

Optics

- 1] Wavefront: Focus of all points which vibrating in same phase is known as wavefront.

Speed of wave: Speed with which wave propagates is known as speed of wave.

Types of wavefront.

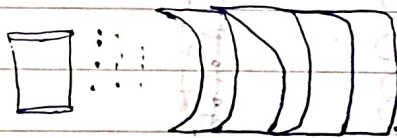
- Transverse wavefront.
- Longitudinal wavefront

Depends on nature of source.

- 1] Point source → always generate spherical wavefront.
Eg stone through in water.

- 2] Line source / linear slit → Cylindrical wavefront.

Eg fluorescent-tube.

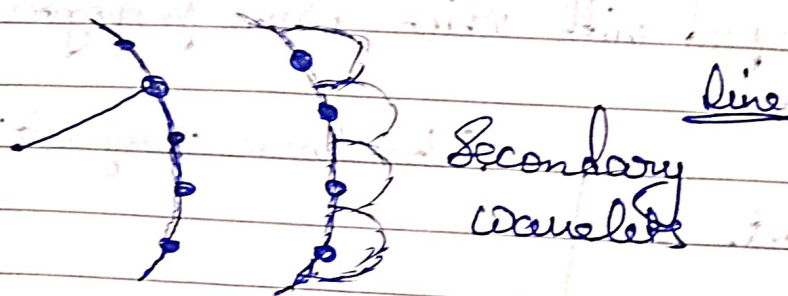


phase wavefront

plane wavefront source [point or line] should be placed at infinite distance.

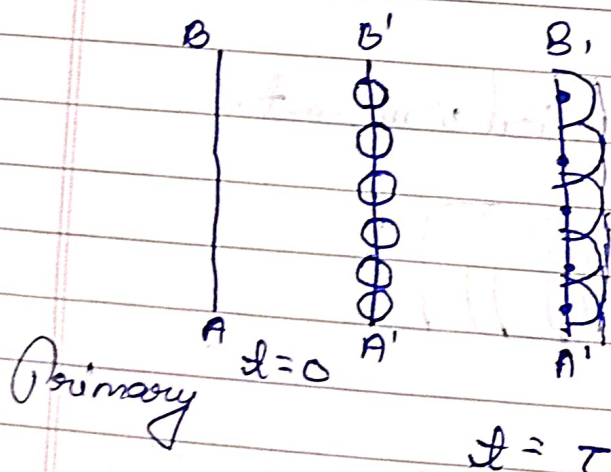
Hygen's Principle.

→ It state that every point of wavefront acts as a source of secondary wavelets and new wavelets move forward with speed of light.

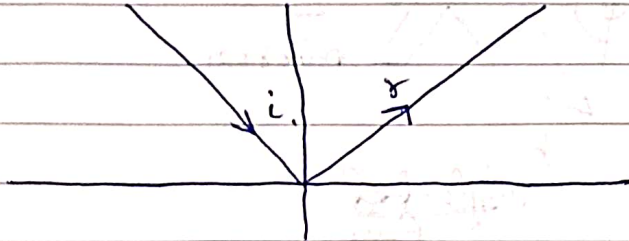


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Plane wavefront



Reflection



Law of Reflection.

① Incident Ray and reflected ray lies on same plane.

② $\angle i = \angle r$

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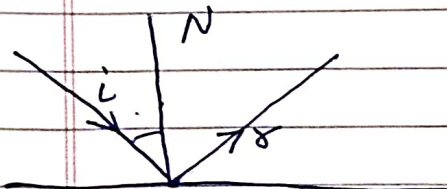
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Smooth Surface

① Specular Reflection

② Smaller irregularities or defects as compared to wavelength of light.

Eg Polished metal surface, Mirror, Water surface.



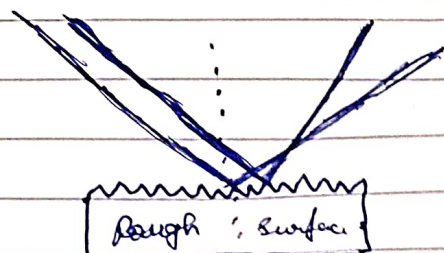
Rough Surface

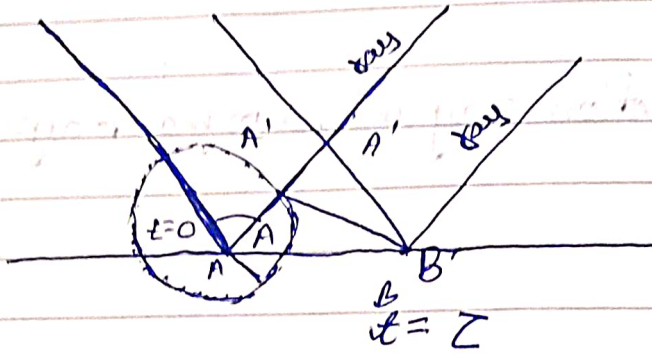
Diffused Reflection

Larger irregularities or defects as compared to wavelength of light.

Eg wall, floorings.

$\angle i \neq \angle r$



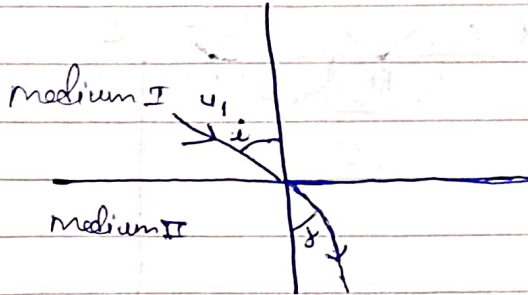


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Refraction.

→ Bending of light when it travel it from one medium to medium 2.

$$u_1 < u_2$$

Laws of Reflection

1] Incident ray, Reflected ray and Normal lies in same plane.

2] Snell's law

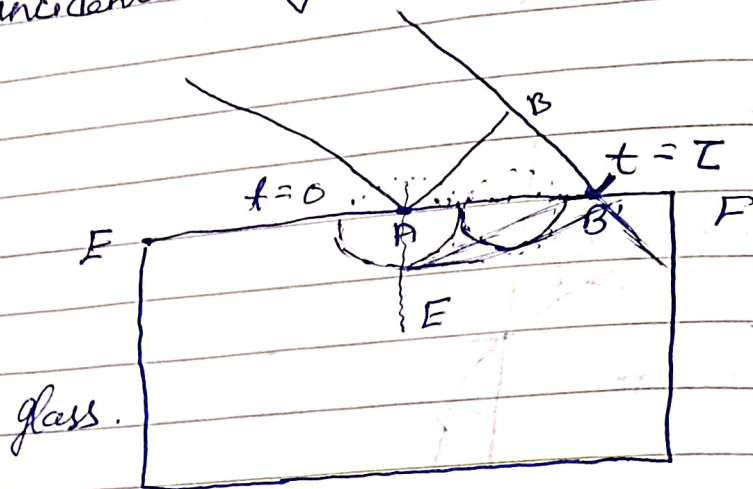
$$\frac{\sin i}{\sin r} = \frac{u_1}{u_2} = \frac{c/u_1}{c/u_2} = \frac{u_2}{u_1}$$

3]

* Refl

E

AB - incident wavefront



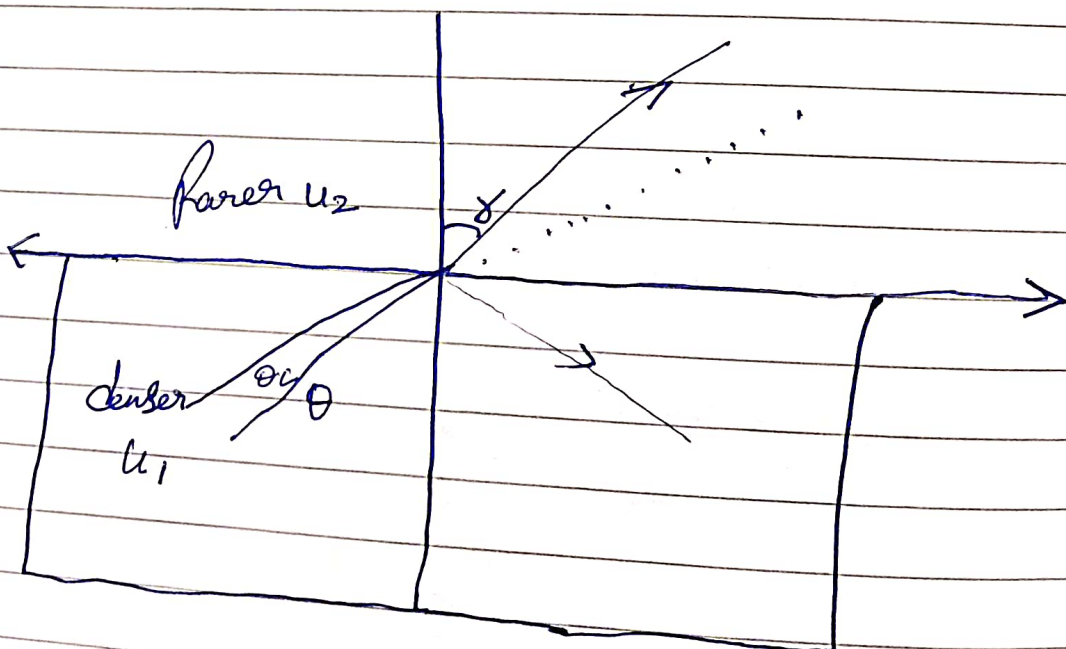
AB - Incident wavelength.

AB - Incident Wavelength.
EB' - Reflected Ray. (wavefront)

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Imp

Total Internal Reflection (TIR)



1] Light rays should travel from denser to rarer medium.

$$u_1 > u_2$$

(denser) (rarer)

2] Angle of incidence $>$ Critical angle.

$$\theta > \theta_c$$

$$\theta = \theta_c$$

$$r = 90^\circ$$

Conditions

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1] If $\theta < \theta_c$ rays are refracted in rarer medium.

2] If $\theta = \theta_c$ refracted rays grazes over the interface.

3] If $\theta > \theta_c$ refracted rays goes inside the medium.

E

* Critical angle

At a specific angle of incidence, angle of refraction becomes 90° is known as critical angle.

By Snell's law.

$$\frac{\sin \theta}{\sin x} = \frac{u_2}{u_1}$$

$$\text{at } \theta = \theta_c, x = 90^\circ$$

If rarer med is air $u_2 = 1$

$$\sin \theta_c = \frac{1}{u_1}$$

$$\theta_c = \sin^{-1} \left(\frac{1}{u_1} \right)$$

R-I of denser medium

Total Reflection

$$(i) u_1 > u_2$$

Q Determine the value of critical angle for a ray traveling from water to air.

$$\mu = 1.33.$$

$$\rightarrow \theta_c = \sin^{-1}\left(\frac{1}{\mu}\right)$$

$$\theta_c = 48.60^\circ.$$

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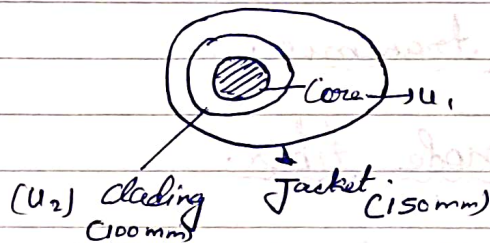
Optical fiber.

→ Very thin & flexible medium, cylindrical shape consist of

1] Core

2] Cladding

3] Buffer Coating / Jacket



Gross-sectional view of fiber optics.

→ 1] Very thin and flexible medium cylinder shape consist of

2] Core → innermost part of fiber optics with higher R.I u_1 ,

2] Cladding: Surrounds the core medium and have less R.I u_2 Dielectric material.

3] Jacket → outermost layer which provides protection and strength of fiber optics.

4] optical fiber works on the principle of [TIR] Total Internal reflection.

E

Type of optical fibre

Material of fibre —
 — glass
 — polymer
 — plastic.

* Depending on Refractive Index [R.I] of core and cladding.

1] Step-Index Fibre → The R.I of core material is constant and less than R.I of cladding.

2] Graded-index fibre.

The R.I of core material decreases gradually towards the cladding.

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Mode of transmission

1] Single mode fiber.

(a) Core diameter is small $\approx 10 \mu\text{m}$.

Use in long distance communication.

Provide single path for propagation of light wave.

2] Multi-mode

Core Diameter $\approx 20 \mu\text{m} - 50 \mu\text{m}$

Short distance communication multiple path for propagation.

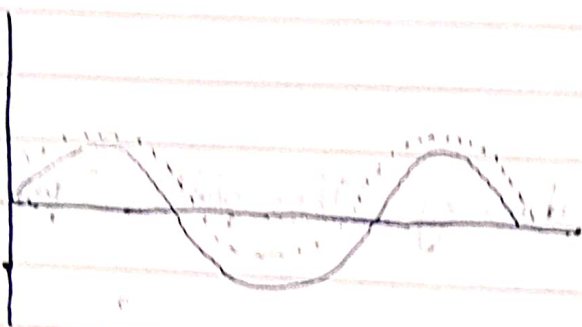
Depending on nature of material.

- 1] All glass fiber.
- 2] All plastic fiber.
- 3] glass-plastic fiber.
- 4] polymer fibres.

Advantages and application of Fibre optics 5 points.

Interference

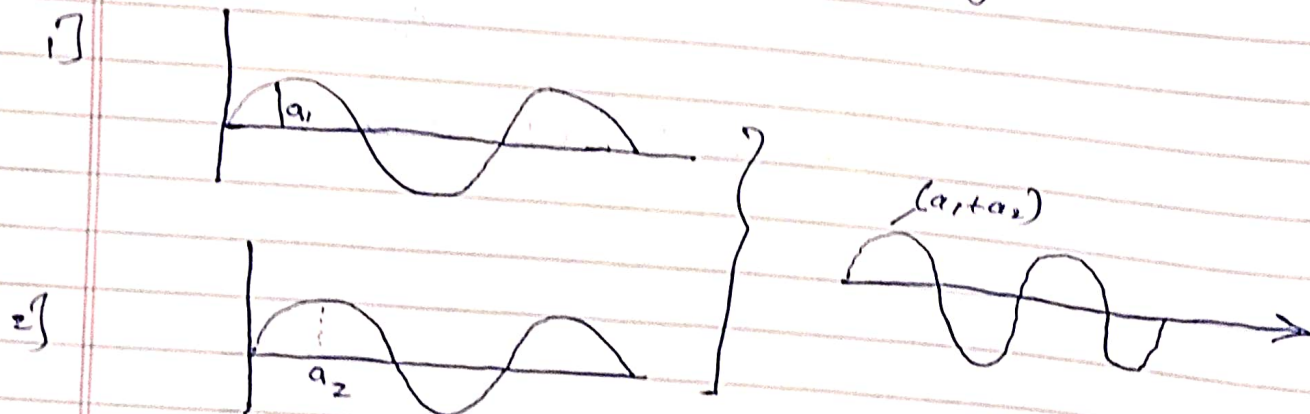
→ Given by Young's Double slit experiment.



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Interference → Redistribution of energy after overlapping of 2 or more waves.

Constructive Interference → When two waves meet at point in phase then resultant amplitude will be addition of individual waves.



- 3) When crest of one wave falls on crest of another wave C-I will take place then destructive interference will happen.

Intensity $\propto$ (Amplitude)².

$$I_1 = a_1^2$$

$$I_2 = a_2^2$$

$$a^2 - a_2^2$$

$$I_R = (a_1 - a_2)^2$$

$$I_R = a_1^2 + a_2^2 - 2a_1a_2$$

$$I_R = a_1 = a_2 = a$$

$$\star I_R = 0$$

Resultant Intensity.

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$\star$ Condition of stable / sustained Interference pattern.

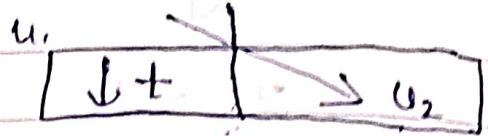
- 1] The source should be monochromatic in nature (single λ)
- 2] The sources should be coherent (phase difference is constant)
- 3] The source should emit waves of equal amplitude

Geometrical path length [GPL]



Shortest path between A & B point is known as GPL
GPL remains same in every medium.

Optical path length [OPL]



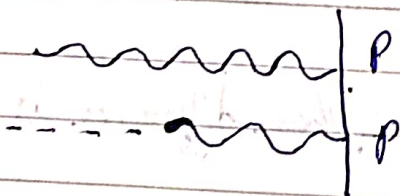
Light travels u time slower medium so

$$OPL = u[GPL]$$

$$* \Delta = ut$$

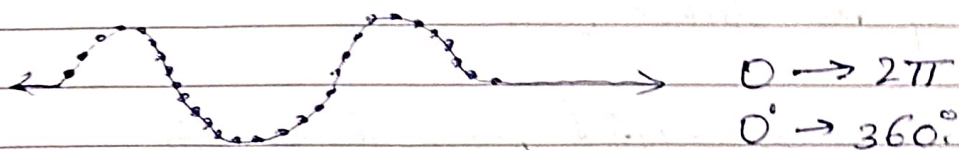
Path Difference [Δ]

The difference between optical path length of two waves travelling in different is known as Path difference.



$$AP = AP - A'P$$

* Phase Difference (ϕ)



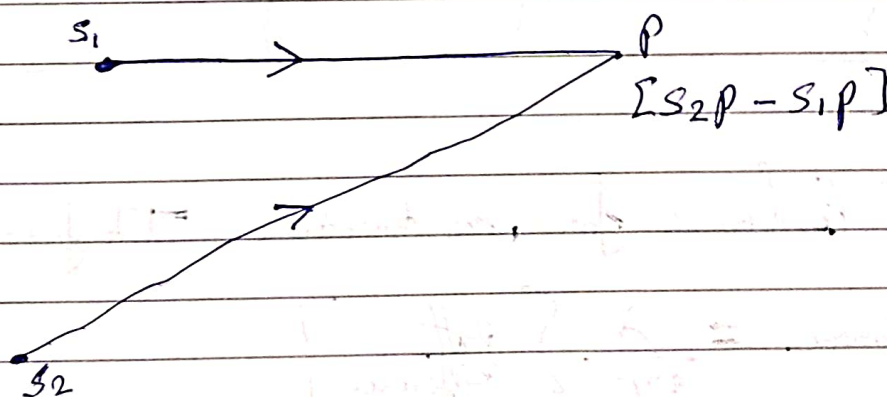
phase difference is defined as different between phase angles

$$* \text{ Phase difference} = \frac{2\pi}{\lambda} [\text{path difference}]$$

$$* (\text{path difference}) = \frac{\lambda}{2\pi} [\text{phase difference}]$$

* Reasons of generating phase difference.

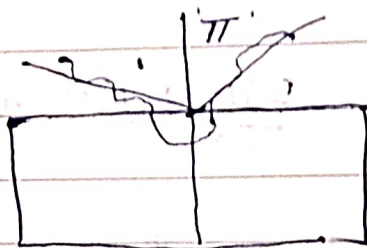
1] Due to optical path difference.



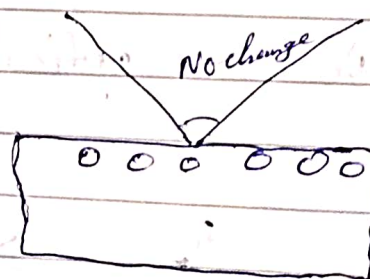
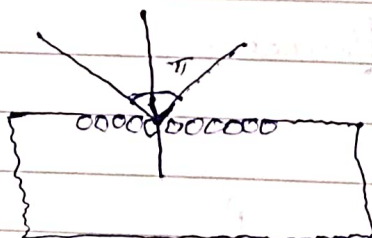
2] Due to reflection at denser surface.

According to Stokes' law.

When wave is reflected from denser to rarer then phase change by ' π '



When light wave is reflected from rarer to denser then there will be no change in phase.



* Standard conditions for constructive Interference.

$$\text{Path Difference} = \frac{\lambda}{2\pi} \left[\text{Path Difference} \right]$$

$$\text{path diff} = n\lambda$$

$$(n = 0, 1, 2, 3, \dots)$$

Phase Diff $= 2n\lambda$

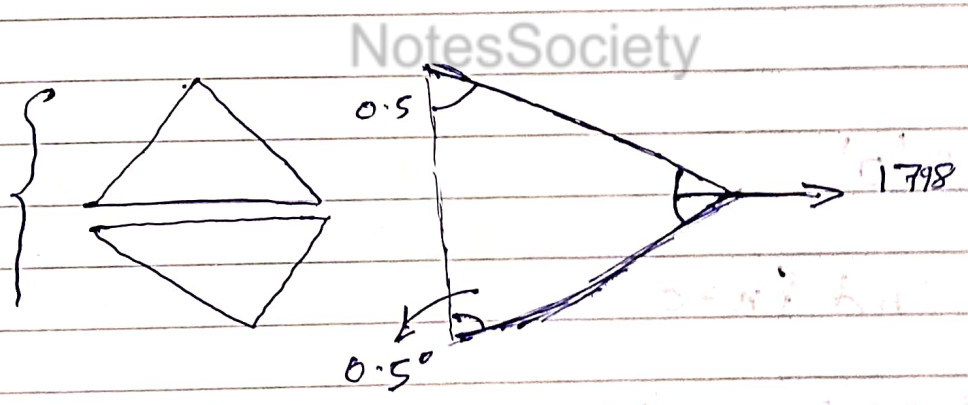
Conditions for D.I

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

phase diff $= (2n+1)\pi$

* Division of wavelength.

Fresnel's bipry, biprism.



* Optical path difference is Fresnel's biprism.

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At point 'O' . . .

$$\Delta \leq 0 \Rightarrow n \in \{n \geq 0\}$$

If it satisfy conditions of C-I point 'O' will be always bright.

$$(s_2\rho)^2 = D^2 + \left(\frac{x+d}{2}\right)^2 \quad \text{--- (3)}$$

At arbitrary point P
path difference: $S_2P - S_1P = n\lambda_2$ — (I)

In ΔS_1EP

$$[S_1P]^2 = [S_1E]^2 + [PE]^2$$

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

In ΔS_2FP

$$[S_2P]^2 = [S_2F]^2 + [PF]^2$$

by equation (3) - Equation (2)

$$[S_2P]^2 - [S_1P]^2 = D^2 + \left[x + \frac{d}{2}\right]^2 - \left[D^2 + \left[x - \frac{d}{2}\right]^2\right]$$

$$[S_2P - S_1P][S_2P + S_1P] = 2xd$$

$$\text{Path difference} = \frac{2xd}{[S_2P + S_1P]}$$

$$\text{If } S_2P = S_1P = 0$$

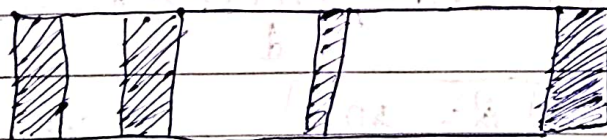
$$\text{Path Diff} = \frac{2xd}{2}$$

$$\text{path diff} = \frac{xd}{D} \quad (4)$$

$$1] \text{ Path Diff} = S_2P - S_1P$$

$$= S_2N$$

$$\text{path Diff} = \frac{xd}{D}$$



In pattern (2)

2] Bright Fringe [C.F.]

$$\Delta = n\lambda$$

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

Condition of bright fringe (mark)

3] Dark Fringe

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

$$\frac{x d}{D} = (2n+1) \frac{\lambda}{2}$$

$$\frac{x d}{D} = (2n+1) \frac{\lambda}{2}$$

4] Fringe width [B]

$$n^{\text{th}} \text{ \& } (n+1)^{\text{th}}$$

Bright fringe

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

$$x_{n+1} = \frac{(n+1) \lambda D}{d}$$

$$x_{n+1} - x_n = \frac{(n+1) \lambda D}{d} - \frac{n \lambda D}{d}$$

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

d = Distance between two
Coherent sources.

- Q1] A biprism is placed such that a slit illuminated by sodium light of wavelength $\lambda = 5890 \text{ \AA}$. The fringe width obtained on the screen is $\beta = 0.9424 \text{ mm}$. Find the separation between two coherent sources if distance between biprism and screen is $= 75 \text{ cm}$.

→ Given

$$\lambda = 5890 \text{ \AA} = 5890 \times 10^{-8} \text{ cm}$$

$$\beta = 0.9424 \text{ mm} = 0.9424 \times 10^{-1} \text{ cm}$$

$$D = [a+b] = [5+75] = 80 \text{ cm}$$

$$a = 5 \text{ cm}$$

$$d = ?$$

$$\text{Formula} = \beta = \frac{\lambda D}{d}$$

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

$$d = 0.05 \text{ cm}$$

- Q2] A Fresnel's biprism is used to form interference fringes. The distance between the source and biprism is 20 cm and that between biprism and screen is 80 cm . If λ wavelength $\lambda = 6563 \text{ \AA}$ and the separation between virtual sources is 3.6 cm , then find out the fringe width.

$$\lambda = 6563 \text{ \AA} = 6563 \times 10^{-8} \text{ cm} \quad D = (20+80) = 100 \text{ cm}$$

$$B = ?$$

$$d = 3.6 \text{ cm} = 3.6 \times 10^{-1} \text{ cm}$$

$$\text{Formula} \quad \beta = \frac{\lambda D}{d} \quad \beta = \frac{6563 \times 10^{-8} \times 100}{3.6} = \frac{6563 \times 10^{-6}}{3.6 \times 10^{-1}}$$

$$= 1.82 \times 10^{-2}$$

E

Eg :- The biprism experiment the distance between 2 virtual sources is 0.1 cm and the distance between source and screen is 1 m . If the fringe width is 0.058 cm find out the wavelength of light. (λ)

→ Given :- wavelength (λ) = ?

$$d = 0.1 \text{ cm}$$

$$D = 100 \text{ cm}$$

$$\beta = 0.058 \text{ cm}$$

Formula :- $\beta = \frac{\lambda D}{d}$

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

$$= \frac{0.058 \times 0.1}{100}$$

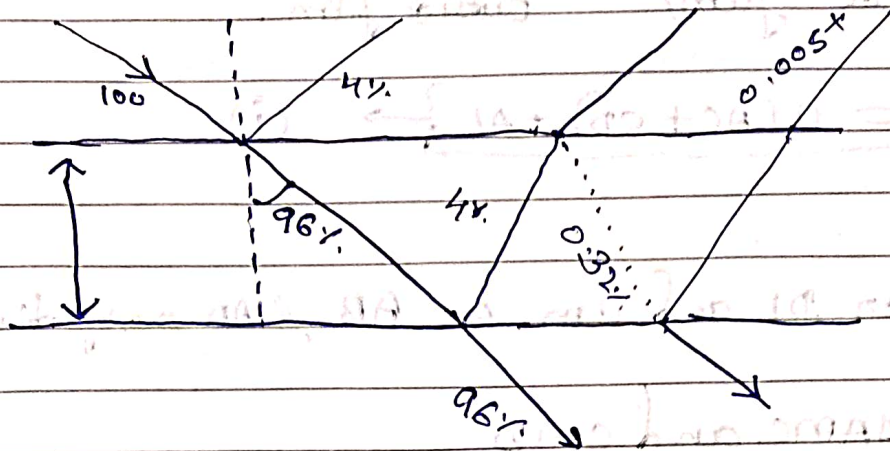
$$= \frac{5.8 \times 10^{-3}}{100}$$

$$1 \text{ \AA} = 10^{-8} \text{ cm} = 5.8 \times 10^{-5}$$

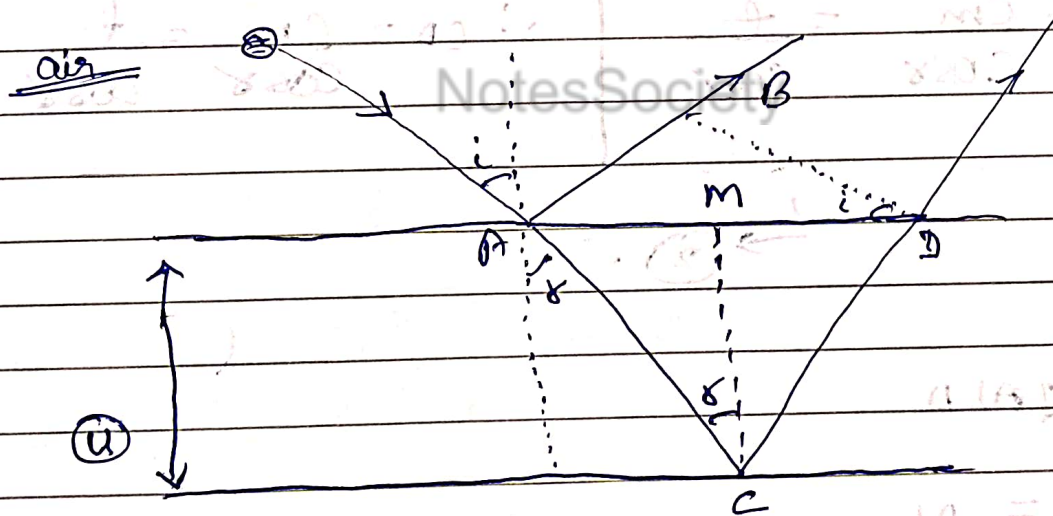
$$5.8 \times 10^8 = 5.8 \times 10^3$$

$$= 5800$$

* Division of Amplitude.
* Interference in thin film.



* Condition max and min of thin film.



S = Extended source.

SA = Incident ray

AB = reflected ray

AD = Refracted ray } coherent ray

$\angle i$ = angle of incidence

$\angle r$ = angle of refraction

Path diff betⁿ ray AB and DE.

$$= u(AC + CD) - u(A)$$

(inside film) outside film.

$$\Delta = u(AC + CD) - AL \rightarrow \textcircled{1}$$

put len DL and cm on AB & AD respectively.

In $\triangle AMC$ and CMD

$$\cos x = \frac{CM}{AC}$$

$$AC = \frac{CM}{\cos x} = \frac{t}{\cos x}$$

$$\cos x = \frac{CM}{CD}$$

$$\therefore CD = \frac{CM}{\cos x} = \frac{t}{\cos x}$$

$\rightarrow \textcircled{2}$

In $\triangle ALD$

$$\sin i = \frac{AL}{AD}$$

$$\therefore AL = AD \cdot \sin i$$

$$AL = (AM + MD) \cdot \sin i \rightarrow \textcircled{3}$$

In $\triangle AMC$ & $\triangle CMD$

$$\therefore \tan \theta = \frac{AM}{CM}$$

$$\therefore AM = CM \cdot \tan \theta$$

$$AM = t \cdot \tan \theta$$

$$\tan \theta = \frac{MD}{CM}$$

$$\therefore MD = CM \tan \theta$$

$$MD = t \cdot \tan \theta \quad \text{--- (4)}$$

From (4) eqn (3) become

$$AL = (t \cdot \tan \theta + t \cdot \tan \theta) \sin i$$

$$AL = 2t \cdot \tan \theta \sin i$$

$$AL = 2t \cdot \frac{\sin \theta}{\cos \theta} \left[\frac{\sin i}{\sin \theta} \right] \sin \theta$$

$$AL = 2ut \frac{\sin^2 \theta}{\cos \theta} \quad \text{--- (5)}$$

By using equation (2) and (3)

$$\Delta = u(AC + CD) - AL$$

$$\Delta = u \left[\frac{t}{\cos \theta} + \frac{t}{\cos \theta} \right] - 2ut \cdot \frac{\sin^2 \theta}{\cos \theta}$$

$$\Delta = \frac{2ut}{\cos \theta} - \frac{2ut}{\cos \theta} \cdot \sin^2 \theta$$

$$\Delta = \frac{2ut}{\cos \alpha} [1 - \sin^2 \alpha]$$

$$\boxed{\Delta = 2ut \cos \alpha} \rightarrow \textcircled{6}$$

Corrected path difference.

$$\Delta = 2ut \cos \alpha \pm \frac{\lambda}{2} \left\{ \begin{array}{l} \rightarrow \text{By Stoke's law} \\ \text{Reflected ray} \\ \text{denser - rarer} \\ \pi \rightarrow \frac{\lambda}{2} \end{array} \right.$$

NotesSociety

Condition of Bright light.

$$\Delta = n\lambda \rightarrow \text{Constructive Interference}$$

$$2ut \cos \alpha \pm \frac{\lambda}{2} = n\lambda$$

$$\therefore 2ut \cos \alpha = 2n \cdot \frac{\lambda}{2} - \frac{\lambda}{2}$$

$$\therefore 2ut \cos \alpha = (2n-1) \frac{\lambda}{2}$$

$$\{ n = 0, 1, 2, \dots \}$$

Condition of Dark ness $\rightarrow$

$$\Delta = (2n+1) \frac{\lambda}{2} \rightarrow \text{Destructive interference}$$

$$2ut \cos x + \frac{\lambda}{2} = (2n+1) \frac{\lambda}{2}$$

$$2ut \cos x = (2n+1) \frac{\lambda}{2} - \frac{\lambda}{2}$$

$$\boxed{2ut + \cos x = n\lambda} \rightarrow \text{Question can be}$$

$$\rightarrow (n = 0, 1, 2, \dots)$$

Numericals

- 1) A parallel beam of sodium light strikes a film of oil floating on water when viewed at an angle of 30° from the normal 8th dark is seen. Determine the thickness of the film.
 CR-I of oil = 1.46, $\lambda = 5890 \text{ \AA}$.

$\rightarrow$ Given

$$i = 30^\circ$$

$$n = 8$$

$$\mu_2 = 1.46$$

$$\lambda = 5890 \text{ \AA} = 6890 \times 10^{-8} \text{ cm}$$

Sol Dark band is given by

$$2ut \cos x = n\lambda$$

$$\therefore t = \frac{n\lambda}{2u \cos x}$$

by Snell's law

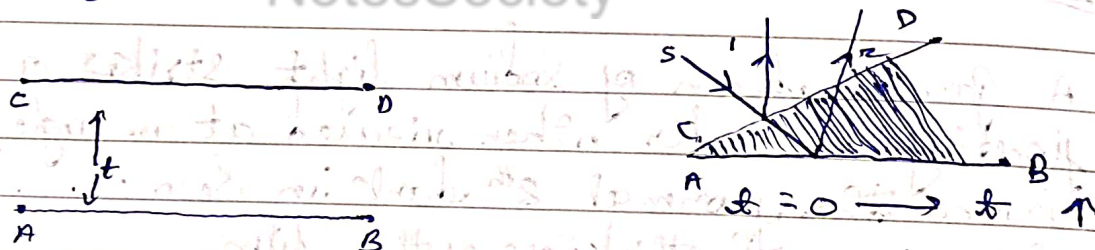
$$\mu = \frac{\sin i}{\sin r}$$

$$\sin r = \frac{\sin 30}{1.48}$$

$$r = 19.87^\circ$$

*

Wedge shaped air film [without derivation] $\rightarrow$ It is defined as thin film having zero thickness at one end and at the other end thickness increases.



$$P.L \Delta = 2ut \cdot \cos(\gamma + \theta) + \frac{d}{2}$$

1]

maxima

$$2ut \cdot \cos(\gamma + \theta) = (2n+1) \frac{d}{2} \quad \left\{ n = 0, 1, 2, 3, \dots \right.$$

2]

minima

$$2ut \cos(\gamma + \theta) = n\lambda \quad \left\{ n = 1, 2, 3, 4, \dots \right.$$

* Fringe width (β)

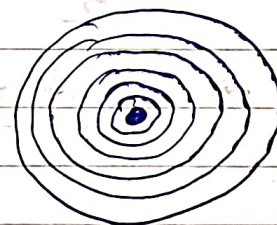
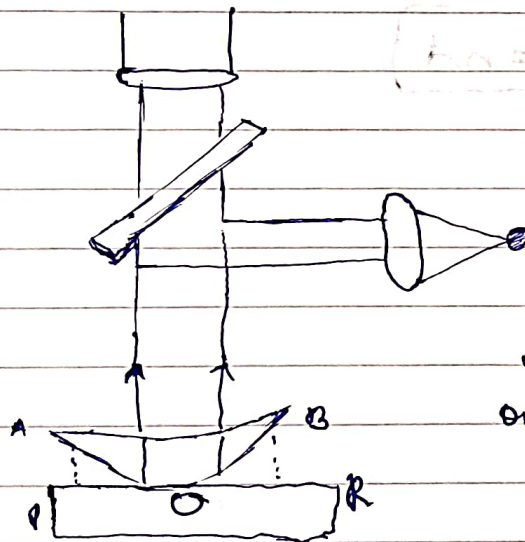
$$\beta = \frac{\lambda}{2\mu \tan \theta}$$

as $\theta \Rightarrow$ very small $\tan \theta \approx \theta$.

$$\boxed{\beta = \frac{\lambda}{2\mu \theta}}$$

Newton's Ring.

* Experimental Setup.



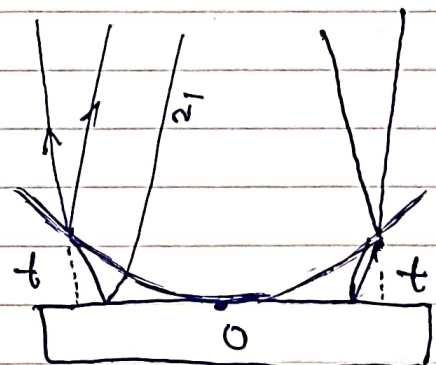
Plano concave lens of large radius of curvature is placed on plane glass plate.

Path Difference.

$$\Delta = 2\mu t \cos \alpha + \frac{\lambda}{2}$$

Newton's ring rays incident along the normal $i=0$, $\alpha=0$

$$\boxed{\Delta = 2\mu t + \frac{\lambda}{2}}$$



Condition of bright light [ring]

$$\Delta = n\lambda$$

$$2ut + \frac{d}{2} = n\lambda$$

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

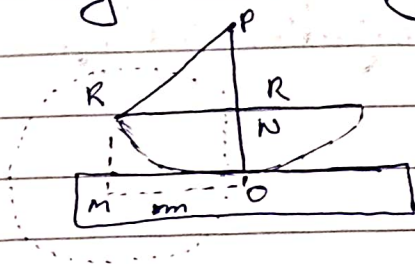
* Dark ring

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

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

$$\therefore 2ut = n\lambda$$

* Radius of Dark Ring.



ΔPNM

$$PM^2 = PN^2 + MN^2$$

$$R^2 = (R-t)^2 + r_m^2$$

$$\therefore R^2 = R^2 - 2Rt + t^2 + r_m^2$$

$$\therefore r_m^2 = 2Rt - t^2$$

$$\boxed{r_m^2 = 2Rt} \quad \text{--- (1)}$$

By using condition of dark ring

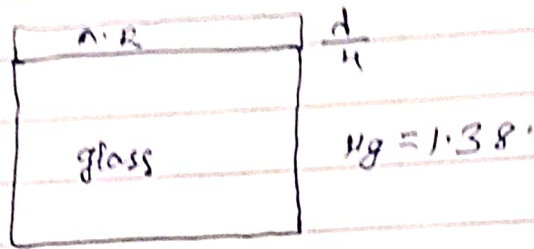
$$2t = n\lambda$$

$$r_m^2 = n\lambda R$$

$$* \boxed{r_m = \sqrt{n\lambda R}}$$

$$* \boxed{D_m = 2\sqrt{n\lambda R}}$$

* Anti-reflection Coating → Reduced reflection and enhance transmission



Eg: 1) Binoculars
2) Camera lens
3) Solar lens

Condition

1) Thickness $\frac{d}{4} = \frac{\lambda}{4}$

2) $\mu_{\text{air}} < \mu_{\text{film}} < \mu_{\text{glass}}$

Path Difference

$$\Delta = 2ut \cos x + \frac{d}{2} + \frac{d}{2}$$

$$\Delta 2ut \cos x \pm d = 2ut \cos x$$

If $i = 0$ $x = 0$

$\Delta 2ut$ — (1)

$$\frac{d}{2} = 2ut$$

* $t = \frac{d}{4\mu_{\text{film}}}$

To have Ray D.E between ray 1 and 2

$$\Delta = \frac{d}{2}$$

Numericals

- 1] Fringes of equal thickness are observed in a thin glass wedge of R.I 1.52. The fringe spacing is 1 mm and the wavelength of light is $5893 \text{ \AA}$. Calculate the angle of wedge.

→ Fringe width $= \beta = 1 \times 10^{-1} \text{ cm}$.

$\mu =$

Q Find the minimum thickness of film deposited on the lens of $\mu = 1.5$ with magnesium fluoride of $[\text{MgF}_2]$ $\mu = 1.38$ so that it increases the transmission of normally incident line of wavelength is $5850 \text{ \AA}$.

→

~~$\mu = 1.5$~~ $\mu = 1.5$ magnesium fluoride of $\mu = 1.38$

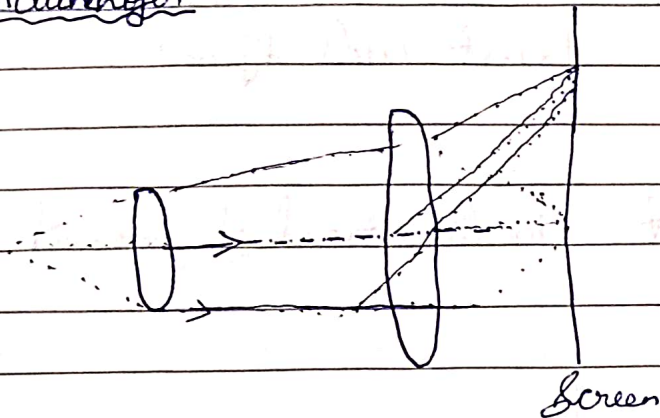
$$\lambda = 5800 \text{ \AA}$$

$$t_{\min} = \frac{\lambda}{4\mu_{\text{film}}}$$

$$\lambda = 1051 \text{ \AA}$$

$$= 10.51 \times 10^{-6} \text{ cm}$$

Fraunhofer



② Pair of Biconcave lens is used.

2] NO lenses are used

3] Fraunhofer Fresnel

1] Pair of biconcave lens are used NO lenses are used.

2] Source and screen is placed at infinite distance from slit. 2] Source and screen are placed at finite distance from the slit.

3] Incident wavefront is plane wavefront 4] Incident wavefront can be spherical or cylindrical.

4] The diffraction pattern is not sensitive to distance. The pattern is sensitive to distance.

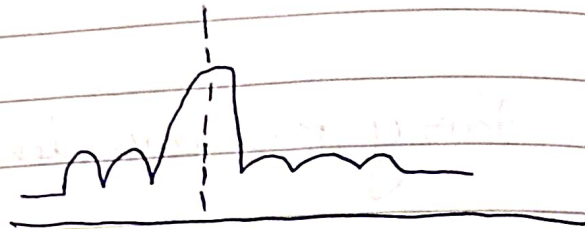
5] The maxima and minima are well defined

6] Mathematical treatment is easy



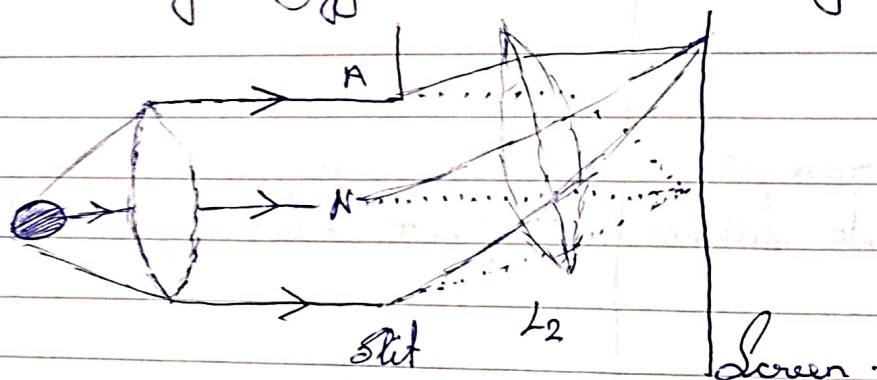
The maxima are minimise are not well defined.

Mathematical treatment is complex

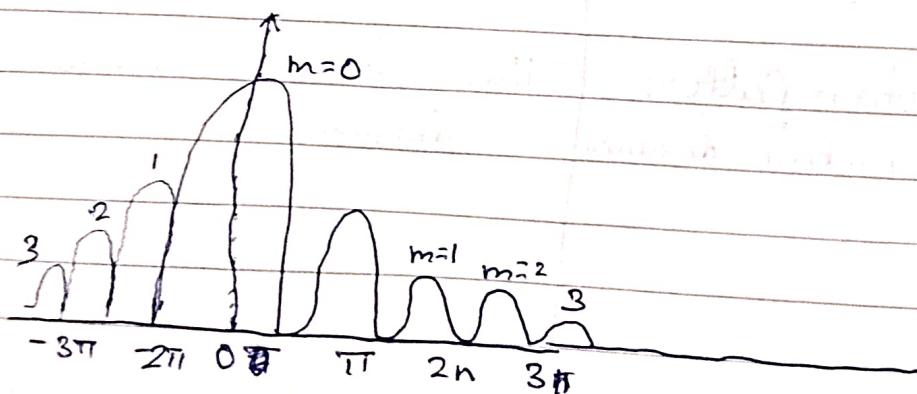


Notes Society

Q Fraunhofer Diffraction due to single slit.



Intensity Pattern.



* I] At ~~point~~ point O

$$\text{Path difference} = 0$$

$$\Delta = n\lambda = 0\lambda$$

Central bright ~~maximal~~ maxima.

2] At point P $\rightarrow$ Condition of minima.

$$MP - AP = m\lambda$$

$\triangle AND$.

$$\sin \theta = \frac{Mn}{AM} = \frac{Mn}{AM} = \frac{Mn}{\frac{d}{2}}$$

$$Mn = \frac{d}{2} \sin \theta$$

$$P \cdot d = \frac{d}{2}$$

$$\frac{d \sin \theta}{2} = \frac{d}{2}$$

$$\therefore d \cdot \sin \theta = \pm n\lambda$$

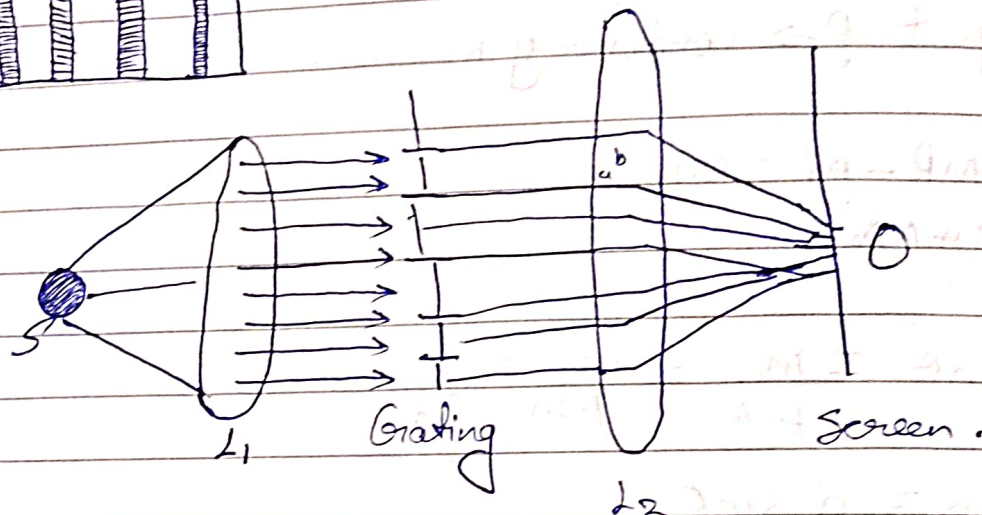
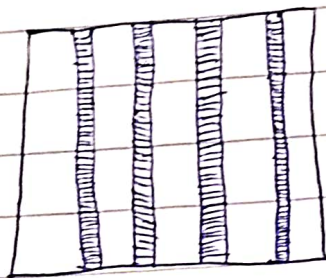
Condition of minima.

3] Condition of Secondary maxima.

$$d \cdot \sin \theta = \pm (2n+1) \frac{\lambda}{2}$$

physics.

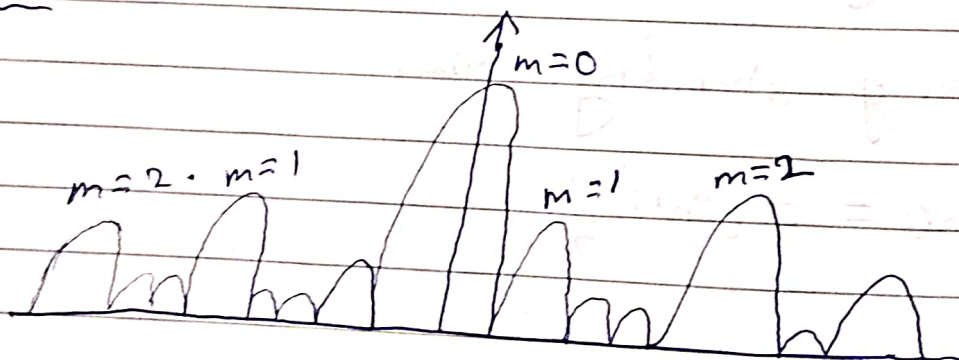
Plane Diffraction Grating → fine parallel and Equidistant lines drawn on glass surface by fine diamond

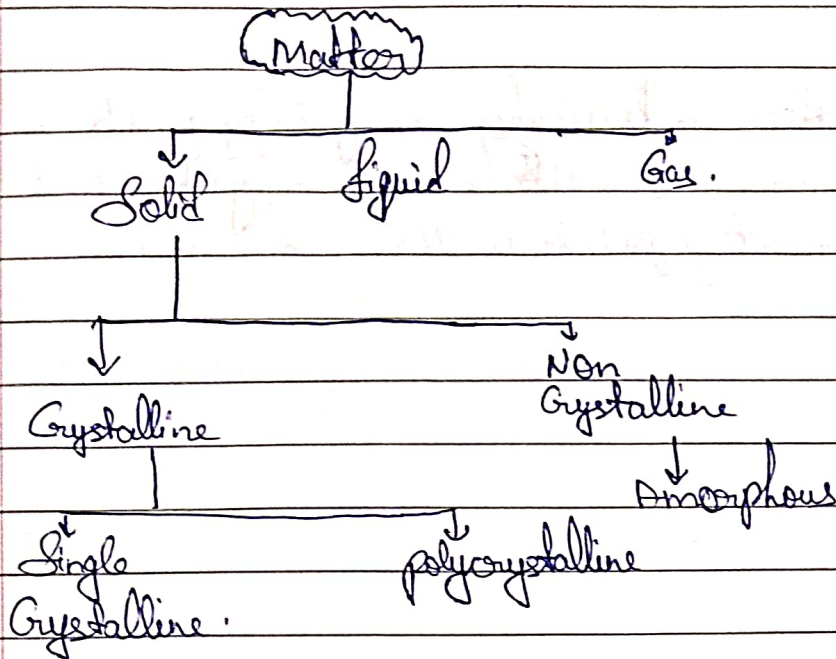


Path Difference $[a+b] \sin \theta$

- 1] Condition of maxima $[a+b] \sin \theta = \pm n \lambda$
- 2] Condition of minima $[a+b] \sin \theta = (2n+1) \frac{\lambda}{2}$

Intensity pattern



Solid State unit 2

Crystalline	Amorphous.
1] Regular arrangement of atoms give definite and geometric shape	Random arrangement of atoms does not give definite and geometrical shape.
2] They are anisotropic	They are isotropic.
3] Melting point have sharp	They do not have sharp melting point.
4] They possess internal symmetry	They do not possess internal symmetry.
5] Metallic crystal Cu, Ag, Al, Mg etc and Non-metallic crystal Carbon, Silica, Germanium.	Examples Glass, plastics, Rubbers etc.

Crystalline Nature.

1] Space lattice: Lattice is basically imaginary points on space with a periodic manner or a lattice is a regular and periodic arrangement of points in three dimensions.

2] Et

NotesSociety

3] Basis: A crystal structure is formed by associating every lattice point with an unit assembly of atoms or

Crystal Structure Theory

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Miller Indices [Can Com]

- 1] Determine the intercepts of the plane along the axes x , y , and z in terms of the lattice constants a , b and c
- 2] Determine the reciprocals of these numbers.
- 3] Find the least common multiplier (L , C , M) and multiply each by this LCM .
- 4] The result is written in parenthesis this is called the "Miller Indices of the plane in the form (hkl) ".

Intercepts $(a, 2b, 3c)$

Q Find out miller indices.

$$\rightarrow \frac{6bc}{a}, \frac{3abc}{2b}, \frac{6abc}{3a}$$

$$6bc \quad 3abc \quad 2bc$$

$$6bc \quad 3ac \quad 2ab$$

$$[6 \ 3 \ 2]$$

$$2a, 3b, 6c$$

$$(2 \ 3 \ 6)$$

$$\frac{1}{2} \quad \frac{1}{3} \quad \frac{1}{6}$$

LCM 12

$$\times \frac{6}{6} \frac{1}{2} \quad \times \frac{4}{4} \frac{1}{3} \quad \times \frac{2}{2} \frac{1}{6}$$

$$(6 \ 4 \ 2)$$

$$(3 \ 2 \ 1)$$

Q Determine the miller indices of a plane which is parallel to the x-axis and cuts intercepts of 2, $\frac{1}{2}$ respectively along y and z are.

$$[\infty \ a, \ 2 \ \frac{1}{2}]$$

$$\frac{1}{\infty} \quad \frac{1}{2} \quad \frac{1}{\frac{1}{2}} = (0, 2, 4)$$

$$2 \times \frac{1}{\infty} \quad 2 \times \frac{1}{2} \times 2 \times 2$$

$$(\approx 0.14)$$

Notes Society

Derivation of Bragg's law.

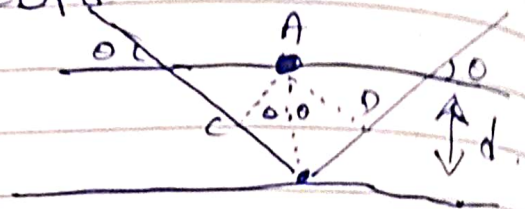
→ whether the material is crystal or Amorphous.

$$\text{Path Difference} = CD + BD = n\lambda$$

$$n = 0, 1, 2, 3, 4, \dots \text{ etc.}$$

$$\text{For } \triangle ACB \quad \sin \theta = CB/AB = CB/d$$

$$\text{So } CB = d \sin \theta$$



Similarly

$$\text{For } \triangle ADB \quad \sin \theta = BD/AB = BD/d$$

$$\text{So } DB = d \sin \theta$$

$$d \sin \theta + d \sin \theta = n\lambda$$

$$\boxed{2d \sin \theta = n\lambda}$$

θ = Diffraction Angle.

λ = X-ray wavelength

d = Distance between the atomic planes

n = integer $\{1, 2, 3\}$.

→

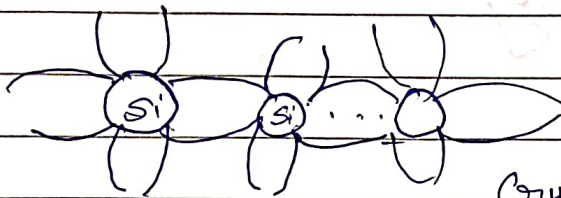
Semiconductors.

Conducting in betⁿ conductors and insulators

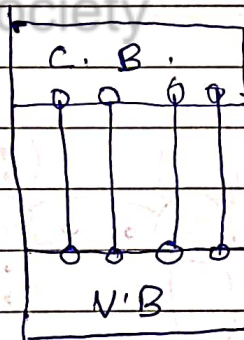
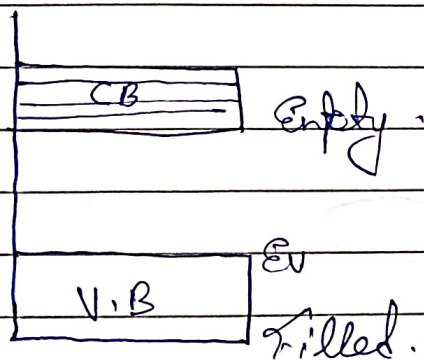
Eg Silicon $\rightarrow 1.1 \text{ eV}$
Germanium $= 0.7 \text{ eV}$.

Intrinsic Semic [pure semic]

Si, Ge, Tetravalent stable.



Crystal structure Room temperature.



$$n_e = 4$$

$$n_h = 4$$

$$* \boxed{n_e = n_h}$$

* Extrinsic Semiconductor.

To increase the conductivity intrinsic semic. is doped with impurity atoms.

addition of controlled quantity of impurity atom.

1 atom $\rightarrow 10^9$ atoms of Intrinsic Semiconductor

N-Type

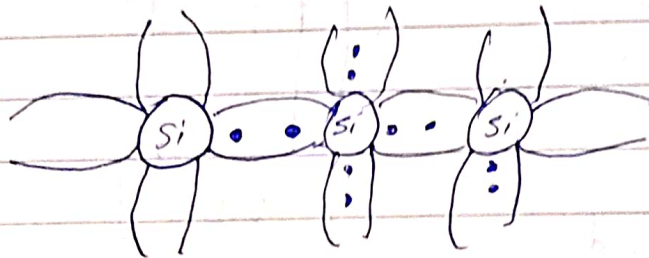
When pentavalent impurity added to intrinsic semiconductor then it is known as n-type semiconductor.

Eg. Pentavalent impurity

Phosphorus [P]

Arsenic [As]

Antimony [Sb]



Crystal Structure.

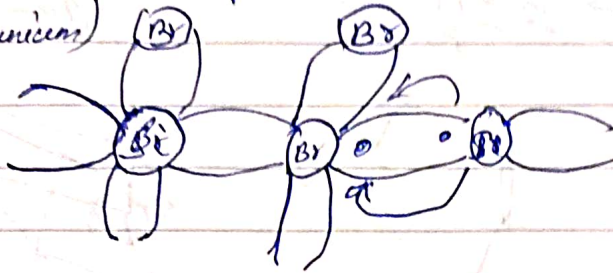
* The conductivity is given by negatively charged particles. So known as n-type semiconductor.

P-Type

When trivalent impurity added to intrinsic semiconductor then it is known as n-type semic.

eg. Trivalent impurity.

Boron [Accept].
(acceptor)



Crystal structure

① The conductivity is given by positively charged particles so known as p-type semic.

Nearest neighbor = 2π
Lattice constant

$$a = 2\pi$$

$$a = 2\pi$$

$$CN = 6$$

Num of atom = 1

$$\frac{1}{3} a^3$$

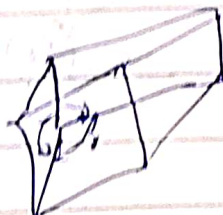
$$\frac{4\pi r^3}{3}$$

$$\frac{4\pi r^3}{3} = \frac{\pi}{6} = 0.52$$

$$\frac{2}{2} = 1$$

$$Packing = \frac{4\pi r^3}{3} \times \frac{6}{a^3}$$

6 No. of atom



$$\frac{4\pi r^3}{3} \times \frac{6}{a^3}$$

Volume = $\frac{4}{3}\pi r^3$

$$\frac{4 \times \pi}{\sqrt{3}}$$

$$\frac{4 \times \pi}{\sqrt{3}}$$

$$\frac{4 \times \pi}{\sqrt{3}}$$

$$\frac{4 \times \pi}{\sqrt{3}}$$

Notes Society

$$\text{Mean} = \frac{\sqrt{3}}{2} a$$

$$\text{Mean} = \frac{\sqrt{3}}{2} a$$

$$\text{Lact} = \frac{4 \times \pi}{\sqrt{3}} \times \frac{4 \times \pi}{\sqrt{3}} \times \frac{4 \times \pi}{\sqrt{3}} \times \frac{4 \times \pi}{\sqrt{3}} \times \frac{4 \times \pi}{\sqrt{3}} \times \frac{4 \times \pi}{\sqrt{3}}$$

$$\text{Mean} = \frac{\sqrt{3}}{2} a \times \frac{\sqrt{3}}{2} a \times \frac{2 \times 4 \times \pi}{3} = \frac{64 \pi}{3 \sqrt{3}}$$

Fact

$$\frac{64 \pi}{3 \sqrt{3}} \times \frac{64 \pi}{3 \sqrt{3}}$$

$$\frac{4 \sqrt{3}}{8} \times \frac{\pi \sqrt{3}}{8} \times \frac{\pi \sqrt{3}}{8} \times \frac{\pi \sqrt{3}}{8}$$

$$\frac{\pi \sqrt{3}}{8} \times \frac{\pi \sqrt{3}}{8} \times \frac{\pi \sqrt{3}}{8} \times \frac{\pi \sqrt{3}}{8}$$

12(1, 2, 3)

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ux.

(1, 2, 3)

Nearest = 28

Lattice content = 28

com = 6

lowest common multiple, 1

1,

6, 8
24, 6, 8

2 3 4
4 6 8
6 9 12
8 12 16
10 15 20
12 18 24

2
3
4

6, 3, 2
8, 6, 4

2(2, 3, 4)

2(1/2, 1/3, 1/4)

2(12/2, 12/3, 12/4)

12, 8, 6

(2, 3, 4)

1/2 1/3 1/4

12x1 12x1 12x1

2x1 + 1/3x4 + 1/4x3
1x12 + 1x8 + 1x6
2x12 3x8 4x6
12+8+6
24

12x1 + 12x1 + 12x1
12x1 + 8x2 + 6x4
12x1 + 8x2 + 6x4
12x1 + 8x2 + 6x4

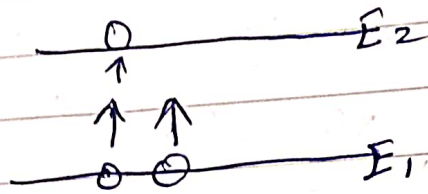
16/24

12x1

Laser

light amplification by stimulated emission of radiation

1] Stimulated Absorption



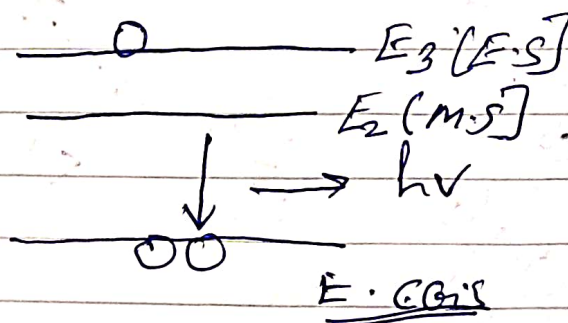
$$N_{ab} = B_{12} N_1 \phi \Delta t \quad \text{--- (I)}$$

2] Spontaneous Emission



$$N_{sp} = A_{21} N_2 \Delta t$$

3] Stimulated Emission



$$N_{st} = B_{21} N_2 \phi \Delta t$$

* Einstein coeff

Under equilibrium condition
No. of upward transition = No. of downward transition

$$B_{12} N_1 \phi \Delta T = A_{21} \Delta t + B_{21} N_2 \phi \Delta T$$

$$B_{12} N_1 \phi \Delta T - B_{21} N_2 \phi \Delta T = A_{21} \Delta t$$

$$(B_{12} N_1 - B_{21} N_2) \phi = A_{21}$$

$$\phi = \frac{A_{21} N_2}{B_{12} N_1 - B_{21} N_2}$$

Divide N.S.D by $B_{21} N_2$.

$$\phi = \frac{\frac{A_{21} N_2}{B_{21} N_2}}{\frac{B_{12} N_1}{B_{21} N_2} - 1}$$

$$\phi = \frac{A_{21}}{B_{21}}$$

$$\frac{B_{12}}{B_{21}} e^{\left[\frac{h\nu}{kT} \right] - 1}$$

$$\left\{ \frac{N_1}{N_2} = \frac{h\nu}{e^{kT}} \right.$$

By plank constant.

~~As N.~~

Let by Planck's theory of Radiation

$$\rho = \frac{8\pi h \nu^3}{c^3} \frac{1}{e^{\left(\frac{h\nu}{kT}\right)} - 1} \quad \text{--- (2)}$$

By comparing Equation (1) and (2)

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

$$2] B_{12} = B_{21}$$

NotesSociety

* Population Inversion.

→ When the population of higher energy level is greater than the energy of ground state is known as population Inversion.

Pumping mechanism.

→ The technique to achieve population inversion is called as pumping.

1] Optical pumping → Light source is applied to pump
Eg: Solid state laser - Ruby laser.

2] Electrical pumping → Elec → Electric discharge is used as source
Gas laser: He-Ne laser, CO₂ laser.

3] Chemical pumping: Chemical is applied.

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Chemical Pumping → Chemicals are used as a source to pump [Chemical vapour]
Eg Dye laser.

1] Characteristics of Laser.
→ Coherent
→ Monochromatic
→ Unidirectional
→ High Intensity.

a] Coherent.

→ ordinary light.

→ Spontaneous emission photon random direction different phase, wavelength and direction.

Laser.

→ Stimulated emission photons emit in same direction same phase, wavelength and same direction.

b] Monochromaticity.

a] ordinary light → Spontaneous emission photon random direction different phase, wavelength and direction and No of different colours are observed.

b] Stimulated emission photons emit in same direction same phase and wavelength and same direction single colour is observed.

3] Unidirectional

① Ordinary light.

1] Spontaneous emission photons random direction different phase, wavelength and direction.

2] Photons are emitted in all direction.

2] Laser

Stimulated emission photons exists in same direction same phase, wavelength and direction.

4] high Intensity. →

q] Hall Effect.

Sr. NO.	Current [A]	
1	0.01	-0.01
2	0.15	-0.05
3	0.25	-0.10
4	0.55	-0.20
5	0.65	-0.25
6	0.80	-0.30
7	1.00	-0.35
8	1.30	-0.45
9	1.45	-0.50
10	1.70	-0.60



Hall Coefficient $[R]$.

$$R = [\text{slope} \times t] / H.$$

$$= \frac{(-0.3 \times 0.4 \times 10^{-1})}{2 \times 10^3}$$

$$= \frac{-0.12}{2 \times 10^4}$$

$$= -6 \times 10^{-6}$$

Charge Carrier Density $[n]$.

$$n = \frac{1}{Rq} = \frac{1}{6 \times 10^{-6} \times 1.6 \times 10^{-19}}$$

$$n = 1.04 \times 10^{24} \text{ cm}^{-3}$$

Common mobility :- (μ_n)

$$\mu_n = R \omega$$

$$= 6 \times 10^{-6} \times 0.1$$

$$= 6 \times 10^{-7}$$

Ans.

Magnetization and Superconductivity:

- 1] Magnetization: The magnetic moment per unit area volume developed inside a solid is called magnetization and it is denoted by m .

Formula

$$m = \chi H$$

where χ is proportionality constant or susceptibility.

2] Magnetic field:

→ The magnetic field in which a material is kept is called magnetizing field.
[A/m]

$$3] \text{ Magnetic susceptibility } [\chi] = \chi = \frac{M}{H}$$

→ The magnetic susceptibility of a material is a measure of the ease with which the material can be magnetized.

$$\boxed{\chi = \frac{M}{H}} \text{ --- (3)}$$

4] Magnetic Induction [B].

→ A magnetic field is schematically represented by lines of magnetic induction.

$$B = \frac{\text{magnetic flux}}{\text{area}} = \frac{\phi}{A}$$

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The number of field lines passing through a unit area of cross-section is called magnetic flux density.

Unit wb/m^2 or Tesla.
 $1\text{G} = 10^{-4}\text{T}$.

5] Relation between B and H.

→ When a material is kept in a magnetic field, two types of induction arise, one due to the magnetizing field ~~H~~.

$$B = \mu_0 [H + M]$$

$$\text{Permeability} = 4\pi \times 10^{-7} \text{ henry per metre } [\text{H/m}],$$

$$B = \mu_0 (H + M) \\ = \mu_0 (H + \chi H)$$

$$\boxed{B = \mu_0 H}$$

→ Absolute permeability.

1] μ_0 = Permeability of free space.

2] μ = absolute permeability.

3] μ_r = Relative permeability.

6] Absolute Permeability.

→ When a magnetic material is placed in a magnetic field the magnetic field lines are redistributed.

$$\mu = \frac{B}{H}$$

It is defined as the ratio of the magnetic induction B , in the medium to the magnetizing field, H .

$$\mu = \frac{B}{H}$$

Unit Henry per metre [H/m].

7] Relative Permeability: [μ_r].

→ The relative permeability of a material is defined as the ratio of the absolute permeability of that material to the permeability of free space.

$$\mu_r = \frac{\mu}{\mu_0} \quad \dots \text{Unit}$$

no unit

Relation Between μ_r and χ .

We know that

$$\mu = \mu_0 (1 + \chi)$$

using equation

$$\mu_r = (1 + \chi)$$

This equation relates the permeability to susceptibility of the material.

3

Notes Society

Origin of Magnetism.

Classification of magnetic material.

- 1] Diamagnetic material = $\mu_r < 1$
- 2] Paramagnetic material = $\mu_r > 1$
- 3] Ferromagnetic material = $\mu_r \gg 1$

1] Diamagnetic Material.

→ Diamagnetic material have weak, negative, susceptibility to magnetic fields.

NotesSociety

2] Paramagnetic materials.

1] Paramagnetic materials have a small, positive susceptibility to magnetic fields.

2]

3] Paramagnetic properties are due to the presence of some unpaired electrons and from the realignment of the electron paths caused by the external magnetic field.

4] P.M includes magnetism, molybdenum, lithium and strontium.

3] Ferromagnetic material. [Fe, Co, Ni].

→ 1] F.M have a large, positive susceptibility to an external magnetic field.

2]

- 1] Antiferromagnetic material.
- 2] Ferromagnetic materials.

NotesSociety

Curie Temperature:

- 1] The curie temperature is the temperature at which a ferromagnetic material loses its ferromagnetic properties and becomes paramagnetic.
- 2] When heated above a certain temperature the atoms in a ferromagnetic substance no longer their organized magnetic movements and become paramagnetic.

→ 3 Numerical Laser and molecular Spectroscopy

$$E_g = h\nu = \frac{hc}{\lambda}$$

$$\begin{cases} h = 6.63 \times 10^{-34} \text{ J.s} \\ c = 3 \times 10^8 \text{ m/s} \end{cases}$$

Unit 4 Magnetization & Superconductivity

$$1] \chi = \frac{M}{H}$$

$$2] B = \frac{\Phi}{A}$$

$$3] B = \mu_0 (H + M)$$

$$4] \mu_0 (1 + \chi) H$$

$$B = \mu H$$

$$5] \mu_r = \frac{\mu}{\mu_0}$$

1] A semiconductor diode laser has a peak emission wavelength of $1.55 \mu\text{m}$. Find its bandgap in eV.

$$E_g = h\nu = \frac{hc}{\lambda}$$

$$\frac{6.63 \times 10^{-34} \times 3 \times 10^8}{1.55 \times 10^{-6}}$$

$$= 1.287 \times 10^{-19} \text{ J}$$

$$1.6 \times 10^{-19}$$

$$= 8.043 \text{ eV}$$

$$E_g = 1.2$$

$$\lambda = 1.55 \mu\text{m} = 1.55 \times 10^{-6} \text{m}$$

$$E_g = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{1.55 \times 10^{-6}}$$

$$= 1.238 \times 10^{-19}$$

$$E_g = \frac{1.238 \times 10^{-19}}{1.6 \times 10^{-19}} = 0.8 \text{ eV}$$

2) Calculate the wavelength of emitted radiation of GaAs laser which has a bandgap of 1.44 eV.

$$\rightarrow E_g = 1.44 \text{ eV} = 1.44 \times 10^{-19}$$

$$\lambda = \frac{hc}{E_g} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{1.44 \times 10^{-19}}$$

$$= \frac{19.89 \times 10}{1.44 \times 1.6 \times 10^{-19}}$$

$$= \frac{19.89 \times 10^{-7}}{2.3}$$

$$= 8.647 \times 10^{-7} \text{ m}$$

$$\lambda = \underline{0.8647 \times 10^{-6} \text{ m}}$$

wavelength

Q Find the energy of Argon laser give the wavelength of laser light is 514.5 nm .

$$\lambda = 514.5 \text{ nm} = 514.5 \times 10^{-9} \text{ m}$$

$$E_g = \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{(514.5 \times 10^{-9}) \times 1.6 \times 10^{-19}}$$

$$E_g = \frac{19.89 \times 10^{-6}}{823.2 \times 10} = 0.0241 \times 10^{-6} \text{ eV}$$

→ Q Find the magnetic susceptibility of the ferromagnetic material if the magnetic field strength 250 A/m produces $m = 330 \text{ A/m}$

$$\chi = \frac{m}{H}$$

$$\chi = \frac{m}{H}$$

$$\frac{3300}{220} = 15$$

$$\boxed{\chi = 15}$$

Q21 A magnetic material has a magnetization of 2300 A/m and produces flux density of 0.00314 wb/m^2 . Calculate magnetizing field.

$$M = 2300 \text{ A/m}$$

$$B = 0.00314 \text{ wb/m}^2$$

$$H = ?$$

$$\mu_0 = 4\pi \times 10^{-7} \text{ H/m}$$

$$B = 0.00314 \text{ wb/m}^2 = 314 \times 10^{-3} \text{ wb/m}^2 \dots$$

$$\mu = \frac{B}{H} - \mu_0$$

$$\frac{3.14 \times 10^{-3}}{2\pi \times 10^{-7}} - 2300$$

$$\frac{3.14 \times 10^{-3}}{2\pi \times 10^{-7}}$$

$$\frac{3.14 \times 10^4}{4 \times 3.14} - 2300$$

$$0.25 \times 10^4 - 2300$$

$$2500 - 2300$$

$$\boxed{H = 200 \text{ A/m}}$$

NotesSociety

Q Consider a vacuum with permeability $\mu_0 = 4\pi \times 10^{-7}$ if a material has permeability of $1.2 \times 10^{-6} \text{ H/m}$. What is the relative permeability of the material?

$$\mu_0 = 4\pi \times 10^{-7}$$

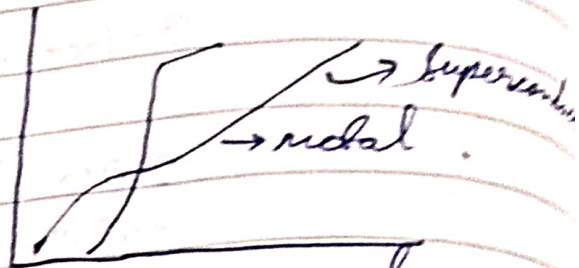
$$\mu_r = \frac{\mu}{\mu_0} = \frac{1.2 \times 10^{-6}}{4\pi \times 10^{-7}}$$

$$\mu_r = \underline{\underline{0.95}}$$

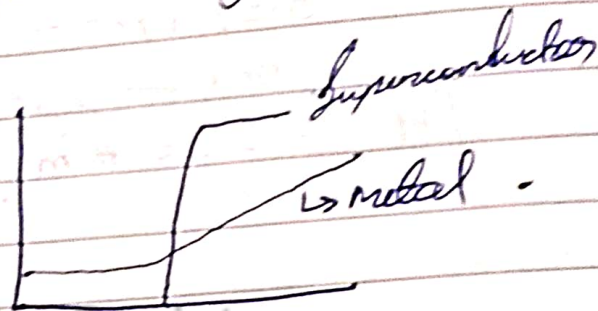
Superconductors:

Conductor = $R \rightarrow$ minimum -

T_c = Transition Temperature
Critical Temperature.



The specific temperature at which resistance of the material abruptly goes to zero is known as critical temp.

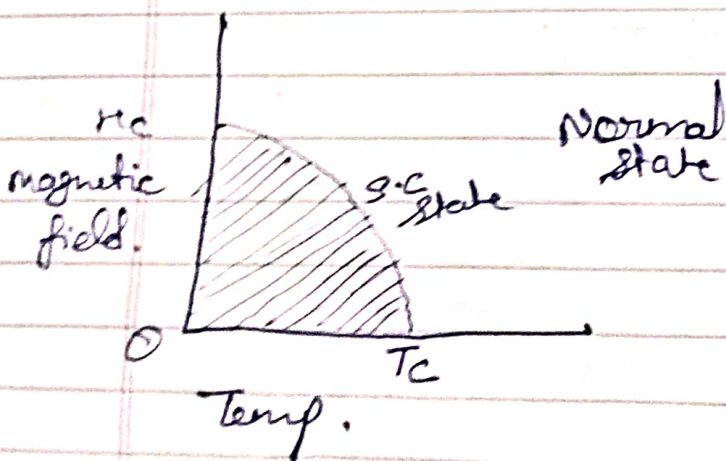


NotesSociety

T_c = Transition Temperature / critical temperature.

The specific temperature at which resistance of the material abruptly goes to zero is known as critical temp.

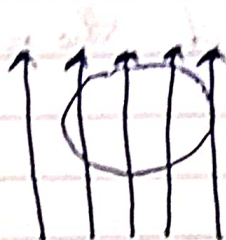
Critical magnetic field. $[H_c]$



The minimum magnetic field $[H_c]$ below which material remains in superconducting state is known as critical magnetic field.

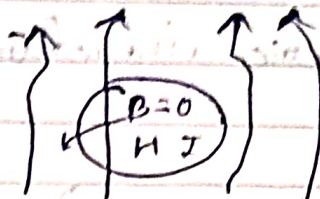
Meissner effect.

↳ H. Meissner and R. H. Oxford. [1933].
Oxford



$$T > T_c$$

Normal state



$$T < T_c$$

S.C. state

→ 1] When the material converts into superconducting state the magnetic lines of force repelled by superconducting material known as Meissner effect.

2]

$$At \quad T > T_c$$

magnetic lines of force passing through the material and current I is following on the surface of material,

3]

$$\text{When } T < T_c$$

There should be repulsion due to the formation of superconduction.

2] At $T < T_c$

Material converted into S.C. state having almost zero resistance and hence magnetic field generated by surface current I repels external magnetic lines of force.

∴ Magnetic induction $\rightarrow B = 0$ inside the material.

$$B = \mu_0 (H + M)$$

at $T < T_c$

$$B = 0$$

$$0 = \mu_0 (H + M)$$

$$H = -M$$

$$\chi = \frac{M}{H}$$

$$\chi = \frac{M}{-M} = -1$$

∴ Diamagnetic material

From Superconduct as a diamagnetic material

Critical magnetic field.

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

Num Ex

* London penetration Depth.

Type of Superconductor.

1] Soft superconductor

2]

NotesSociety

Property Type-I Superconductor

Misener: They exhibit complete misener effect

Diamagnetic: They show perfect diamagnetic behaviour

Critical magnetic field: They have only one critical magnetic field H_c

Variation of magnetic field with temperature: They have only one critical magnetic field.

6] Item: Material exists in two states for $T < T_c$

$H < H_c$ - Superconductor

$H > H_c$ - Conductor.

Type-II Superconductor

They do not exhibit effect completely.

They do not show perfect diamagnetic

They do not show perfect diamagnetic behaviours

NotesSociety

1] Interaction of Radiation with matter.

2] $E_g = \frac{hc}{\lambda}$ Numerical

3] Einstein's excitation

4] Population inversion

5] Characteristics of laser

6] Monograph

7] Application of laser.

8] FTIR

Raman

Classical

Quantum

1] Magnetisation

2] mag field

3] mag Susceptibility

4] mag Induction

5] Relative permeability

6] Curie Temp

7] Neel Temp

8] Magnetoresistance

9] magnetocaloric effect

10] Adiabatic demagnetization

1] diamagnetic

2] paramagnetic

3] Ferromagnetic

4] Antiferromagnetic

Ferrimagnetic

* Hysteresis Curve.

Nanoscience and Nanomaterials

- 1] Bulk
 - 2] Quantum well
 - 3] Quantum well
 - 4] Quantum wire
- } confinement → surface and volume ratio.
- 2] Properties → optic
→ chemical
→ physical.

- 1] Bottom up-approach
 - 2] Top-Down-approach.
- Sol-Gel
→ Chemical Vapour Deposition

Notes Society

- 1] Precursor solution
- 2] Hydrolysis
- 3] Condensation
- 4] Gel formation

Process [Fabrication process]

hydrolysis
→ Condensation process
→ Drying and calcination process

- 1] Precursor solution
 - 2] hydrolysis
 - 3] Condensation
 - 4] Gel formation
 - 5] Drying
Calculation / Sintering
- } Process of making nanoparticles.

Adv.

]

Chemical vapor deposition.

Nanolithography.

1) Coating

2) Exposer

3) ~~exposer~~ layer

↓
4) Each process

1) Coat

2) Expose photoresist

3) Develop the resist

4) Transfer the pattern.

Different properties of