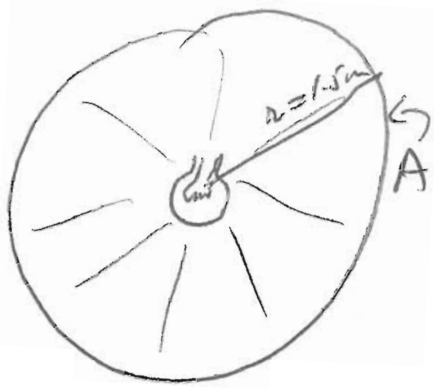
34.61

Peak E & B at $r = 1.5\,m$ from a light bulb of 60-W

$$\frac{\bar{P}}{A} = \bar{S} = \frac{EB}{2\mu_0} = \frac{E^2}{2c\mu_0} \rightarrow E = \sqrt{\frac{2c\mu_0 \bar{P}}{A}}$$

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



$$= \sqrt{\frac{2 \times 3 \times 10^8 \times \cancel{4\pi} \times 10^{-7} \times 60}{\cancel{4\pi} \times 1.5^2}}$$

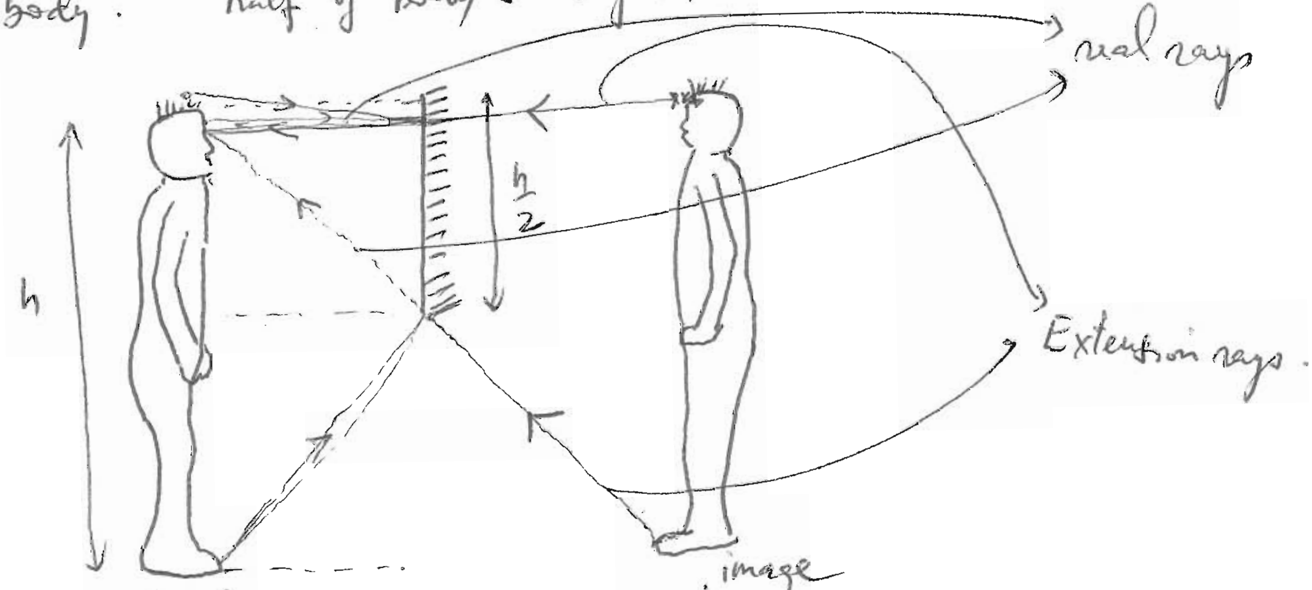
$$= \sqrt{\frac{60^2}{1.5^2}} = 40\ \frac{V}{m}$$

$$B = \frac{E}{c} = \frac{40}{3 \times 10^8}\,T = 133 \times 10^{-9}\,T$$
$$= 133\,nT$$

Ch. 36: Mirrors and Lenses and Image Formation:

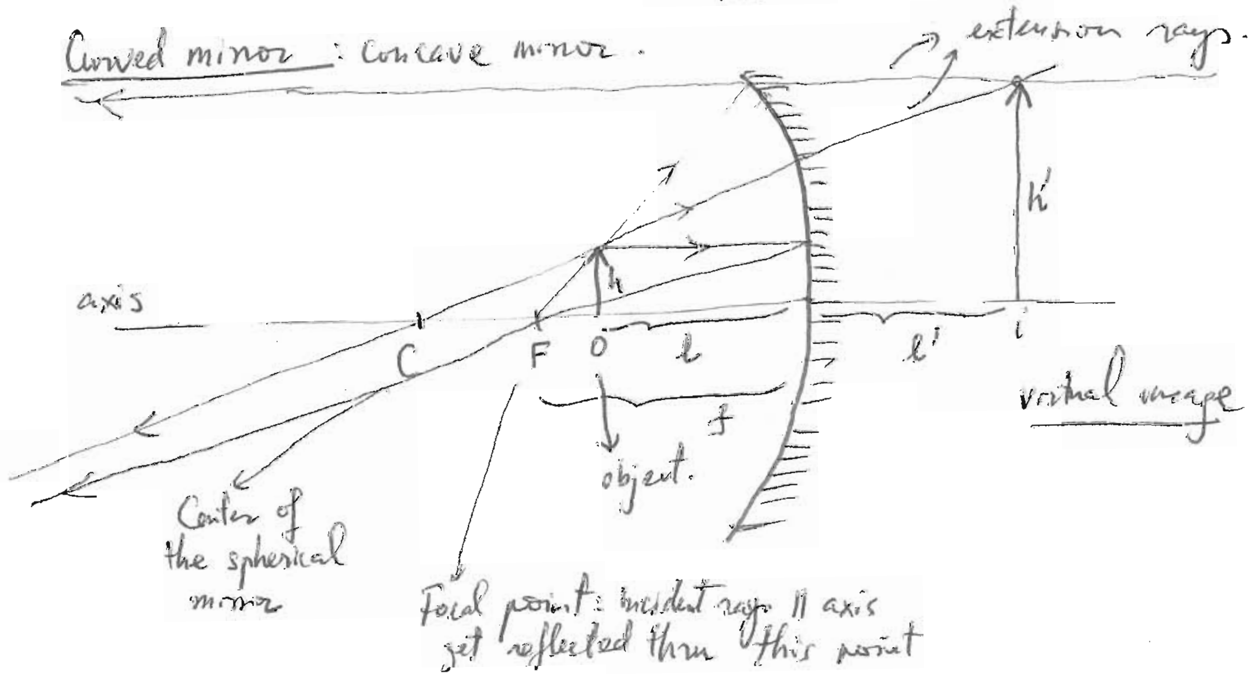
Image formation by a mirror: look at more than one ray

How large (tall) a mirror we need to see our whole body? half of body's length:



virtual image: formed by extension rays. (no light converging at this location actually) it just seems as there is.

Curved mirror: concave mirror.



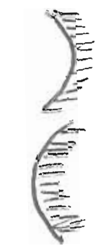
Geometrical Optics

Mirror equation : $\boxed{\dfrac{1}{\ell} + \dfrac{1}{\ell'} = \dfrac{1}{f}}$

Magnification : $M = \dfrac{h'}{h} = -\dfrac{\ell'}{\ell}$ (by geometry)

Signs : Mirrors.

f : { + concave mirror ; − convex mirror }



ℓ' { + if image on same side as object ; − if image on different side as object (virtual image) }

(There could be a real image using curve mirrors)

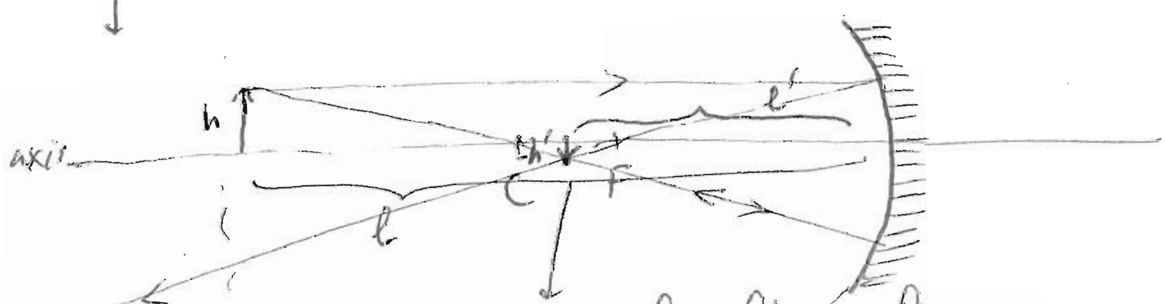
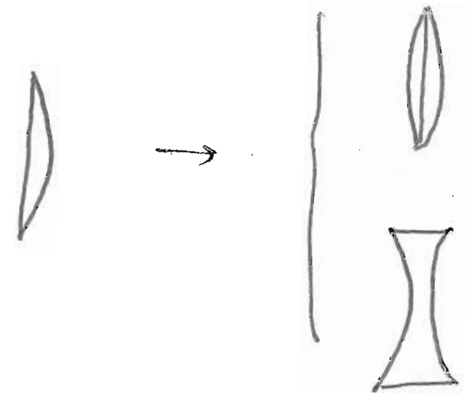


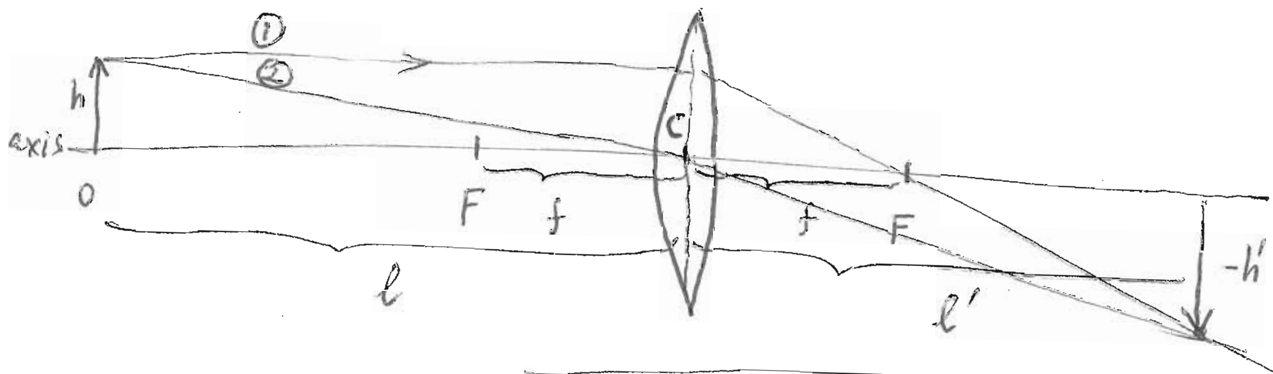
image formed by real rays.
→ real image ℓ' is +

Lenses:



converging lense (convex)

diverging lense (concave)



Lense equation: $$\boxed{\frac{1}{\ell} + \frac{1}{\ell'} = \frac{1}{f}}$$ same as mirror equation

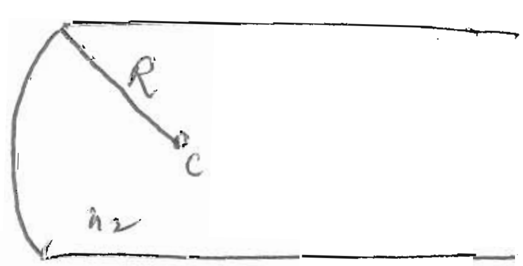
Signs for lenses:

- f
  - $-$ concave lense (diverging)
  - $+$ convex lenses (converging)
- ℓ'
  - $+$ if image on the other side of lense
  - $-$ if image on same side as object

A different type of lense:

$$\boxed{\frac{n_1}{\ell} + \frac{n_2}{\ell'} = \frac{n_2 - n_1}{R}}$$

n_1

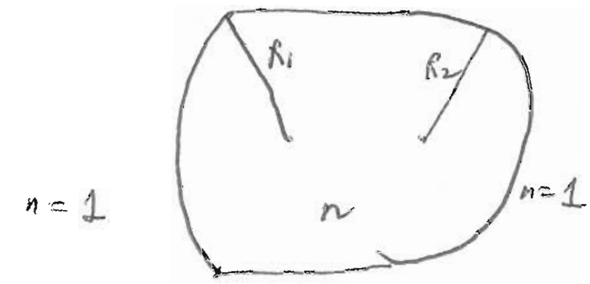


convex: R +

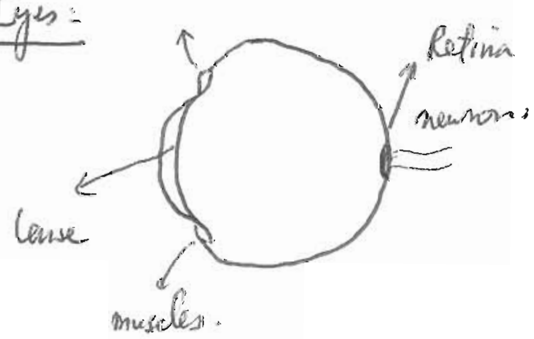
Lense with different radius of curvature on left and right side:

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

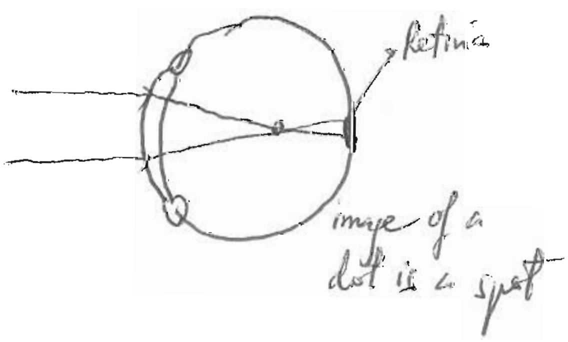
↓ Lensemaker's equation.



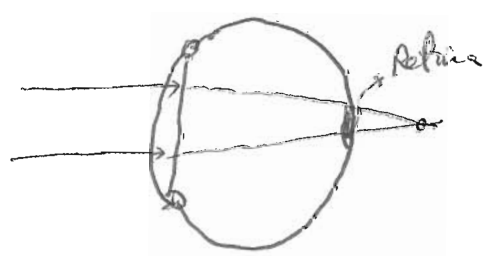
Eyes:



Near sighted (myopic)



~~Far~~ Far sighted (hyperopic)



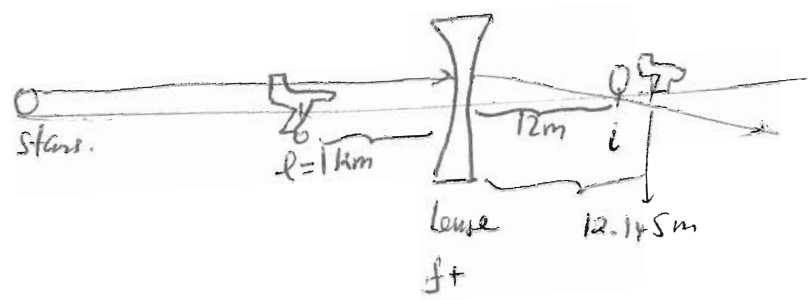
Correction: diverging lense converging lense

→ diopters: $\frac{1}{f(m)}$: (−) (+)

$l=\infty \rightarrow$ parallel inc. rays.

36.25 lense: $d = 1m$; $f = 12m$. } Refracting telescope of one lense!

images of airplane: 1km versus distant stars ? $l = \infty$



Where is the image of airplane?

$$\frac{1}{l} + \frac{1}{l'} = \frac{1}{f}$$

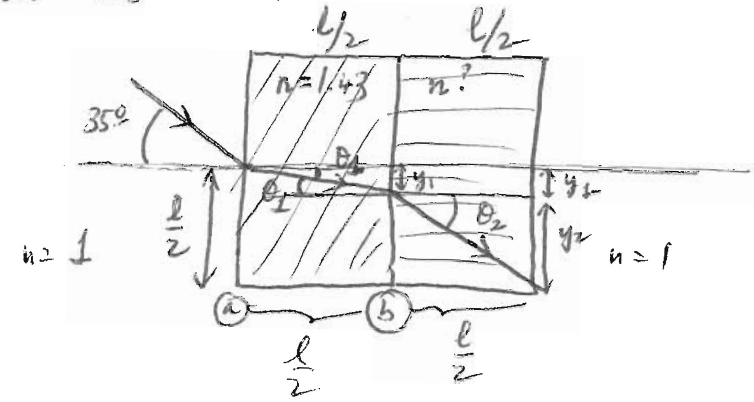
$$l' = \left(\frac{1}{f} - \frac{1}{l}\right)^{-1}$$

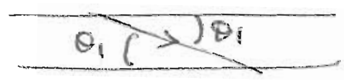
$$= \frac{fl}{l-f} = \frac{12 \times 1000}{1000-12}$$

$$= \frac{12000}{988} = 12.145m$$

air plane image is 14.5cm further

35.53 Front view 2D:





Snell's law: a) $1 \sin 35° = 1.43 \sin \theta_1 \rightarrow \theta_1 = \sin^{-1}\left(\frac{\sin 35°}{1.43}\right)$

$= 23.6°$

b) $1.43 \sin 23.6° = n \sin \theta_2$

I need one more equation to get θ_2 and then n.

From geometry: $\tan \theta_2 = \frac{y_2}{\frac{\ell}{2}} = \frac{\frac{\ell}{2} - y_1}{\ell/2} = \frac{\frac{\ell}{2} - \frac{\ell}{2}\tan\theta_1}{\ell/2}$

$\tan \theta_2 = 1 - \tan(23.6°)$

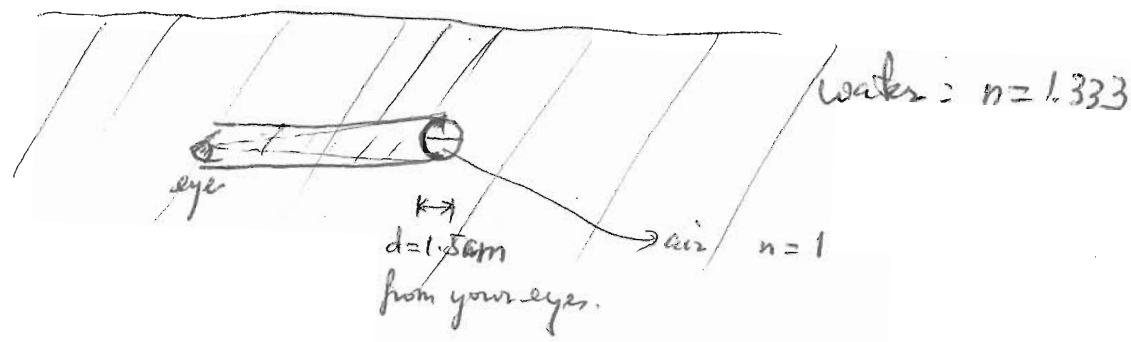
$\theta_2 = \tan^{-1}(1 - \tan 23.6°)$

$\boxed{\theta_2 = 29.3°}$

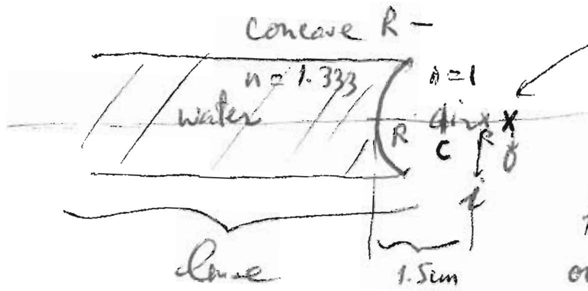
($n < 1.43$!)

$n = \frac{1.43 \sin 23.6°}{\sin(29.3°)} = 1.17 < 1.43$ ✓

36.34



what is actual d ? $\longrightarrow$ is $2R$.



the other side of bubble: our object. $\ell = 2R$

the image of this object by our bubble/water lense is at $\ell' = 1.5$ cm

$$\frac{n_1}{\ell} + \frac{n_2}{\ell'} = \frac{n_2 - n_1}{R}$$

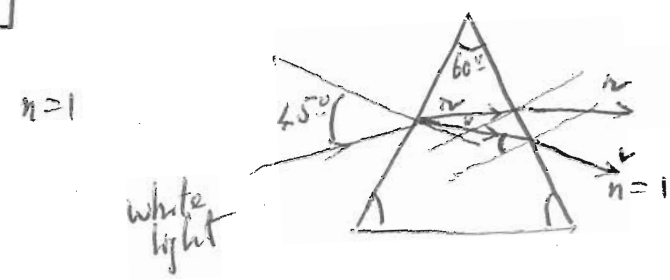
$$\frac{1}{2R} + \frac{1.333}{-1.5\text{cm}} = \frac{1.333 - 1}{-R} \rightarrow \frac{1.666}{2R} = \frac{1.333}{1.5} \rightarrow R \approx 0.937\text{cm}$$

image same side as object in a lense.

$\rightarrow$ Actual diameter $= \boxed{2R = 1.87\text{cm}}$

35.36

$n_{red} = 1.582$; $n_{violet} = 1.633$

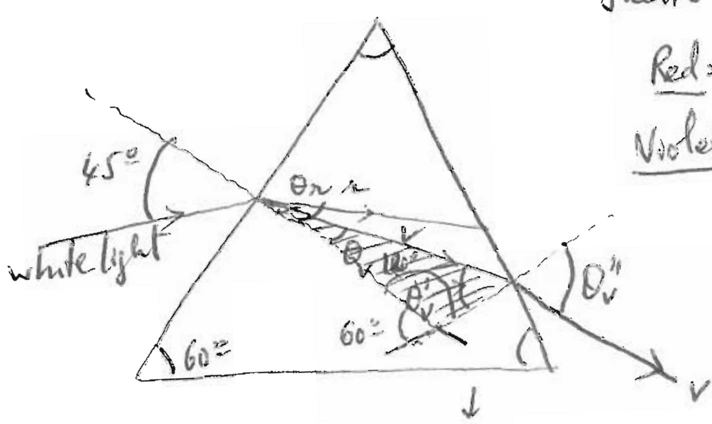


Angular dispersion γ (gamma)

Snell's law :

Red: $1 \sin 45° = 1.582 \sin \theta_r \rightarrow \theta_r = \sin^{-1}\left(\frac{\sin 45°}{1.582}\right) = 26.5°$

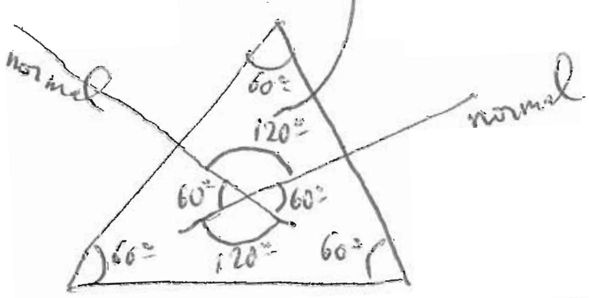
Violet: $1 \sin 45° = 1.633 \sin \theta_v \rightarrow \theta_v = \sin^{-1}\left(\frac{\sin 45°}{1.633}\right) = 25.5°$



$\theta_v + \overset{120°}{\cancel{90}} + \theta_v' = 180° \rightarrow \boxed{\theta_v' = 180 - \overset{120°}{\cancel{90}} - 25.5° = 34.5°}$ ✓

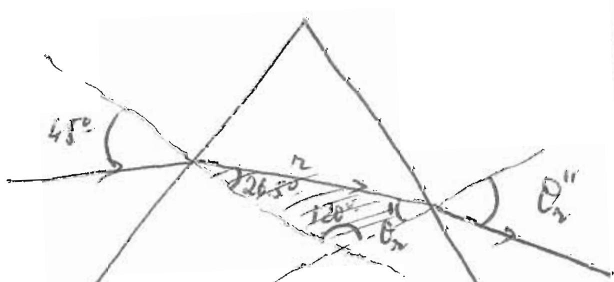
$\theta_v = 25.5°$

$1.633 \sin \theta_v' = 1 \sin \theta_v'' \rightarrow \theta_v'' = \sin^{-1}(1.633 \sin 34.5°) = 67.7°$



$\boxed{\theta_r' = 180° - 120° - 26.5° = 33.5°}$

$1.582 \sin \theta_r' = 1 \sin \theta_r'' \rightarrow \theta_r'' = \sin^{-1}(1.582 \sin 33.5°) = 60.8°$



Angular Dispersion $\gamma = \theta_v'' - \theta_r'' = 67.7° - 60.8° = 6.85°$

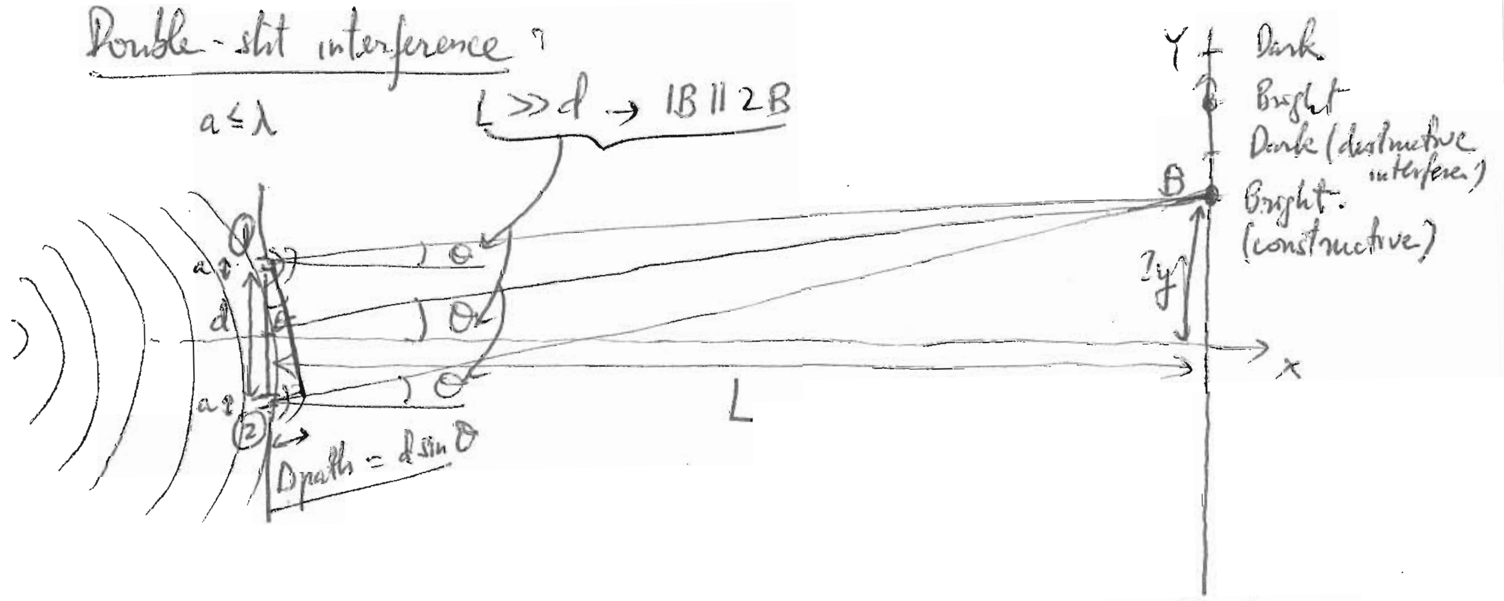
Ch. 37 Interference & Diffraction

So far we used geometry to trace the rays. (geometrical optics)
Now wave properties (physical optics):

↳ superposition: $\begin{cases} 1+1 = 2 & \text{(arithmetic)} \\ 1+1 = 0 & \text{(waves)} \end{cases}$

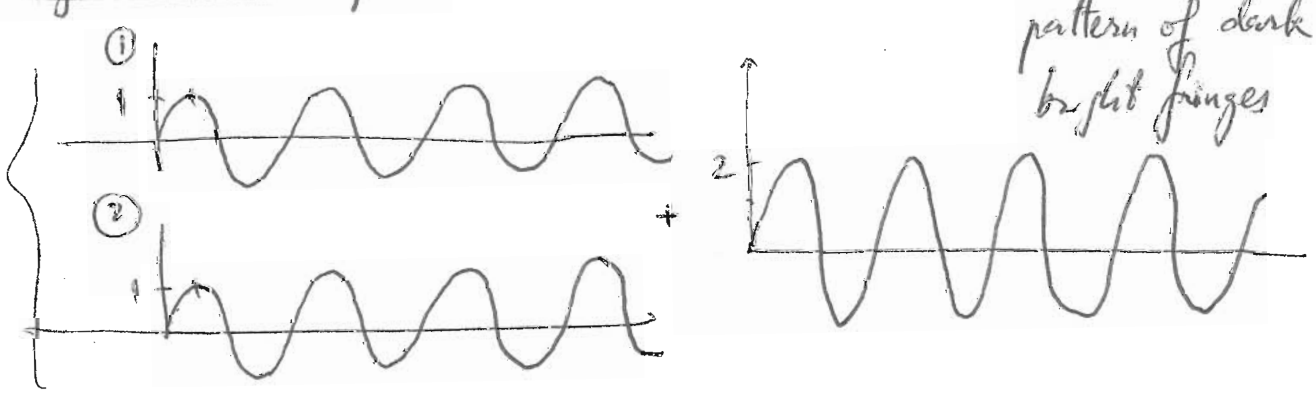
Double-slit interference:

$a \leq \lambda$ $\quad L \gg d \rightarrow 1B \parallel 2B$



Result of superposition of 2 wave here: pattern of dark & bright fringes

• Bright or constr. interference:



$\Delta phase = m\, 2\pi \quad (m = 0, 1, 2, \ldots)$ in phase. $\parallel$ $\Delta path = m\lambda \quad (m = 0, 1, 2, \ldots)$

$\frac{\text{(one wave length)}}{2\pi}$ ← length ← angle

$$\boxed{d \sin\theta_m = m\lambda \quad (m = 0, 1, 2, 3, \ldots)}$$

$y_m = L \tan\theta_m$

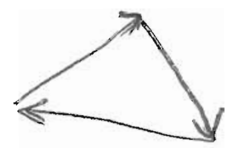
Destructive interference of 3 waves:

Need to be out of phase by 120° or $\frac{\lambda}{3}$

↓ angle

↓ length ~ Δpath

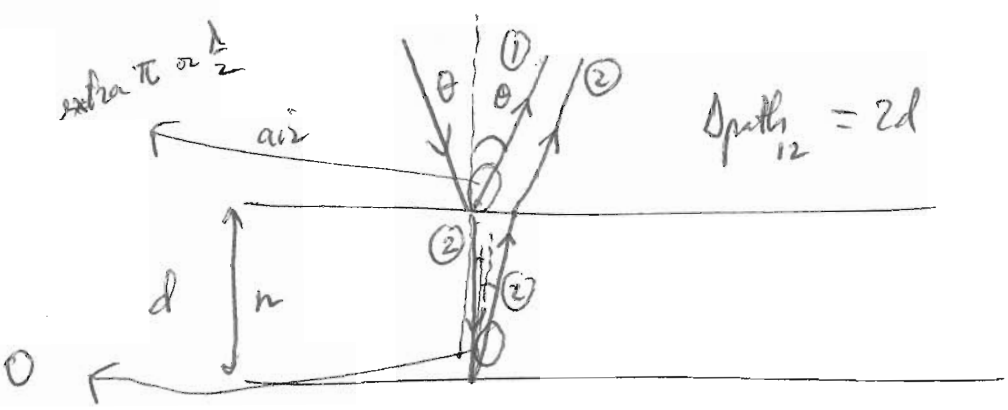
\# of slits N



$$d\sin\theta = \left(n + \frac{1}{3}\right)\lambda$$

$$\boxed{d\sin\theta = \frac{n}{N}\lambda}$$

Interference of thin films



$\Delta path_{12} = 2d$

air

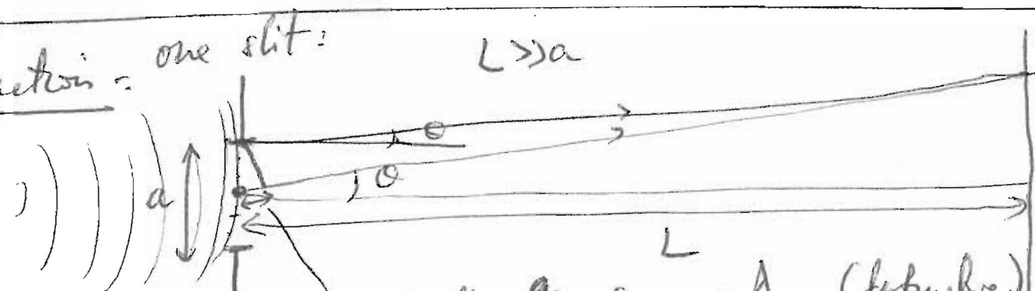
Interference b/w 1 & 2

constructive: $(2n+1)\frac{\lambda}{2} = 2d$ b/c there is already a $\frac{\lambda}{2}$ added to wave #1

destructive: $n\lambda = 2d$.

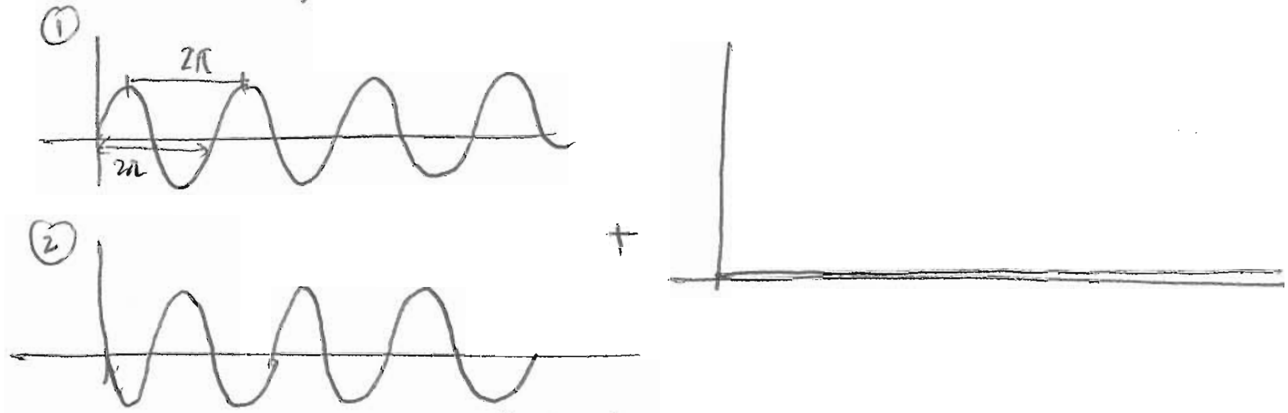
Diffraction: one slit:

$L \gg a$



$\Delta path = \frac{a}{2}\sin\theta = n\frac{\lambda}{2}$ (destructive) → $\boxed{a\sin\theta = n\lambda}$

- Destructive interference (Dark):



odd multiple of π $\left(\frac{\lambda}{2}\right)$ out of phase w.r.t. ①

$$\Delta\text{phase} = m\pi \quad (m \text{ odd})$$
$$= (2n+1)\pi \quad (n = 0, 1, 2, 3, \dots)$$

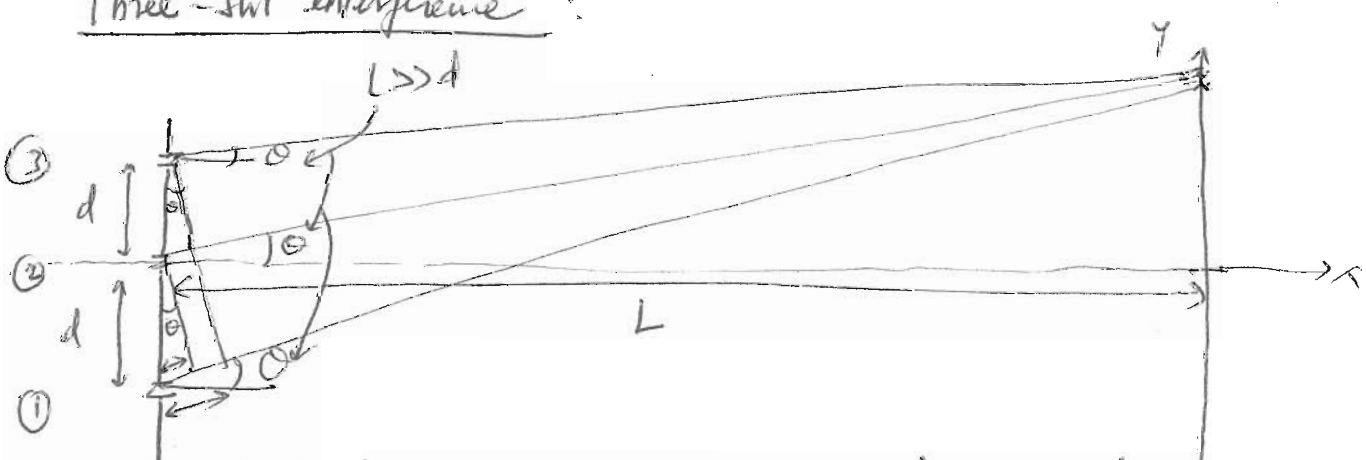
$\longrightarrow$ $\Delta\text{path} = m\frac{\lambda}{2}$ (m odd)

$= (2n+1)\frac{\lambda}{2}$ $(n = 0, 1, 2, 3 \dots)$

$$\boxed{d\sin\theta_n = (2n+1)\frac{\lambda}{2} \quad (n = 0, 1, 2 \dots)}$$

$$y_n = L\tan\theta_n$$

Three-slit interference:



Constructive interference of 3 waves:

① & ② : $d\sin\theta = m\lambda$

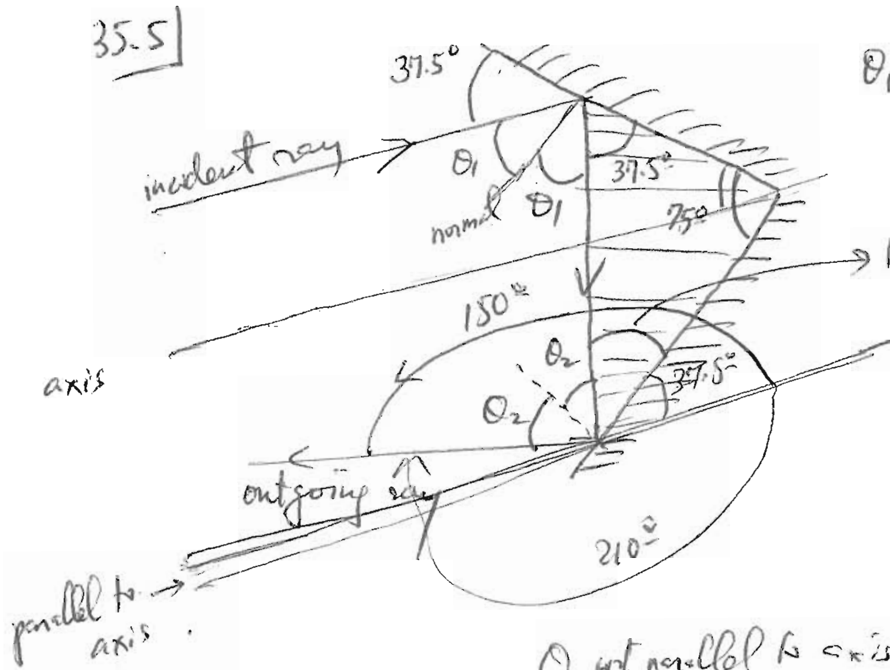
② & ③ : " "

① & ③ : $2d\sin\theta = 2m\lambda$

$$\boxed{d\sin\theta_m = m\lambda}$$

Diffraction limit: $\theta_{min} = \frac{1.22\lambda}{D}$

35.5



$\theta_1 = 90 - 37.5° = 52.5°$

$180 - 75 - 37.5° = 67.5°$

$\theta_2 ? = 90° - 67.5° = 22.5°$

θ_2 w.r.t. normal to second mirror is 22.5°

θ_2 wrt parallel to axis of system is

$37.5° + 67.5° + 22.5° + 22.5°$

$= 150°$ ccw

or $\underbrace{(360 - 150°)}_{210°}$ cw