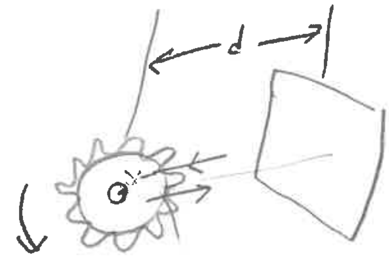
Chpt 35



① $d = 11.50$ km

$N = 720$ notches

$c = 2.995 \times 10^8$ m/s

$\Delta X = 2d$ (round trip distance)

Δt = time for round trip travel

$c = \frac{\Delta X}{\Delta t}$, $\Delta\theta = \frac{2\pi}{N}$ (angular spacing between successive notices)

$= \omega \Delta t$ (ω = angular velocity)

solve for ω:

$$\omega = \frac{\Delta\theta}{\Delta t} = \frac{2\pi}{N}\frac{c}{\Delta X} = \frac{2\pi}{N}\frac{c}{2d} = \frac{\pi c}{Nd} = \boxed{114 \ \frac{rad}{s}}$$

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②

$R = 1.5 \times 10^8$ km

$\Delta t = 22$ min $= 22 \times 60$ s

$$c = \frac{2R}{\Delta t} = \boxed{2.27 \times 10^8 \text{ m/s}}$$

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③ Red helium - neon laser light : $\lambda = 632.8$ nm , $c = 3 \times 10^8$ m/s

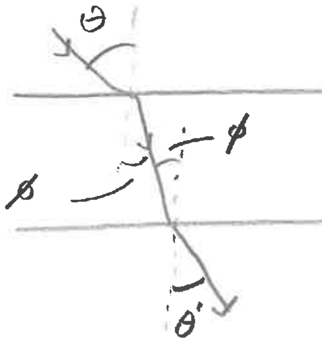
a) $c = f\lambda \rightarrow f = c/\lambda = \boxed{4.7 \times 10^{14} \text{ Hz}}$

b) glass: $n = 1.64 \rightarrow c_{glass} = \frac{c}{n} = 1.8 \times 10^8$ m/s

$\rightarrow \lambda_{glass} = \frac{c_{glass}}{f} = \frac{c}{nf} = \boxed{385 \text{ nm}}$

c) $c_{glass} = \frac{c}{n} = \boxed{1.83 \times 10^8 \text{ m/s}} = \boxed{183 \text{ Mm/s}}$

4.



air $(n_1 = 1)$

linseed oil $(n_2 = 1.48)$, $\phi = 25.6°$

water $(n = 1.33)$

$n_1 \sin\theta_1 = n_2 \sin\theta_2$ (Snell's law)

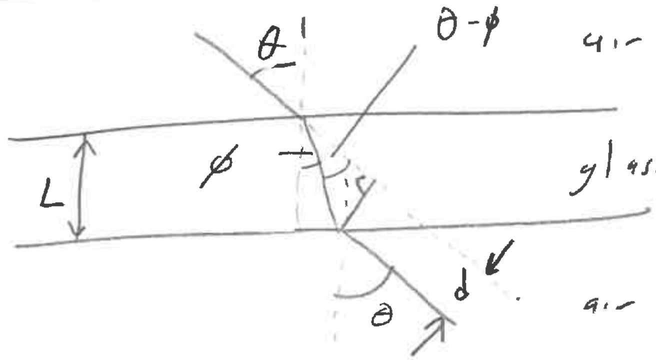
a) $n_1 \sin\theta = n_2 \sin\phi$

$\rightarrow \sin\theta = \frac{n_2}{n_1}\sin\phi \quad \rightarrow \quad \theta = \arcsin\left[\frac{n_2}{n_1}\sin\phi\right] = \boxed{39.8 \text{ degrees}}$

b) $n_2 \sin\phi = n_3 \sin\theta'$

$\rightarrow \sin\theta' = \frac{n_2}{n_3}\sin\phi \quad \rightarrow \quad \theta' = \arcsin\left[\frac{n_2}{n_3}\sin\phi\right] = \boxed{28.7 \text{ degrees}}$

5.

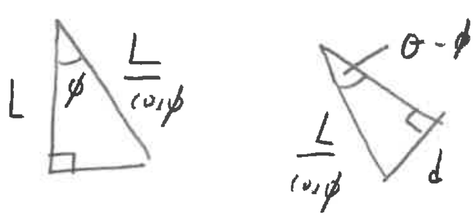


air $(n_1 = 1)$

glass $(n_2 = 1.5)$

air $(n_3 = 1)$

$L = 1.27$ cm
$\theta = 33$ deg



$\sin(\theta - \phi) = \frac{d}{L/\cos\phi} = \frac{d}{L}\cos\phi$

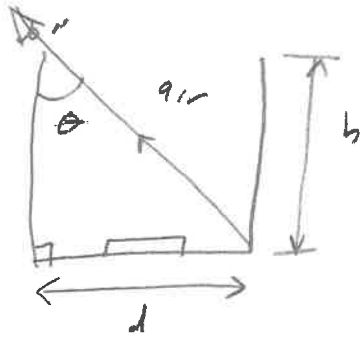
Thus, $\boxed{d = \frac{L\sin(\theta-\phi)}{\cos\phi}}$

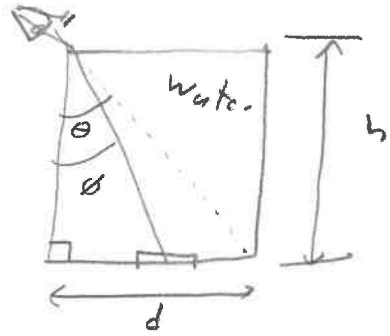
Now: $n_1 \sin\theta = n_2 \sin\phi$

$\rightarrow \phi = \arcsin\left[\frac{n_1}{n_2}\sin\theta\right] = \boxed{21.3 \text{ degrees}}$

(a) Thus, $d = \frac{L\sin(\theta-\phi)}{\cos\phi} = \boxed{0.28 \text{ cm}}$, (b) $\Delta t = \frac{L/\cos\phi}{c} = \boxed{45 \text{ ps}}$

(6.)





a) $n_1 \sin\theta = n_2 \sin\phi$, $n_1 = 1$ (air)
$n_2 = n = 1.33$ (water)

$\rightarrow \sin\theta = n \sin\phi$

$\sin\theta = \frac{d}{\sqrt{h^2+d^2}}$, $\sin\phi = \frac{d/2}{\sqrt{h^2+\left(\frac{d}{2}\right)^2}}$

write in terms of $\frac{h}{d}$:

$$\frac{\cancel{d}}{\sqrt{h^2+d^2}} = \frac{n\cancel{d}}{2} \frac{1}{\sqrt{h^2+\left(\frac{d}{2}\right)^2}}$$

square: $\frac{1}{h^2+d^2} = \left(\frac{n}{2}\right)^2 \frac{1}{h^2+\left(\frac{d}{2}\right)^2}$

$$\frac{1}{\cancel{d^2}\left(\left(\frac{h}{d}\right)^2+1\right)} = \left(\frac{n}{2}\right)^2 \frac{1}{\cancel{d^2}\left(\left(\frac{h}{d}\right)^2+\frac{1}{4}\right)}$$

$$\left(\frac{h}{d}\right)^2 + \frac{1}{4} = \left(\frac{n}{2}\right)^2\left(\left(\frac{h}{d}\right)^2+1\right)$$

$$\left(\frac{h}{d}\right)^2\left[1-\left(\frac{n}{2}\right)^2\right] = \left(\frac{n}{2}\right)^2 - \frac{1}{4} = \frac{n^2-1}{4}$$

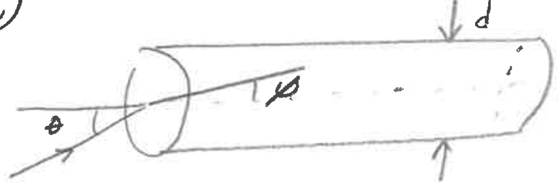
$$\left(\frac{h}{d}\right)^2 = \frac{\frac{n^2-1}{4}}{1-\frac{n^2}{4}} = \frac{n^2-1}{4-n^2}$$

$$\rightarrow \boxed{\frac{h}{d} = \sqrt{\frac{n^2-1}{4-n^2}}}$$

b) $d = 5.51$ cm, $n = 1.33$ water $\rightarrow h = d\sqrt{\frac{n^2-1}{4-n^2}} = \boxed{3.2 \text{ cm}}$

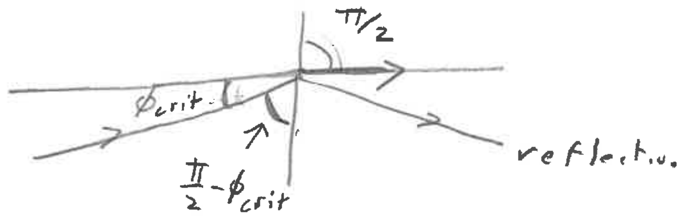
c) No solution when $4-n^2 \leq 0 \rightarrow \boxed{n \geq 2}$

(7.)



air

$d = 6.81\ \mu m$
$n = 1.34$



$\frac{\pi}{2} - \phi_{crit}$: critical angle for total internal reflection

$$n \sin\left(\frac{\pi}{2} - \phi_{crit}\right) = 1 \cdot \sin\left(\frac{\pi}{2}\right)$$

$$\sin\left(\frac{\pi}{2} - \phi_{crit}\right) = \frac{1}{n}$$

$$\underbrace{\sin\left(\frac{\pi}{2}\right)}_{=1} \cos\phi_{crit} - \cancel{\cos\left(\frac{\pi}{2}\right)}^{0} \sin\phi_{crit} = \frac{1}{n}$$

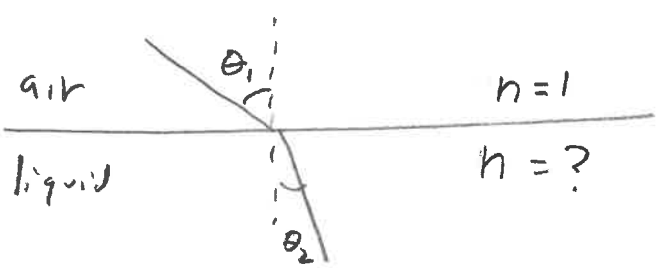
$$\rightarrow \boxed{\cos\phi_{crit} = \frac{1}{n}}$$

<u>Now:</u>

$$1 \cdot \sin\theta_{max} = n \sin\phi_{crit}$$
$$= n\sqrt{1 - \cos^2\phi_{crit}}$$
$$= n\sqrt{1 - \left(\frac{1}{n}\right)^2}$$
$$= \sqrt{n^2 - 1}$$

$$\rightarrow \quad \theta_{max} = \arcsin\left(\sqrt{n^2-1}\right) = \boxed{63^\circ}$$

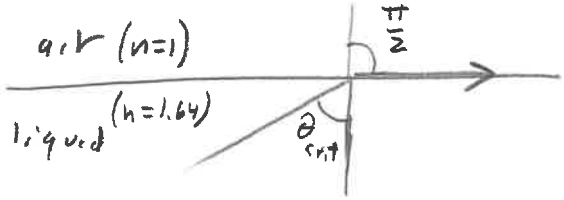
(8.)



$\theta_1 = 45^\circ$
$\theta_2 = 25.5^\circ$

$$1 \cdot \sin\theta_1 = n \cdot \sin\theta_2$$

$$\rightarrow \quad n = \frac{\sin\theta_1}{\sin\theta_2} = \boxed{1.64}$$

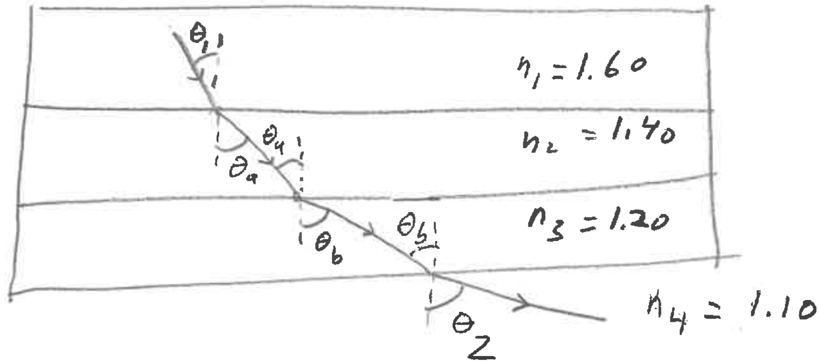


$$n \sin\theta_{crit} = 1 \cdot \sin\left(\frac{\pi}{2}\right)$$

$$\sin\theta_{crit} = \frac{1}{n}$$

$$\theta_{crit} = \arcsin\left(\frac{1}{n}\right) = \boxed{37.5^\circ}$$

9.



$\theta_1 = 34°$

a) $n_1 \sin\theta_1 = n_2 \sin\theta_a$

$n_2 \sin\theta_a = n_3 \sin\theta_b$

$n_3 \sin\theta_b = n_4 \sin\theta_2$

$\rightarrow n_4 \sin\theta_2 = n_1 \sin\theta_1$

Thus, $\sin\theta_2 = \dfrac{n_1}{n_4} \sin\theta_1$

$$\theta_2 = \arcsin\left(\frac{n_1}{n_4} \sin\theta_1\right)$$

$$= \boxed{48.2°}$$

b) For total internal reflection between n_3 and n_4 layer

$\rightarrow \theta_2 = \pi/2$

so $n_4 \sin\theta_2 = n_1 \sin\theta_1$

$\rightarrow n_4 \underbrace{\sin\left(\frac{\pi}{2}\right)}_{1} = n_1 \sin\theta_1$

$$\sin\theta_1 = \frac{n_4}{n_1}$$

$$\theta_1 = \arcsin\left(\frac{n_4}{n_1}\right) = \boxed{48.6°}$$