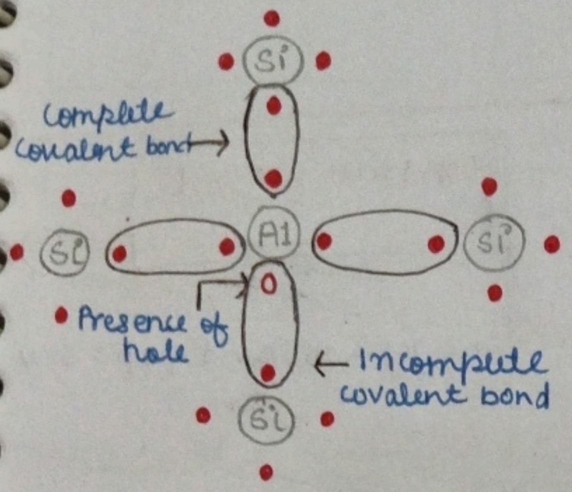
Applied Physics

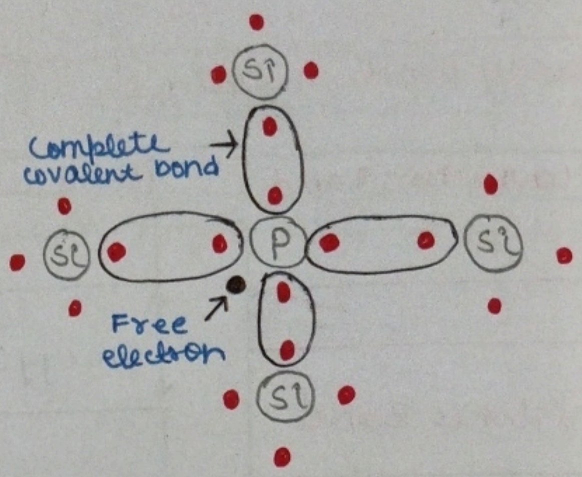
Unit 1 : Semiconductor Physics

→ Types of semiconductor



- Si = Intrinsic semiconductor atom
- Al = Trivalent impurity atom

P-Type Semiconductor



- Si = Intrinsic semiconductor atom
- P = Pentavalent impurity atom

N- Type Semiconductor

→ Current Density

The amount of electric current travelling per unit cross-section area is called as current density and expressed in amperes per square meter.

$$\boxed{J = \frac{I}{A} \ \frac{\text{amp}}{m^2}}$$

J = current Density
I = current
A = Area

→ Electric Field Intensity

It is a strength of an electric field at a given point or it can also be defined as the force experienced by a unit positive charge placed in electric field.

$$\boxed{E = \frac{F}{q}} \quad - (1)$$

$$W = Vq \Rightarrow q = \frac{W}{V} \quad - (2)$$

$$W = F \times d \Rightarrow F = \frac{W}{d} \quad - (3)$$

Subsiteting (2) & (3) in (1)

$$E = \frac{\cancel{W}/d}{\cancel{W}/V}$$

$$\boxed{E = \frac{V}{d}}$$

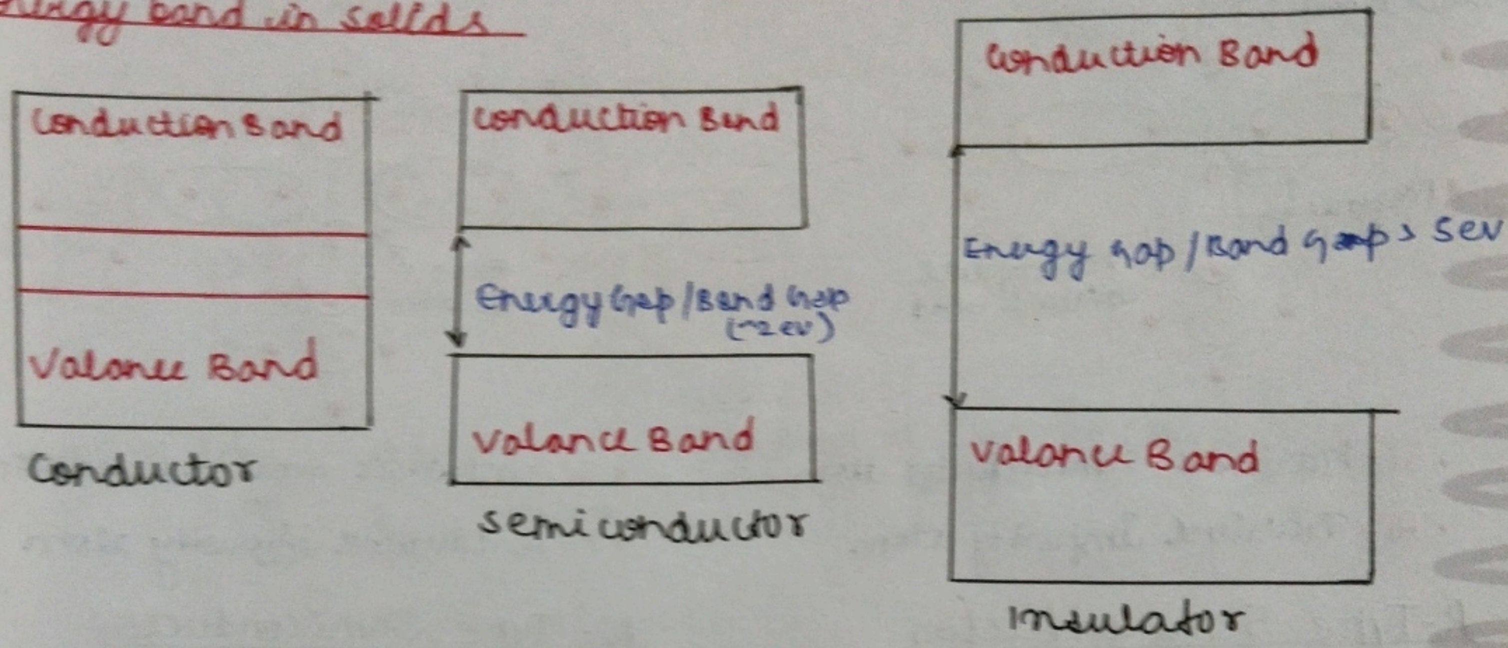
→ Resistivity & conductivity

$R \propto L$

$R \propto \frac{1}{A}$

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

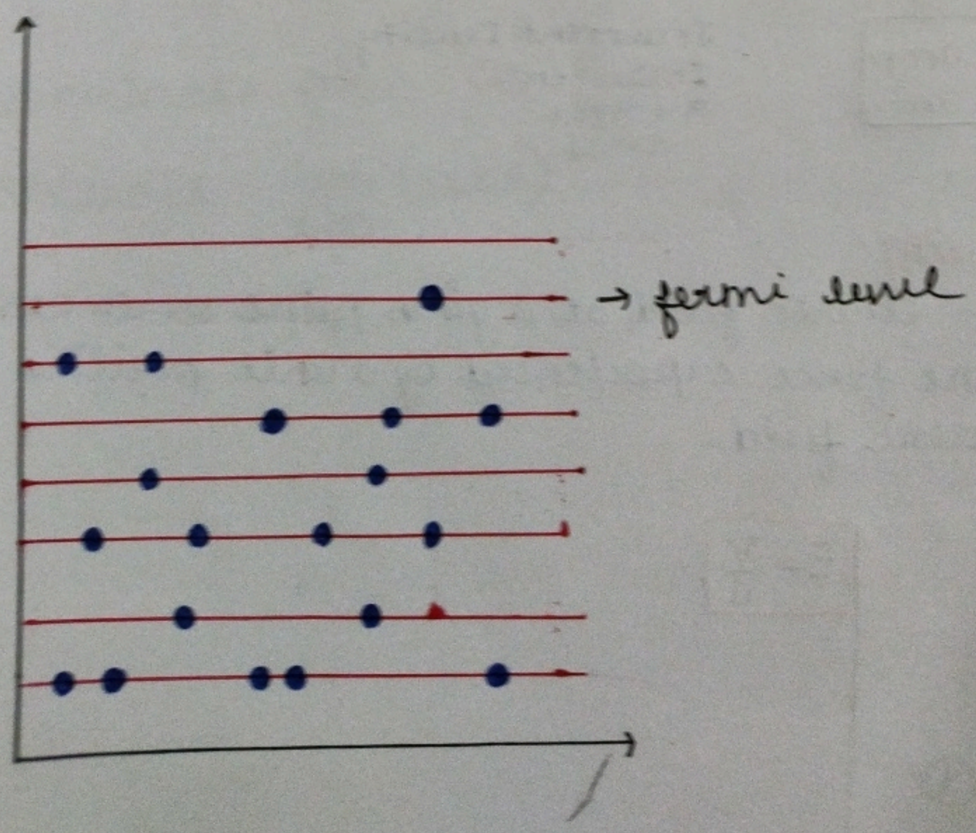
Energy band in solids

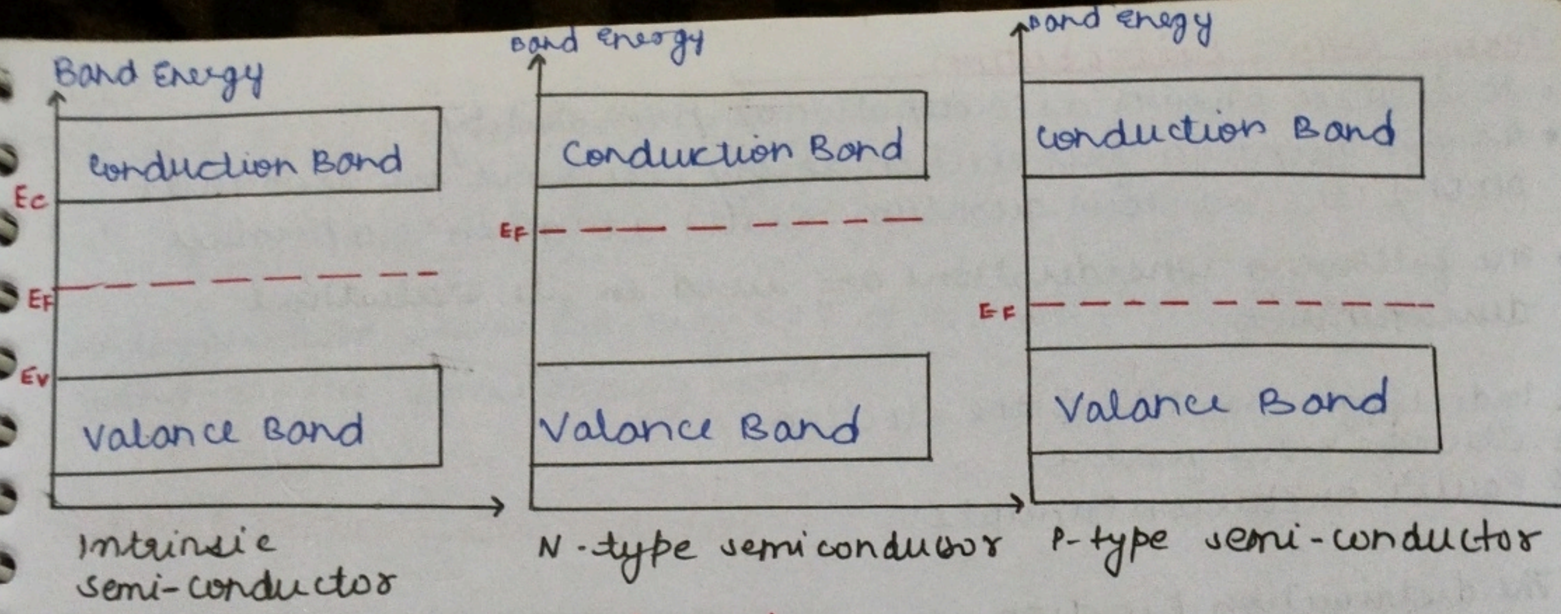


Fermi level & Fermi distribution function

Fermi Energy: It is maximum energy possessed by a free electron at absolute zero temperature.

Fermi level: It is the highest energy state occupied by a free electron at absolute zero temperature.





Fermi Levels

Fermi level of intrinsic semiconductor:

$$n_e = N_c e^{-\left[\frac{E_c - E_F}{KT}\right]}$$

$$n_h = N_v e^{-\left(\frac{E_F - E_v}{KT}\right)}$$

$N_c = N_v$, $\boxed{n_e = n_h}$

For intrinsic semiconductor, we know that $\cancel{N_c} e^{-\left[\frac{E_c - E_F}{KT}\right]} = \cancel{N_v} e^{-\left[\frac{E_F - E_v}{KT}\right]}$

$$e^{-\left(\frac{E_c - E_F}{KT}\right)} = e^{-\left(\frac{E_F - E_v}{KT}\right)}$$

(e to the power something is equal to the e to the power something.)

so, $\cancel{e}\,\cancel{-}\left[\frac{E_c - E_F}{\cancel{KT}}\right] = \cancel{-}\left(\frac{E_F - E_v}{\cancel{KT}}\right) = E_c - E_F = E_F - E_v$

$= E_c + E_v = E_F + E_F$

$$\Rightarrow \boxed{E_F = \frac{E_c + E_v}{2}}$$

Fermi Dirac Distribution

- It is also known as occupational probability
- As per quantum free electron theory, electrons are distributed among the various quantum states at given temperature.
- The following considerations are used in its statistical development:

1. Indistinguishability of the electron
2. Electron wave nature
3. Pauli's exclusion principle

- The distribution function is:

$$\boxed{f(E) = \frac{1}{1+e^{(E-E_F)/KT}}}$$

F(E): probability that the electron will energy equal to E

E: energy level

E_F: fermi energy

K: Boltzmann constant → 1.38×10^{-23} J/K

T: Temperature in kelvin

case 1:

T = 0 and $E < E_F$, $E - E_F < 0$ (negative)

$$f(E) = \frac{1}{1+e^{(E-E_F)/KT}} = \frac{1}{1+e^{-\infty}} = 1$$

- All energy levels below the fermi level are full
- 100% probability of finding electron below the fermi level

case 2:

T = 0 and $E > E_F$, $E - E_F > 0$ (positive)

$$f(E) = \frac{1}{1+e^{(E-E_F)/KT}} = \frac{1}{1+e^{\infty}} = 0$$

- All energy levels above the fermi level are empty.
- 0% probability of finding electron above the fermi level.

case 3:

$T > 0$ and $E = E_F$, $E - E_F = 0$

$$f(E) = \frac{1}{1+e^0} = \frac{1}{1+1} = \frac{1}{2} = 0.5$$

- At temperature above 0K, only 50% of the electrons are to be found at the fermi energy level.

Intrinsic & Extrinsic semiconductors

semi-conductors

- **Intrinsic**
  - Pure germanium (Ge) or silicon (Si) crystal
  - Cannot conduct electricity
- **Extrinsic**
  - Pure (Ge) or (Si) crystal is 'doped'
  - can conduct electricity
  - **n-type**
    - pentavalent impurity
    - doping by: N, P, As, Sb, Bi
    - electrons are majority carriers
  - **P-type**
    - trivalent impurity
    - doping by B, Al, Ga, In, Th.
    - holes are majority carriers.

P-N Junction

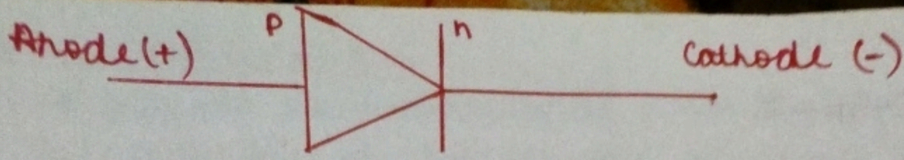
→ when half of a Si crystal is doped with trivalent impurity and half with pentavalent impurity, we get p-n junction diode.

→ When electrons leave n-region, create + ion and Recombining with holes create - ion in p-region.

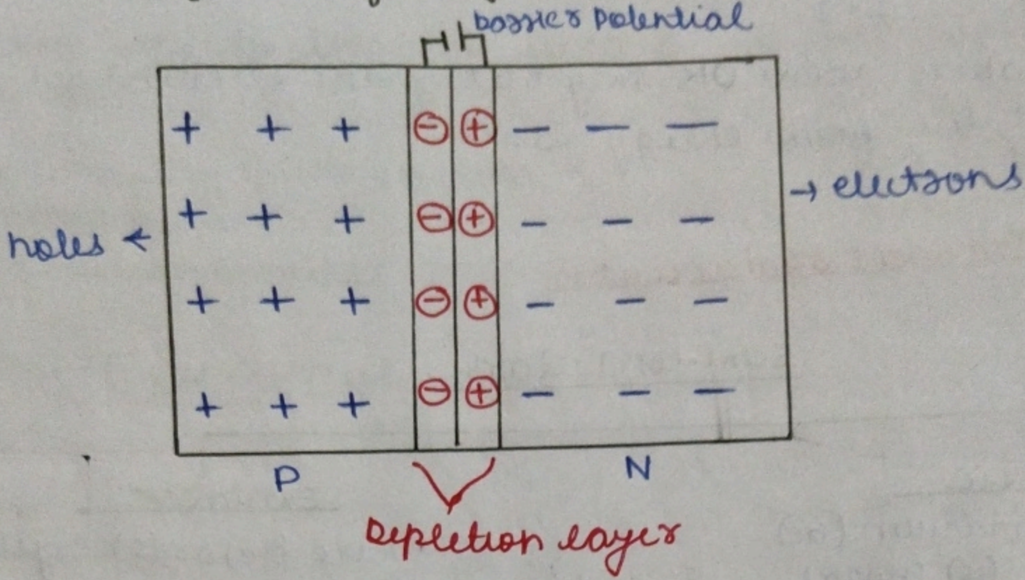
→ Region near the junction is depleted of free charges is called depletion layer.

→ Potential difference prevents continuous diffusion of electrons and holes across the junction hence called Barrier Potential [for Si diode = 0.7V]

→ when no external source is conneted to diode it is said to be unbiased diode.



symbol of P-N juntion diode



→ **Depletion Region**

The depletion region refers to a region where flow of charge carriers are decreased over a given time and finally results in empty mobile charge carriers or full of immobile charge carriers.

→ **Potential barrier / stopping potential**

The potential barrier in the P-N junction diode is the Barrier in which the charge requires additional force for crossing the region.

Effect of doping concentration on depletion width

* as the doping concentration increases the depletion width decreases.

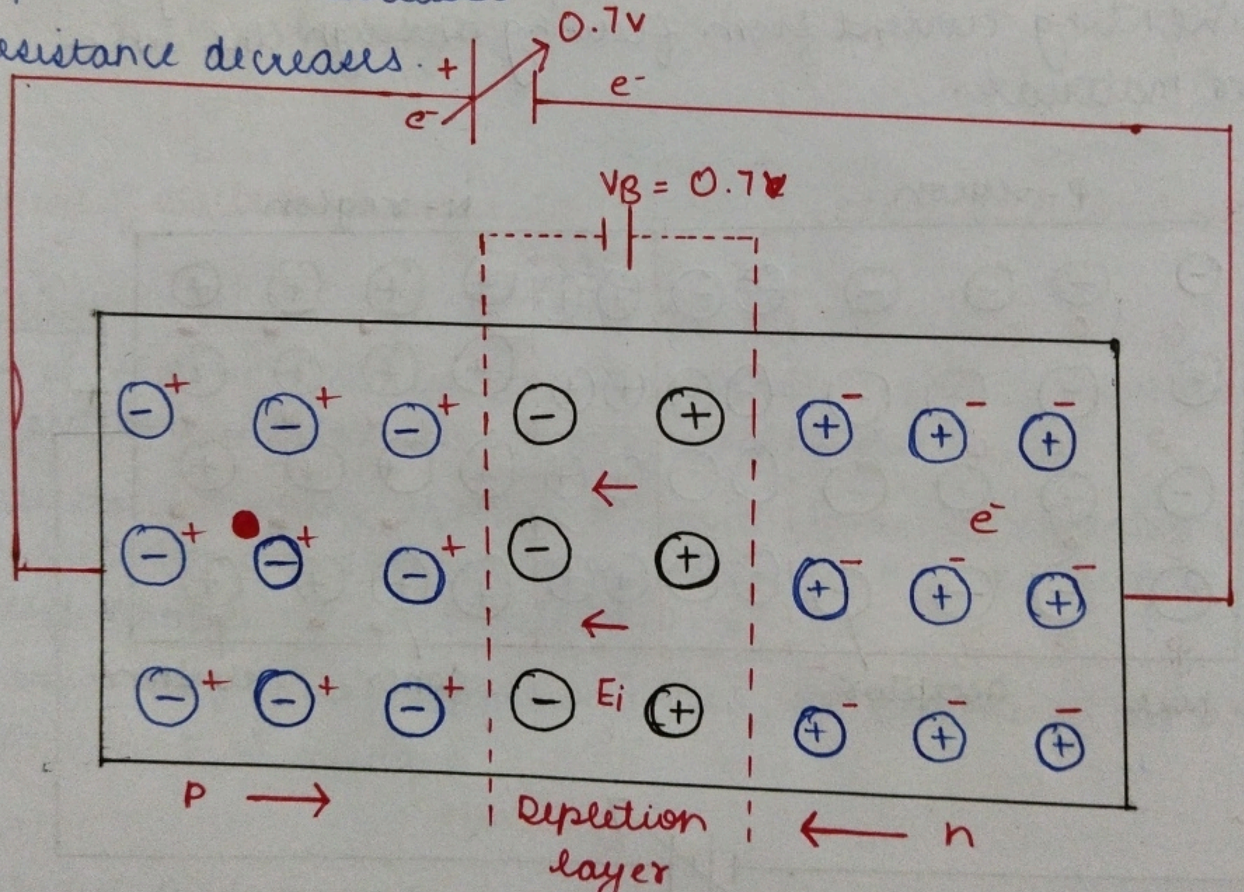
* No effect on barrier potential.

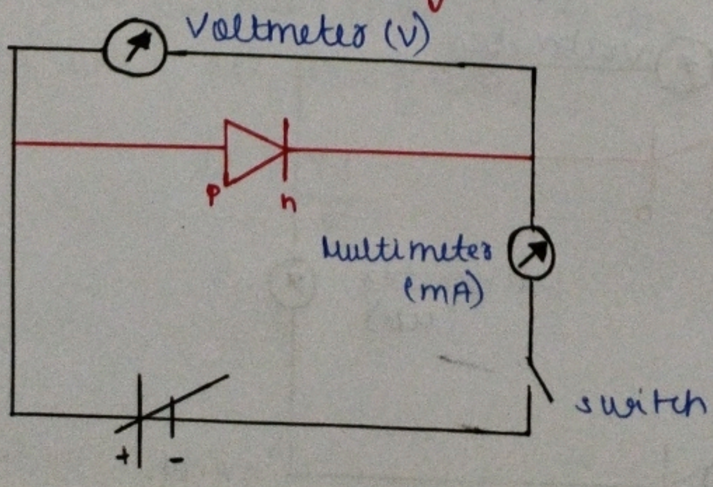
→ **Types of baising**

- Forward Bais
- Reverse Bais

Forward Bais

- When a diode is connected in a Forward Bais condition, a lower voltage is applied to the N-type material and a higher voltage is applied to the P-type material.
- If this external voltage becomes greater than the value of barrier, approx 0.7 volts for S and 0.3 volts for Gr, the potential barrier opposion will be overcome and current will start to flow.
- This is because the negative voltage pushes and repels electrons towards the junction giving them the energy to cross over and combine with the holes being pushed in the opposite direction towards the junction by the positive voltage.
- Depletion width decreases
- Resistance decreases.



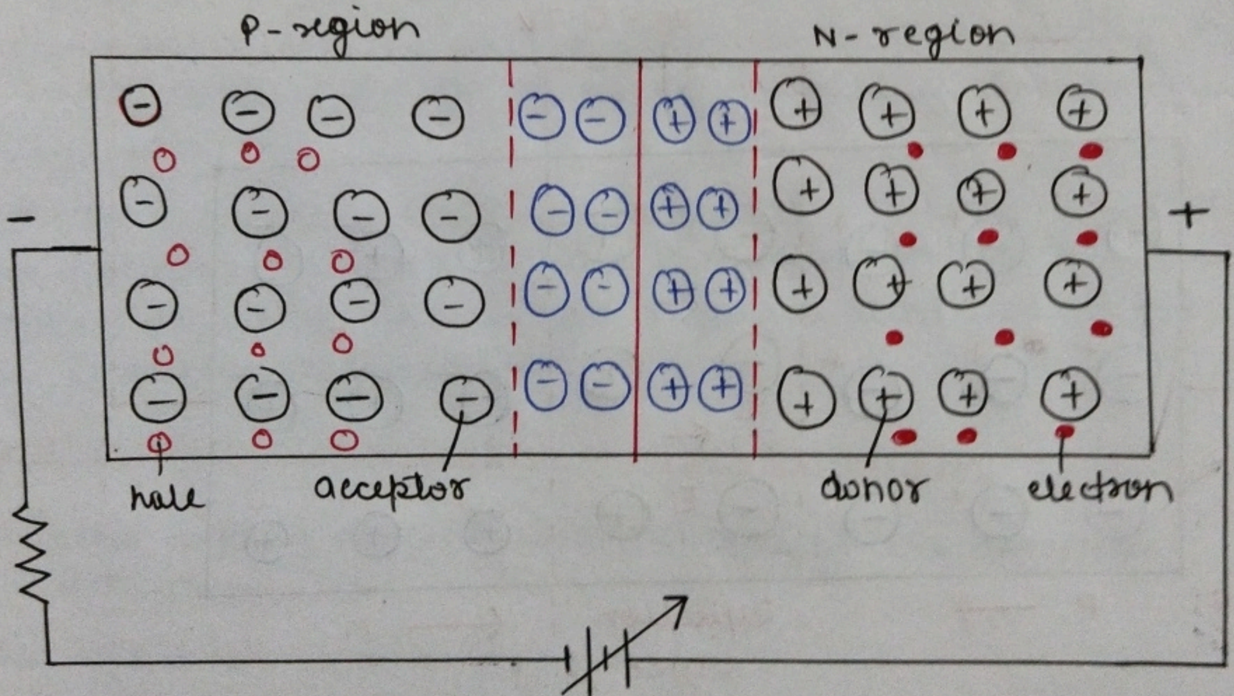


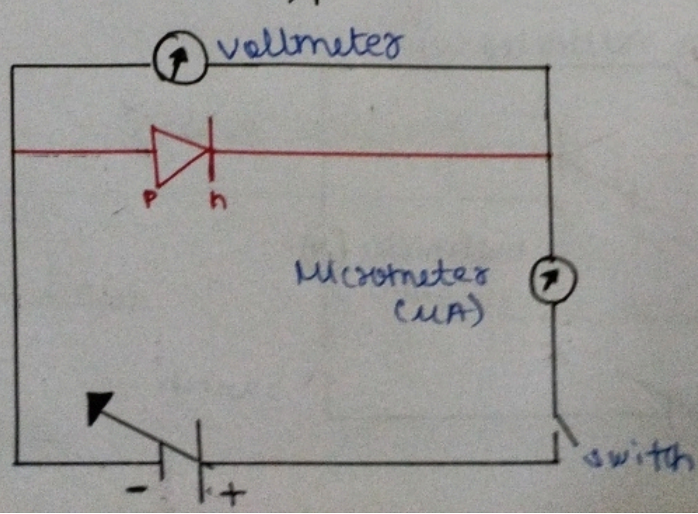
Reverse Bais

→ When a diode is connected in Reverse Bais condition, a positive Voltage is applied to the N-type & a negative voltage is applied to the P-type material.

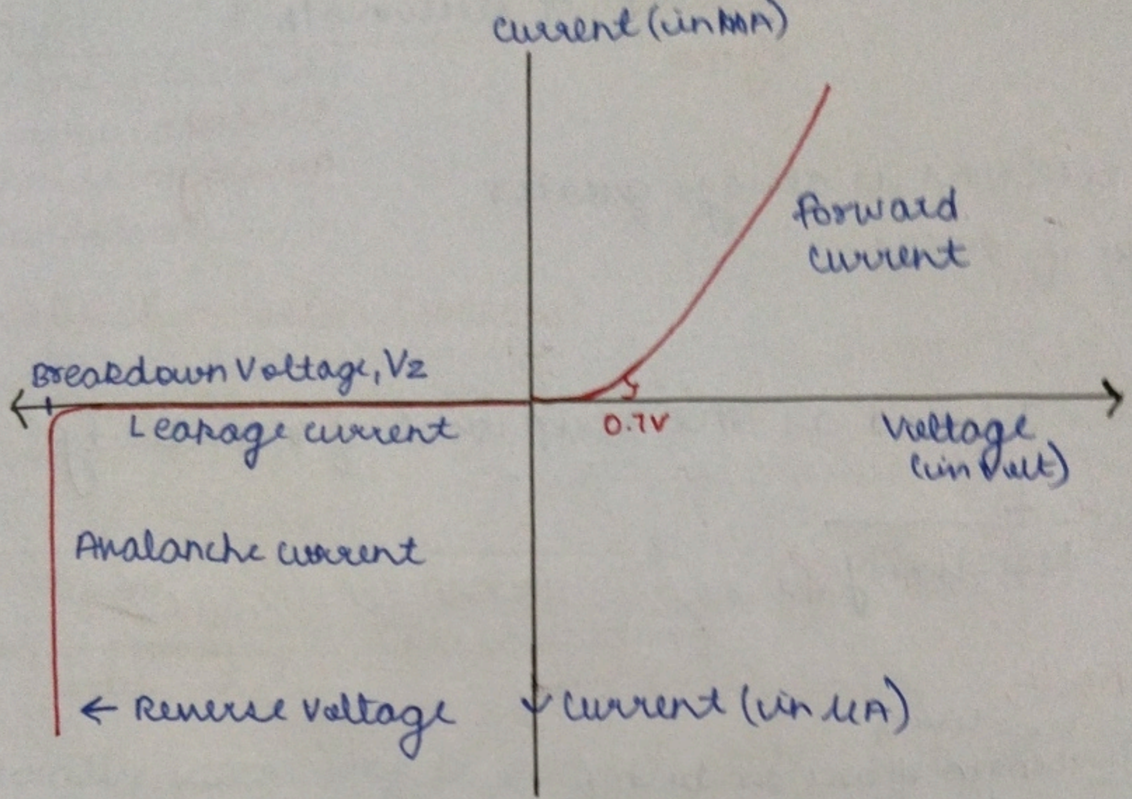
→ The positive voltage applied to the N-type material attracts electrons towards the positive electrode and away from the junction, while the holes in the P-type end are also attracted away from the junction towards the negative electrode.

→ The net result is that the depletion layer grows wider due to a lack of electrons and holes and presents a high ~~temperature~~ impedance path, almost an insulator and a high potential barrier is created accross the junction thus preventing current from flowing through the semi-conductor material.





I-V Characteristics for Diode



Mobility of electrons & holes, Drift velocity, electrical conductivity resistivity

Mobility

When an electric field is applied across a solid, it accelerates the electrons in the direction of electric field.

As electrons moving through a solid undergo repeated collisions with the atoms in the solid and therefore move with a steady velocity known as drift velocity, V_d

The drift velocity is proportional to the electric field applied,

Thus, $V_d \propto E \Rightarrow V_d = \underbrace{\mu}_{\text{Mobility}} E$

Hence, we define electron mobility as the drift velocity of electrons per unit electric field,

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

Mobility is also given by $\boxed{\mu = \frac{\sigma}{ne}}$ where n is the number of electrons/m^3

sigma

electron density

→ Mobility of electrons is always greater than mobility of holes.

Conductivity

Conductivity (σ) is defined as the reciprocal of resistivity

$$\text{Conductivity} = \frac{1}{\text{Resistivity}(\rho)}$$

We know that,

$$R = \frac{\rho L}{A}$$

ρ → resistivity

L → Length of the conductor.

A → Area of cross section

R → Resistance offered by conductor

$$\Rightarrow \text{Resistivity}(\rho) = \frac{RA}{L} \quad \frac{(\Omega \times m^2)}{(m)} = \Omega m$$

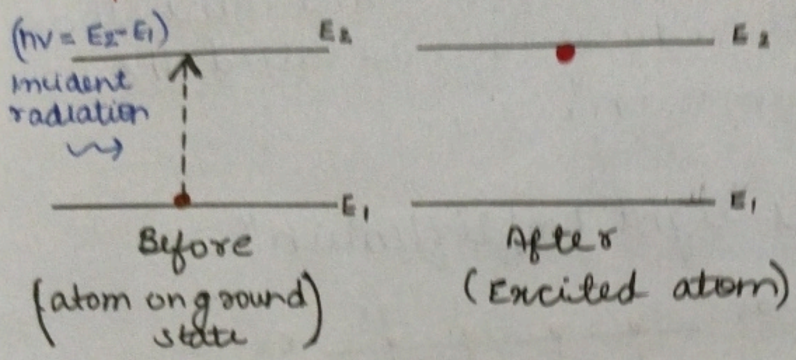
$$\Rightarrow \text{conductivity}(\sigma) = \frac{L}{RA} \quad (\Omega m)^{-1} = mho.m^{-1}$$

→ zener diode from Pdf

unit 2: Lasers

L → Light
A → Amplification by
S → stimulated
E → Emission of
R → Radiation

Absorption & Emission Processes:



Naturally atom stay in ground state (E_1) by absorption of photon of energy $h\nu$, atom excited and raised to higher energy state (E_2)

→ Probability of transition from 1 to 2 (by absorption process)

$P_{12} \propto u(\nu)$, $u(\nu)$ = energy density of radiation

$\boxed{P_{12} = B_{12}\, u(\nu)}$

↳ Einstein's coefficient of absorption

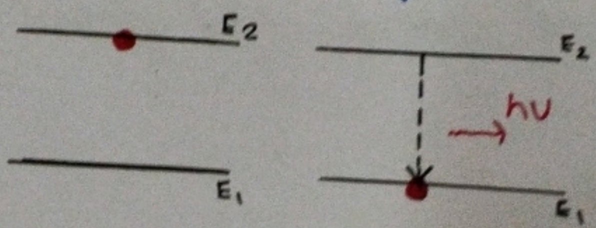
Emission Energy

Transition from higher energy state (E_2) to (E_1) is emission

Spontaneous Emission | Stimulated Emission

→ Spontaneous emission

Atom from E_2 transit back to E_1 spontaneously and emitted photon of energy $h\nu = E_2 - E_1$



$P_{21}' = A_{21}$

Probability of spontaneous emission

Einstein's coefficient of spont. emission

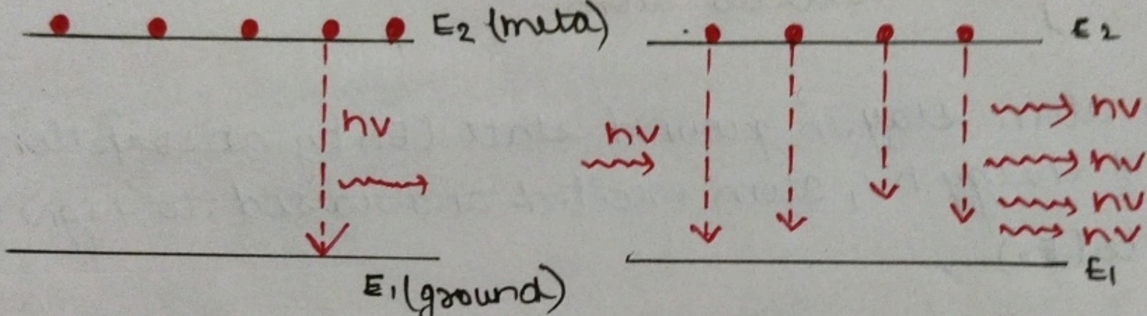
Stimulated Emission

- Einstein considered the possibility of long lived energy state (meta stable state)
- Normally the atoms are present in ground state and very less are excited or say present in excited state this is called "Normal population".

→ If number of atoms are excited at the same time than no. of atom in ground state reduces. This is called the condition of "population inversion".

↓

Precondition for the "light amplification."



$P''_{21} \propto u(\nu)$ $\quad$ $u(\nu)$ = energy density of radiation

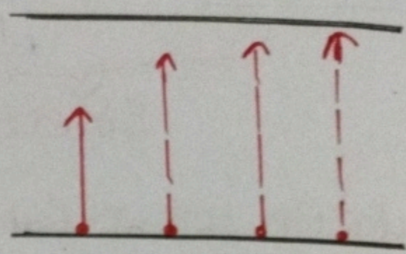
$$\boxed{P''_{21} = B_{21}\, u(\nu)}$$

B_{21} → Einstein coeffecient of stimulated emission

Total probability of Absorption = Probability of spontaneous emission + Probability of stimulated emission

Relation between Einstein's coeffecient

TOPIC IS NOT COMING !
BYE :)



EINSTEIN'S COEFFICIENTS :

$A_{21} \rightarrow$ Spontanious Emission
$B_{12} \rightarrow$ stimulated Absorption
$B_{21} \rightarrow$ stimutlated emission

In thermal equilibrium :

The number of transition from E_1 to E_2 = The number of transition from E_2 to E_1

$\rho(v)$ = Photon density

$$N_1 P_{12} = N_2 P_{21} \text{ (spont + stimulated)}$$

$$N_1 B_{12} \rho(v) = N_2 [A_{21} + B_{21} \rho(v)]$$

$$\rho(v)[N_1 B_{12} - N_2 B_{21}] = N_2 A_{21}$$

$$\rho(v) = \frac{N_2 A_{21}}{N_1 B_{12} - N_2 B_{21}}$$

, divide the numerator (both) by $B_{12} N_2$

$$\rho(v) = \frac{A_{21}/B_{12}}{\frac{N_1}{N_2} - \frac{B_{21}}{B_{12}}}$$

→ Maxwell Boltzmann Distribution law

$$N \propto e^{-E/KT}$$

$$\frac{N_1}{N_2} = \frac{e^{-E_1/KT}}{e^{-E_2/KT}}$$

$$\frac{N_1}{N_2} = e^{(E_2-E_1)/KT}$$
$$= e^{h\nu/KT}$$

$$\rho(v) = \frac{A_{21}/B_{12}}{e^{h\nu/KT} - \frac{B_{21}}{B_{12}}}$$

→ Planck's Radiation law

$$\rho(v) = \frac{8\pi h\nu^3}{c^3}\left[\frac{1}{e^{\frac{h\nu}{KT}} - 1}\right]$$

$$\frac{B_{21}}{B_{12}} = 1 \quad \& \quad \frac{A_{21}}{B_{12}} = \frac{8\pi h\nu^3}{c^3}$$

$$\boxed{B_{21} = B_{12}} \quad \& \quad \boxed{\frac{A_{21}}{B_{21}} = \frac{8\pi h \nu^3}{c^3}}$$

Einstein's relation

Population Inversion

The condition of getting large no of atoms in the upper energy state in comparison to lower energy states is called "Population inversion"

→ Precondition for the light Amplification

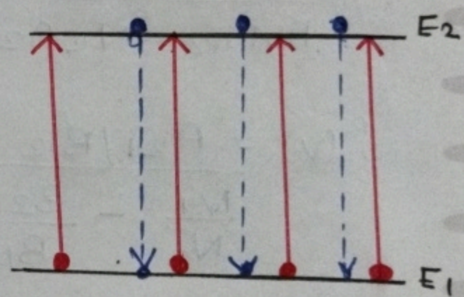
→ Pumping methods are used to get it.

- optical pumping
- Mechanical pumping
- Thermal, chemical etc.

Schemes for Population Inversion

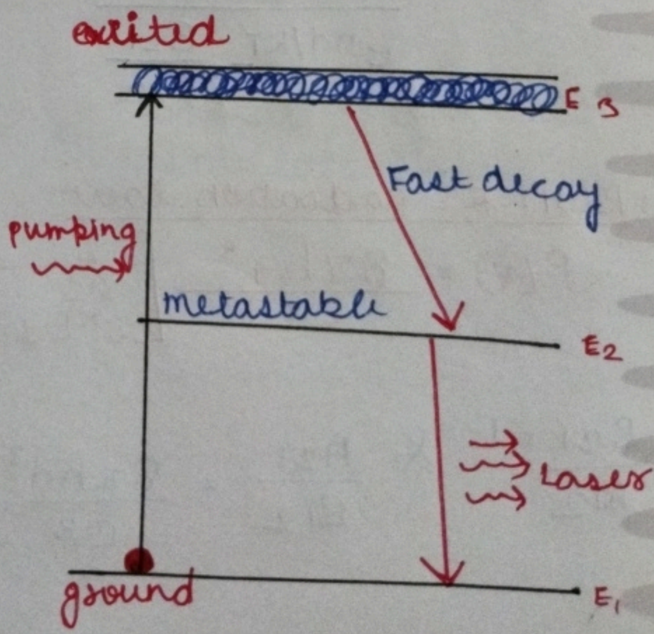
1) Two level system :

- No metastable system
- strong pumping required but $N_1 = N_2$ equally populated
- No population inversion achieved



2) Three level system :

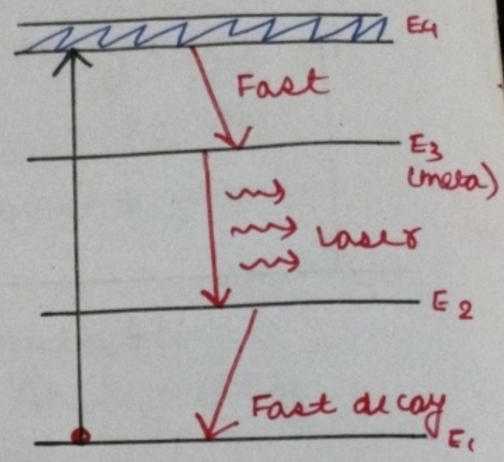
- By optical pumping atoms transit from E_1 to E_3
- E_3 to E_2 transition is fast and radiationless / non radiative.
- As atoms populated in E_2 population inversion take place.
- Transition from E_2 to E_1 gives laser action.



5) Since E_1 (ground state) is involved so large input power for pumping required → Low efficiency.

→ Ruby laser is three level.

Four level system:



1) Laser action takes place between meta state and state E2 (not a ground state) so less energy is required in population inversion.

2) Very efficient method.

3) Between $E_4 \to E_3$ $E_2 \to E_1$ the transition is radiationless

Properties of Laser Light:

1) Coherent: Highly ordered → a constant phase relation between waves.

$\boxed{\text{cohero}}$ → to stick together

↳ temporal coherence
↳ spatial coherence

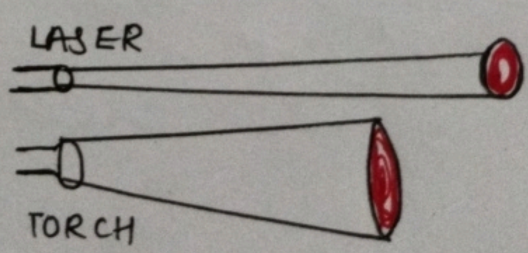
2) Monochromatic:

mono → single
chromo → colour

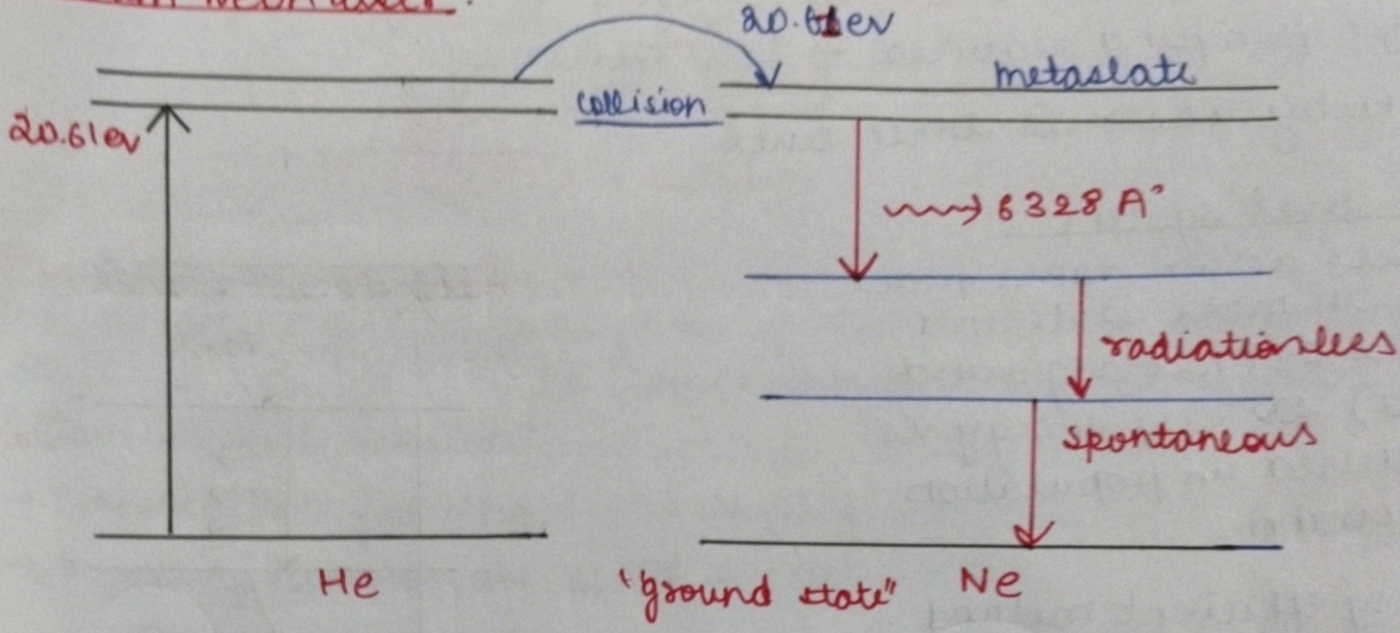
3) Collimated:

- laser beam does not spread much
- Because of design of laser cavity
- Laser intensity is given by

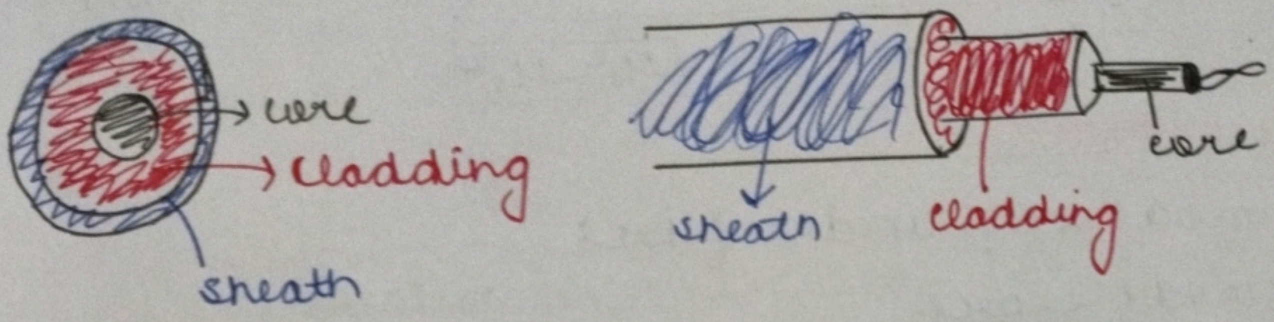
$$\boxed{I = \frac{P}{A}}$$



Helium-Neon laser:

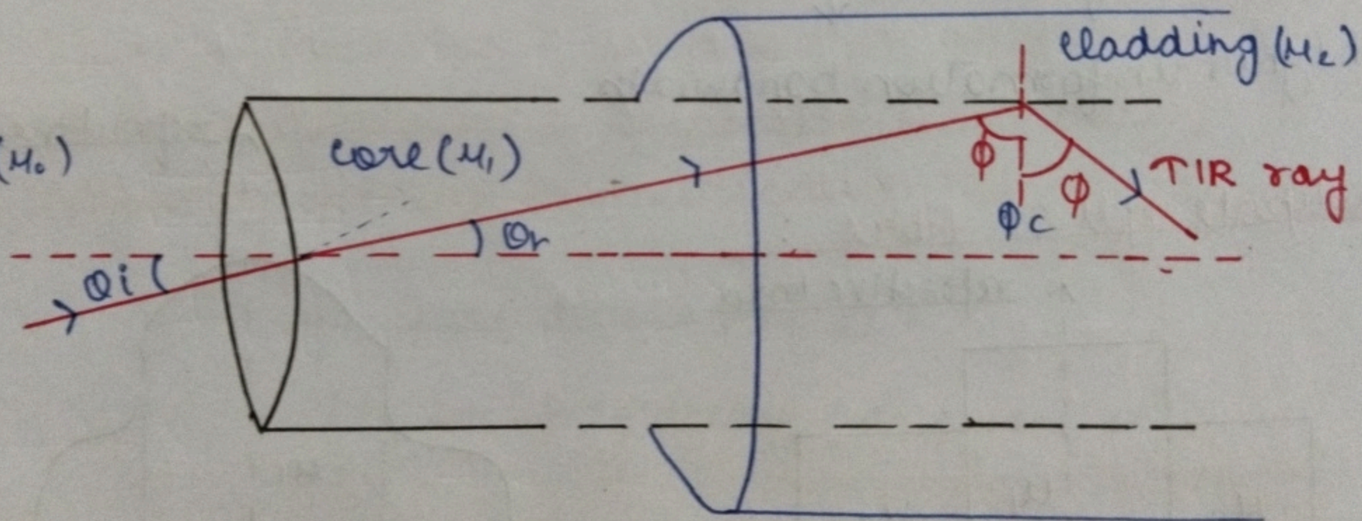


Unit 3: Optical Fibre (Fiber optics)



- Fibre optic cable carry more data because of greater bandwidth.
- Fibre is much thinner/lighter than metal wire
- Data is transmitted digitally not by 'Anologically'
- Attenuation in fibre is much less than metal wire

Acceptance Angle & Numerical Aperture:



when $\theta_i = \theta_{i\,max}$ $\phi > \phi_c$ (critical angle) $\sin\phi_c = \frac{\mu_2}{\mu_1}$

$$\sin\theta_{i\,max} = \frac{\sqrt{\mu_1^2 - \mu_2^2}}{\mu_0}$$

$\mu_0 = 1$ (air)

$$\sin\theta_0 = \sqrt{\mu_1^2 - \mu_2^2}$$

$\theta_{i\,max} = \theta_0 =$ Angle of Acceptance.

Numerical Aperture:

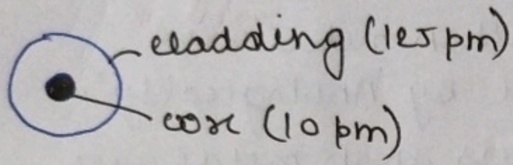
"How much light can be collected by optical fiber".

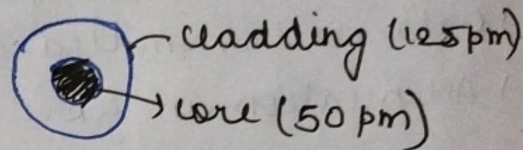
$$\boxed{NA = \sin\theta_0 = \sqrt{\mu_1^2 - \mu_2^2}}$$

Types of optical Fibre:

1) single mode step index fibre
2) Multimode fibre

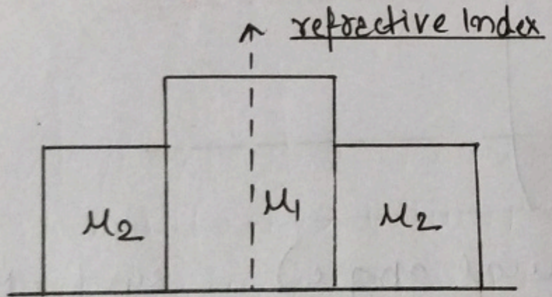
Single Mode | Graded index



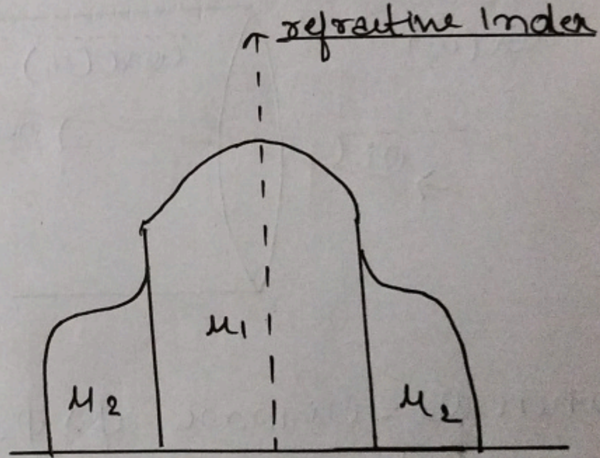


1) useful for longer cable runs.
2) lower signal loss
3) higher information bandwidth

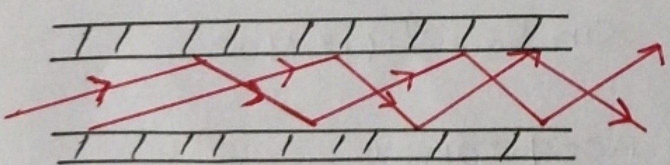
Multipole optical fibre:

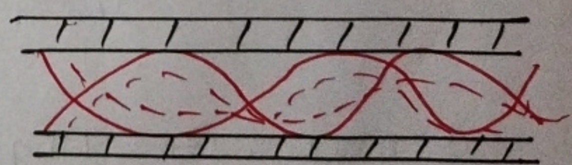


step index



Graded index





Attenuation in optical Fibre:

$\left\{ \begin{array}{l} \text{Power of signal} \\ \text{at output end} \end{array} \right\} < \left\{ \begin{array}{l} \text{Power of signal at} \\ \text{input end} \end{array} \right\} \Rightarrow$ Attenuation Takes place

⇓

Attenuation is ASSOCIATED with decrease in light transmission

Bachpan wale Badal :)

formula : $\boxed{\alpha = \frac{10}{L} \log_{10} \left(\frac{P_o}{P_i} \right) dB/km}$

α = attenuation coefficient

P_o = output power

P_i = Input power

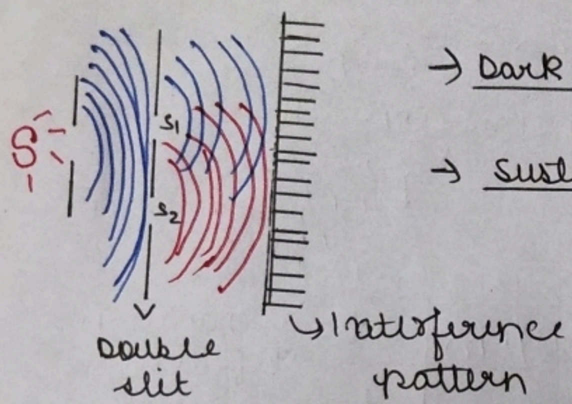
→ Attenuation Mechanism & Dispersion Mechanism, Application of optical communication (Block diagram only)

ye sare topics Pdf se karlo (sirf theory hai pyari se) :)

Wave Optics

Interference

→ Huygen initiated the concept of wave theory of light.
→ 1802 - Young explained the interference by "double slit experiment"



→ Dark & bright fringes

→ sustained interference

Interference : When two coherent light waves of same or nearly same amplitude moving in same direction in space they superimpose each other due to this an intensity distribution is observed"

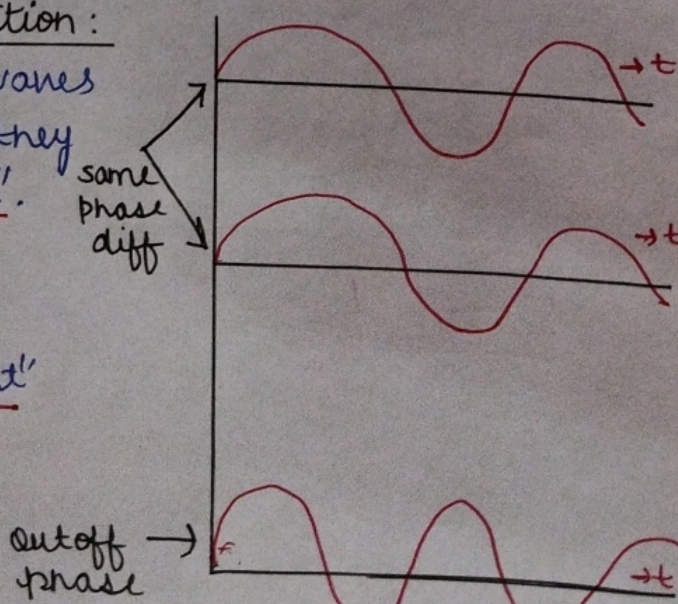
↓

Interference of light waves

Phase Difference : Coherent condition :

If phase difference between waves is either zero or constant they are called "coherent waves".

When the phase changes continuously waves are "incoherent"



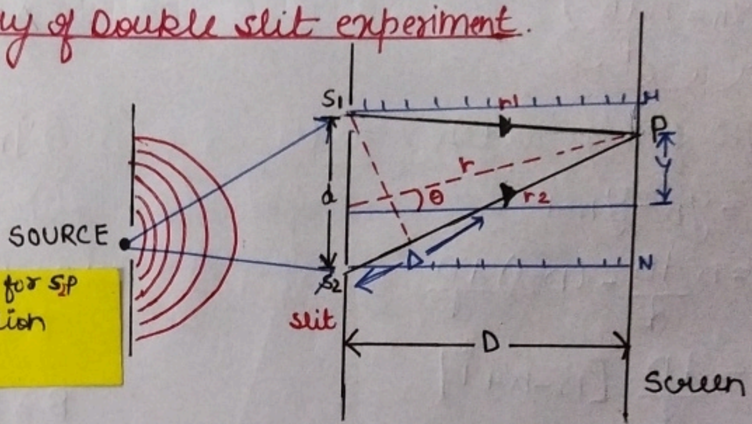
Conditions for Sustained Interference :

→ For sustained interference following conditions are required :

1) The light source should be "monochromatic"
2) The light source must be "coherent".
3) The seperation between two light sources should be small.
4) The distance between light source & screen should be large.
5) The state of polarization of both the light waves must be same.

Analytical theory of Double slit experiment.

When,



- FIND two Δ's for S_1P and for S_2P
- substract two equation
- $d << D$, $S_1P \approx S_2P \approx D$

→ Path difference $= \Delta = S_2A$

$$\Delta = S_2P - S_1P \quad -(1)$$

→ In ΔS_1PM

$$(S_1P)^2 = (PM)^2 + (S_1M)^2$$

$$(S_1P)^2 = \left(y - \frac{d}{2}\right)^2 + D^2 \quad -(2)$$

→ In ΔS_2PN

$$(S_2P)^2 = (PN)^2 + (S_2N)^2$$

$$(S_2P)^2 = \left(y + \frac{d}{2}\right) + D^2 \quad -(3)$$

→ eq (3) & eq (2) (minus)

$\left[(a+b)^2 = a^2 + b^2 + 2ab\right)$ $\quad a^2 + b^2 - 2ab$

$$(S_2P)^2 - (S_1P)^2 = \left\{\left(y + \frac{d}{2}\right)^2 + \cancel{D^2}\right\} - \left\{\left(y - \frac{d}{2}\right)^2 + \cancel{D^2}\right\}$$

$$(S_2P - S_1P)(S_2P + S_1P) = \left\{\left(\cancel{y^2} + \cancel{\frac{d^2}{4}} + \cancel{2}y\frac{d}{2}\right) - \left(\cancel{y^2} + \cancel{\frac{d^2}{4}} - \cancel{2}y\frac{d}{2}\right)\right\}$$

as $d << D$

$S_2P \approx S_1P \approx D$

$\Delta(D+D) = [yd + yd]$

$\Delta(2D) = 2yd$

$$\boxed{y = \frac{\Delta D}{d}}$$

Linear position of Bright fringe

$\Delta = n\lambda$

$$y_n = \frac{n\lambda D}{d}$$

→ Bright fringe width

$\beta = y_n - y_{n-1}$

$\beta = n\frac{\lambda D}{d} - (n-1)\frac{\lambda D}{d}$

$\beta = \frac{\lambda D}{d}[\cancel{n} - \cancel{n} + 1]$

$$\boxed{\beta = \frac{\lambda D}{d}}$$

Linear position of dark fringe

$\Delta = (2n-1)\frac{\lambda}{2}$

$$y_n = (2n-1)\frac{\lambda D}{2d}$$

→ Dark fringe width

$\beta = y_n - y_{n-1}$

$\beta = (2n-1)\frac{\lambda D}{d} - [2(n-1)-1]\frac{\lambda D}{2d}$

$\beta = \frac{\lambda D}{2d}[(\cancel{2n}-1) - (\cancel{2n}-2-1)]$

$\beta = \frac{\lambda D}{2d}[-1+3]$

$$\boxed{\beta = \frac{\lambda D}{d}}$$

Newton's Ring :

A good practical way to see interference in Lab.

Newton performed this to check the curvature of the lens used in telescope

For Bright Rings:

$D_n \propto \sqrt{2n-1} = \sqrt{\text{odd no.}}$

For Dark Ring :

$D_n \propto \sqrt{n} = \sqrt{\text{natural no.}}$

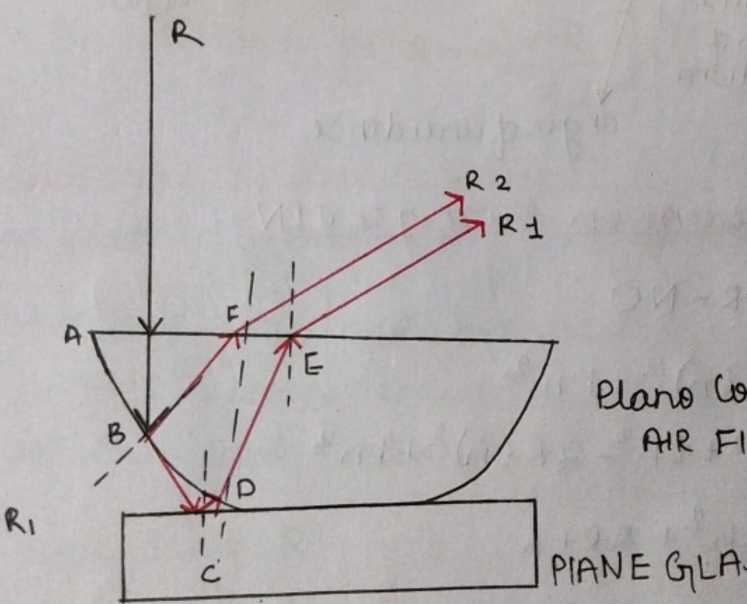
Wavelength of light source

$$\lambda = \frac{D_{n+p}^2 - D_n^2}{4pR}$$

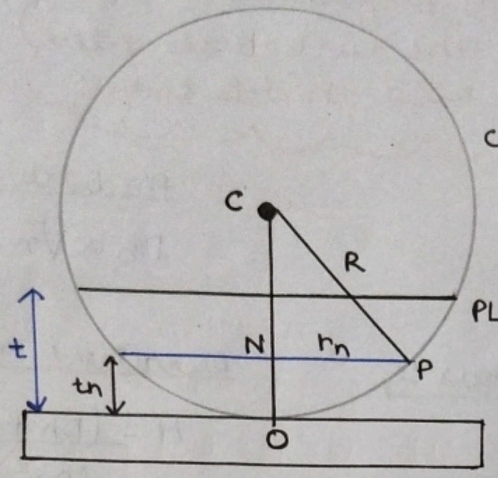
Refractive index of any liquid

$$\mu = \frac{(D_{n+p}^2 - D_n^2)_{air}}{(D_{n+p}^2 - D_n^2)_{liquid}}$$

→ Newton's ring are a series of concentric circular rings (Bright & Dark) which appears about the point of contact between the glass plate convex lens when illuminated with monochromatic light.



Determination of Thickness of Air Film using N.R EXPERIMENT



The path difference produced between the waves reflected by the wedge-shaped air film is

$$\underbrace{\Delta}_{\text{path diff.}} = 2\underbrace{\mu}_{\text{refractive index of medium}}\overbrace{t}^{\text{thickness of AIR film}}\cos\underbrace{r}_{\text{angle of incidence}} + \frac{\lambda}{2}$$

λ → wavelength of monochromatic light.

→ **Applying Pythagoras theorem on triangle CPN**

$R^2 = (CN)^2 + r_n^2$, $CN = R - NO$

$\boxed{CN = R - t_n}$ $\Rightarrow R^2 = (R-t_n)^2 + r_n^2$

$\Rightarrow \cancel{R^2} = (\cancel{R^2} + t_n^2 - 2Rt_n)^2 + r_n^2$

$\Rightarrow r_n^2 = -t_n^2 + 2Rt_n$

$\therefore t_n^2 \simeq 0 \quad \because t_n << R$

$\Rightarrow r_n^2 = 2Rt_n$

$$\boxed{\Rightarrow t_n = \frac{r_n^2}{2R}}$$

Diameter of Bright Rings:

The path difference $\Delta = 2\mu t \cos\theta + \frac{\lambda}{2}$

so for nth order of bright fringe, since condition for bright fringe ⇒>>>>>

Path difference should be equal to the $n\lambda$

i.e $\Delta = n\lambda$

equating RHS:

$$2\mu t_n \cos\theta + \frac{\lambda}{2} = n\lambda$$

$$2\mu t_n \cos\theta = (2n-1)\frac{\lambda}{2}$$, since $\theta = 0°$, $\cos 0° = 1$

$$2\mu t_n = (2n-1)\frac{\lambda}{2}$$

$$\cancel{2}\mu \frac{r_n^2}{\cancel{2}R} = (2n-1)\frac{\lambda}{2}$$

$$r_n = \left[(2n-1)\frac{\lambda R}{2\mu}\right]^{1/2}$$

$$D_n = 2r_n = \left[4(2n-1)\frac{\lambda R}{2\mu}\right]^{1/2}$$

Diameter of Dark Rings:

The path difference in reflected rays R_1 & R_2

$$\Delta = 2\mu t \cos(\theta) + \frac{\lambda}{2}$$

Condition for dark Fringes

PATH Difference should be equal to the odd multiples of $\frac{\lambda}{2}$

$$\Delta = (2n+1)\frac{\lambda}{2}$$

equating RHS -:

$$2\mu t \cos(\theta) + \frac{\lambda}{2} = (2n+1)\frac{\lambda}{2}$$

$$2\mu t \cos(\theta) = \cancel{2}n\frac{\lambda}{\cancel{2}} + \cancel{\frac{\lambda}{2}} - \cancel{\frac{\lambda}{2}}$$

$$= 2\mu t \cos\theta = n\lambda$$

$\cos\theta = 1$

$2\mu t_n = n\lambda$

But we know, $t_n = \frac{r_n^2}{2R}$

$\cancel{2}\mu \frac{r_n^2}{\cancel{2}R} = n\lambda$

$r_n^2 = \frac{n\lambda R}{\mu} \Rightarrow r_n = \sqrt{\frac{n\lambda R}{\mu}}$

$D_n = \sqrt{\frac{2n\lambda R}{\mu}}$

Determination of λ of Monochromatic Light using N.T EXPER.

since we know : Diameter of n^{th} ring is $D_n = [4n\lambda R]^{1/2}$

$D_n^2 = [4n\lambda R]$

for $(n+p)^{th}$ ring (dark)

$D_{n+p}^2 = [4(n+p)\lambda R]$

$D_{n+p}^2 - D_n^2 = [4(n+p)\lambda R] - [4n\lambda R]$

$$\lambda = \frac{D_{n+p}^2 - D_n^2}{4PR}$$

Diffraction of light waves:

Extending the idea of interference to many light sources. A more clear view will be developed by comparing the resultant intensity pattern i.e ~~of~~ interfere pattern & diffraction patterns.

The bending of light waves from its straight path nature by the sharp edges of obstacles called the diffraction.

The diffraction (bending of light) will be maximum when the order of wavelength of incident wave is same order as that of dimention of obstacle.

Two classes of diffraction:

1) Fraunhofer diffraction: (Far field differaction)

Here the light wavefront reaching at obstacle are plane in nature. Possibly when source-obstacle (source) are supposed to be at ∞ distance. so this is called " Far field diffraction".

This condition may be achived by the use of two convex lenses (to produce plane wave fronts)

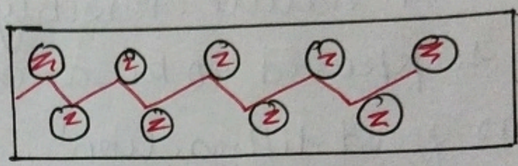
TO BE Continued

Super Conductivity

Super conductors :

super → very large/excellent
conductor → a medium that allows flow of current
↳ very good conductor such as $\boxed{R \to 0}$ Resistance?

Why resistance is present?



→ Vd (drift velocity)
→ multiple collisions
↓
Resist the flow of $\bar{e}$ → Resistance

if somehow collisions are removed or reduced $\boxed{R \to 0}$

But how?

→ Onnes discovered superconductivity in 1911
→ He also developed the methods for liquification of Helium.
→ At temperature below 4.2K, the resistance of Hg drop to nearly zero abruptly → superconductivity
→ ~~4K~~ 4.2K is called transition temperature
→ 1933 - Meissner & Ochsenfield discovered "diamagnetic nature" of superconductors
→ Important property not related with $R \to 0$ nature
→ London Brothers proposed free energy theory.

→ 1950 Landau - Ginzburg give major theory for super conductor by considering its phase - transition nature.
→ Leads to theory of type I-II superconductor

→ Isotopic effect was discovered (1950)

→ 1957 - BCS theory proposed.

Bardeen, cooper & schrieffer proposed first microscopic theory was superconductivity by considering - electron ~~in~~ phonon - electron interaction.

→ 1962 commercial superconducting wire niobium - titrate developed.

→ Josephson effect discovered.

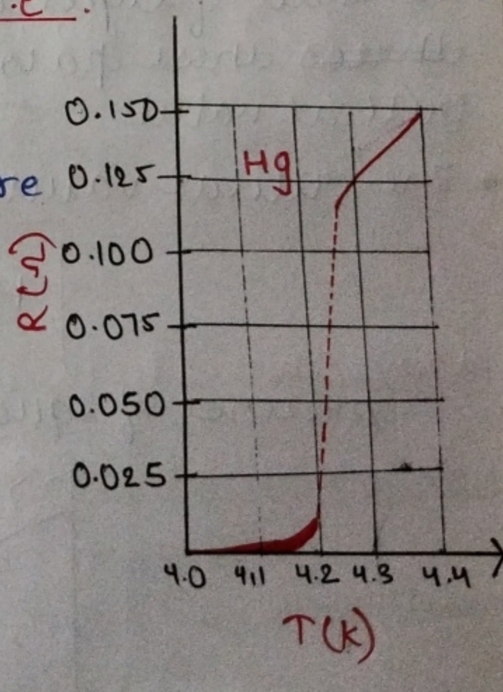
Basic Defination:

superconductivity is a state of any element where at very low temperature the resistivity of element becomes ~~also~~ almost zero. The materials that shows these are called "superconductors".

Transition of normal state to superconducting state is done at a "Transition temperature".
↳ characteristic of the material

Temperature dependent resistivity of S.C:

→ Normally the resistance of material decreases with decrease in temp. because by reduction in temperature the collision of conduction electron also decreases.



→ Materials have residual resistance at very low temperature. This residual resistance is very large for impure sample.

Superconductivity is not very sensitive for impurity of material
But magnetic impurity tends to decrease the transition temperature:

→ some materials shows superconductivity only in purest state
→ some pure materials also not showing superconductivity even when $T \to 0$ Kelvin.

→ Onnes show that width of transition region increases by adding the impurity to the sample.

Temperature Dependence of critical field:

(Role of external magnetic field over superconductivity)

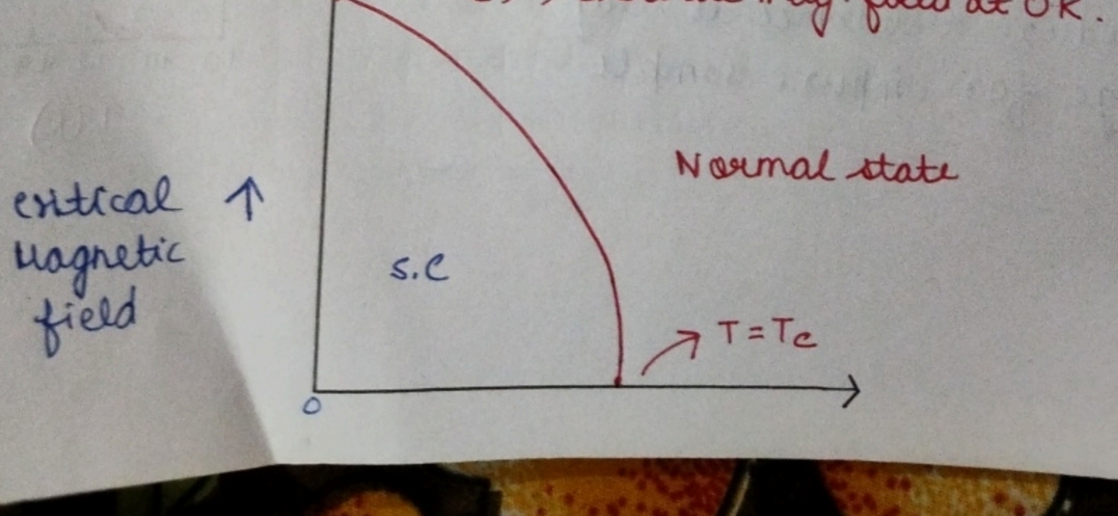
- Not only the temperature but also the presence of magnetic field influences the state of "superconductivity"

→ so two factors are important:
- ↳ critical magnetic field (H_c)
- ↳ critical Temperature (T_c)

- The state of superconductivity destroyed if either of ~~those~~ these parameters become greater than their critical values.
- The critical values H_c & T_c are related as:

$$\boxed{H_c = H_c(0)\left[1 - \left(\frac{T}{T_c}\right)^2\right]}$$

presence of square term shows the parabolic relation as

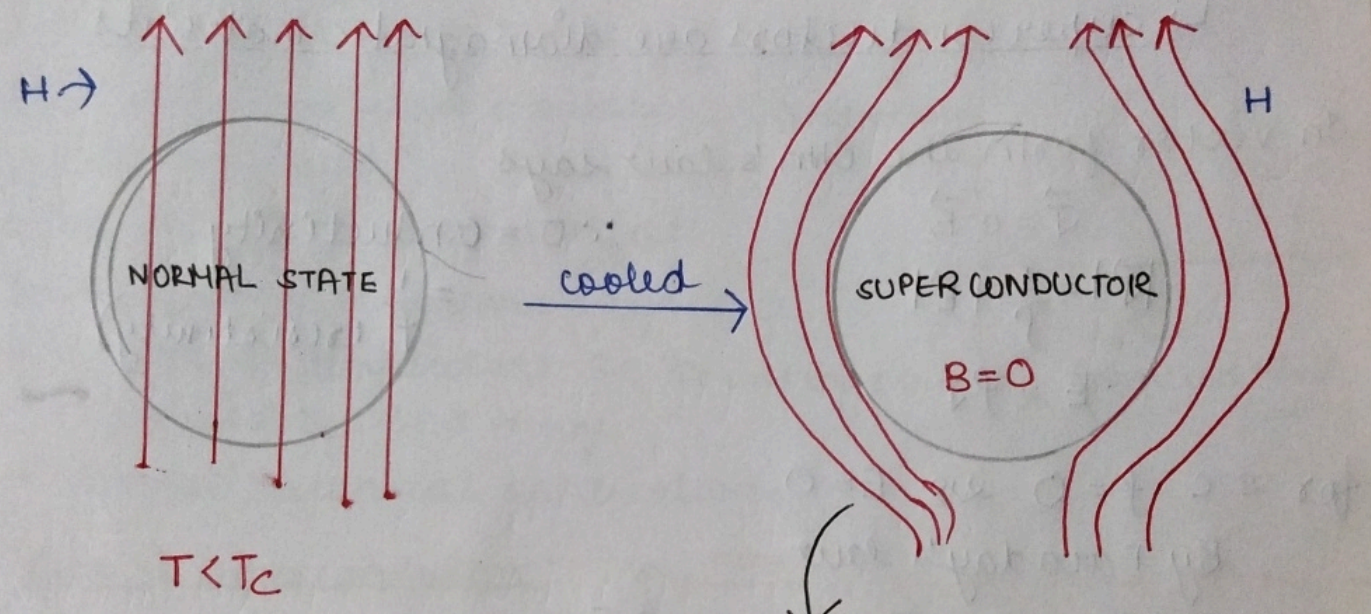


→ At any temperature below T_c the material remains in superconducting state untill applied magnetic field is less than corresponding magnetic field's critical value.

→ If magnetic field applied over material is more than $H_c(0)$ the material will never convert to S.C state even at $T = 0K$.

Meissner Effect :

"when a material transit from Normal to superconductivity state, it actively repel magnetic fields lines from its interior. This phenomenon is called "Meissner effect""



expelling magnetic lines is a property of diamagn-etic element so superconductors are diamagnetic

→ B=0 and R→0 are two independent properties; not inter related

By electric theory of materials, if $\vec{B}$ is magnetic induction, $\vec{H}$ is magnetic intensity and $\vec{M}$ is magnetisa-zation vector, they are interrelated as

$$\vec{B} = \mu_0(\vec{H} + \vec{M}) \quad \text{—} \; (1)$$

But Meissner shows that in S.C state $B=0$
so, equation ① gives -

$$0 = \mu_0(\vec{H}+\vec{M})$$

$\because \mu_0 \neq 0$, so $\boxed{\vec{H} = -\vec{M}}$

the magnetic susceptibility $\chi = \frac{|\vec{M}|}{|\vec{H}|} = -1$

$\chi = -1$ is the characteristic property of diamagnetic material.

↳ <u>superconductors are diamagnetic materials</u>

In vector form the ohm's law says

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

$$|\vec{J}| = \frac{1}{\rho}|\vec{E}|$$

$\because \sigma =$ conductivity $= \frac{1}{\rho}$ (resistivity)

$$E = \rho J$$

for s.c $\rho = 0$ so $E = 0$

By Faraday's law

$$\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\Rightarrow 0 = -\frac{\partial \vec{B}}{\partial t} \Rightarrow \boxed{B = \text{const}}$$

→ This contradicts meissner's observation

This means : Zero resistivity of material and perfect diamagnetism are two independent properties of the "superconductors".

Type I & Type II superconductors:

→ The magnetic field over superconductors and critical temperature are two important characteristics of superconductors.

→ In the presence of large magnetic field the superconductor breakdown (transit to Normal state) so, two possibilities are there :

Type I superconductor:

→ superconductivity abruptly distroyed at $H = H_c$

→ this is first order transition

→ shown by "Pure state of metals like Hg, Pb, Al."

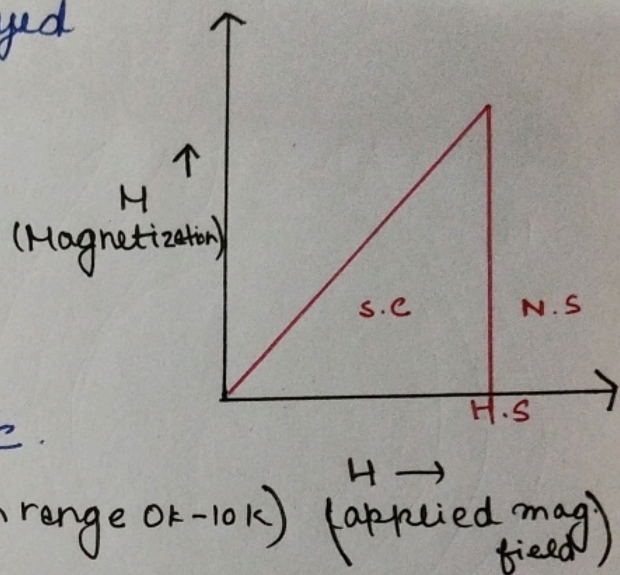
→ Perfectly obey Meissner effect

→ Low value of H_c means → soft S.C.

→ called low temperature S.C (T_c in range 0K - 10K)

→ Explained by BCS theory

→ limited technical applications.



Type II superconductor:

→ Has two critical magnetic fields H_{c1} & H_{c2}