SA

27/09/23

Relativity

Postulates of special theory of relativity

Galilean Transformation

Failure's of :

Consequences of Einstein's postulates

SA

03/10/23

Lorentz trans
Time dilation
Len contraction
} outline

Lorentz transformation

$$k = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$x' = \frac{x - vt}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$t' = \frac{t - \frac{vx}{c^2}}{\sqrt{1-\frac{v^2}{c^2}}}$$

} w/ derivations

Inverse transformation

$$x = \frac{x' + vt}{\sqrt{1-\frac{v^2}{c^2}}}$$

$$t = \frac{t' + \frac{vx'}{c^2}}{\sqrt{1-\frac{v^2}{c^2}}}$$

Length contraction / Lorentz-Fitz Gerald Contraction

$$L_0 = x_2' - x_1'$$

$$= \frac{x_2 - vt}{\sqrt{1 - \frac{v^2}{c^2}}} - \frac{x_1 - vt}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$= \frac{x_2 - x_1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$= \frac{L}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$\Rightarrow L = L_0 \sqrt{1 - \frac{v^2}{c^2}}$$

Soln:

$$L = L_0 \sqrt{1 - \frac{v^2}{c^2}}$$

$$= 5\sqrt{1 - 0.8^2}, \quad 5\sqrt{1-1}, \quad 5\sqrt{1-0}$$

Time dilation

$$t_0 = t_2' - t_1'$$

$$t = t_2 - t_1$$

$$t_1 = \frac{t_2' + \frac{vx'}{c^2}}{\sqrt{1 - \frac{v^2}{c^2}}} - \frac{t_1' + \frac{vx'}{c^2}}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$= \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Soln:

$$t = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$= \frac{1}{\sqrt{1 - \frac{(3 \times 10^7)^2}{(3 \times 10^8)^2}}}$$

$$= 1.005 \text{ s}$$

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Relativistic velocity transformation

$$v_x' = \frac{dx'}{dt'} = \frac{v_x - u}{1 - \frac{u}{c^2} v_x}$$

$$v_x = \frac{v_x' + u}{1 + \frac{u}{c^2} v_x}$$

—

Relativistic mass transformation

(until eq. iv)

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08/10/23

$$m_1 = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

CT1 → Lec 1 – Lec 4

Energy mass relationship

$$F = \frac{d}{dt}(mv) = m\frac{dv}{dt}$$

$$= \frac{1}{dt}(mv)$$

...

$$\Rightarrow E = mc^2$$

1. a) Definition, short notes — 8/10

b) Expression —

c) Math — 11. (4, 5, 6), 12. (10, 12, 13, 14, 16, 17, 18, 19, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34)

Rough / CT 1

Inertial Frame of Reference: A reference frame which is at rest on moving at a const velocity.

Postulates of special theory of relativity

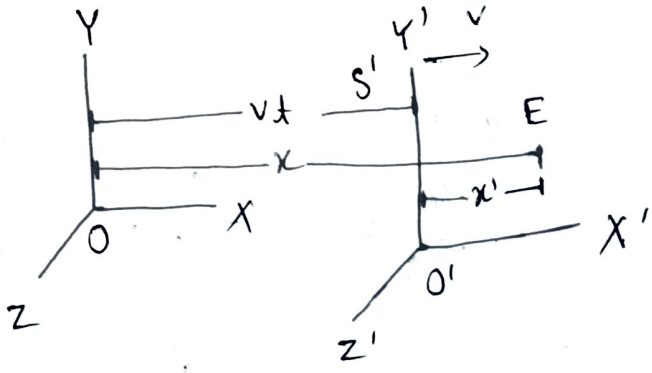
i. The laws of physics are same in all inertial frames of refenence.

ii. The speed of light is the same in all inertial frames of refs.

Lorentz Transformation

According to the 2nd postolates:

$x = ct, \quad x' = ct'$



Given the classical transformation equations, let

$x' = (x - vt)k$ — (I)

$x = (x' + vt')k$ — (II)

$x = k(x' + vt')$

$t' = \frac{x - kx'}{v}$

Now,

$$ct' = (ct - vt)k$$

$$\Rightarrow \frac{ct'}{t} = (c - v)k$$

$$\Rightarrow \frac{t'}{t} = \frac{(c-v)}{c}k$$

again,

$$ct = (ct' + vt')k$$

$$\Rightarrow \frac{ct}{t'} = (c+v)k$$

$$\Rightarrow \frac{t'}{t} = \frac{c}{(c+v)k}$$

Hence,

$$\frac{(c-v)k}{c} = \frac{c}{(c+v)k}$$

$$\Rightarrow k^2 = \frac{c^2}{c^2 - v^2}$$

$$\Rightarrow k = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Again,

$$x' = (x - vt)k$$

$$= ((x' + vt')k - vt)k$$

$$= (kx' + kvt' - vt)k$$

$$= k^2x' + k^2vt' - kvt$$

$$\Rightarrow t' = \frac{x' - k^2x' + k^2vt}{k^2v}$$

$$= \frac{x'}{k^2v} = x' + \frac{vt}{k}$$

$$t' = tk\left\{\frac{1}{t} - \frac{v}{c}\right\}$$

$$= \frac{t - \frac{vt}{c}}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$= \frac{t - \frac{vx}{c^2}}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$x' = \cdots$

$y' = y$

$z' = z$

Time dilation

$$t = t_2 - t_1$$

$$= \frac{t_2' + \frac{vx}{c^2} - t_1' - \frac{vx}{c^2}}{\sqrt{1 - \frac{v^2}{c^2}}}$$

$$= \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Velocity trans ---

$$x' = K(x - ut), \quad t' = K\left(t - \frac{ux}{c^2}\right)$$

$$v_x' = \frac{dx'}{dt'} = \frac{K(dx - u\,dt)}{K\left(dt - \frac{u}{c^2}dx\right)} = \frac{\frac{dx}{dt} - u}{1 - \frac{u}{c^2}\cdot\frac{dx}{dt}}$$

$$= \frac{v_x - u}{1 - \frac{u}{c^2}v_x}$$

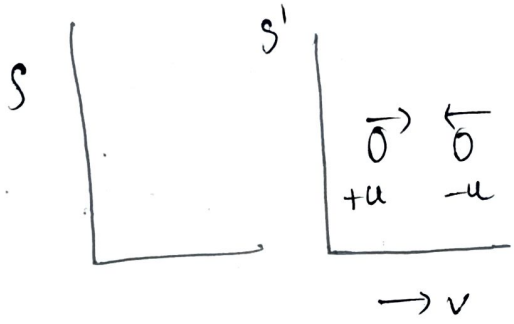
$$v_x = \frac{v_x' + u}{1 + \frac{u}{c^2}v_x'}$$

$$v_x = \frac{v_x' + u}{1 + \frac{u}{c^2} v_x'}$$

Mass trans.

$$u_1 = \frac{u+v}{1+\frac{uv}{c^2}}$$

$$u_2 = \frac{-u+v}{1-\frac{uv}{c^2}}$$



we know,

$$m_1 u_1 + m_2 u_2 = (m_1 + m_2) v$$

$$\Rightarrow m_1 (u_1 - v) = m_2 (v - u_2)$$

$$\Rightarrow m_1 \left(\frac{u+v}{1+\frac{uv}{c^2}} - v \right) = m_2 \left(v - \frac{-u+v}{1-\frac{uv}{c^2}} \right)$$

$$\Rightarrow m_1 \left\{ \frac{u+v-v-\frac{uv^2}{c^2}}{1+\frac{uv}{c^2}} \right\} = m_2 \left\{ \frac{v-\frac{uv^2}{c^2}+u-v}{1-\frac{uv}{c^2}} \right\}$$

$$\Rightarrow m_1 \left\{ \frac{u\left(1-\frac{v^2}{c^2}\right)}{1+\frac{uv}{c^2}} \right\} = m_2 \left\{ \frac{u\left(1-\frac{v^2}{c^2}\right)}{1-\frac{uv}{c^2}} \right\}$$

$$\Rightarrow \frac{m_1}{m_2} = \frac{1+\frac{uv}{c^2}}{1-\frac{uv}{c^2}} \Rightarrow$$

Now,

$$\frac{\sqrt{1-\frac{u_2^2}{c^2}}}{\sqrt{1-\frac{u_2^2}{c^2}}} = \frac{1+\frac{uv}{c^2}}{1-\frac{uv}{c^2}}$$

Hence,

$$\frac{m_1}{m_2} = \frac{\sqrt{1-\frac{u_2^2}{c^2}}}{\sqrt{1-\frac{u_1^2}{c^2}}}.$$

$$\Rightarrow m_1\sqrt{1-\frac{u_1^2}{c^2}} = m_2\sqrt{1-\frac{u_2^2}{c^2}} = m_0$$

$$\Rightarrow m_1 = \cdots$$

$$m_2 = \cdots$$

Energy - mass relⁿ

$$F = \frac{d}{dt}(mv)$$

$$= m\frac{dv}{dt} + v\frac{dm}{dt}$$

For work dT, dx distance may be moved

$$dT = F\,dx$$

$$= m\frac{dv}{dt}dx + v\frac{dm}{dt}dx$$

$$= mv\,dv + v^2 dm$$

$$= v(m\,dv + v\,dm)$$

we know,

$$m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}} \Rightarrow$$

$$\Rightarrow m^2 = \frac{m_0^2 c^2}{c^2 - v^2}$$

$$\Rightarrow m^2c^2 - m^2v^2 = m_0^2c^2$$

$$\Rightarrow 2mdm\,c^2 = 2m\,dm\,v^2 + 2v\,dv\,m^2 + 0$$

$$\Rightarrow c^2 dm = v^2 dm + mv\,dv$$

$$\Rightarrow dT = c^2\,dm$$

$$T = \int_0^v dT = c^2 \int_{m_0}^{m} dm = c^2(m - m_0)$$

$$E = T + m_0c^2 \Rightarrow E = mc^2$$

11.4/

$$v = \frac{v_x' + u}{1 + \frac{u}{c^2} v_x'} = \frac{0.5c + 0.9c}{1 + \frac{(0.9 \times 0.5)c^2}{c^2}}$$

$$= \ldots$$

~~11.5/~~

11.12/ (i) $0.5 = \sqrt{1 - \frac{v^2}{c^2}}$

$\therefore v = 2.6 \times 10^8 \text{ ms}^{-1}$

(ii) $t = \frac{t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$

$= 2 \text{ s}$

SA

11/10/23

Photo Electric Effect

Photo electric work func.

The threshold freq / cutoff freq

Photo current

Kinetic energy

Stopping potential

Observation / Characteristics of photoelectric effect

Einstein's explanation

—

$$h\nu = K_{max} + \phi$$

$$K_{max} = h\nu_c - \phi$$

$$\phi = h\nu_c$$

$$\Rightarrow \nu_c = \frac{\phi}{h}$$

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Determination of Planck's constant

Compton effect

Kinetic energy of recoil electron

$E_R = h\nu - h\nu'$

Pair production

defn only

De Broglie Dual nature

SA .

22/10/23

Wave mechanical atom model

Nucleus

SA

25/10/23

Math from photoelectric & compton | CT 2

slides: 5, 6, 7, 8

Rough/ CT 2

Photoelectric effect

Photoelectric work function:

Cutoff frequency

Photocurrent: when a metal surface is exposed to electromagnetic wave above a threshold freq, the incident radiation is absorbed and the surface emits e^- then the electricity induced is photocurrent

Stopping potential

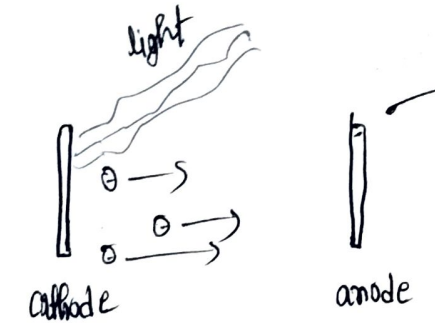
$E_{incident_photon} = \varphi + K_{max}$ → work func.

$\Rightarrow h\nu = K_{max} + \varphi$

when $K_{max} = 0$,

$\nu = \frac{\varphi}{h}$ → cutoff freq

Defⁿ of max kinetic energy of e^-



w/ such voltage the e^- wont emit from cathode

$$V = k\frac{q_1}{r^2}$$

$$E = k\frac{q_1 q_2}{r^2}$$

$$E = V \times q_2$$

$$K_{max} = V_0 e$$

$$= eV_0$$

Det^{n} of planck's const

$$h\nu = eV_0 + \phi$$

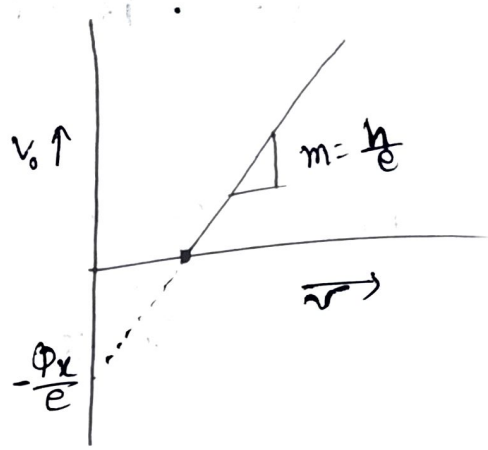
$$\Rightarrow eV_0 = h\nu - \phi$$

$$\Rightarrow V_0 = \frac{h}{e}\nu - \frac{\phi}{e} \quad ; \quad y = mx + c$$

($\frac{h}{e}$ → slope; y → V_0, x → ν, m → slope)

i.e., $\text{slope} = \frac{h}{e}$

$\therefore h = \text{slope} \times e$



P1. $\phi = 4eV$

$\nu = 10^{15}$ Hz

we know,

$$h\nu = \phi + k_{max}$$

$$= \phi + \frac{1}{2}mv^2$$

$$\therefore v = 2.185 \times 10^5 \, ms^{-1}$$

P2. $\phi = 2.3eV$

$$\nu = \frac{c}{4300 \times 10^{-10}} = 6.98 \times 10^{14} \text{ Hz}$$

we know...

P4. $h\nu = eV_0 = \phi$

$\therefore \nu = 5 \times 10^{14}\ Hz$

$4.99 \times 10^{14}\ Hz$

$\lambda = \frac{c}{\nu} = 601\ nm$

—

P5. $\nu = \frac{c}{2500 \times 10^{-10}} = 1.2 \times 10^{15}\ Hz$

$\phi =$

$h\nu = \phi + K_{max}$

$= \phi + eV_0$

$\therefore \phi = 6.35 \times 10^{-19}$ J

$= 3.96$ eV

P6. $\Phi = 4.52$ eV

a) $h\nu = \Phi + K_{max}$;

$\Rightarrow h\nu = \Phi$; given $K_{max} = 0$

$\therefore \nu = 1.1 \times 10^{15}$ H_z

$\therefore \lambda_c = \frac{c}{\nu} = 2727$ Å

b) $K_{max} = h\nu - \Phi$

however a minimum of λ_c wavelength light is needed for PE effect to occur

$= 1.75$ eV

c) 1.75 eV

Compton wavelength shift

$$\lambda' - \lambda = \frac{h}{m_e c} (1 - \cos\theta)$$

$$E_R = h\nu \left[\frac{2\alpha \sin^2 \theta/2}{1 + 2\alpha \sin^2 \theta/2} \right]; \quad \alpha = \frac{h\nu}{m_e c^2}$$

$$E_R = h\nu - h\nu'$$

Prob: a) $\lambda = 10 \times 10^{-12}$ m

$\theta = 45°$

$$\lambda' - \lambda = \frac{h}{m_e c} (1 - \cos\theta)$$

$\therefore \lambda' = 10.7 \times 10^{-12}$ m

$= 10.7$ pm

b) max when reflected in opposite dir: $\theta = 180°$

$\therefore \lambda'_{max} = 14.85$ pm

c) max recoil: $E_{R\,max} = hc\left[\frac{1}{\lambda} - \frac{1}{\lambda'_{max}}\right] = 6.48 \times 10^{-15}$ J

$= \ldots$ eV

De Broglie wavelength for an e^-

$$p = \frac{E}{c}$$

$$= \frac{h\nu}{c}$$

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

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

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

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

$$= \frac{h}{m\sqrt{\frac{2E}{m}}}$$

$$= \frac{h}{\sqrt{2mE}}$$

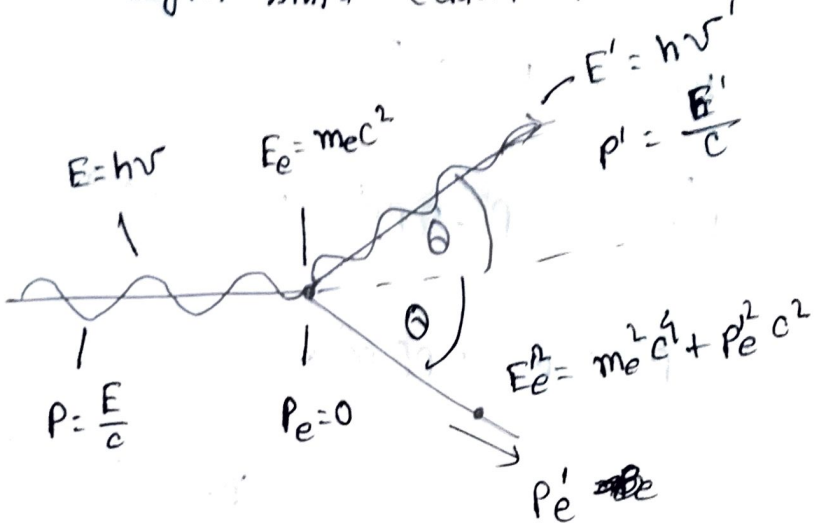
$$= \frac{h}{\sqrt{2meV}}$$

$$= \cdots$$

$$E = \frac{1}{2}mv^2$$

$$\Rightarrow v = \sqrt{\frac{2E}{m}}$$

Compton wavelength shift derivat^{n}:



Now,

$E + m_e c^2 = E' + E_e'$ and ——— (iii)

$\frac{E}{c} + 0 = \frac{E'}{c} + p_e'$

$\Rightarrow p_e' =$

$p = p' \cos\theta + p_e' \cos\theta$; in x dir

$\Rightarrow p_e' \cos\theta = p - p' \cos\theta$ and ——— (i)

$0 = p' \sin\theta - p_e' \sin\theta$

$\Rightarrow p_e' \sin\theta = p' \sin\theta$ ——— (ii)

$①^2 + ⑪^2 \Rightarrow$

$$p_e'^2 = p'^2 \sin^2\theta + (p - p'\cos\theta)^2$$

$$= p'^2 \sin^2\theta + p^2 - 2pp'\cos\theta + p'^2\cos^2\theta$$

$$= p'^2 + p^2 - 2pp'\cos\theta$$

~~$(hv - hv' + m_e c^2)^2 =$~~

Now,

$$E_e^2 = m_e^2 c^4 + p_e'^2 c^2$$

$$\Rightarrow (E - E' + m_e c^2)^2 = m_e^2 c^4 + (p'^2 + p^2 - 2pp'\cos\theta) c^2$$

$$\Rightarrow E^2 - 2EE' + E'^2 + 2[E - E']m_e c^2 + m_e^2 c^4 =$$

~~$m_e^2 c^4 + (p'^4 + p^4 + 2p^2 p'^2 - 2[p'^2 + p^2][2pp'\cos\theta] + 4p^2 p'^2 \cos^2\theta)$~~

$$m_e^2 c^4 + p'^2 c^2 + p^2 c^2 - 2pp' c^2 \cos\theta$$

$$\Rightarrow \cancel{E^2} - 2EE' + \cancel{E'^2} + 2Em_e c^2 - 2E'm_e c^2 + \cancel{m_e^2 c^4} =$$

$$\cancel{m_e^2 c^4} + \cancel{E^2} + \cancel{E'^2} - 2EE'\cos\theta$$

$$\Rightarrow 2m_e c^2 (E - E') = 2(EE' + EE'\cos\theta) = 2EE'(1 + \cos\theta)$$

$$\Rightarrow \frac{E - E'}{EE'} = \frac{1}{m_e c^2}(1 + \cos\theta) \Rightarrow \frac{1}{E'} - \frac{1}{E} = \frac{1}{m_e c^2}(1 - \cos\theta)$$

$$\Rightarrow \lambda' - \lambda = \frac{h}{m_e c}(1 - \cos\theta)$$

Kinetic energy of recoil electron:

$$E_R = h\nu - h\nu' \quad \text{---(1)}$$

$$\lambda' - \lambda = \frac{h}{m_e c^2}(1 - \cos\phi)$$

$$\Rightarrow \frac{c}{\nu'} - \frac{c}{\nu} = \frac{h}{m_e c^2}(1 - \cos\phi)$$

SA

01/11/23

SA

01/11/23

Wavefronts

Huygens's Principle

Superposition of waves

Coherent source

Slit



Interference in Thin Films

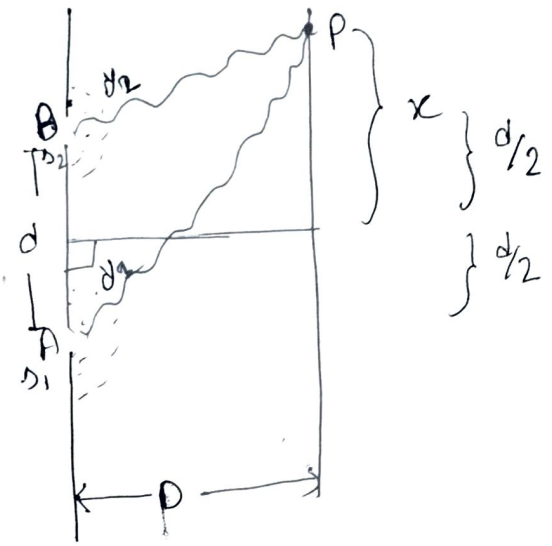
SA/mid

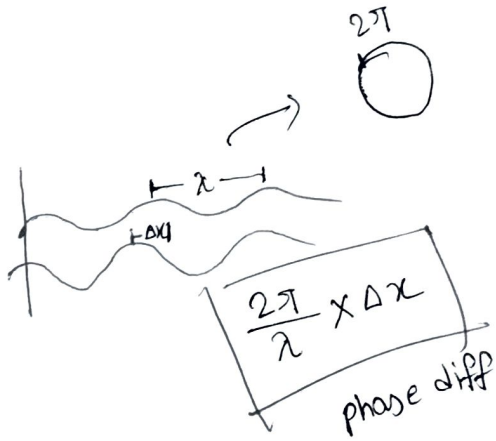
Find bright, dark cond of phase diff

figure path diff

phase diff → total dist corresponding to x path diff

bright → $n\lambda$, dark → $(2n+1)\frac{\lambda}{2}$





$y_1 = A\sin(\omega t)$

$y_2 = A\sin(\omega t + \Delta x)$

Find $AP - BP \rightarrow \Delta x$

$$AP^2 = D^2 + (x + d/2)^2 = D^2 + x^2 + xd + \frac{d^2}{4} \quad \text{— (I)}$$

$$BP^2 = D^2 + (x - d/2)^2 = D^2 + x^2 - xd + \frac{d^2}{4} \quad \text{— (II)}$$

(I) − (II) $\Rightarrow AP^2 - BP^2 = 2xd$

$\Rightarrow (AP + BP)(AP - BP) = 2xd$

$\Rightarrow AP - BP = \frac{2xd}{AP + BP} = \frac{2xd}{2D} = \frac{xd}{D}$ $[AP \approx D \approx BP]$

Phase diff of light at point P → $\frac{2\pi}{\lambda} \times \frac{xd}{D}$

Cond. for bright fringes: path ~~phase~~ diff = $n\lambda$ [for n multiples]

$$\frac{xd}{D} = n\lambda \quad \text{---} \quad (iii)$$

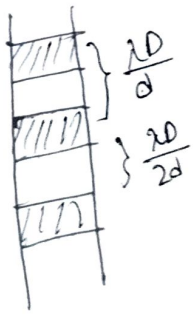
Cond. for dark fringes: path ~~phase~~ diff = $\frac{\lambda}{2}$ [for odd n multiples]

$$\frac{xd}{D} = (2n+1)\frac{\lambda}{2} \quad \text{---} \quad (iv)$$

Fringe width:

(iii) $\Rightarrow x_n = \frac{n\lambda D}{d}$; $x_2 = \frac{2\lambda D}{d}$, $x_1 = \frac{\lambda D}{d}$

$\therefore$ $x_2 - x_1 = \frac{\lambda D}{d}$



Breadth of bright/dark fringe:

$$\frac{\lambda D}{2d}$$

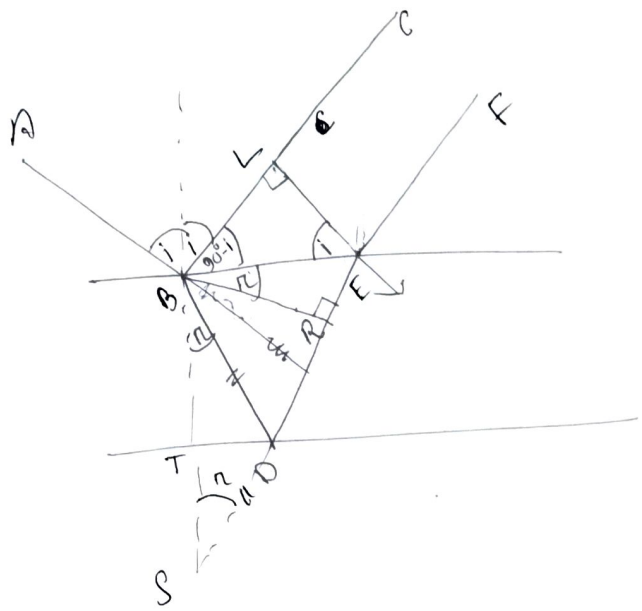
$$x_4 = \frac{4\lambda D}{d} = 8.5 \text{ mm}$$

$$\therefore \lambda = 1089 \text{ nm}$$

$d = 0.41 \text{ mm}$

$D = 80 \text{ cm}$

Interference in Thin Films



Defⁿ path diff. on BC & BDEF:

$$x = \mu(BD + DE) - BL$$

$$= \mu(BD + DR + RE) - BL$$

Now, $\mu = \frac{\sin i}{\sin r} = \frac{BL/BE}{RE/BE} = \frac{BL}{RE}$ and $BD = DS$

$\Rightarrow BL = \mu RE$

$\therefore x = \mu(PR + DS) = \mu(DS + DR)$

$= \mu RS$

In triangle BSR,

$$\cos r = \frac{RS}{BS} \Rightarrow RS = BS\cos r$$

$$= (BT+TS)\cos r$$

$$= 2t\cos r$$

$$\therefore x = 2\mu t\cos r \pm \boxed{\frac{\lambda}{2}}$$

[when reflected phase is changed by π which $\rightarrow$ $x = 2\pi$, $\pi = \lambda/2$]

Cond. for bright:

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

$$\Rightarrow 2\mu t\cos r = (2n \pm 1)\lambda/2$$

Phase diff:

$$\rightarrow \frac{2\pi}{\lambda} \times (2n \pm 1)\frac{\lambda}{2}$$

$$= (2n \pm 1)\pi$$

Cond. for dark:

$$2\mu t\cos r \pm \lambda/2 = (2n \pm 1)\lambda/2$$

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

$$\rightarrow \frac{2\pi}{\lambda} \times n\lambda = 2n\pi$$

SA 03/12/23

Resolving power of an optical instrument

–

Theory of plane diffraction grating

SA

17/12/2023

Diffraction maths

28(2, 4, 5, 6, 7, 8, 9, 16)

8 type math } 28.2, 28.4 ...

Polarization

30(1, 2, 3, 4)

4 type math

Interference + lens Diffraction + polarization	Question pattern for Anal

SA

20/12/23

SA

24/12/23

SA

27/12/23

M. Physics (3 sets)

Relativity — 1 set (comp) } set B
Photo - bohr - 1 set }
Nuclear — 1 set] set A

Optics (2 sets)

Lens + interference — 1 set } set B
Diffraction + polarization - 1 set }

Each set having at least 1 math

Relativistic velocity X

Pain prop ✓

Nuclear power plant — end except power plant use X

Dispersion of prism X

Fresnel, defn of wavelength X

Polarization — D law, M law ✓
next X