Physics Question Bank

UT - 2

1. The resistivity of Cu is 1.72×10^{-8} ohm-m. Calculate the mobility of electrons in Cu. Number of electrons per unit volume is 10.41×10^{28} ~~atoms~~ $/m^3$.

Resistivity of Cu $\rho = 1.72 \times 10^{-8}$ ohm-m

~~mobi~~ Number of electrons per unit vol^m $(n) = 10.41 \times 10^{28} /m^3$

Mobility = ?

We know

$$\mu = \frac{1}{\rho n e}$$

$$\therefore \mu = \frac{1}{1.72 \times 10^{-8} \times 10.41 \times 10^{28} \times 1.6 \times 10^{-19}}$$

$$= 3.49 \times 10^{-3}$$

2. The mobility of holes is $0.025\ m^2/V\ sec$. What would be the resistivity of p type silicon if the Hall coefficient of the sample is $2.25 \times 10^{-5}\ m^3/c$.

Given :- $\mu_H = 0.025\ m^2/Vsec$

$R_H = 2.25 \times 10^{-5}\ m^3/c$

Find Resistivity ρ = ?

We know

$$\mu = \sigma R_H.$$

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

$$\therefore \mu_H = \frac{R_H}{\rho}$$

$$\therefore \rho = \frac{R_H}{\mu_H}$$

$$\therefore \rho = \frac{2.25 \times 10^{-5}\ m^{\cancel{3}}\ Vsec}{0.025\ C\ \cancel{m^2}}$$

$$\rho = 9 \times 10^{-4}\ \text{ohm-m.}$$

3. In Newton's ring experiment, the diameter of 4th and 12th dark ring are 0.40cm and 0.70cm. Find diameter of 20th dark ring.

Given :- $D_4^\bullet = 0.40cm$

$D_{12}^\bullet = 0.70cm$

Find $D_{20}^n = ?$

Sol^n :- $D_m^2 = 4R(n)\lambda$

$D_4^2 = 4R(4)\lambda$

$\cancel{D_4^2 = 16R\lambda \longrightarrow (1)}$

$\therefore (0.40)^2 = 16R\lambda$

$\therefore R\lambda = 0.01 \longrightarrow (1)$

$\cancel{D_{12}^2 = 4R(12)\lambda}$

$\cancel{(0.70)^2 = 12 \times 4 \times 0.01 \longrightarrow (\text{from } (1))}$

$D_{20}^2 = 4R(20)\lambda$

$D_{20}^2 = 80 \times 0.01 \longrightarrow (\text{from } (1))$

$D_{20}^2 = 0.8$

$\boxed{D_{20} = 0.89}$

4. In Newton's ring exp, the diameter of 15th dark ring is 0.75 cm and wavelength is 5893 Å. Find the radius of curvature of plano convex lens.

Given :- $D_{15} = 0.75cm.$

$\lambda = 5893\ \text{Å} = 5893 \times 10^{-8}\ cm.$

Find :- $\cancel{f = ?}$ $R = ?$

We know,

$D_n^2 = 4Rn\lambda.$

$D_{15}^2 = 4(R)(15) \times 5893 \times 10^{-8}$

$\cancel{R} = (0.75)^2 = 3.53 \times 10^{-3} \times R.$

$\therefore R = \dfrac{(0.75)^2}{3.53 \times 10^{-3}}$

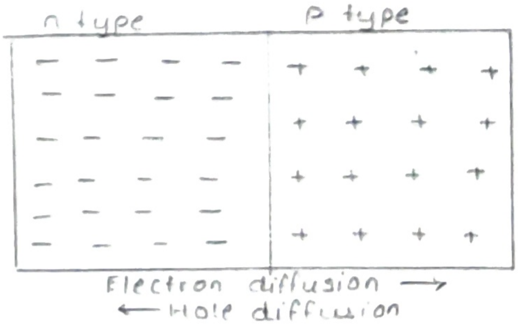
$= \cancel{15.93 \times 10^{6}}$

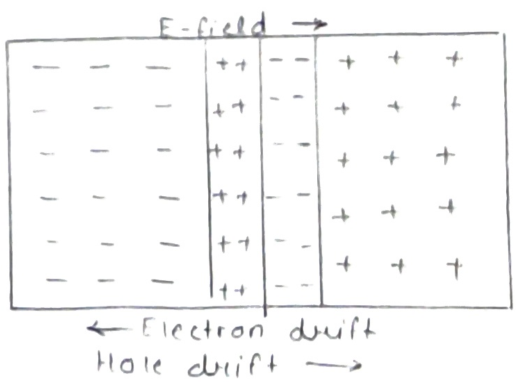
$R = 159.35\ cm.$

5 Define drift current, diffusion current and mobility of charge carriers with SI units.

5 <u>Drift current</u> :- When ever a potential difference is applied to the conductor, the charge stored in the material flows in the direction of Electric field. This constitute current in the material and is termed as drift current. This is also called as load current which flows through the ~~app~~ load applied in the circuit.

<u>Diffusion current</u> :- When ever two materials are joined together i.e n type (rich in free electrons) and p type (rich in holes), there exists charge concentration. This charge concentration difference leads to flow of electrons from n-type to p-type material. The flow of electrons constitute flow of charge, hence a current exists accross the junction. This current is expressed as diffusion current. This current is very small and also called as leekage current.





Mobility of charge carriers :- Mobility of charge carriers is defined as magnitude of drift velocity per unit electric field.

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

where μ = mobility of charge carrier

V_d = drift velocity

E = Electric field.

SI unit of μ is $m^2/V\,sec$

6. Define mobility of charge carriers and state its SI unit.

Mobility of charge carriers :- Mobility of charge carrier is defined as ~~d~~ magnitude of drift velocity per unit Electric field.

$$\mu = \frac{V_d}{E} \quad \text{—— (1)}$$

We know

$$V_d = \frac{I}{Ane} \quad \text{and} \quad E = \frac{V}{l}$$

$$\therefore \mu = \frac{Il}{AneV}$$

We know $V = IR$.

$$\therefore \mu = \frac{\cancel{I}\,l}{Ane\,\cancel{I}R}$$

$$\mu = \frac{l}{AneR} \quad \text{—— (2)}$$

Now

$$\rho = \frac{RA}{l}$$

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

$$\therefore \sigma = \frac{l}{RA}$$

Eqn (2)

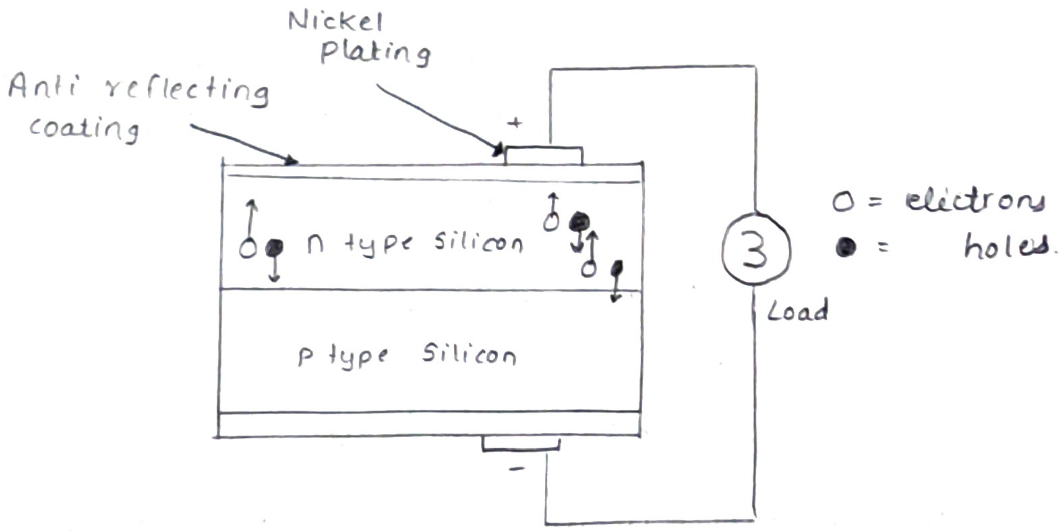
$$\boxed{\mu = \frac{\sigma}{ne}}$$

7. Explain construction and Working of photovoltaic cell.

→ 1. Certain materials when exposed to solar radiation, generate electron - hole pair which is available for conduction. As a result, voltage is developed across the material and the effect is known as photovoltaic effect.

2. The radiation energy $E = h\nu$ should be greater than band energy E_g of material.

3. In this, light energy is converted to electrical energy.



~~Construction and Working~~:

4. This is a p-n junction with high doping level. The top most layer is a coating of anti-reflecting material and a thin layer of p-type semiconductor. so that incident ray can reach the junction area.

5. As the solar ~~energy~~ radiation is incident on cell and $E = h\nu \geqslant E_g$, electron- holes pairs are generated in n and p side.

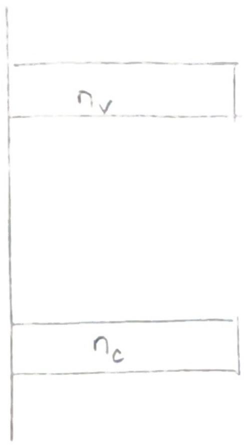
6. It is observed that ~~elec~~ the generated electrons in the conduction band of p region moves towards conduction band of n region. and it is at lower level. Similarly, holes generated in the valence band of n-region moves towards valence band of p-region

and is at ~~the~~ lower holes energy level.

7. The diffusion of electrons and holes through the junction accumulates charge carriers on both side, resulting in a potential difference called photo emf. This photo emf is proportional to the intensity of incident solar radiation and thus current flows across the load.

8. Show that in intrinsic semiconductors, fermi levels lies midway betn conduction band and valence band.

8.



Let n_v = no. of valence electrons

n_c = no. of conduction electrons.

N = Total electrons.

$$\therefore N = n_c + n_v \quad \text{—— (1)}$$

We know

$$P(E) = \frac{1}{1 + e^{\frac{(E - E_F)}{KT}}} \quad \text{—— (2)}$$

Probability of occupancy of energy level in conduction band is given by

$$P(E_c) = \frac{n_c}{N} \qquad \therefore n_c = P(E_c) N$$

Probability of occupancy of energy level in valence band is given by

$$P(E_v) = \frac{n_v}{N} \qquad \therefore n_v = P(E_v) N$$

$\therefore$ Eqn (1) becomes.

$$\cancel{N} = \cancel{P} \; \cancel{N(P} \; \cancel{N} P(E_c) + \cancel{N} P(E_v)$$

$$1 = P(E_c) + P(E_v) \quad \text{—— (3)}$$

From (2) and (3)

$$\frac{1}{1 + e^{\left(\frac{E_c - E_F}{KT}\right)}} + \frac{1}{1 + e^{\left(\frac{E_v - E_F}{KT}\right)}} = 1$$

$$1 + e^{\frac{E_V - E_F}{KT}} + 1 + e^{\frac{E_C - E_F}{KT}} = \left(1 + e^{\frac{E_C - E_F}{KT}}\right)\left(1 + e^{\frac{E_V - E_F}{KT}}\right)$$

$$= 1 + e^{\frac{E_V - E_F}{KT}} + e^{\frac{E_C - E_F}{KT}} + e^{\frac{E_C - E_F + E_V - E_F}{KT}}$$

$$\cancel{1} + e^{\frac{E_V - \cancel{E_F}}{\cancel{KT}}} + 1 + e^{\frac{E_C \cancel{- E_F}}{\cancel{KT}}} = \cancel{1} + e^{\frac{E_V - \cancel{E_F}}{\cancel{KT}}} + e^{\frac{E_C - \cancel{E_F}}{\cancel{KT}}} + e^{\frac{E_C + E_V - 2E_F}{KT}}$$

$$\therefore 1 = e^{\frac{E_C + E_V - 2E_F}{KT}}$$

$$\therefore e^0 = e^{\frac{E_C + E_V - 2E_F}{KT}}$$

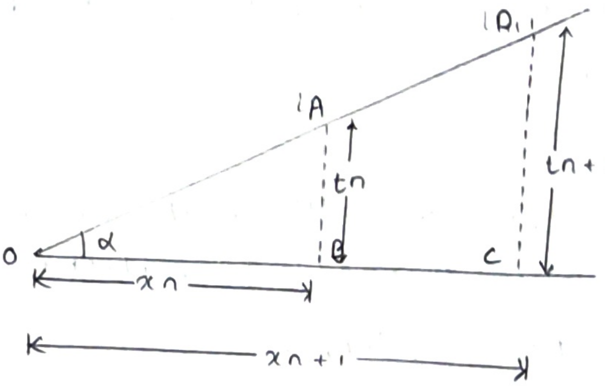
$$\therefore \frac{E_C + E_V - 2E_F}{KT} = 0$$

$$\therefore E_C + E_V = 2E_F$$

$$\therefore \frac{E_C + E_V}{2} = E_F$$

Hence, proved.

9. Derive an expression for fringe width for wedge shaped exp.



~~For nth fringe:~~

$$\cancel{2\mu t_n \cos(\alpha + r) + \frac{\lambda}{2}} = n\lambda$$

For n^{th} fringe

$$2\mu t_n \cos(\alpha + r) + \frac{\lambda}{2} = n\lambda \quad — ①$$

For $(n+1)^{th}$ fringe.

$$2\mu t_{n+1} \cos(\alpha + r) = \frac{\lambda}{2} = (n+1)\lambda \quad — ②$$

In ΔAOB, $\tan\alpha = \frac{t_n}{x_n}$ $\quad\therefore\quad t_n = x_n \tan\alpha$

In ΔOOC, $\tan\alpha = \frac{t_{n+1}}{x_{n+1}}$ $\quad\therefore\quad \cancel{x_{n+1} \tan\alpha}$. $t_{n+1} = x_{n+1} \tan\alpha$.

$\therefore$ Eq^n (1) becomes

$$\cancel{2\mu t} \quad 2\mu x_n \tan\alpha \cos(\alpha + r) + \frac{\lambda}{2} = n\lambda \quad \text{--- (3)}$$

Eq^n (2) becomes

$$2\mu x_{n+1} \tan\alpha \cos(\alpha + r) + \frac{\lambda}{2} = n\lambda + \lambda \quad \text{--- (4)}$$

Subtracting eq^n (3) and (4)

$$2\mu \tan\alpha \cos(\alpha + r) \left[x_{n+1} - x_n \right] = \lambda$$

$$\therefore \quad x_{n+1} - x_n = \frac{\lambda}{2\mu \tan\alpha \cos(\alpha + r)}$$

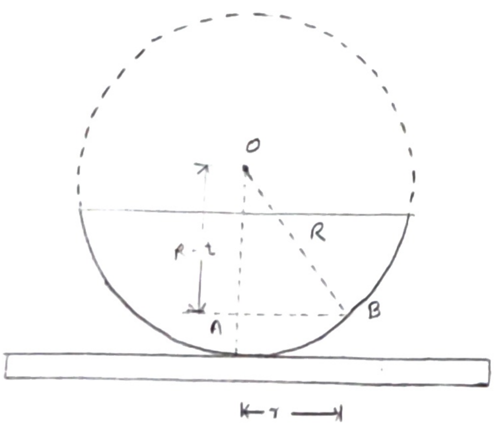
$$\beta = \frac{\lambda}{2\mu \tan\alpha \cos(\alpha + r)} \qquad \text{where } \beta = x_{n+1} - x_n$$

β = constant.

10. Obtain expression for diameter of nth dark ring in Newton's ring

OR.

Prove that diameter of nth dark ring is proportional to square root of natural number in case of reflected system.



The space filled bet^n the plane convex lens and glass plate is wedge shaped.

$$\therefore \Delta x = 2\mu t \cos(\alpha + r) + \frac{\lambda}{2}$$

α is very very small

$\therefore \alpha \approx 0$ $\quad$ ~~$\therefore \cos$~~

Light is vertically incident

$\therefore r \approx 0$

$\therefore$ ~~$\cos$~~$(\alpha + r) \approx 0$

$\therefore \Delta x = 2\mu t \cos(0) + \frac{\lambda}{2}$

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

$\mu = 1$ — (air film)

$\therefore \Delta x = 2t + \frac{\lambda}{2}$ — ①

In ΔAOB

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

$\cancel{R^2} = \cancel{R^2} + t^2 - 2Rt + r^2$

$2Rt = t^2 + r^2$

If t is very small, $t^2 \approx 0$

$\therefore r^2 = 2Rt$

$\therefore 2t = \frac{r^2}{R}$ — ②

where r = radius of convex lens

R = radius of curvature.

$\therefore$ Diameter = 2 radius

$D = 2r$

$\therefore r = \frac{D}{2}$

$\therefore$ Eq^n ②

$2t = \frac{D^2}{4R}$.

$\therefore$ Eq^n ① becomes,

$\Delta x = \frac{D^2}{4R} + \frac{\lambda}{2}$ — ③

For Dark ring,

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

$\frac{D^2}{4R} + \frac{\lambda}{2} = \frac{\cancel{2}n\lambda}{\cancel{2}} + \frac{\lambda}{2}$ — (from ③)

$\frac{D^2}{4R} + \cancel{\frac{\lambda}{2}} = n\lambda + \cancel{\frac{\lambda}{2}}$

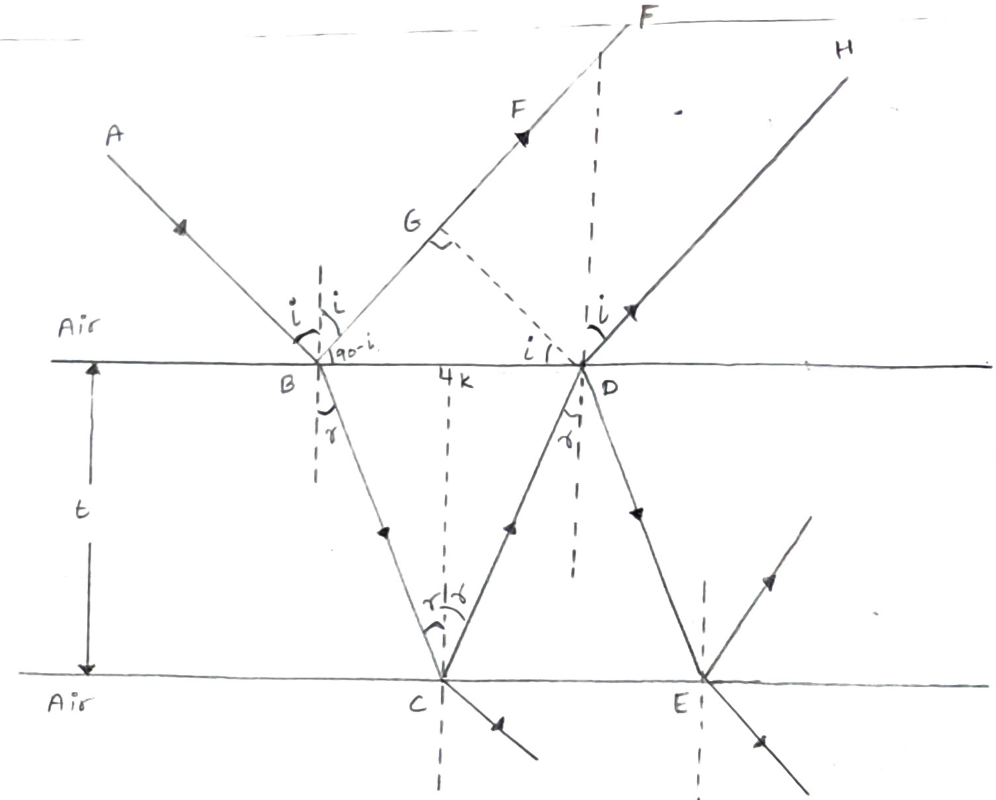
$\frac{D^2}{4R} = n\lambda$

$\boxed{D^2 = 4Rn\lambda}$

12. Distinguish bet^n Type I and Type 2 semiconductors.

Type I	Type II
1. Commercially, ~~they ar~~ these superconductors are called as soft superconductors.	1. Commercially, these superconductors are called as hard superconductors.
2. These superconductors exhibit only one critical field (H_c)	2. These superconductors exhibit two critical fields namely lower critical field (H_{c1}) and higher critical field (H_{c2}).
3. The critical magnetic field value is low.	3. The critical magnetic field value is high.
4. These are explained on the basis of BCS theory.	4. There is no any fixed theory developed to explain it.
5. These superconductors exhibit perfect and complete Meissner effect	5. These super conductors do not exhibit perfect and complete Meissner effect.
6. These materials have limited technical applications because of very low field strength value.	6. These materials have wider technical applications because of high field strength value.
7. Pb, Hg, Zn, etc.	7. ~~Nb~~ Nb_3Ge, Nb_3Si, Y, Ba_2, Cu_3O_7, etc.

13. Dereive ~~express~~ condition for maximum and minimum due to interference of light reflected from thin ~~layer~~ film of uniform thickness.



Path difference $= \Delta x = \mu(BC+CD) - BG$ —— ①

Δ BCK and Δ DCK are congruent

$\therefore$ $BC = CD$ and $BK = KD$ —— ②

$\therefore$ Eq^n ①

$\Delta x = \mu(BC + BC) - BG$

$\Delta x = \mu(2BC) - BG$. —— ③

~~In Δ BGD~~, In Δ BKC,

~~sin~~ $\cos r = \frac{CK}{BC} = \frac{t}{BC}$.

$BC = \frac{t}{\cos r}$ —— ④

$\therefore$ From ③ and ④

$\Delta x = \frac{2\mu t}{\cos r} - BG$

In ΔBGD

$$\sin i = \frac{BG}{BD} = \frac{BG}{BK + KD} = \frac{BG}{BK + BK} \quad \text{— (from ②)}$$

$$\therefore \sin i = \frac{BG}{2BK} \Rightarrow BG = 2BK \sin i$$

$$\Delta x = \frac{2\mu t}{\cos r} - 2BK \sin i \quad \text{—— ⑤}$$

In ΔBKC,

$$\tan r = \frac{BK}{CK} = \frac{BK}{t}$$

$$BK = t \tan r.$$

$\therefore$ Eqⁿ ⑤

$$\Delta x = \frac{2\mu t}{\cos r} - 2t \tan r \sin i$$

using snells law,

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

$$\therefore \Delta x = \frac{2\mu t}{\cos r} - 2t \tan r \, \mu \sin r$$

$$= \frac{2\mu t}{\cos r} - 2t \frac{\sin r}{\cos r} \mu \sin r$$

$$= \frac{2\mu t}{\cos r}\left(1 - \sin^2 r\right)$$

$$= \frac{2\mu t \cos^{2} r}{\cancel{\cos} r}$$

$$\Delta x = 2\mu t \cos r$$

Since, reflected ray BF undergoes phase shift of π.

$\therefore$ We must add $\frac{\lambda}{2}$ in path difference.

$$\therefore \Delta x = 2\mu t \cos r + \frac{\lambda}{2}$$

Condition for maxima and minima in reflected light.

1. Two rays will ~~be~~ interfere constructively if path difference betn them is an integral multiple of λ.

i.e

$$2\mu t\cos r + \frac{\lambda}{2} = n\lambda.$$

$$2\mu t\cos r = n\lambda - \frac{\lambda}{2}$$

$$2\mu t\cos r = \frac{2n\lambda - \lambda}{2}$$

$$2\mu t\cos r = \frac{\lambda(2n-1)}{2} \quad (6)$$

where $n = 1, 2, 3, 4, \ldots$ (for maxima)

2. The two rays will interfere destructively if the path difference betn them is an odd multiple of $\lambda/2$ i.e

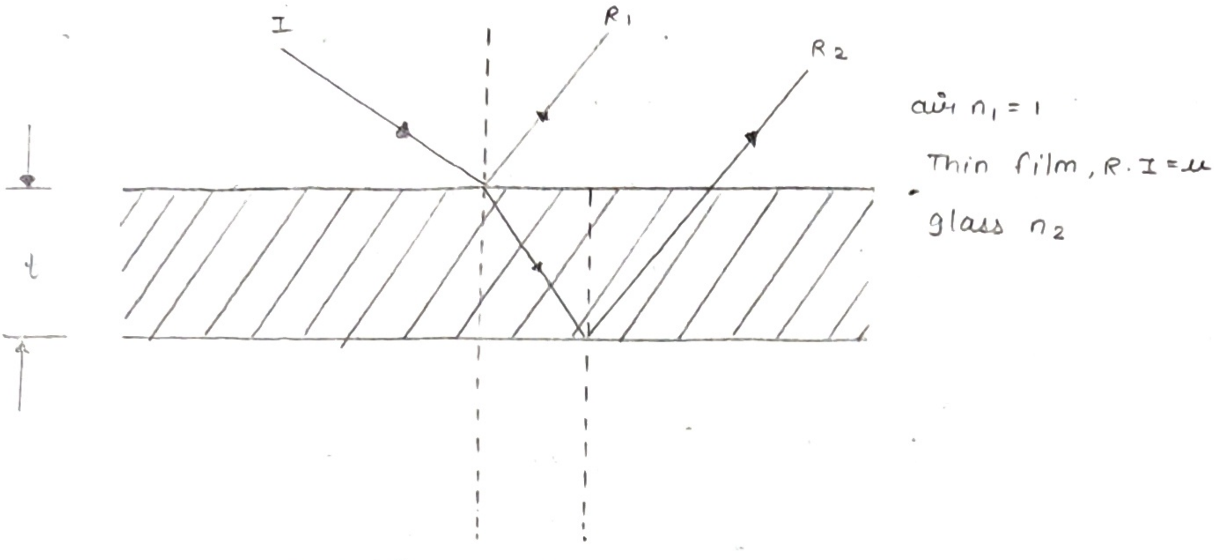
$$\cancel{\Delta x =} \; 2\mu t\cos r + \frac{\lambda}{2} = (2n+1)\frac{\lambda}{2}$$

$$2\mu t\cos r + \cancel{\frac{\lambda}{2}} = \frac{\cancel{2}n\lambda}{\cancel{2}} + \cancel{\frac{\lambda}{2}}$$

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

where $n = 0, 1, 2, 3, \ldots$ (for minima).

11. What do you understand by antireflecting coating? Derive the conditions with proper diagram.



Thin film coating

1. Let a ray I be incident upon thin film of MgF_2 coated on glass. This ray is reflected from upper surface as R_1 and from lower surface as R_2.
2. The optical path diff^n bet^n these two rays is $n_1(2t)$, as the incident ray enters from rarer to denser twice i.e at air to film and film to glass.
3. If both the rays R_1 and R_2 interfere with each other and path difference is $(2n+1)\lambda/2$ (for $n = 0, 1, 2, \cdots$) then destructive interference will take place.

$$\therefore\ 2n_1 t = \frac{\lambda}{2}$$

$$\therefore\ n_1 t = \frac{\lambda}{4\mu}$$

It means, in order to have destructive interference, a layer of $n_1 t = \frac{\lambda}{4}$ is coated on glass ~~tube~~ plate.

Amplitude condition :-

- The amplitude condition requires that the amplitudes of reflected rays, ray 1 and ray 2 are equal. That is $I_1 = I_2$ $\because E_1 = E_2$

- For complete destructive condition, intensities of two reflected beams should be equal.

- It requires that,

$$\left[\frac{\mu_f - \mu_a}{\mu_f + \mu_a}\right]^2 = \left[\frac{\mu_g - \mu_f}{\mu_g + \mu_f}\right]^2$$

- Where μ_a, μ_f and μ_g are the refractive indices of air, thin film and glass substrate respectively. As $\mu_a = 1$, the above expression may be rewritten as

$$\left[\frac{\mu_f - 1}{\mu_f + 1}\right]^2 = \left[\frac{\mu_g - \mu_f}{\mu_g + \mu_f}\right]^2$$

- Take square root

$$\frac{\mu_f - 1}{\mu_f + 1} = \frac{\mu_g - \mu_f}{\mu_g + \mu_f}$$

$$(\mu_g + \mu_f)(\mu_f - 1) = (\mu_g - \mu_f)(\mu_f + 1)$$

$$\cancel{\mu_f^2 + \mu_f \mu_g - \mu_g - \mu_f = \mu_f \mu_g + \mu_f^2 - \mu_g - \mu_f}$$

$$= \mu_g \mu_f + \mu_g - \mu_f^2 - \cancel{\mu_f}$$

$$\mu_g \cancel{\mu_f} - \mu_g + \mu_f^2 - \cancel{\mu_f} = \mu_g \cancel{\mu_f} + \mu_g - \mu_f^2 - \cancel{\mu_f}$$

$$-2\mu_g + 2\mu_f^2 = 0$$

$$\mu_f^2 - \mu_g = 0$$

$$\mu_f = \sqrt{\mu_g}$$