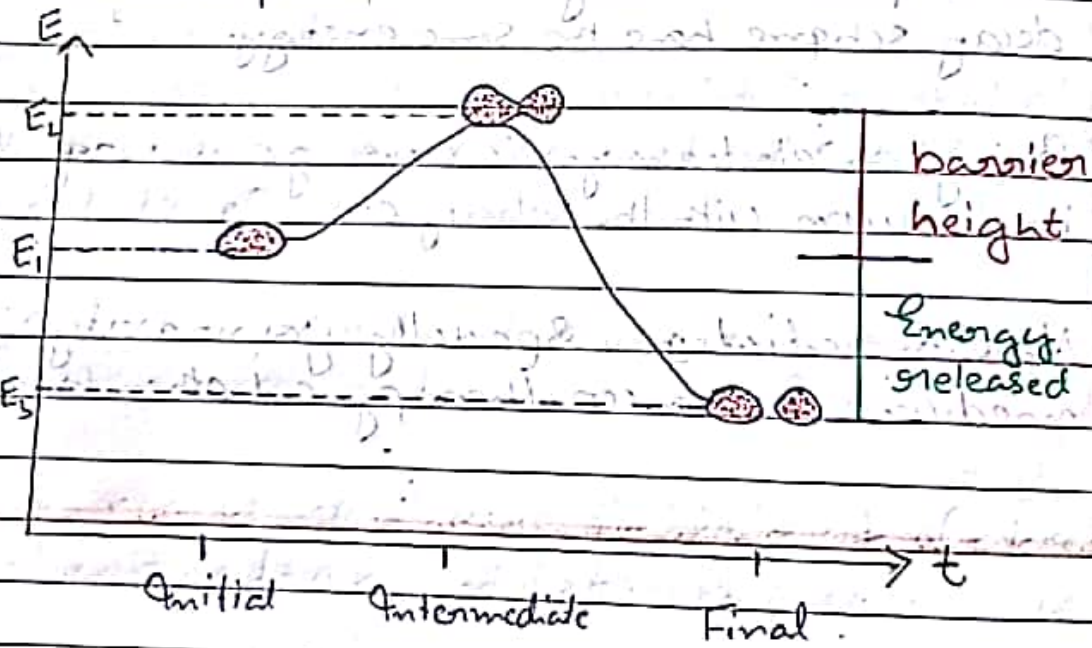
⇒ Nuclear radiation, specially gamma ray, is used in medicine for cancer therapy and other treatement.

Scanned by CamScanner

⇒ Energy from the Nucleus

① Nuclear fission

"Nuclear fission is a process in which the nucleus of a particle splits into two smaller parts".



⇒ According to classical physics, the process is impossible unless energy is supplied to the heavy nucleus to reach the intermediate state. Once it reaches the intermediate state, it can break into two parts and release energy.

Scanned by CamScanner

⇒ According to quantum mechanics, if the final state has lesser energy than the energy in the initial state, there is a chance that the process will take place even if the intermediate state has energy greater than the initial one and no energy is supplied externally.

→ Such processes are called barrier penetration.

⇒ The energy seems to be created out of nothing, a violation of energy conservation! But this is a fact of the physics of small particles. The energy conservation in the usual sense may be violated for "short time".

⇒ The amount of energy seems to be created and the time for which it is created are related through Heisenberg uncertinity relation,

$$\boxed{\Delta E \cdot \Delta t \simeq h/2\pi}$$

Scanned by CamScanner

★ Uranium fission reaction

⇒ The most attractive bid, from a practical point of view, to achieve energy from nuclear fission is to use $^{236}_{92}U$ as the fission material.

⇒ This nuclide is highly fissionable and hence is not found in nature.

⇒ Natural uranium contains about 99.3% of $^{238}_{92}U$ and 0.7% of $^{235}_{92}U$.

⇒ The technique is to hit a uranium sample by slow-moving neutrons.

⇒ A $^{235}_{92}U$ nucleus has large probability of absorbing a slow neutron and forming $^{236}_{92}U$ nucleus.

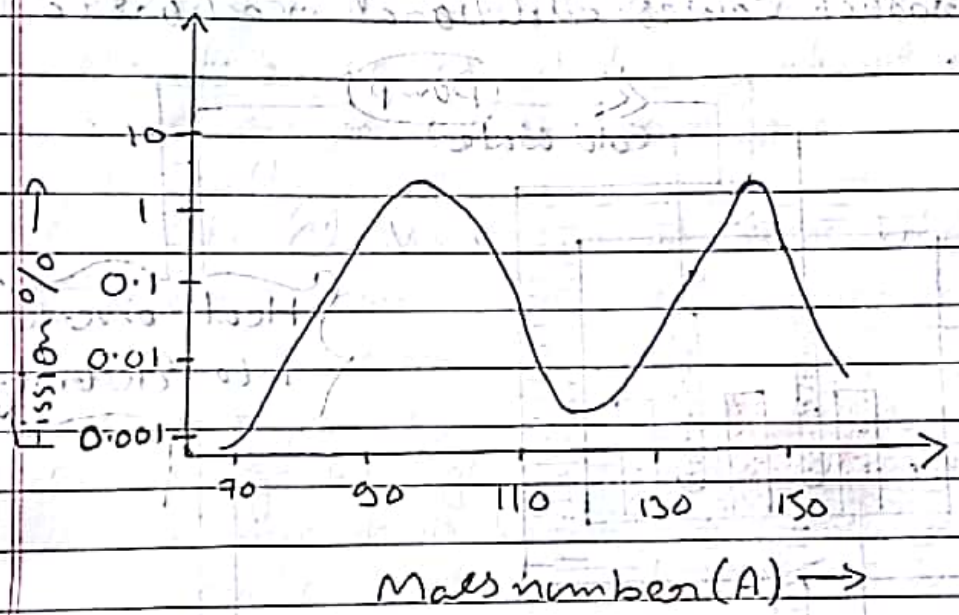
⇒ This nucleus then fissions in two parts and a verity of combinations of the middle-weight nuclei may be formed due to the fission.

- $^{236}_{92}U \longrightarrow {}^{137}_{53}I + {}^{97}_{39}Y + 2n$
- $^{236}_{92}U \longrightarrow {}^{140}_{56}Ba + {}^{94}_{36}K + 2n$

{Examples}

Scanned by CamScanner

⇒ The two fragments generally have unequal mass numbers. ~~as the case is~~

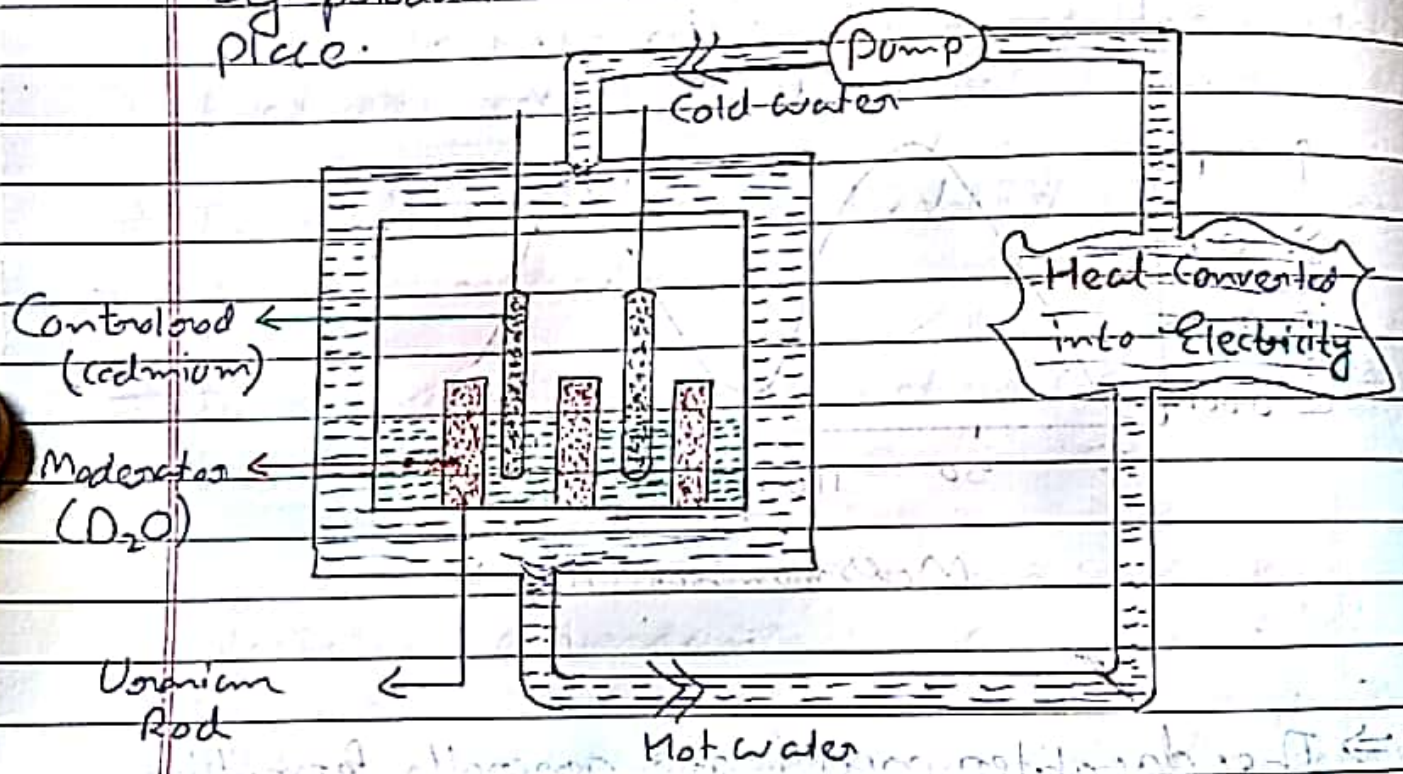


⇒ These daughter nuclei are generally formed in exicited states and consequently emit gamma rays.

* Delayed neutron ⇒ Delayed neutron is a neutron emitted after a nuclear fission event, by one of the fission products any time, from few milliseconds to few minutes after the fission event.

Scanned by CamScanner

* Chain reaction ⇒ A chain reaction is a sequence of reactions where a reactive product or by-product causes additional reactions to take place.



Scanned by CamScanner

② Nuclear Fusion

"Nuclear fusion is a nuclear reaction in which two or more atomic nuclei collides at a very high speed and join to form a new type of atomic nucleus"

⇒ When two light nuclei come close to one another, within the range of attractive nuclear force (≈1 fm), they may combine to form a bigger nucleus.

⇒ To bring the light within the separation of about a femtometre is, however, a difficult task.

⇒ The technique thus is to heat a gas to an extremely high temperature so that the electrons are completely detached and the nuclei move within the gas with large random speeds.

* Thermonuclear fusion ⇒ Thermonuclear fusion is a way to achieve nuclear fusion by using extremely high temperature.

Scanned by CamScanner

★ Fusion in Sun

$$^{1}H + {}^{1}H \rightarrow {}^{2}H + e^{+} + V$$

$$^{2}H + {}^{1}H \rightarrow {}^{3}He + \gamma$$

$$^{3}He + {}^{3}He \rightarrow {}^{4}He + 2\,{}^{1}H$$

$$\boxed{4\,{}^{1}H \longrightarrow {}^{4}He + 2e^{+} + 2V + 2\gamma}$$

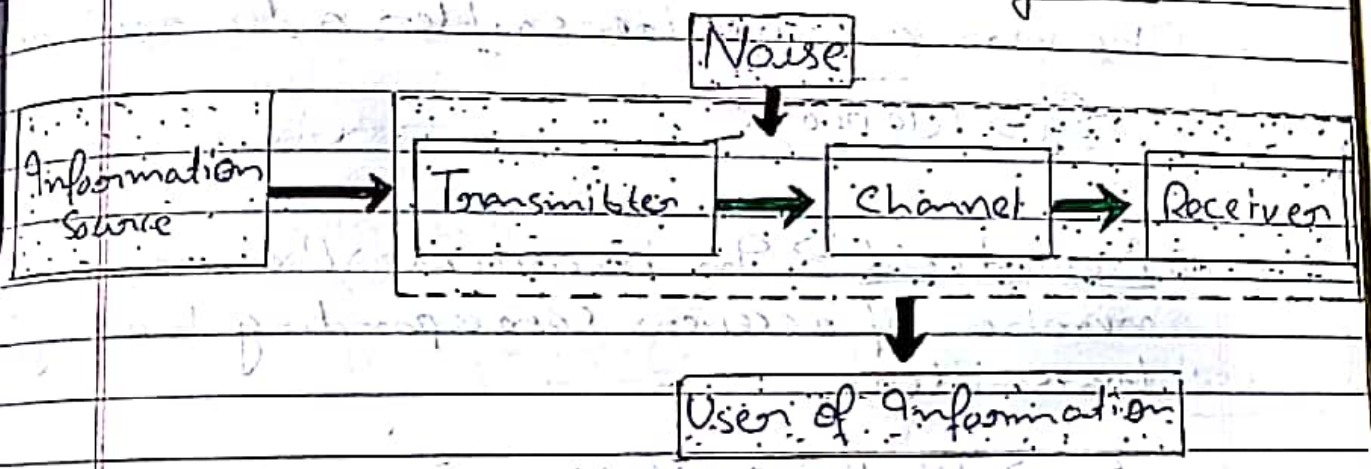
Scanned by CamScanner

6

Communication System

"Communication is the act of transmission of information"

⇒ Elements of a Communication system



* Transmitter ⇒ Transmitter convert the message signal produced by the source of information into a form suitable for transmission through the channel

* Channel ⇒ Channel is the information propagating medium, it may be wire or anything else.

* Receiver ⇒ Receiver receives signal and reconstructs a recognisable form of the original message signal for delivering to the user of information.

Scanned by CamScanner

⇒ There are two basic modes of communication :-

(i) Point-to Point ⇒ In point to point communication mode, communication takes place over a link between a single transmitter and a receiver.

Eg → Telephone

(ii) Broadcast ⇒ In broadcase there are large number of receivers corresponding to a single transmitter.

Eg → TV, Radio etc...

⇒ Basic Terminology used in Electronic Communication Systems

① Transducer ⇒ Any device that converts one form of energy into another can be termed as a transducer.

② Signal ⇒ Information converted in electrical form are suitable for transmission is called a signal

Scanned by CamScanner

Signal

- **Analog** → Analog Signals are ~~[illegible]~~ Continuous various of voltage or current.
- **Digital** → Digital Signals are those which can take only discrete stepwise value.

③ Noise ⇒ Noise refers to the unwanted signals that tend to disturb the transmission and processing of message signals in a communication system.

④ Transmitter ⇒ A transmitter processes the incoming message signal so as to make it suitable for transmission through a channel and subsequent reception.

⑤ Receiver ⇒ A receiver extracts the desired message signal from the received signal at the channel output.

Scanned by CamScanner

⑥ Attenuation ⇒ The loss of strength of a signal while propagating through a medium is known as attenuation.

⑦ Amplification ⇒ It is the process of increasing the amplitude of a signal using an electronic circuit called the amplifier.

⑧ Range ⇒ It is the largest distance between a source and a destination up to which the signal is received with sufficient strength.

⑨ Bandwidth ⇒ Bandwidth refers to the frequency range over which an equipment operates or the portion of the spectrum occupied by the signal.

⑩ Modulation ⇒ Modulation is the process of varying one or more properties of a periodic wave form with a modulating signal that typically contain information to be transmitted.

Scanned by CamScanner

(11) Demodulation ⇒ The process of retrieval of information from the carrier wave at the receiver is termed demodulation.

(12) Repeater ⇒ A repeater is a combination of a receiver and a transmitter.

⇒ Propagation of Electromagnetic Wave

(A) Ground Wave {0 MHz – 3 MHz}

(B) Sky Wave {3 MHz – 30 MHz}

(C) Space wave {40 MHz – ∞ MHz}

Scanned by CamScanner

⇒ Modulation and its necessity

* Baseband ⇒ Baseband is an adjective that describes signals and systems whose range of frequency is measured from close to zero to cut-off frequency.

★ Factors prevents transmitting information and how we overcome

(1) Size of the antenna or aerial

"Antenna should have a size comparable to the wavelength of the signal (atleast $\lambda/4$) so the the antenna properly senses the time variation of the signal"

⇒ For an electromagnetic wave of frequency 20kHz, the wavelength λ is 15 Km.

⇒ ~~Obvious~~ Obviously, such a long antenna is not possible to construct and operate.

⇒ Hence direct transmission with reasonable antenna length is not practical.

Scanned by CamScanner

⇒ Therefore, there is a need of translating the information contained in our original low frequency baseband signal into high or radio frequencies before transmission.

(ii) Effective power radiation by an antenna

⇒ A theoretical study of radiation from a linear antenna (length l) shows that the power radiated is proportional to $(l/\lambda)^2$.

⇒ This implies that for the same antenna length, the power radiated increases with decreasing λ.

(iii) Mixing up of Signals from different transmitters

⇒ If many transmitters are transmitting baseband information signal ~~sim~~ simultaneously. All these signals will get mixed up and there is no simple way to distinguish between them.

⇒ This points out towards a ~~possibility~~ possible solution by using communications at high frequency and alloting a band of frequencies to each message signal for its transmission.

Scanned by CamScanner

⇒ A Sinusoidal carrier wave can be represented as

$$\boxed{c(t) = A_c \sin(\omega_c t + \phi)}$$

⇒ During the process of modulation, any of the three parameters viz, A_c, ω_c and ϕ_c of the carrier wave can be controlled by the message or information signal.

Modulation

- Amplitude modulation (AM)
- Frequency modulation (FM)
- Phase modulation (PM)

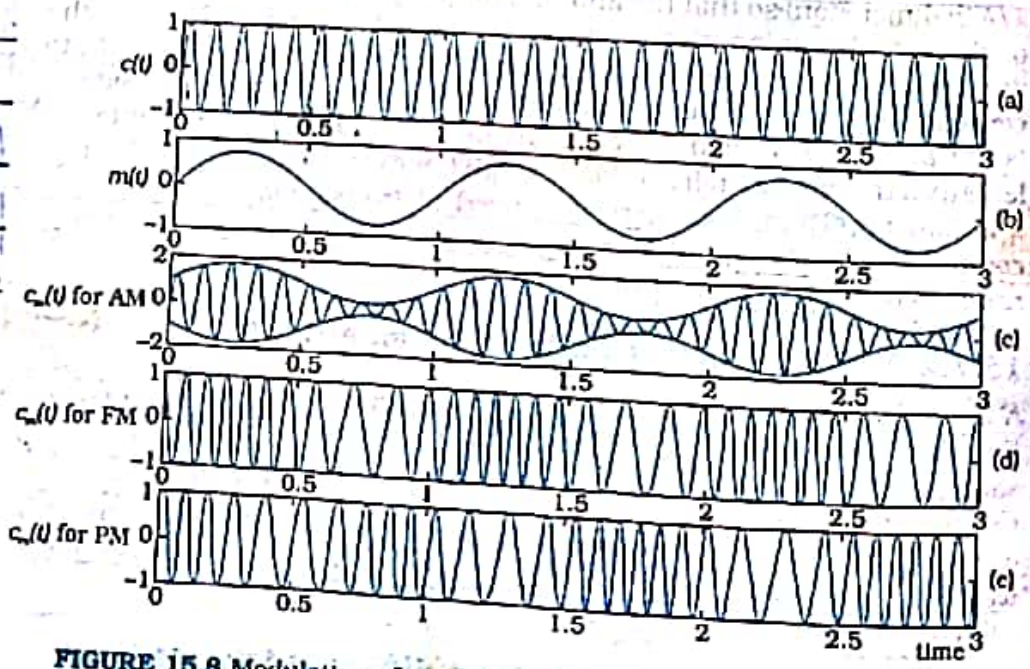


FIGURE 15.8 Modulation of a carrier wave: (a) a sinusoidal carrier wave; (b) a modulating signal; (c) amplitude modulation; (d) frequency modulation; and (e) phase modulation.

Scanned by CamScanner

★ Amplitude modulation

⇒ In amplitude modulation the amplitude of the carrier is varied in accordance with the information signal.

⇒ Let $C(t) = A_c \sin \omega_c t$ represent carrier wave and $m(t) = A_m \sin \omega_m t$ represent the message and $C_m(t)$ represent modulating signal.

⇒ The modulated signal $C_m(t)$ can be written as:-

$$C_m(t) = (A_c + A_m \sin \omega_m t) \sin \omega_c t$$

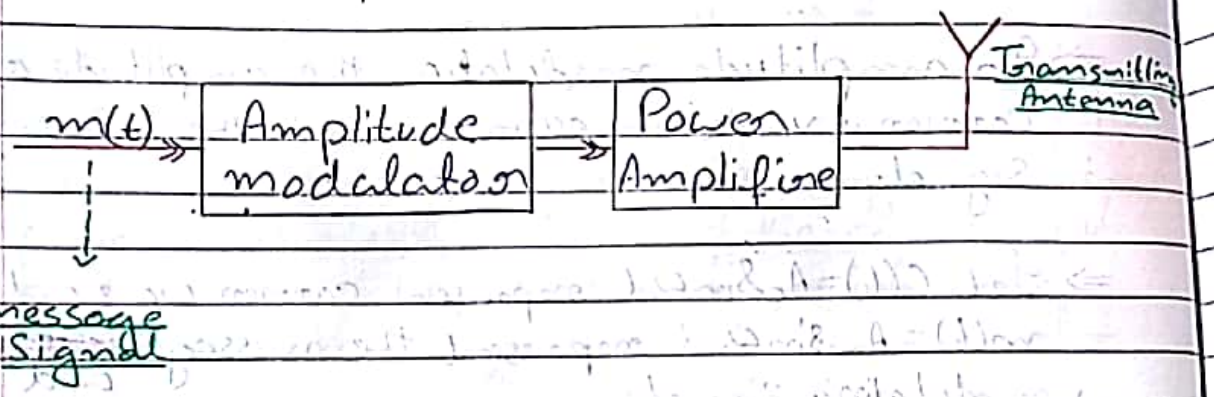
$$\Rightarrow A_c\left(1 + \frac{A_m}{A_c} \sin \omega_m t\right) \sin \omega_c t$$

$$\Rightarrow A_c \sin \omega_c t + \mu A_c \sin \omega_m t \sin \omega_c t$$

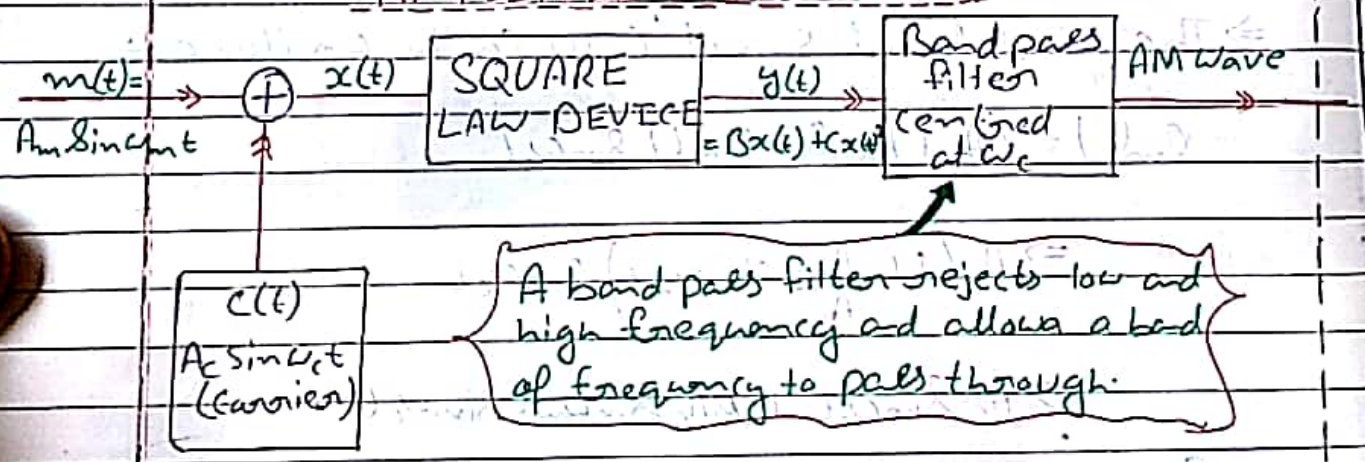
{where, $\mu = A_m / A_c$ is the modulation index}

Scanned by CamScanner

★ Production of Amplitude Modulated wave

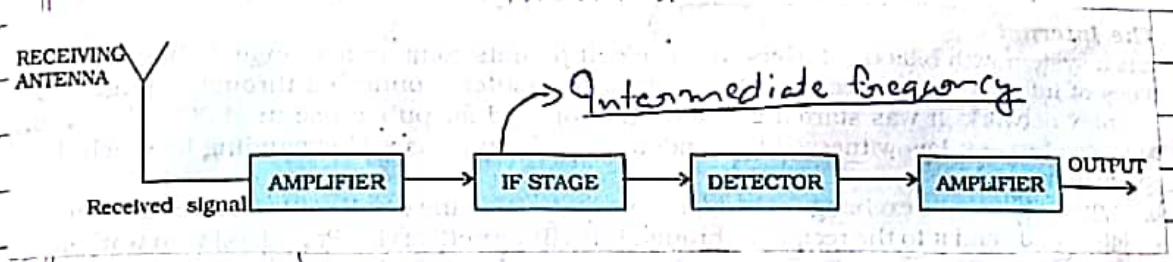


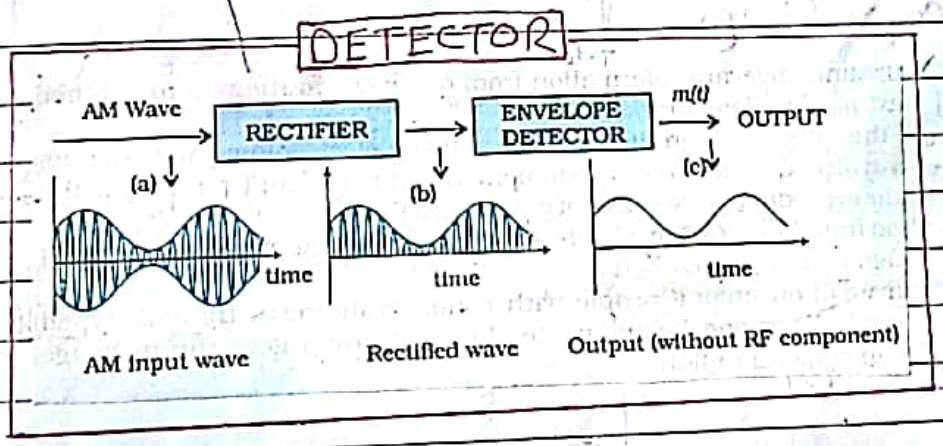
AMPLITUDE MODULATOR



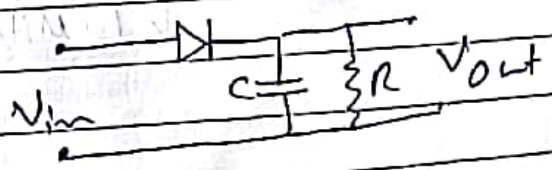
Scanned by CamScanner

★ Detection of Amplitude modulated wave





- Diode detector



⇒ Maximum modulation frequency it can detect is :

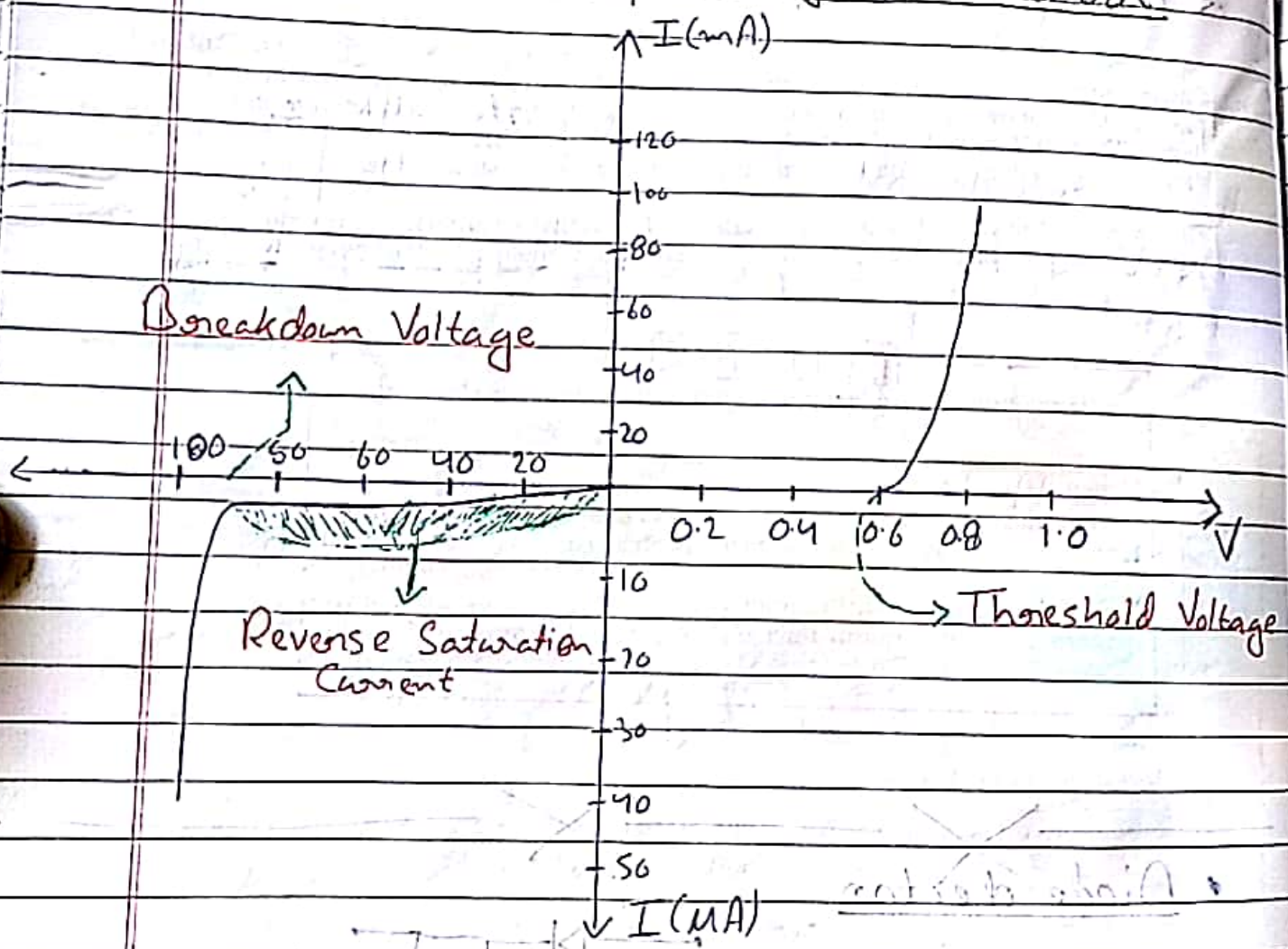
$$f = f_c\sqrt{\frac{1}{m^2}-1}$$

$$f_c = \frac{1}{2\pi RC} \quad \left\{\omega_c = \frac{1}{RC}\right\}$$

Scanned by CamScanner

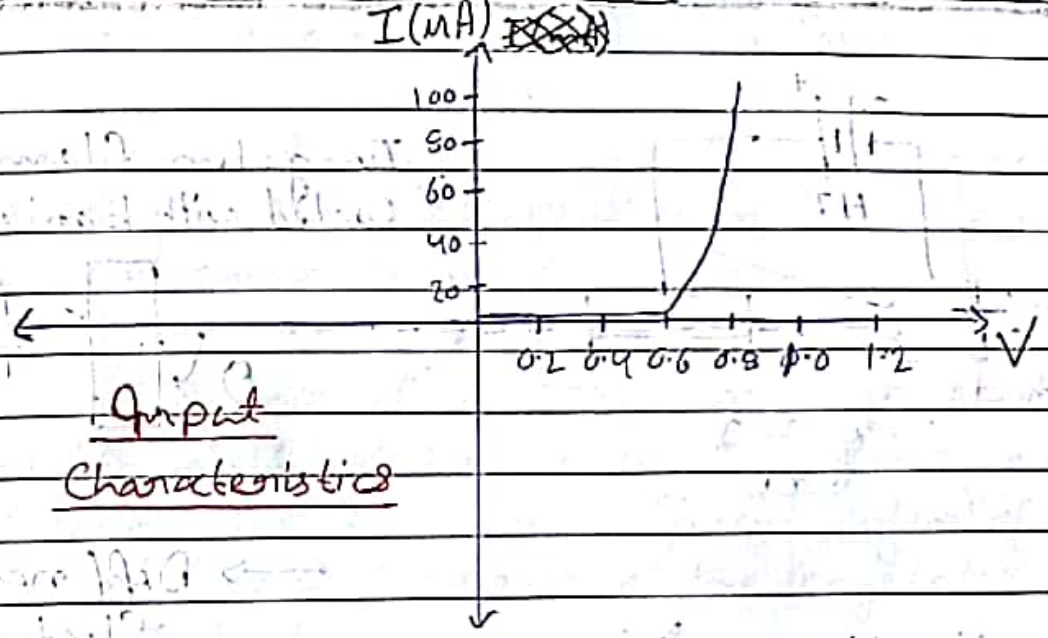
Additional topics

① Characteristics of P-N junction diode

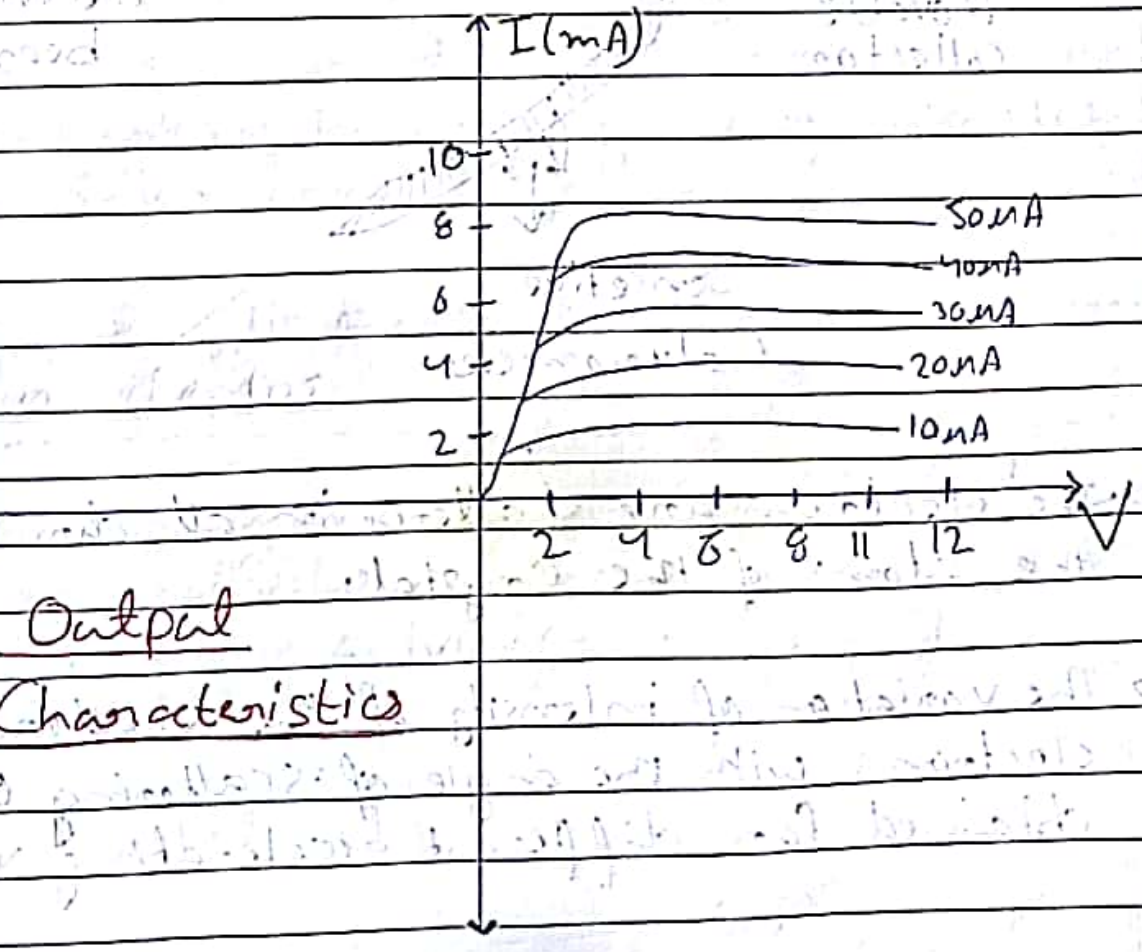


Scanned by CamScanner

(2) Transistor characteristics

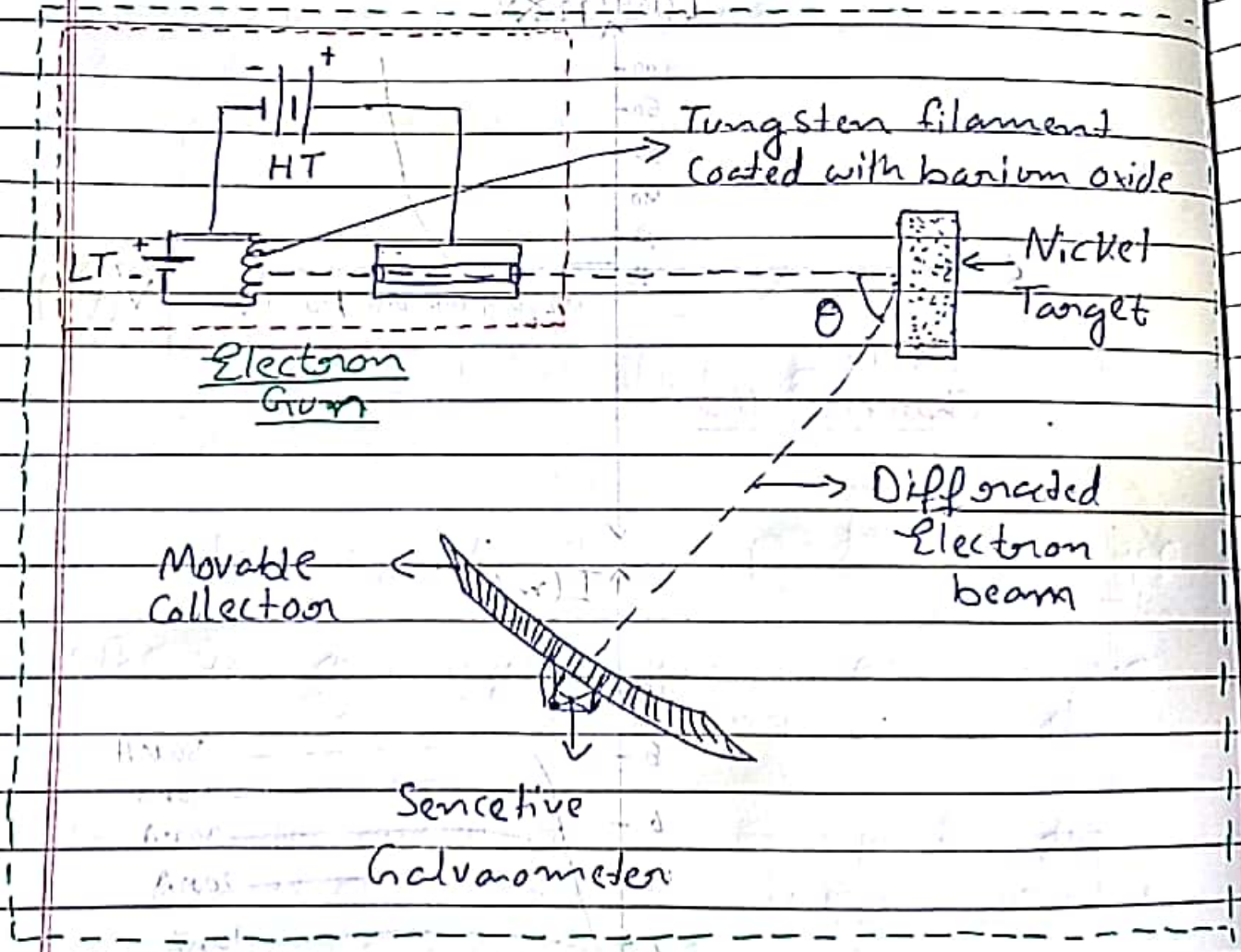


Input Characteristics



Output Characteristics

③ Davisson and Germer Experiment



⇒ The electrons are scattered in all direction by the atoms of the crystal.

⇒ The variation of intensity of the scattered electrons with the angle of scattering θ is obtained for different accelerating voltage.

Scanned by CamScanner

⇒ The experiment was performed by varying the accelarating voltage from 44V to 68V.

⇒ It was noticed that a strong peak appeared in the intensity of the scattered electron for an accelerating voltage 54V at a scattering angle 54°.

⇒ The appearance of the peak in a particular direction is due to the constructive interference of electrons scattered from different layers of the regularly spaced atoms of the crystal.

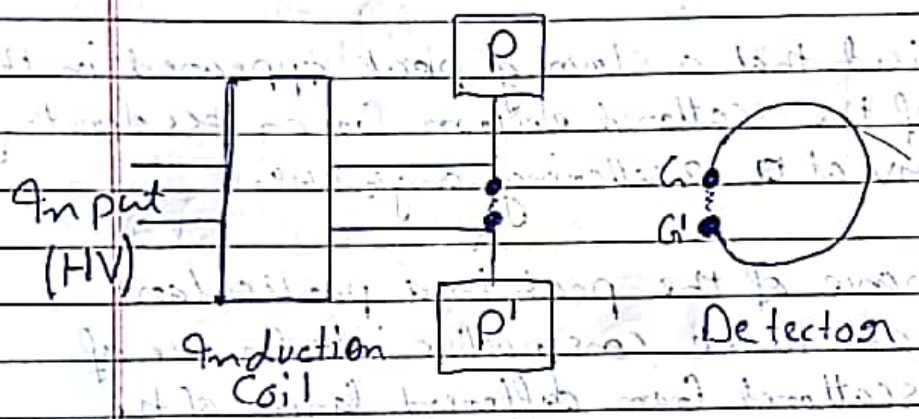
⇒ From the electron diffraction measurements, the wavelength of matter waves was found to be 0.165 nm.

⇒ The de Broglie wavelength λ associated with electrons is 0.167 nm.

⇒ Thus, there is ~~an~~ an excellent agreement between the theoretical value and the experimental value of de Broglie wavelength.

Scanned by CamScanner

(4) Hertz's experimental setup to produce electromagnetic waves.



⇒ • A Sudden high voltage is applied across the gap.

• The voltage is high enough to ionise the air in the gap and a spark jumps the gap.

• Since the air is ionised, the sparks gap consists of electrons and the ions from the air which oscilate back and forth.

• The process results in the production of electromagnetic waves.

• The frequency of electromagnetic wave is determined by the inductance and capacitance of the coils.

Scanned by CamScanner

⇒ • To detect electromagnetic wave, Hertz designed a detector which consisted of a single loop of wire connected to two spheres.

• It had its own effective Inductance Capacitance and natural frequency of oscillation.

• The electromagnetic waves reaching the gap of the detector has an electric filed strong enough to establish a high potential difference between the gap 'G' and cause a spark.

• Hertz could observe tiny sparks jumping between the gap GG', thereby proving detection of electromagnetic radiations.

Scanned by CamScanner

⑤ Nuclear physics

ⓐ α-Decay

$$^{238}_{92}U \longrightarrow ^{234}_{92}Th + ^{4}_{2}He$$

ⓑ β-Decay

$$^{32}_{15}P \longrightarrow ^{32}_{16}S + e^{-} + \bar{V}$$

$$^{22}_{11}Na \longrightarrow ^{22}_{10}Ne + e^{+} + V$$

Scanned by CamScanner

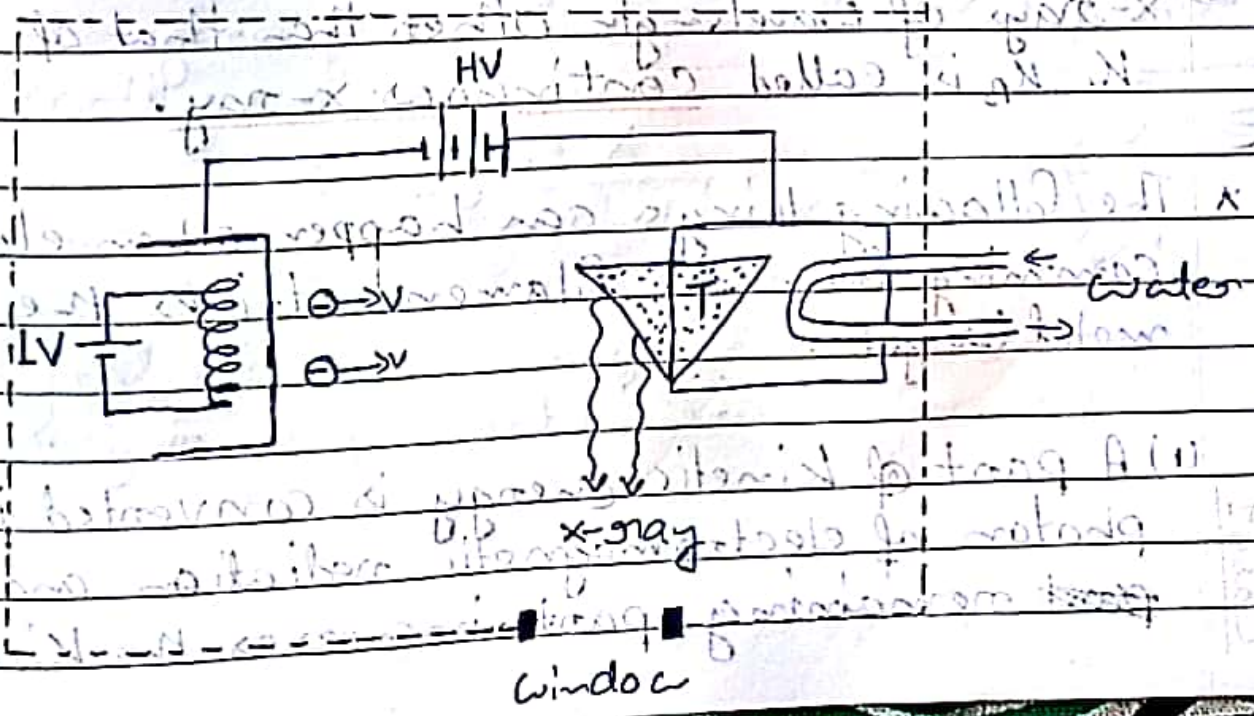
7
X-Rays

⇒ Production of X-rays

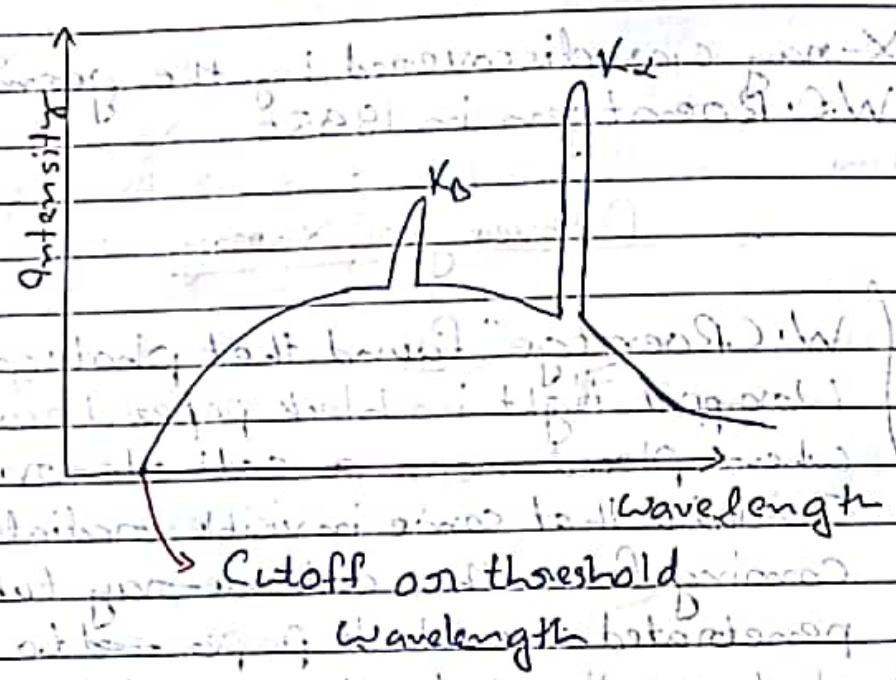
⇒ X-ray was discovered by the german physicist W.C. Roentgen in 1895.

Discovery of X-ray

W.C. Roentge found that photographic film wrapped tight in black paper becom exposed when placed near a cathode-ray tube. He concluded that some invisible radiation was coming from the cathode-ray tube which penetrated the black paper ~~and~~ to affect the photographic plate. He named the radiation as X-ray.



⇒ Continuous and Characteristic X-rays



⇒ K_α and K_β are known as Characteristic X-ray.

⇒ X-rays of wavelength other than that of K_α, K_β is called continuous X-ray.

* The following things can happen when electron comming from the filament stricks the metal target :-

Case I

(1) A part of kinetic energy is converted into a photon of electromagnetic radiation and the ~~part~~ remaining part increases the kinetic

energy of the colliding particle of the target (goes as heat).

(ii) The electron knocks out an inner electron of the atom with ~~this it~~ which it collides.

★ Conciquences of Case 1

⇒ Let the potential difference applied between the target and the filament is V.

$K_{max} = eV$

⇒ $\lambda \geq \frac{hc}{eV}$ {λ is wavelength of photon emitted}

⇒ The above inequation provide reason for continuous X-ray.

$\lambda_{min} = \frac{hc}{eV}$ {Threshold wavelength}

Scanned by CamScanner

★ Conciquences of case 2

⇒ Let $K_\alpha, K_\beta, K_\gamma$ be the x-rays produced when electron from 1st, 2nd & 3rd higher energy level with respect to K shell jumps to K shell. Similarly ∀ L_α, M_α etc...

⇒ $$\lambda = \frac{hc}{E_K - E_L} \quad \forall K_\alpha$$

$$\left\{ (E_K - E_L) \text{ \& } (E_K - E_m) \text{ varies from metal to metal} \right\}$$

$$\lambda = \frac{hc}{E_K - E_m} \quad \forall K_\beta$$

⇒ The K_α, K_β etc are named characteristic x-ray as they may be used to identify the element from which they originated.

⇒ Soft and Hard X-rays

"The X-rays of low wavelengths are called hard-X-rays and those of large wavelength are called soft x-rays."

Scanned by CamScanner

⇒ Moseley's Law

⇒ Moseley measured the frequencies of characteristic X-rays from a large number of elements and plotted the square root of frequency against its position number in the periodic table. He discovered that the plot is very close to a straight line.

⇒ From this linear relation moseley concluded that there must be a fundamental property of the atom which increases by regular steps as one moves from one element to the other.

$$\boxed{\sqrt{f} = a(Z-b)}$$

{a = Universal constant
b = depends on metal but mostly, b ≈ 1}

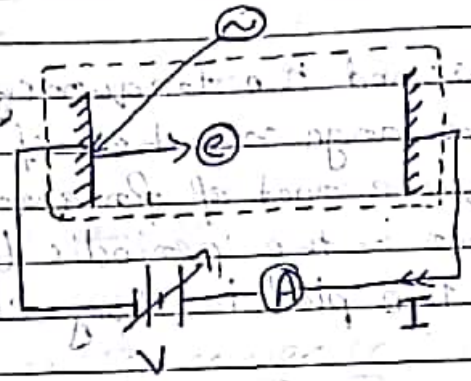
⇒ Bragg's Law

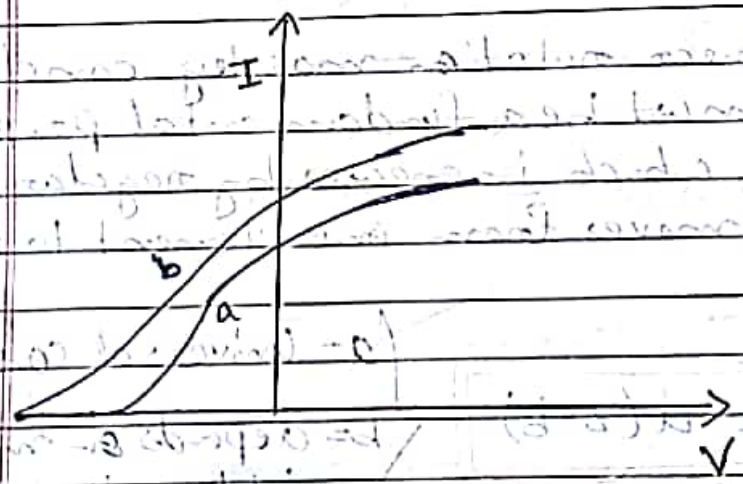
A Crystal is a natural grating for diffraction of X-rays, since the spacing d between the crystal planes is of the order of the wavelength of X-ray. The analysis shows that there will be a strong reflected X-ray beam only if

$$\boxed{2d\sin\theta = n\lambda}$$ {Bragg's Equation}

Scanned by CamScanner

PHOTO CELL





⇒ Radiation used while forming curve b has more Intensity (as it results in more current) and ~~more~~ high frequency (as current began to flow even in high negative voltage) as compared to the radiation used while forming curve a.

⇒ Nature of curve depend upon the metal.

⇒ Stopping potential depends upon photon.

Scanned by CamScanner

Carbon dating

"Radiocarbon dating is a method of determining the age of an object by using the properties of radio active carbon"

⇒ C^{14} is produced by the bombardment of nitrogen atoms present in the upper atmosphere with neutrons (from cosmic rays)

$$_7N^{14} + _0n^1 \longrightarrow _6C^{14} + _1H^1$$

⇒ The C^{14} isotope enters the biosphere when carbon dioxide is taken up in plants by photosynthesis.

{C^{14} got oxidised to form $C^{14}O_2$}

⇒ Plants are eaten by animals, which exhale C^{14} as CO_2. Eventually C^{14} participates in many aspects of the carbon cycle.

⇒ The C^{14} lost by radioactive decay is constantly replenished by the production of new isotopes in the atmosphere. In this decay-replenishment process, a dynamic equilibrium is established whereby the ratio C^{14} to C^{12} remains constant in living matter.

Scanned by CamScanner

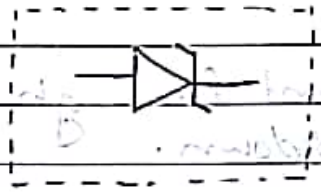
⇒ But when an individual plant or an animal dies, the C^{14} isotope in it is no longer replenished, so the radio as C^{14} decays.

$$_{6}C^{14} \longrightarrow {}_{7}N^{14} + {}_{-1}\beta^{0}$$

⇒ So, the number C^{14} nuclei after time t would be less than in a living matter which ~~help~~ helps us to predict its age.

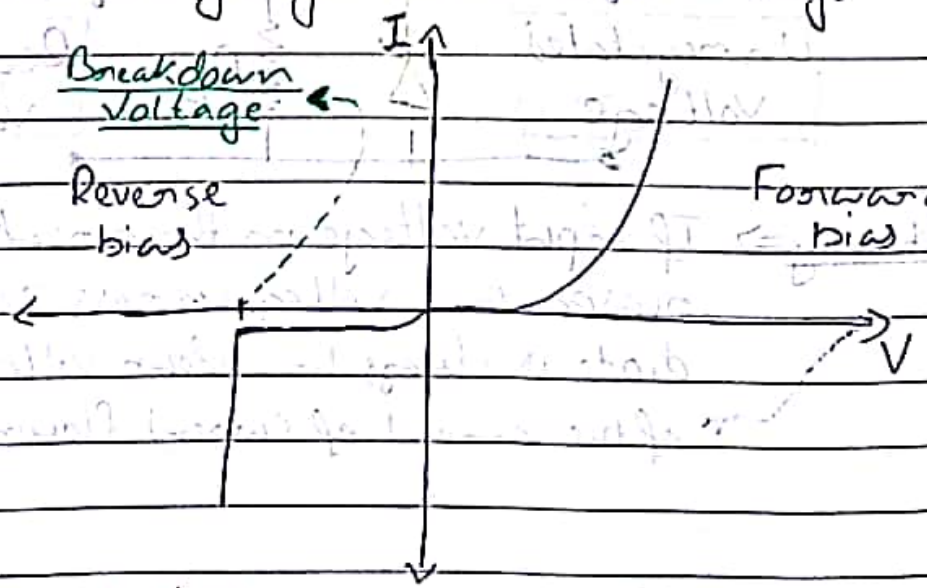
$$t_{1/2}\{C_{14}\} = 5760 \text{ years}$$

* Zener diode ⇒ Zener diode is a diode which allows current to flow in the forward direction in the same manner as an ideal diode, but also permits it to flow in the reverse direction when the voltage is above a certain value known as the breakdown voltage.



⇒ Zener diode is fabricated by heavily doping both P- and n-sides of the junction

⇒ Due to this, depletion region formed is very thin ($< 10^{-6}$ m) and the electric field of the junction is extremely high even at low voltage.



I-V Characteristics of Zener diode

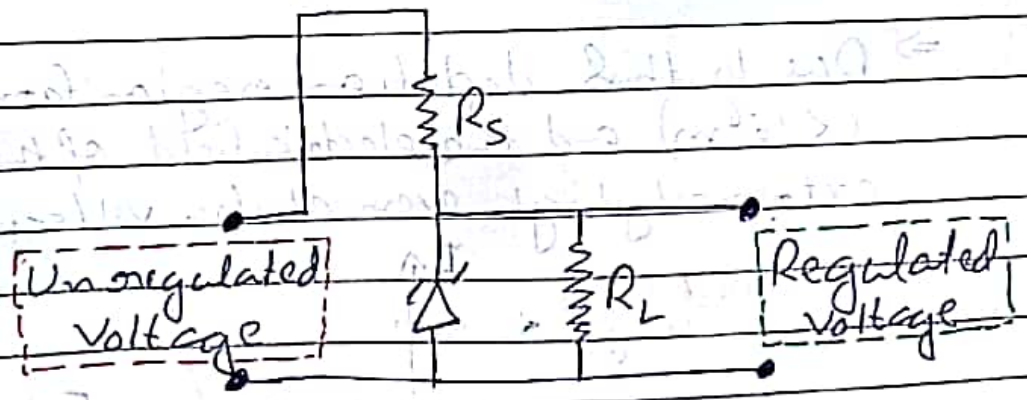
Scanned by CamScanner

★ Describing behaviour of Zener diode

⇒ When reverse biase voltage is made equal to or greater than breakdown voltage, then the electric field strength becomes high enough to pull valence electrons from the host atoms on the p-side and accelerate it to n-side.

→ These electrons account for high current observed at the breakdown.

★ Zener diode as a voltage regulator



⇒ basic theory ⇒ If input voltage in the breakdown region then voltage across Zener diode is always breakdown voltage irrespective of the amount of current flowing.

Scanned by CamScanner