Ray Optics

12 March 2022 14:12

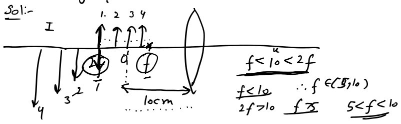
Lens Formula

$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$ $m = \frac{v}{u} = \frac{h_I}{h_O}$

If $h_I > h_O \Rightarrow m > 1$

Q1:- A thin convex lens is used to form an image, the object being placed 10 cm away from the lens. What should be the focal length such that image is larger than the object?

Sol:-



$f < 10 < 2f$

$f < 10$, $2f > 10$, $f > 5$ $\therefore f \in (5, 10)$ $5 < f < 10$

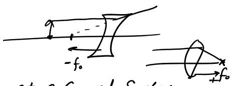
Q2:- An object is placed at a distance of 20cm from a concave lens of focal length 10 cm. Find the nature, position and magnification of the image.

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ $m = \frac{v}{u} = \frac{h_I}{h_O}$

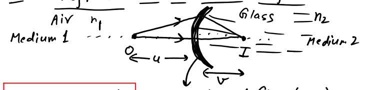
$\frac{1}{v} - \frac{1}{-20} = \frac{1}{-10}$

$v = -20$

$m = 1$

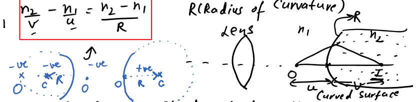


Refraction at a Curved Surface



$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$

R (Radius of Curvature)



Q3:- A fish is placed outside a thin glass bowl. The bowl has water of refractive index 1.44. If the fish is placed at a distance of 15 cm from the glass surface, find the location of the image of the fish. Given that R = 20.

Sol:- $\frac{1.44}{v} - \frac{1}{-15} = \frac{1.44 - 1}{+20} \Rightarrow \frac{1.44}{v} = \frac{0.44}{20} - \frac{1}{15}$

$\frac{1.44}{v} = \frac{0.44 \times 3 - 4}{60} = \frac{0.11 \times 3 - 1}{15}$

$\frac{1.44}{v} = \frac{-0.67}{15}$

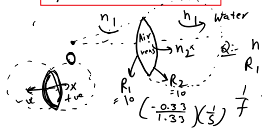
$\frac{1.44}{v} = -0.044$

$v = \frac{1.44}{0.044} = -38 cm$

Lens maker's Formula

focal length of a lens: f

$\frac{1}{f} = \left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$



Q:- $n_1 = 1$ $n_2 = 1.33$

$R_1 = +10$ $R_2 = -10$

$\frac{1}{f} = \left(\frac{1.33}{1} - 1\right)\left(\frac{1}{10} - \frac{1}{-10}\right) = \frac{0.33}{5}$

Eg 9.8 (i) If $f = 0.5$ for a glass lens, what is the power of the lens?

POWER OF A LENS

$P = \frac{1}{f}$ → metres

Dioptre (D)

$P = \frac{100}{f}$ → cm

Dioptre (D)

(ii) The radii of curvature of the faces of a double convex lens are 10cm and 15cm. Its focal length is 12cm. What is the refractive index of glass?

(iii) A convex lens has 20cm focal length in air. What is focal length in water? [Refractive index of air-water = 1.33, refractive index for air-glass = 1.5]

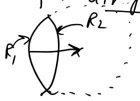
Sol:- (ii) $R_1 = +10cm$

$R_2 = -15cm$

$f = +12cm$

$\mu_1 = 1$

$\mu_2 = \mu_{glass}$



$\frac{1}{f} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

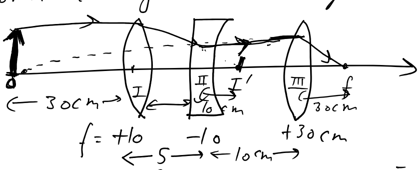
(iii) $\frac{1}{20} = \left(\frac{1.5}{1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ → Glass

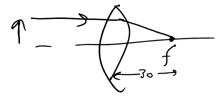
$\frac{1}{f} = \left(\frac{1.33}{1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ → Water

$\frac{1/20}{1/f} = \frac{1}{20} \times f$

$\frac{f}{20} = \frac{(0.5)}{(0.33)} \Rightarrow f = \frac{20(0.50)}{(0.33)} = \frac{1000}{33} = 30.3 cm$

Eg 9:- Find the position of the image formed by the lens combination given in the Fig 9.22.





Sol:-

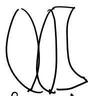
I $\frac{1}{v} - \frac{1}{-30} = \frac{1}{10} \Rightarrow \frac{1}{v} = \frac{1}{10} - \frac{1}{30} = \frac{3-1}{30} = \frac{2}{30}$

~~v = 7.5cm~~ $v = 15cm$

II $u = +10$ $\frac{1}{v'} - \frac{1}{+10} = \frac{1}{-10} \Rightarrow \frac{1}{v} = 0 \Rightarrow v = \infty$

II $u = +10$ $\frac{1}{v'} - \frac{1}{+10} = \frac{1}{-10} \Rightarrow \frac{1}{v} = 0 \Rightarrow v = \infty$

Combination of lenses in Contact



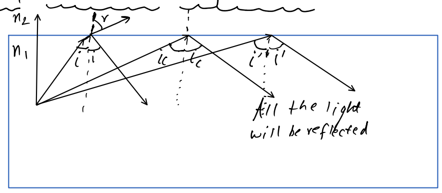
Total (Net) $P = P_1 + P_2 + P_3 + \dots$

$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} + \frac{1}{f_3} + \dots$

$m = m_1 m_2 m_3 \dots$

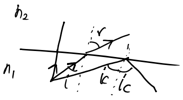
TIR, PRISM, MICROSCOPE, TELESCOPE

Total Internal Reflection



$\sin i_c = n_{21} = \frac{n_2}{n_1}$

i_c = Critical Angle



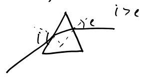
$i' \geq i_c \Rightarrow$ T.I.R will happen

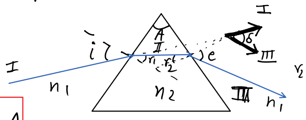
Q:- If T.I.R. happens first at $i = 37°$, when a ray of light moves from water to air, then what is the refractive index of water?

Sol:- $\sin 37 = \frac{3}{5}$ $\sin 53 = \frac{4}{5}$ $\sin 37 = \frac{3}{5} = \frac{1}{n_1}$

$\cos 37 = \frac{4}{5}$ $\cos 53 = \frac{3}{5}$ $\boxed{n_1 = \frac{5}{3}}$

Refraction through a Prism





A → Angle of Prism
i → Angle of incidence
r_2, r_1 → Angles of refraction
e → Angle of emergence
δ → Angle of deviation

$\boxed{\delta = i + e - A}$

$\boxed{n_{21} = \frac{n_2}{n_1} = \frac{\sin\left(\frac{A + D_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}}$

D_m → Minimum angle of deviation (δ_m)
↳ when $i = e$ ie. symmetry is established

In the symmetric case, $\delta = D_m$

If $n_1 = 1$, & let $n_2 = \mu$ & A is very small... Then D_m is also very small & Hence [∵ $\sin\theta \approx \theta$ when θ is small.]

$\mu = \frac{\left(\frac{A + D_m}{2}\right)}{\frac{A}{2}} \Rightarrow \mu = \frac{A + D_m}{A} \Rightarrow D_m = (\mu - 1)A$ — Particular Solution

If n_1, n_2 $\frac{n_2}{n_1} = n_{21} = \mu$

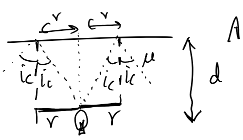
OR $\boxed{D_m = (n_{21} - 1)A}$

$\mu = \frac{A}{A} + \frac{D_m}{A} = 1 + \frac{D_m}{A}$

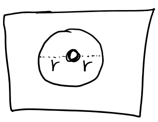
$\Rightarrow \frac{D_m}{A} = \mu - 1$

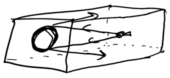
$D_m = (\mu - 1)A$

9.5



$A = \pi r^2$





$\frac{r}{d} = \tan i_c$

$1/\mu = \sin i_c = \frac{r}{\sqrt{d^2 + r^2}}$

$\frac{r}{\sqrt{80^2 + r^2}} = \sin i_c = \frac{1}{1.33} = \frac{3}{4}$

$\frac{4}{3} = 1.33$

$3(80^2 + r^2) = 4r^2$
$9[6400 + r^2] = 16r^2$
$57600 + 9r^2 = 16r^2$
$7r^2 = 57600$
$r^2 = 8230$
$\boxed{r \approx 90}$

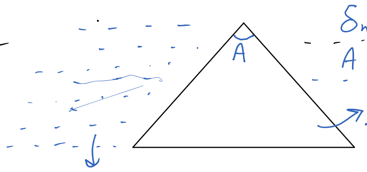
64 × 9 = 576

$2\sqrt{576}$ 82.3

H.W. 9.5 & 9.6

$A = \pi r^2 = (3.14)(90)^2$

Ex-9.6



δ_m or $D_m = 40°$
$A = 60°$
μ_2 (myu) = ? (Unknown)
$\mu_1 = 1.33$

$\mu_{21} = \frac{\sin\left(\frac{A + D_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$

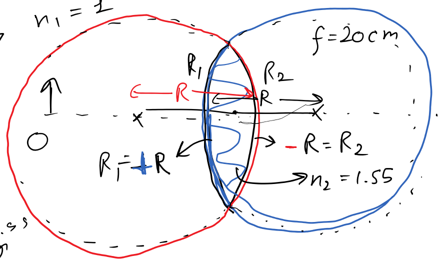
μ_1 μ_2

$$\mu_{21} = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

$$\frac{\mu_2}{\mu_1} = \frac{\mu_2}{1.33} = \frac{\sin\left(\frac{60^\circ+40^\circ}{2}\right)}{\sin\left(\frac{60^\circ}{2}\right)}$$

$$1.53 \leftarrow \frac{\mu_2}{1.33} = \frac{\sin 50^\circ}{\sin 30^\circ}$$

Ex-9.7 $n_1 = 1$



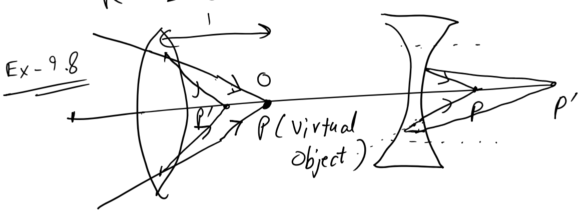
n_1 (Air) = 1

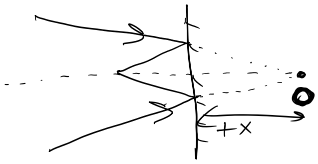
$$\left(\frac{n_2}{n_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = \frac{1}{f}$$

$n_2 \to 1.55$, $n_1 \to 1$, $R_1 \to +R$, $+x$; $R_2 \to -R$, $-x$

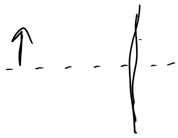
R = 22cm

Ex-9.8

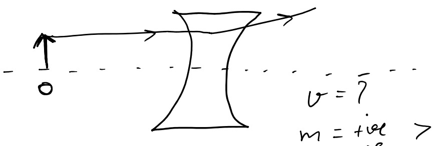




$u = +x$



9.9



$v = ?$

$m = +ve$ >1
$-ve$ <1
Real, Virtual

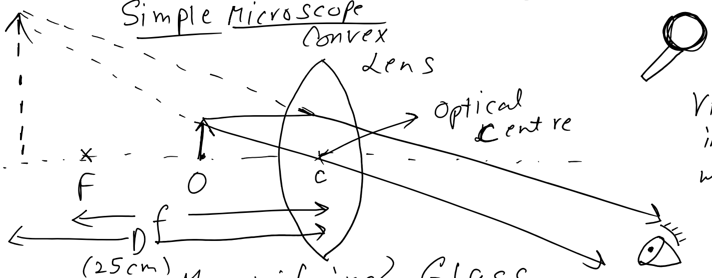
$$m = \frac{h_I}{h_o} = \frac{-v}{u}$$

$m = +ve$

Enlarged

OPTICAL INSTRUMENTS

Simple Microscope



Virtual, Erect & Enlarged image is formed when the object is placed within the focal length & the convex lens acts like a magnifying glass. (Simple Microscope)

Magnifying Glass

* Case-I :- Image forms at the near point (D) of the eye :→ 25cm

$$m_D = \left(1 + \frac{D}{f}\right)$$

More (Magnification)

* Case-II :- Image forms at infinity (∞)

$$m_\infty = \frac{D}{}$$

* Case – II :- Image forms at infinity (∞)

$$m_\infty = \frac{D}{f}$$

Q1:- Find the height of the image of an object of height 1 cm formed by a magnifying glass formed at:
(i) Near Point $\rightarrow$ $1 + \frac{25}{2.5} = 11 (m_D)$
(ii) Infinity

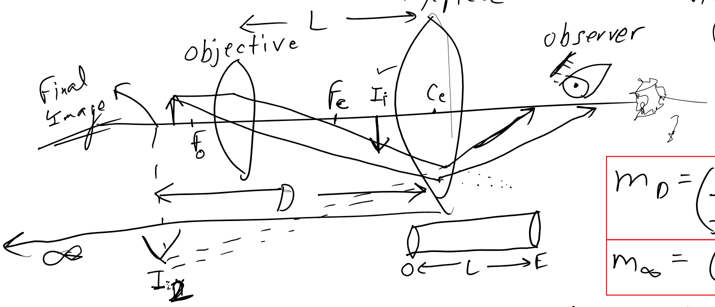
Given:- $f = 2.5\,cm$

(i) $m_D = \frac{h_I}{h_O (1\,cm)}$

$h_I = 11 \times 1\,cm$

$h_I = 11\,cm$

Compound Microscope



* Virtual, inverted & Enlarged Image
* L is the length of microscope.

$$m_D = \left(\frac{L}{f_o}\right)\left(1 + \frac{D}{f_e}\right)$$

(m_o, m_e)

$$m_\infty = \left(\frac{L}{f_o}\right)\left(\frac{D}{f_e}\right)$$

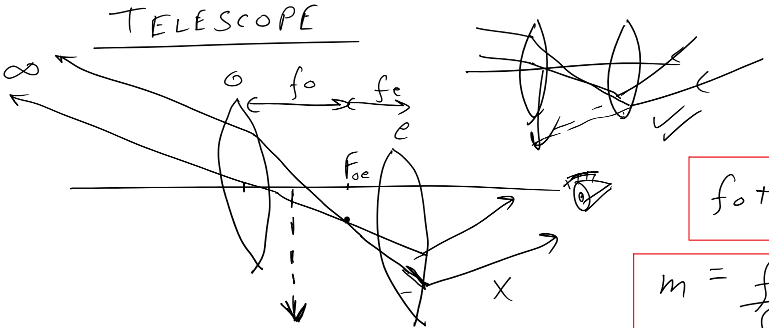
(m_o, m_e)

Ex-2:- An angular magnification of 30X is desired using an objective of focal length 1.25 cm and an eyepiece of focal length 5 cm. How will you set up the compound microscope?

$$30 = \left(\frac{L}{1.25}\right)\left(1 + \frac{25}{5}\right) \Rightarrow 5 \times 1.25 = 6.25$$

($1 + \frac{25}{5} = 6$)

TELESCOPE

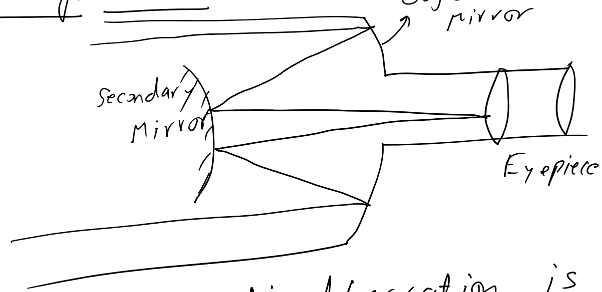


$$f_o + f_e = L$$

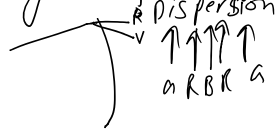
$$m = \frac{f_o}{f_e}$$

* Image is enlarged and Virtual and inverted.
* object is at infinity.
* Terrestrial telescope.

Reflecting / Gallilean / Cassegrain



* Chromatic Aberration is nullified using reflecting telescope.



H.W.

Exercise 9.6, 9.7, 9.8, 9.9, 9.10, 9.11, 9.13, 9.14, 9.15

Exercise 9.8, 9.6, 9.7, 9.10, 9.11, 9.9, 9.12, 9.13, 9.14, 9.15

arBR a

Ex-9.28 A small telescope has an objective lens of focal length 140 cm and an eyepiece of focal length 5.0 cm. What is the magnifying power of the telescope for viewing distant objects when:

(a) The telescope is in normal adjustment (i.e. when the final image is at infinity)?

(b) The final image is formed at the least distance of distinct vision (25 cm)?

Sol :-

9.11 $f_o = 2.0\,cm$

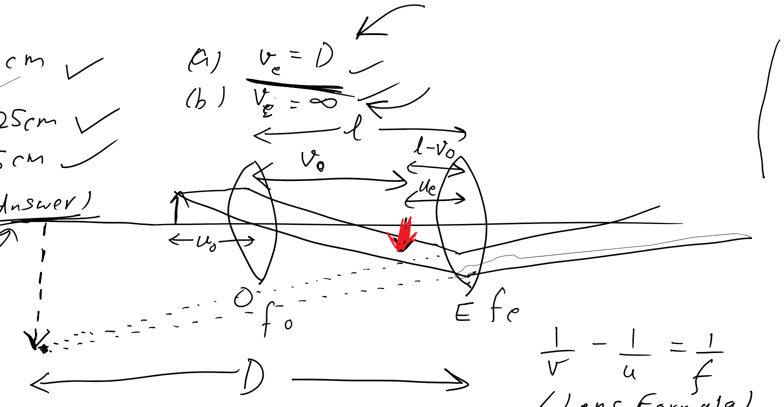
$f_e = 6.25\,cm$

$l = 15\,cm$

$u_o = ?$ (Answer)

(a) $v_e = D$

(b) $v_e = \infty$



$v_e = 25\,cm$

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ (Lens Formula)

Image formed by O

$\frac{1}{v_o} - \frac{1}{u_o} = \frac{1}{f_o}$

$\frac{1}{v_o} - \frac{1}{u_o} = \frac{1}{2.0}$ —(i)

Image formed By E

$\frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{f_e}$

(a) $v_e = 25\,cm$

$\frac{1}{25} - \frac{1}{15-v_o} = \frac{1}{6.25}$ —(ii)

① ② Ans

$\frac{25}{625} - \frac{100}{625} = \frac{1}{15-v_o}$

$-\frac{75}{625} = \frac{1}{15-v_o}$ ($-\frac{3}{25}$)

$\Rightarrow -45 + 3v_o = 25$

$3v_o = 70$

$v_o = \frac{70}{3} = 23.33\,cm$

$\frac{3}{70} - \frac{1}{u_o} = \frac{35}{70}$

$\frac{1}{u_o} = -\frac{32}{70}$

$u_o = -\frac{70}{32}$ 2.2

Check Again

(b) $v_e = \infty$

$\frac{1}{\infty} - \frac{1}{15-v_o} = \frac{1}{6.25}$

$-6.25 = 15 - v_o$

$v_o = 15 - 6.25 = 8.75$

$\frac{1}{8.75} - \frac{1}{u_o} = \frac{1}{2.0}$

$\frac{1}{u_o} = \frac{1}{8.70} - \frac{1}{2.00}$

$\frac{1}{u_o} = \frac{2.00 - 8.70}{17.4}$

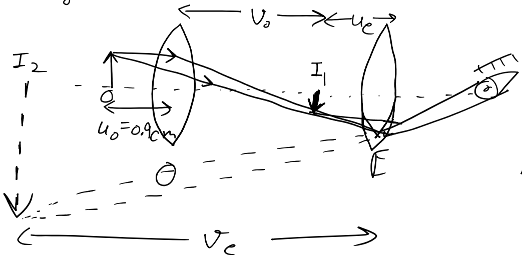
$\frac{1}{u_o} = \frac{-5.70}{17.40}$ $\Rightarrow u_o = 3.05$

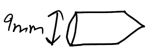
9.12 $D = 25\,cm = v_e$

$f_o = 8.0\,mm = 0.8\,cm$

$f_e = 2.5\,cm$

$u_o = 9\,mm = 0.9\,cm$





magnifying Power

$m = m_o m_e = \left(\frac{L}{f_o}\right)\left(1 + \frac{D}{f_e}\right)$

$\frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{f}$

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

$$\frac{1}{v_o} - \frac{1}{u_o} = \frac{1}{f_o}$$

$$\frac{1}{v_o} - \frac{1}{0.9} = \frac{1}{0.8}$$

$$\frac{1}{v_o} = \frac{1}{0.8} + \frac{1}{0.9}$$

$$\frac{1}{v_o} = \frac{0.17}{0.72} \Rightarrow v_o = \frac{72}{17}$$

$$\frac{1}{v_e} - \frac{1}{u_e} = \frac{1}{f_e}$$

$$\frac{1}{-25} - \frac{1}{l - v_o} = \frac{1}{2.5}$$

$$\Rightarrow \frac{1}{l - v_o} = -\frac{10}{25} - \frac{1}{25} = \frac{-11}{25}$$

$$+\frac{25}{11} = v_o - l$$

$$\frac{72}{11} - l = \frac{25}{11}$$

$$l = \frac{72 - 25}{11} = \frac{47}{11} \text{ cm}$$

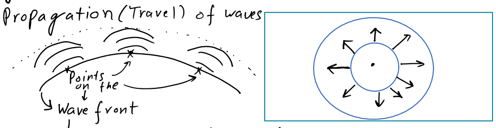
✓ 1:08 PM

H.W. 9.17 - 9.32

Except 9.16, 9.18, 9.23

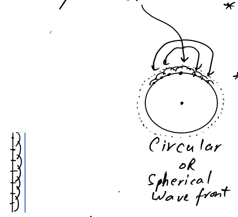
Huygen's Principle

→ Propagation (Travel) of waves



→ Electromagnetic (Light)
→ Mechanical Wave (Sound, Water)

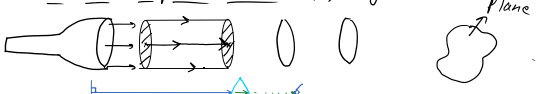
* Each point on a wavefront acts like a point source of "Secondary Wavelets"



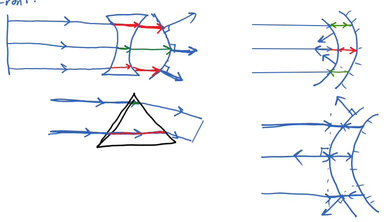
* Spherical wavefront generates a larger spherical wavefront.
* Circular wavefront generates a larger circular wavefront.
* A plane wavefront generates a plane travelling wavefront.

Plane Wavefront

* A beam or pencil (cylinder) of light

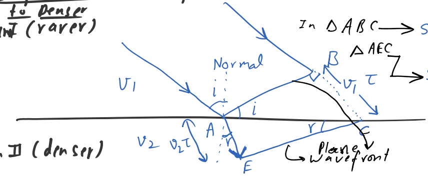


* In a transverse wave, the propagation or travelling happens perpendicular to the wavefront.



Refraction of a Plane wave

(i) Rarer to Denser Medium I (rarer)



$BC = v_1\tau$

In $\triangle ABC$ → $\sin i = \frac{BC}{AC} = \frac{v_1\tau}{AC}$ —(1)

$\triangle AEC$ → $\sin r = \frac{AE}{AC} = \frac{v_2\tau}{AC}$ —(2)

(1)/(2)

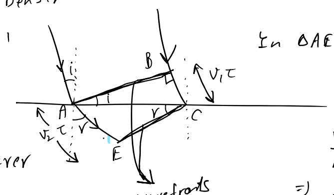
$\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \frac{n_2}{n_1}$

Refractive Index, $n = \frac{\text{Speed of light in vacuum}}{\text{speed of light in medium}}$ ⇒ $n_1 \sin i = n_2 \sin r$ → Snell's Law

$n_1 = \frac{c}{v_1}$ & $n_2 = \frac{c}{v_2}$

$\frac{n_1}{n_2} = \frac{v_2}{v_1}$ $n \propto \frac{1}{v}$

Refraction at a Rarer Medium



In $\triangle ABC$, $\frac{BC}{AC} = \frac{v_1\tau}{AC}$ —(1) ← sin i

In $\triangle AEC$, $\frac{AE}{AC} = \frac{v_2\tau}{AC}$ —(2) ← sin r

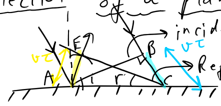
(1)/(2)

$\frac{v_1\tau}{AC} \Big/ \frac{v_2\tau}{AC} = \frac{v_1}{v_2} = \frac{n_2}{n_1}$

⇒ $\frac{n_2}{n_1} = \frac{\sin i}{\sin r}$

⇒ $n_1 \sin i = n_2 \sin r$ → Snell's Law using Huygen's Principle.

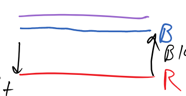
Reflection of a plane wave by a plane Surface



$BC = v\tau$

$AE = BC = v\tau$

The Doppler Effect



* Frequency in light means color.
* Frequency in sound means pitch.

- When a star moves away from us, the apparent frequency of light reduces. (Red-Shift)
- When a star moves towards us, the apparent frequency of light increases. (Blue-Shift)

$$\frac{\text{Change in frequency}}{\text{Actual frequency}} = \boxed{\frac{\Delta \nu}{\nu} = -\frac{v_{radial}}{c}}$$ (Relative speed)

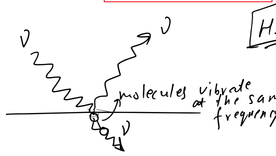
Increase of wavelength means decrease in frequency

$$\boxed{\frac{\Delta \lambda}{\lambda} = \frac{v_{radial}}{c}}$$

$$\boxed{f = \frac{1}{\lambda}}$$

H.W. Exercise :→ 10.1 to 10.3

Eq 10.2



Coherent Sources

- Eg:- Lasers

Both sources have:
(i) Same Frequency
(ii) Phase Locking

Incoherent Sources

- Eg:- Bulb, Candle etc.

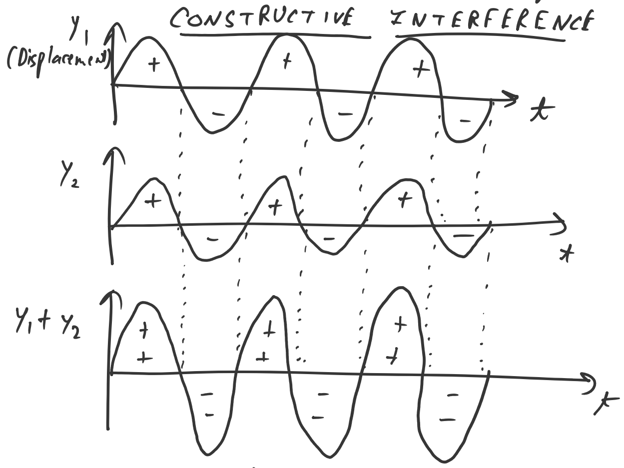
If Both (i) & (ii) are not satisfied, then the sources are incoherent.

Note:- Only coherent sources are studied for interference.

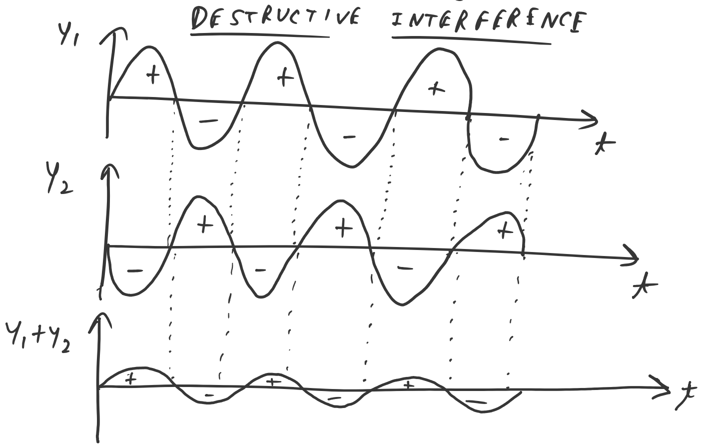
INTERFERENCE OR SUPERPOSITION

↳ Addition or overlapping of Light Waves

CONSTRUCTIVE INTERFERENCE



DESTRUCTIVE INTERFERENCE



CONDITION FOR CONTRUCTIVE INTERFERENCE

Path Difference: $\boxed{\Delta x = n\lambda}$ $n \to$ Integer

Phase Difference:- $\boxed{\Delta \phi = 2n\pi}$ $n \to$ Integer

CONDITION FOR DESTRUCTIVE INTERFERENCE

Path Difference: $\boxed{\Delta x = \left(n + \frac{1}{2}\right)\lambda}$ $n \to$ Integer

CONDITION FOR DESTRUCTIVE INTERFERENCE

Path Difference: $\Delta x = (n + \frac{1}{2})\lambda$ — n → Integer

Phase Difference: $\Delta \phi = (2n+1)\pi$ — n → Integer

RELATION BETWEEN PATH DIFFERENCE & PHASE DIFFERENCE

$\frac{\Delta \phi}{2\pi} = \frac{\Delta x}{\lambda}$ → Path Difference; λ → wavelength; Δφ → Phase Difference

EQUATION OF LIGHT WAVE

$y = a \sin(\omega t + \phi)$

- ω → 2πf, f: frequency (Color); Angular frequency
- φ → Phase
- a → Amplitude
- y → Displacement (Brightness) (Intensity)
- (Displacement, Magnetic field or Electric Field)

If the phase difference between two light waves does not change over time, they are said to be locked in phase.

$y = a \sin(\omega t + \phi)$ — Amplitude, Phase, Angular Frequency ν ("Nyu"), Displacement: (i) E. field (ii) M. Field

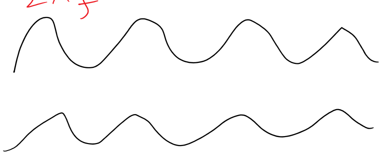
$\omega = 2\pi f$

Source 1: $y_1 = a_1 \sin(\omega t + \phi_1)$ → 60°

Source 2: $y_2 = a_2 \sin(\omega t + \phi_2)$ → 20°

→ $\Delta\phi = 40°$

Phase Difference $= \Delta\phi = |\phi_1 - \phi_2|$



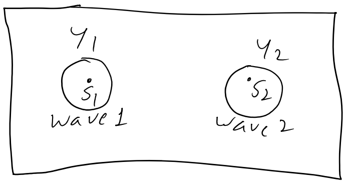
Superposition of Two Coherent Waves

Coherent → Same; $\omega_1 = \omega_2 = \omega$

Wave 1: $y_1 = a_1 \sin(\omega t + \phi_1)$ ← y_1

Wave 2: $y_2 = a_2 \sin(\omega t + \phi_2)$ ← y_2

Phase difference, $\Delta\phi = |\phi_1 - \phi_2|$



0 rad → 0°; $\frac{\pi}{2}$ rad → 90°; π rad → 180°; 2π → 360°

Resultant wave: $y = y_1 + y_2 = a \sin(\omega t + \varepsilon)$ ← $y_1 + y_2$

Amplitude $a = \sqrt{a_1^2 + a_2^2 + 2a_1a_2\cos(\Delta\phi)}$

$\tan\varepsilon = \frac{a_2 \sin\Delta\phi}{a_1 + a_2\cos\Delta\phi}$

V. Imp

Eg 1:- Two waves namely:

(i) $y_1 = (0.1)\sin(200\pi t + \pi)$ → $a\sin(200\pi t + \varepsilon)$; ω_1

(ii) $y_2 = (0.2)\sin(200\pi t + 2\pi)$; ω_2

Find (a) frequency & wavelength of both light waves

(b) Equation of resulting light wave. $y = a\sin(\omega t + \varepsilon)$

(c) Identify whether it is constructive interference or destructive interference

(d) Find the path difference between the two waves

$y_1 = 0.1 \sin(100\pi t + \pi)$

$y_2 = 0.2 \cos(100\pi t)$

$\sqrt{(0.1)^2 + (0.2)^2 + 2(0.1)(0.2)(-1)}$

$= \sqrt{0.01 + 0.04 - 2(0.02)}$

$= \sqrt{0.05 - 0.04}$

$= \sqrt{0.01}$

$= 0.1$

$\frac{\Delta\phi}{2\pi} = \frac{\Delta x}{\lambda}$

$\cos(\pi) = -1$

$\sin(\pi) = 0$

(c), (d), (a), (b)

Sol:- $\phi_1 = \pi$, $\phi_2 = 2\pi$

$\Delta\phi = \pi$

Δφ → $(2n+1)\pi$ odd multiple of π → Destructive

Δφ → $2n\pi$ even multiple of π → Constructive

(c) Destructive Interference

(d) $\frac{\Delta\phi}{2\pi} = \frac{\Delta x}{\lambda}$

$\Rightarrow \Delta x = \frac{\Delta\phi}{2\pi} \cdot \lambda = \frac{\pi}{2\pi}\lambda = \frac{\lambda}{2} = 1.5 \times 10^6$ m

Radian/second ($rad\,s^{-1}$)

(a) Hint:- Angular frequency, $\omega = 2\pi f \Rightarrow f = \frac{\omega}{2\pi}$

$c = f\lambda$

$\Rightarrow \lambda = \frac{c}{f} = \frac{c}{\omega/2\pi} = \frac{2\pi c}{\omega}$

$\lambda = \frac{2\pi c}{\omega} = \frac{2\pi \times 3\times10^8}{200\pi}$

$f = \frac{200\pi}{2\pi} = 100$ Hz

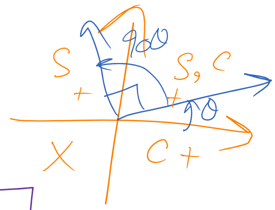
$f = \frac{200\pi}{2\pi} = 100\ Hz$ $\qquad \lambda = \frac{2\pi c}{\omega} = \frac{2\pi \times 3\times10^8}{200\pi}$

$f = \frac{c}{\lambda} = \frac{3\times10^8}{3\times10^6} = 100\ Hz$ $\qquad \lambda = 3\times10^6\ m$

(b) $y = y_1 + y_2 = a\sin(\omega t + \varepsilon)$ $\qquad a = 0.1$, $\varepsilon = 0$

$y = (0.1)\sin(\omega t)$

$y = (0.1)\sin(200\pi t)$



H.W. Revise Notes
Resolve the problem

$\sin(90+\theta) = \cos\theta$

$\cos(90+\theta) = -\sin\theta$

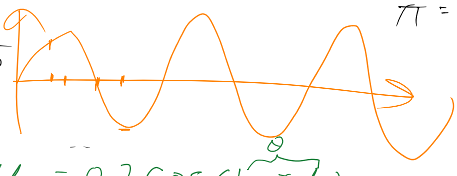
$\sin(180+\theta) = -\sin\theta$

$(0.2)\ N/C$

$\pi = 180°$

$a = \sqrt{(0.1)^2 + (0.2)^2 + 2(0.1)(0.2)\cos\frac{\pi}{2}}$ → 0

$a = \sqrt{0.01 + 0.04}$



$\cos(180+\theta) = \cos\theta$ $\qquad a = \sqrt{0.05}$

$\sin(180-\theta) = \sin\theta$ $\qquad a = \frac{\sqrt{5}}{10} = \frac{2.24}{10}$

$\cos(180-\theta) = -\cos\theta$ $\qquad a = 0.224$ units

$y_2 = 0.2\cos(100\pi t)$

$= 0.2\sin(100\pi t + \frac{\pi}{2})$

$y_1 = 0.1\sin(100\pi t + \pi)$

$\cos(90-\theta) = \cos(\theta - 90) = \sin\theta$

$\sin(90-\theta) = \cos\theta$

$\sin(\theta - 90) = -\cos\theta$

$90° = \frac{\pi}{2}$

$\Delta\phi = |\phi_1 - \phi_2|$

$= |\pi - \frac{\pi}{2}|$

$\frac{180°}{2} = \frac{\pi}{2}$ $\qquad \Delta\phi = \frac{\pi}{2}$

$\omega = 100\pi t$

$2\pi f = 100\pi$ So

$f = 50\ Hz$

$c = f\lambda$

$\lambda = \frac{c}{f} = \frac{3\times10^8}{50}$

$\frac{\Delta\phi}{2\pi} = \frac{\Delta x}{\lambda}$

$\lambda = 6\times10^6$

$\frac{(\pi/2)}{2\pi} = \frac{\Delta x}{6\times10^6}$

* Neither constructive nor destructive Interference

$\Delta x =$

Ans:- a

$(0.224\ V/m)\sin[(100\pi\ rad s^{-1})t + \varepsilon\ rad]$

$0.1\sin(100\pi t + \pi)$

a_1 ← $(0.1\ N/C)\sin[100\pi\ rad s^{-1}\ t + \pi\ rad]$
or $(0.1\ V/m)$ $\qquad$ ↳ ω $\qquad$ ↳ ϕ_1

$\tan 0 = 0$ ✓

$\tan\varepsilon = \frac{(0.2)\sin(\pi/2)}{(0.1) + (0.2)\cos\pi/2}$ → 0 $\qquad = 2$

$\tan\frac{\pi}{6} = \frac{1}{\sqrt{3}}$ ✓ (30°)

$\tan\frac{\pi}{2} = N.D.$ ✓ ∞ (90°)

$\varepsilon = \tan^{-1}(2)$

$\tan\frac{\pi}{4} = 1$ ✓ (45°)

speed of light in medium
$v = f\lambda$

$\tan\frac{\pi}{3} = \sqrt{3}$ ✓ (60°)

$v = \frac{c}{n}$ $\qquad$ OR Given $\tan^{-1}(2) = 63.43°$

$c = f\lambda$

if waves in air/vacuum

$180° = \pi\ rad$

$63.43° = n\ rad$

H.W. → Repeat P1 for

$y_1 = 0.3\cos 50\pi t$

medium of R.I. = n

$\varepsilon = n = \frac{63.43}{...} = 0.35...$

HW: ...

$y_1 = 0.3 \cos 50\pi t$

$y_2 = 0.4 \sin 50\pi t$

Median of R.I. = n or μ ("myu")

$63.43^\circ = n$ rad

$\varepsilon = \frac{n}{\pi} = \frac{63.43}{180} = 0.35$ rad

$\sin(90^\circ + \theta) = \cos\theta$

$0.3 \cos \omega t = 0.3 \cos(\omega t + \frac{\pi}{2})$

Intensity of Light (Brightness)

Light wave Equation, $y = a \sin(\omega t + \phi)$

Intensity, $I \propto a^2$

Now, we know that: If $y_1 = a_1 \sin(\omega t + \phi_1)$

$y_2 = a_2 \sin(\omega t + \phi_2)$

Then, $y = a \sin(\omega t + \varepsilon)$

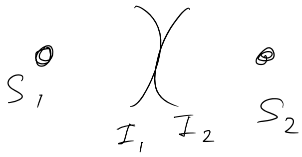
Where, $a = \sqrt{a_1^2 + a_2^2 + 2a_1 a_2 \cos\Delta\phi}$

$\Rightarrow a^2 = a_1^2 + a_2^2 + 2a_1a_2\cos\Delta\phi$

But $I \propto a^2$ or $I = Ka^2$ (K ⇒ Constant of Proportionality)

$\therefore \Rightarrow \frac{I}{K} = \frac{I_1}{K} + \frac{I_2}{K} + 2\frac{\sqrt{I_1}}{\sqrt{K}}\frac{\sqrt{I_2}}{\sqrt{K}}\cos\Delta\phi$

Net Intensity by superposing two waves of intensities I_1 & I_2



If $I_1 \neq I_2$

(i) $I = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos\phi$

$\phi = \Delta\phi$ (Phase diff. b/w 2 waves y_1 & y_2)

If $I_1 = I_2 = I_0$

(ii) $I = 4I_0 \cos^2\frac{\phi}{2}$

$\phi \rightarrow$ Phase difference

Revise Questions & Formulae

Prepare for Test

Mock Test

$4(10)\left(\frac{1}{2}\right) = 20$ $\quad 4I_0\cos^2\frac{\phi}{2} = 4\times10\cos^2\left(\frac{\pi}{4}\right) = 40(\cos 45^\circ)^2 = 20$

① Two source of identical intensity 10 W/m² & wavelength the so... superimposed. If the phase difference between the ...

W/m²

589 nm

urce is

1. Two source of identical intensity 10 W/m² & wavelength ... are superposed. If the phase difference between the so... $\frac{\pi}{2}$, find the resulting intensity of light.

2. Repeat the above problem for two sources wit... 20 W/m² and 40 W/m² but the same phase differ...

$\hookrightarrow I = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos$ ...
$= 20 + 40 + 2(\sqrt{20})(\sqrt{40})$ ...
$I = 60$

3. Two waves: $y_1 = 10\sin(50\pi t + \pi)$
$y_2 = 20\sin(50\pi t + \frac{\pi}{4})$

Find (a) Frequency & wavelength of the waves
(b) Phase difference & path difference
(c) If $I_1 = 1$ W/m², find net intensity.
(d) Find the equation of the resulting wave.

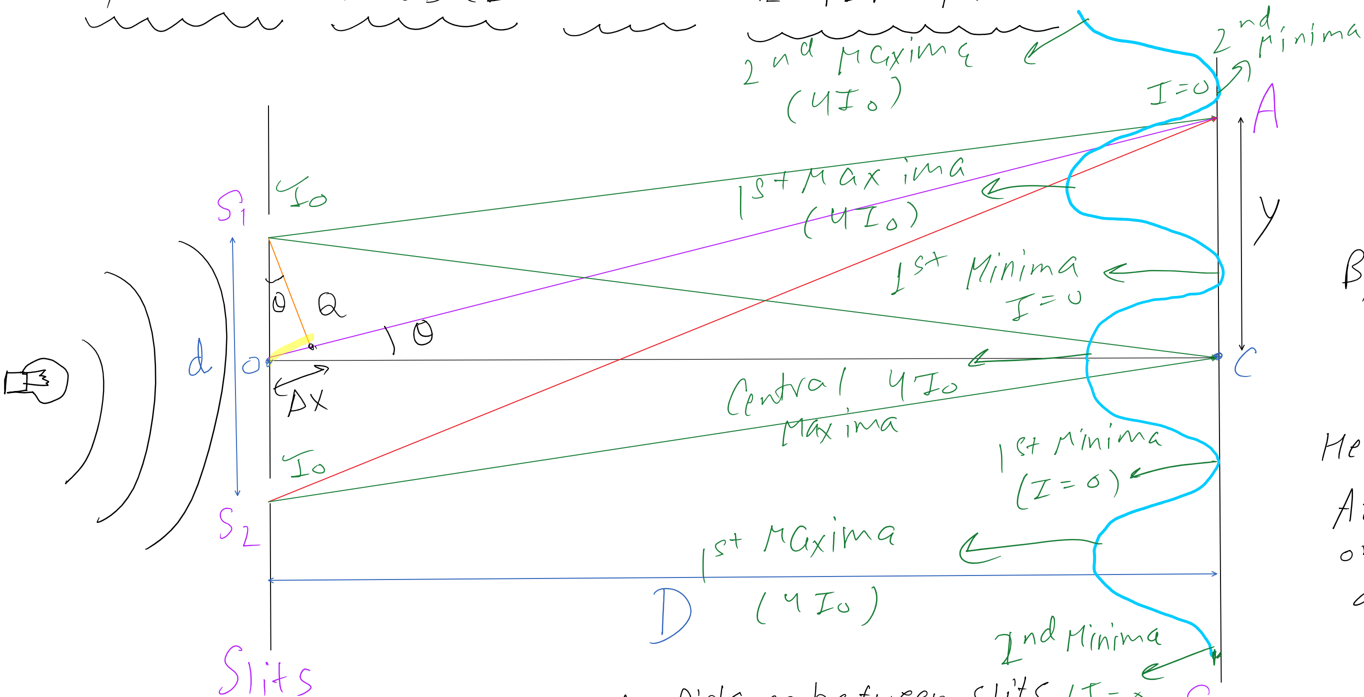
$I \propto a^2$

$\therefore \frac{I_1}{I_2} = \frac{1}{4}$ ...

$I = I_1 + I_2 + 2\sqrt{I_1}\sqrt{I_2}\cos$ ...

$I = 1 + 4 + 2(1)($ ...
$I = 5 - 2\sqrt{2} =$ ...

YOUNG'S DOUBLE SLIT EXPERIMENT



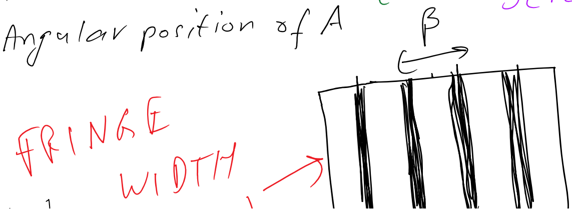
At the c... the scree... Path di...
$\Delta x = |S_1$ ...
By symme... $S_1C = S_2C$ ...
$\therefore \Delta x =$ ...
Hence, $\Delta\phi$ ...
At another ... on the scre... distance ... the cen...
$\Delta x = |S$ ...
$\therefore$ $\Delta x = d$ ...

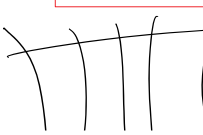
$\Delta x = d\sin\theta$

$d \rightarrow$ Distance between slits
$\theta \rightarrow$ Angular position of A

At A, (dist. y)

If θ is small, then:
$\sin\theta \simeq \tan\theta$





urce is

th intensity
rence.

ϕ
$)\cos\frac{90^\circ}{2}$

$\frac{a_1^2}{a_2} = \frac{10^2}{20^2} = \frac{1}{4}$

$\therefore I_2 = 4I_1$

$\cos\Delta\phi$ $\therefore I_2 = 4$

$-\frac{1}{\sqrt{2}})$

$2)(-\frac{1}{\sqrt{2}})$

$5 - 2.8 = 2.2\ W/m^2$

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$C - S_2C|$

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tre C.

$S_2A - S_1A|$

$d\sin\theta$

If θ is small then:

$\sin\theta \simeq \tan\theta$

$\therefore$ For small θ, $\Delta x = d\tan\theta = d\,\frac{(AC)}{OC}$

FRINGE WIDTH (Fringes) →

V. Imp. $\therefore$ $\boxed{\Delta x = \frac{dy}{D}}$

↳ Path difference at distance y from centre of screen

$y \rightarrow$ Distance on screen from centre of screen

$D \rightarrow$ Distance between slits & screen.

$\Delta\phi = 0 \rightarrow$ Maxima

$\Delta\phi = \pi \rightarrow$ Minima

Now, phase difference

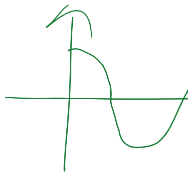
$$\frac{\Delta\phi}{2\pi} = \frac{\Delta x}{\lambda}$$

$$\therefore \Delta\phi = \frac{\Delta x}{2\pi\lambda} = \frac{dy}{2\pi D\lambda}$$

(1) $\boxed{\Delta x = \frac{dy}{D}}$ $\Rightarrow$

(2) $\boxed{\frac{\Delta\phi}{2\pi} = \frac{\Delta x}{\lambda}}$

$\boxed{I = 4I_0\cos^2\frac{\Delta\phi}{2}}$



FOR CONSTRUCTIVE INTERFERENCE

$\Delta x = n\lambda$

$\frac{dy}{D} = n\lambda$

$\Rightarrow$ $\boxed{y = \frac{nD\lambda}{d}}$

← n = integer →

For Destructive Interference

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

$\frac{dy}{D} = \left(n + \frac{1}{2}\right)\lambda$

$\boxed{y = \left(n + \frac{1}{2}\right)\frac{D\lambda}{d}}$

FRINGE WIDTH (β)

↳ Distance between: ▷ 2 consecutive maximas

▷ 2 consecutive minimas

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

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

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

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

$$\beta = \left((n+1) + \frac{1}{2}\right)\frac{D\lambda}{d} - \left(n + \frac{1}{2}\right)\ldots$$

V. Imp → (4) $\boxed{\beta = \frac{D\lambda}{d}}$

Fringe width

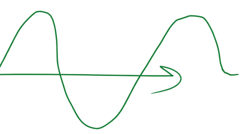
$\lambda \rightarrow$ wavelength of light

$(I = 0)$

$(4I_0)$

$(I = 0)$

3



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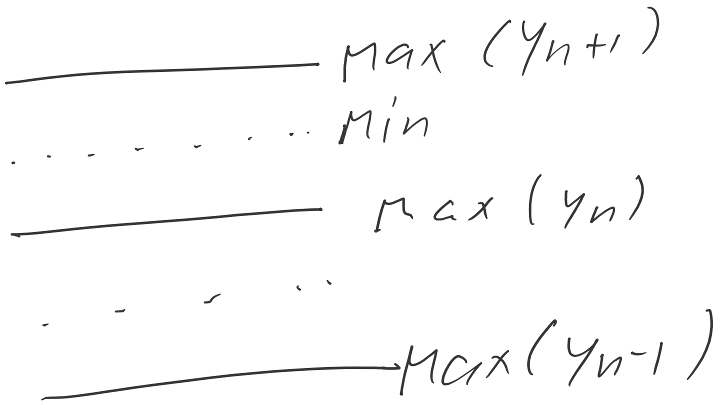


$\frac{D\lambda}{d}$

H.W. → Eq 10.4 Reading

Revise Notes

Derivations (1) Δx (Path Difference)
(4) β (Fringe Width)
↳ Most important formula

▷ For sharp fringes formation, $\frac{s}{S}$

$s \rightarrow$ Size of Source
$S \rightarrow$ Distance of Source from s

▷ If $\frac{\text{size of Source}}{\text{Distance of Source of Slits}} > \frac{\lambda}{d}$, then will

∴ Source must be Small & distance

Angular width → $\Delta\theta = \frac{\Delta\beta}{D} = \frac{D\lambda}{Dd}$

Angular position $\theta = \frac{y\text{(Actual Position)}}{D}$

$$n_1 \frac{D\lambda_1}{d} = n_2 \frac{D\lambda_2}{d} \Rightarrow \frac{n_1}{n_2} = \frac{\lambda_2}{\lambda_1}$$

Note:- Wavelength changes as medium c

$c = f\lambda$ (Air/Vacuum) —

$v = f\lambda'$ (Water) — (2)

$v = \frac{c}{n}$ — (3)
n (Refractive I

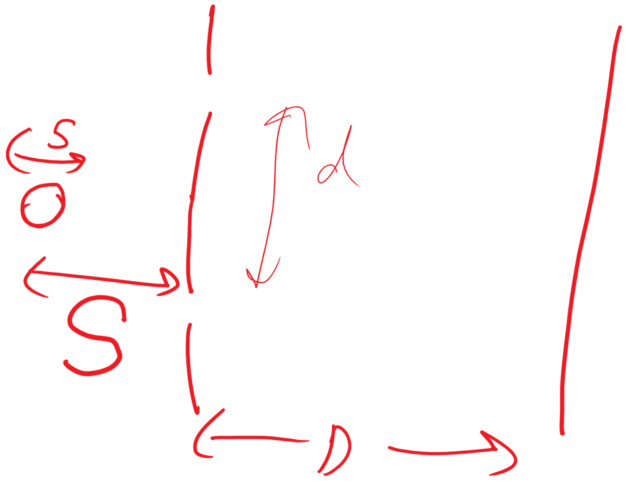
10.7 $0.2°$

$180° = \pi$ rad

$1° = \frac{\pi}{180}$ rad

$0.2° = 0.2 \times \pi$

$< \frac{\lambda}{d}$.



lits

n fringes
be blurred. (or No fringes)

from slits must be large.

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

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

$$\theta = \frac{y}{D}$$

$\Rightarrow \frac{n_1}{n_2} = \frac{4\cancel{520}}{5\cancel{650}} \Rightarrow n_1 = 4, n_2 = 5$

hanges.

ndex)

180

$0.2^\circ = 0.2 \times \frac{\pi}{180}$ rad

$\therefore \Delta\theta = \frac{\pi}{900}$ rad

$D = 1m$

$\lambda = 600nm$

$v = \frac{c}{n}$ (Refractive I

$c = f\lambda$ —(i)

$\frac{c}{n} = f\lambda'$ —(ii)

(i)/(ii)

$n = \frac{\lambda}{\lambda'} \Rightarrow \lambda' = \frac{\lambda}{n}$

$\Delta\theta = \frac{\lambda}{d}$ —(i)

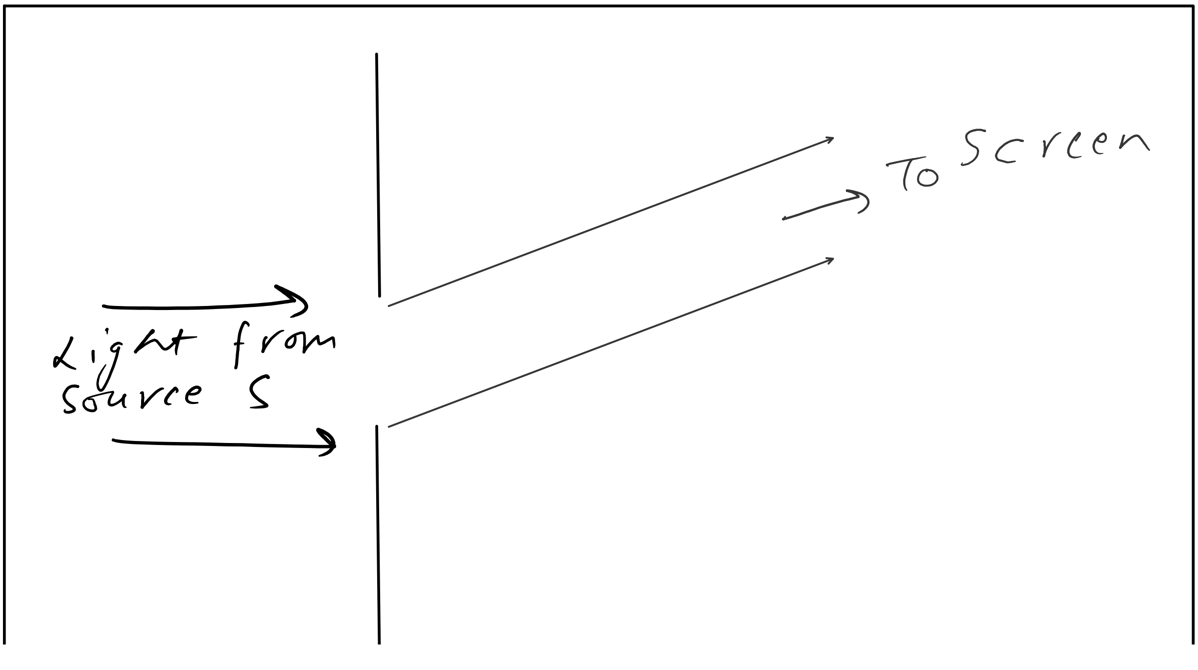
$\Delta\theta' = \frac{\lambda'}{d}$ —(ii)

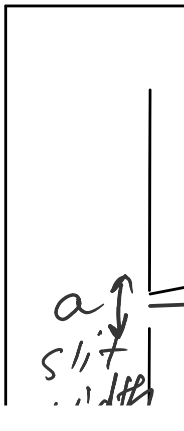
$\Rightarrow$ (i)/(ii) $\Rightarrow \frac{\Delta\theta}{\Delta\theta'} = \frac{(\lambda/d)}{(\lambda'/}$

$\Rightarrow \Delta\theta' = \frac{\lambda'}{\lambda}$

Single Slit Diffraction

Diffraction → Bending of Light ar





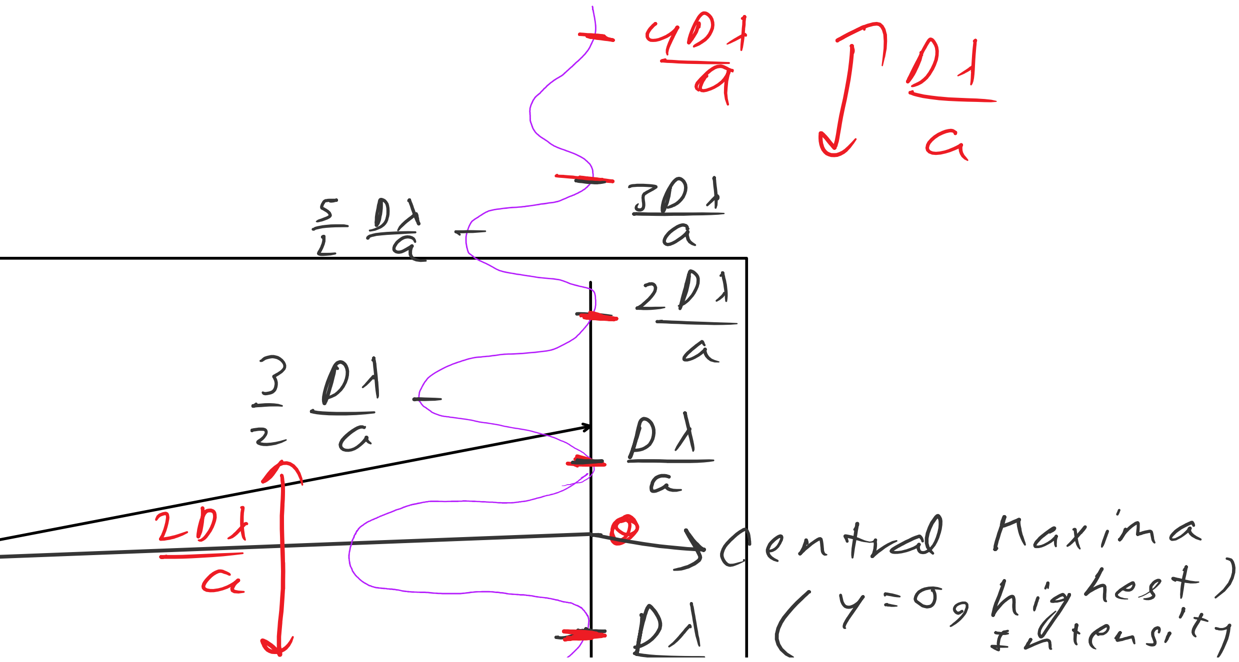
ndex)

$= \frac{600}{(4/3)} = 600 \times \frac{3}{4} = 450\,nm$

$\frac{d)}{d)} = \frac{\lambda}{\lambda'}$

$(0.2^\circ) = \frac{450}{600}(0.2) = \frac{45}{300} = 0.15^\circ$

ound objects or openings



slit width

Sli

* Central Maxima width = $\frac{2D\lambda}{a}$

* other maxima width = $\frac{D\lambda}{a}$

* Central maxima is brightest and widest

Example 10.5
Pg 370

Exercise 10.9
Pg 383

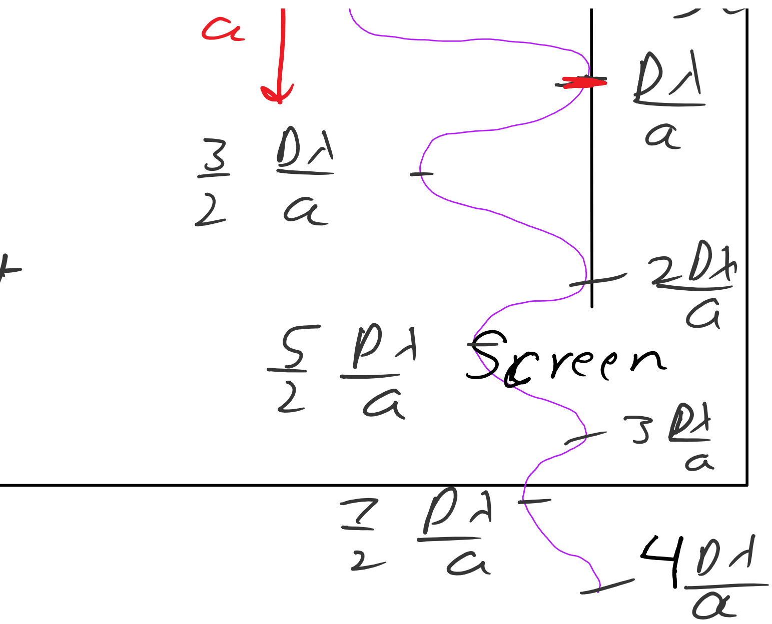
$\frac{2D\lambda}{a}$? = $10\frac{D\lambda}{d}$

I

$i = r$

$i + r = 90°$

$\Rightarrow 2i = 90° \Rightarrow i = r =$



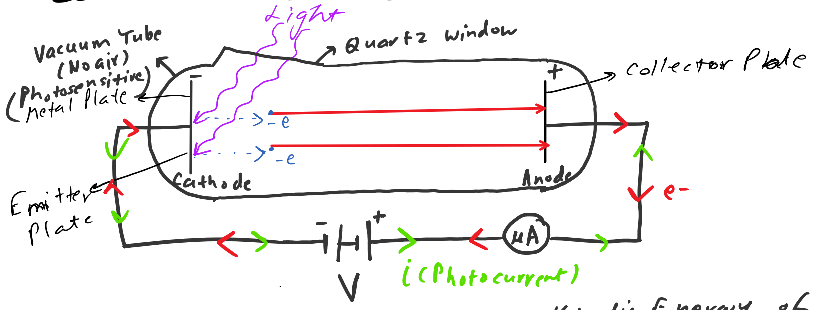
(y = 0, highest intensity)

15°

Electron Emission

- (i) Thermoionic Emission :→ By heating
- (ii) Field Emission :→ By Electric Field
- (iii) Photoelectric Emission :→ By light

PHOTOELECTRIC EFFECT



* Let K_{max} or K be the maximum Kinetic Energy of ejected electrons.

hν → e (Require Minimum Energy to Come Out)
hν → e (Require more Energy to Come Out)

* The minimum energy required for photoelectric emission is known as the "Work Function" of the metal. (ϕ) ←

* Total energy provided to electron by light photon ←

ν → "Nyu" $E = h\nu$

h → Planck's constant = 6.63×10^{-34} Js
ν → Frequency of light.

* Since Surface electrons need least energy to get ejected, they have maximum Kinetic Energy:

$$K = h\nu - \phi$$

K.E. of e- ; Energy Provided by Photon ; Work Function

Einstein's Photoelectric Equation.

If $h\nu > \phi \Rightarrow K > 0$
If $h\nu = \phi \Rightarrow \nu = \nu_0$ & $K = 0$

ν_0 = Threshold Frequency

Note:- If $\nu < \nu_0$, no electron will be ejected.

Note:- $\lambda_0 = \frac{c}{\nu_0}$ = Threshold Wavelength

* If opposite Voltage (negative Voltage) is applied to the plates, then photocurrent becomes zero at stopping potential V_0 or V_s.

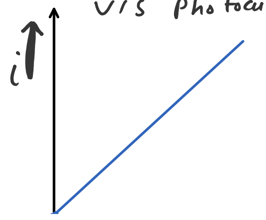
$$eV_0 = K = h\nu - \phi$$

V_0 → Stopping Potential

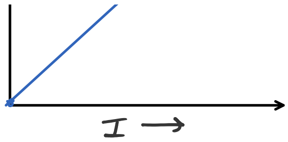
$$K = eV_0$$

GRAPHS

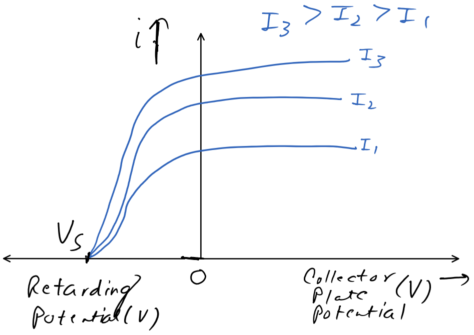
Intensity (Brightness) of light (I) V/S Photocurrent (i)



⊳ More light means more photons & hence more electrons ejected & higher photocurrent.

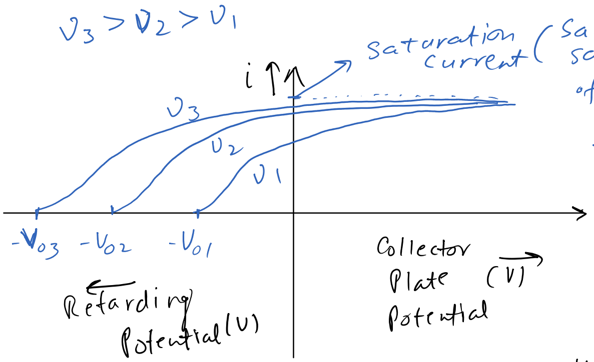


Photocurrent (i) v/s Anode Potential (V) (Variable Intesity)



Note:- Stopping potential is independent of intensity of light & is dependent on frequency of light only.
Hence, particle theory of light is applicable here, not wave theory.

Photocurrent v/s Anode Potential (variable Frequency)

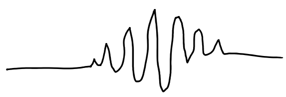


* Stopping potential is different because of different frequency of light.

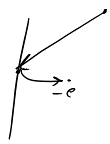
H.W. V.Imp → Revise Notes

REASONS FOR REJECTION OF WAVE THEORY OF LIGHT

→ Light exists as a photon (wave Packet)



Photon (wave Packet)



1. Low intensity light also produces photocurrent given the wavelenght is lower than the Threshold Wavelength. (Not true according to wave theory)

2. The photoelectric emission is an almost instantaneous process. According to wave theory, it can take several hours for electron emission.

That is why, in Photoelectric effect, light acts like a particle.

Eg:- 11.1, 11.2 & 11.3

$K = h\nu - \phi$

$eV_0 = \frac{hc}{\lambda} - \phi$

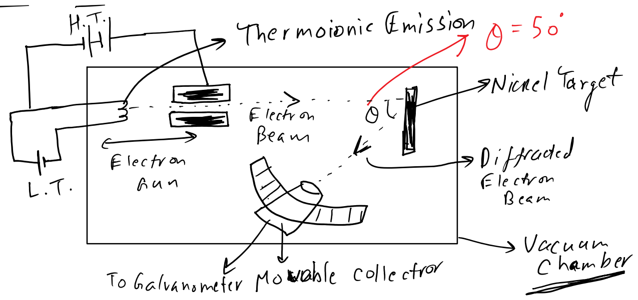
$\nu = \frac{c}{\lambda}$

$h\nu_0 = \phi$ (Th. f.)

$\frac{hc}{\lambda_0} = \phi$ (Th. w.)

WAVE NATURE OF MATTER

* Davisson & Germer Experiment ⇒ Electrons exhibit wave nature



$$\lambda = \frac{1.227}{\sqrt{V}}$$

V → Accelerating (H.T.) Potentia = 54 V

Skippable

- From the electron diffraction measurements, wavelength of matter waves was found to be 0.165 nm. (experimental Value)
- The theoretical value prediced for electron waves is 0.167 nm.
- Hence this experiment proved the wave nature of matter.

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

$h = 6.626 \times 10^{-34}$
p = momentum = mv

* λ is imperceptibly small for macroscopic objects like a ball.
  For small particles (like e-) it can be perceived.

Wavelength of a particle of momentum 'p' (De-Broglie Wavelength)

De-Broglie ("Broy") wavelength

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$ → Wavelength of a particle

* For a photon :- $E = \frac{hc}{\lambda} = \left(\frac{h}{\lambda}\right)c = pc$

$$\Rightarrow p = \frac{E}{c}$$ → Momentum of a Photon

Wavelength of e- Accelerated by Voltage 'V'

K.E. of e- = $K = eV$ → ⓪

Now, $K = \frac{1}{2}mv^2 = \frac{(mv)^2}{2m} = \frac{p^2}{2m}$ ∴

$$K = \frac{p^2}{2m}$$ ← ①

OR

$$p = \sqrt{2mK}$$ ← ②

Also, $p = \frac{h}{\lambda} \Rightarrow \sqrt{2mK} = \frac{h}{\lambda} \Rightarrow \sqrt{2meV} = \frac{h}{\lambda}$

(② ① ...) $\lambda = \frac{h}{...}$

$$\Rightarrow \lambda = \frac{1.227}{...} \text{ nm}$$ ← ③

Also, $p = \frac{h}{\lambda} \Rightarrow \sqrt{2mK} = \frac{h}{\lambda}$ (2) $\Rightarrow \sqrt{2meV} = \frac{h}{\lambda}$ (1)

$\Rightarrow \lambda = \frac{h}{\sqrt{2mV}} \Rightarrow \boxed{\lambda = \frac{1.227}{\sqrt{V}}\ nm}$ ← (3)

$m = m_e = 9.11 \times 10^{-31}\ kg$

$h = 6.626 \times 10^{-34}$

H.W.

Revise Notes ✓

Exercise 11.1 - 11.19

Don't do Additional Exercise

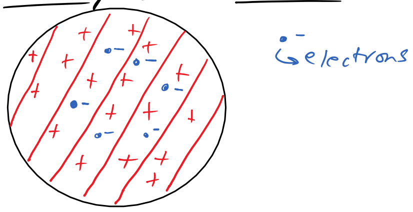
Atoms

13 March 2022 12:22

Thomson's Model of Atom

↳ There exist negative particles called electrons in the atom.

Plum Pudding or Watermelon model of Atom



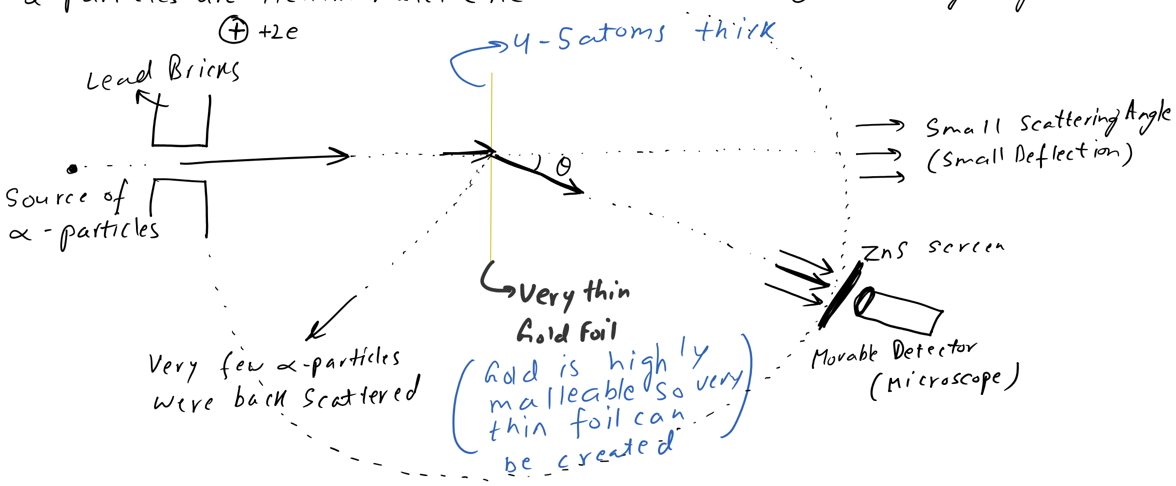
RUTHERFORD'S MODEL OF ATOM

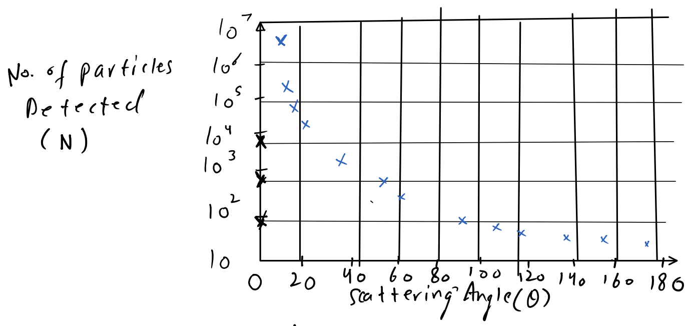
▷ Alpha-Particle scattering or Geiger-Marsden Experiment

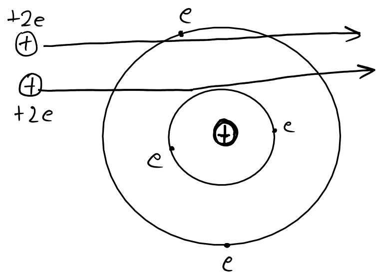
α-particles are Helium Nuclei (He^{2+})

⊕ +2e

θ → Scattering Angle







(i) Most α-particles passed through the Gold foil fairly undeflected.

* This means the atom is mostly empty space.

↳ Electrons cannot affect α-particle trajectory as they are very light.

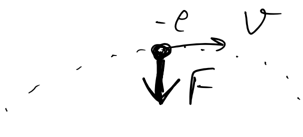
(ii) Very few α-particles actually back scattered ($\theta \in (90°, 180°)$)

* Most of the positive charge and mass of the atom is concentrated in a tiny space at the centre of the atom called the nucleus.

(iii) * The electrons orbit around the nucleus where the electrostatic force binds them inside by acting as the centripetal force.

Centripetal Force = Electrostatic Force

$$F_C = F_E$$

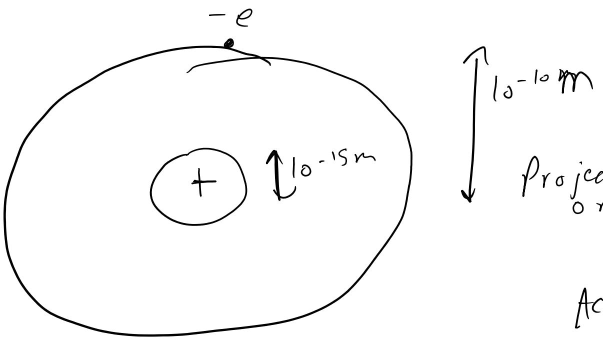


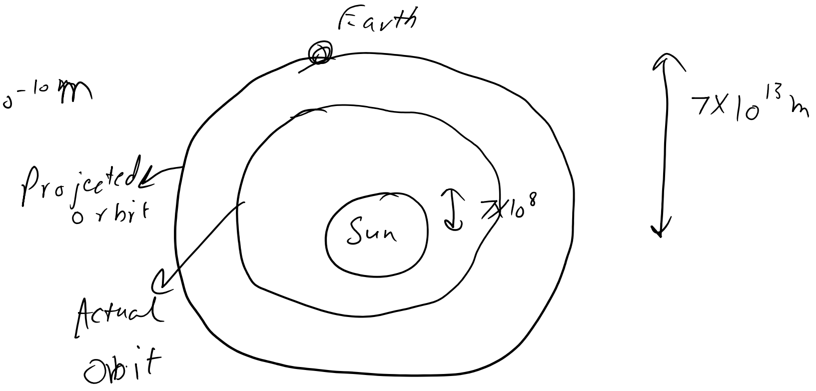
$$\frac{mv^2}{\;} = \frac{K(e)(e)}{\;}$$

$$\frac{mv^2}{r} = \frac{K(e)(e)}{r^2}$$

$$mv^2 = \frac{Ke^2}{r}$$

$$v = \sqrt{\frac{K}{mr}}\, e \Rightarrow v \propto \frac{1}{\sqrt{r}}$$





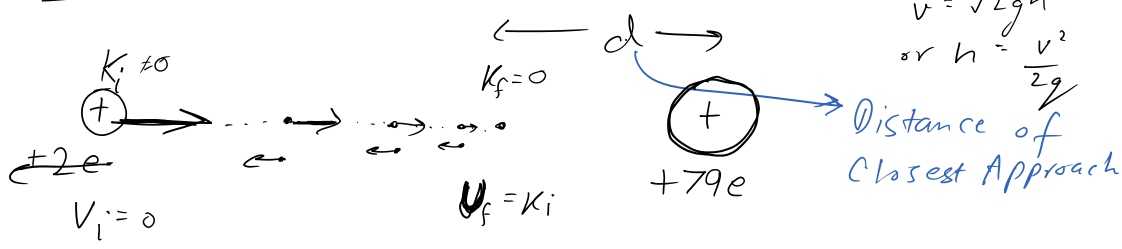
$$K_i = U_f$$

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

$$v = \sqrt{2gh}$$

$$\text{or } h = \frac{v^2}{2g}$$

Ex - 12.2 For gold, $Z = 79$.



By conservation of Energy

Final Potential Energy (U_f) = Initial K.E. (K_i)

$$\left(\frac{1}{4\pi\epsilon_0}\right)\frac{(79e)(2e)}{d^2} = 7.7 \times 10^6 \times \cancel{1.6 \times 10^{-19}}$$

$$d = 30\,fm. = 3 \times 10^{-14}\,m$$

H.W. Revise Notes

Exercise - Ch-11 (NCERT)

Nuclei

13 March 2022 12:22

Semiconductor Electronics: Materials Devices and Simple Circuits

13 March 2022 12:22

Electromagnetic Waves

30 March 2022 19:05