Chapter 4ish - 5ish

wavelength - distance of an oscillation
- one electric field max to another max
- λ, meters, cm, nm

period - time for one oscillation to pass a point as the wave goes by
- T, seconds

kappa cursive kay

wavenumber - $\frac{1}{\lambda}$ K, k

propagation constant $\frac{2\pi}{\lambda} = k$

nu

frequency - $\nu = \frac{1}{T} = Hz$

angular frequency $\frac{2\pi}{T} = 2\pi\nu$

speed $\rightarrow$ $v = \frac{\lambda}{T} = \lambda \cdot f = \lambda\nu$

in materials, light slows down

$c \to$ speed of light in vacuum

$v < c$

$\underbrace{\frac{c}{v}}$ $= n \leftarrow$ index of refraction

conventionally $n \geq 1$

but can be negative (metamaterials)

and can be complex (absorptive materials)

$v = \frac{c}{n} = \lambda \cdot \nu$

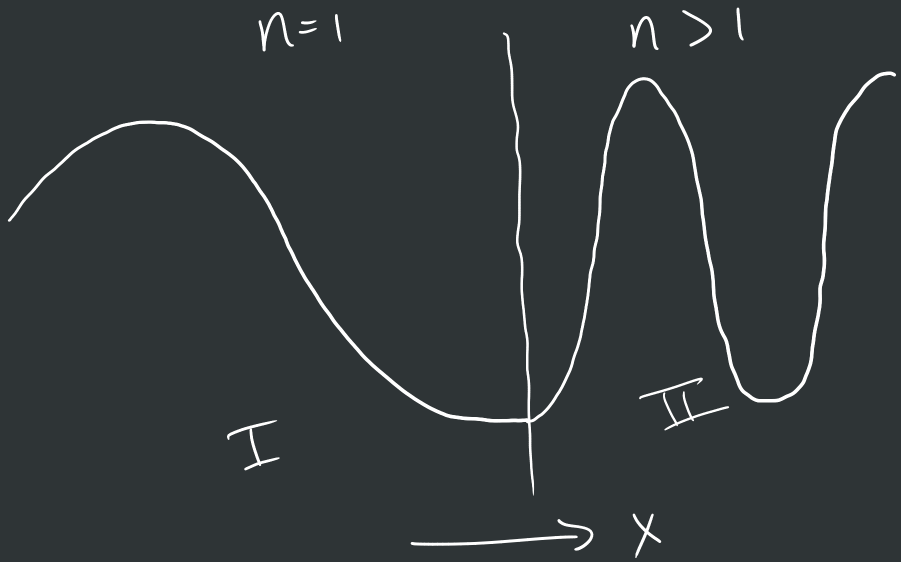
if n increases at some boundary

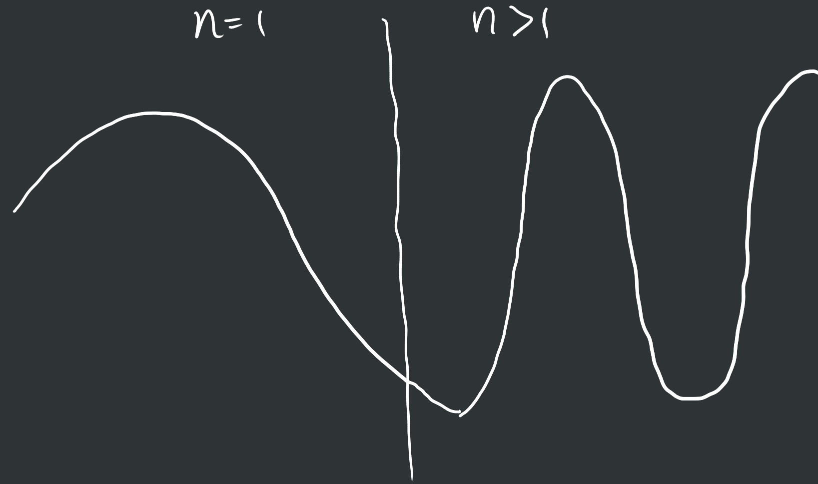
λ decreases, but not ν.

ν is constant

- $E = h \cdot \nu = \frac{hc}{n\lambda}$

Planck's constant





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

$$\frac{c}{n_1 \lambda_1} = \nu = \frac{c}{n_2 \lambda_2}$$

$$\frac{\cancel{c}}{n_1 \lambda_1} = \frac{\cancel{c}}{n_2 \lambda_2}$$

$$\frac{n_2}{n_1} = \frac{\lambda_1}{\lambda_2}$$

$$\frac{n_2}{n_1} = \left(\frac{\lambda_2}{\lambda_1}\right)^{-1}$$

I is vacuum

$$\frac{n}{1} = \left(\frac{\lambda_2}{\lambda_0}\right)^{-1}$$

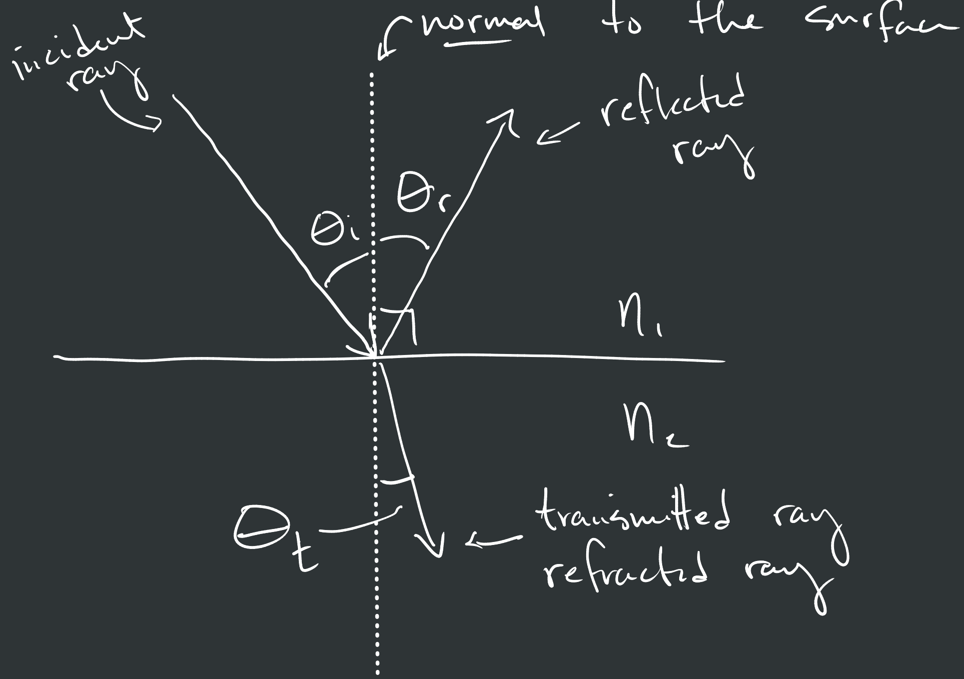
n=1 in vacuum

in vacuum

$$\lambda_2 = \frac{\lambda_0}{n}$$

$n > 1$

so this goes down w/ n



Law of Reflection

$\rightarrow \theta_i = \theta_r$

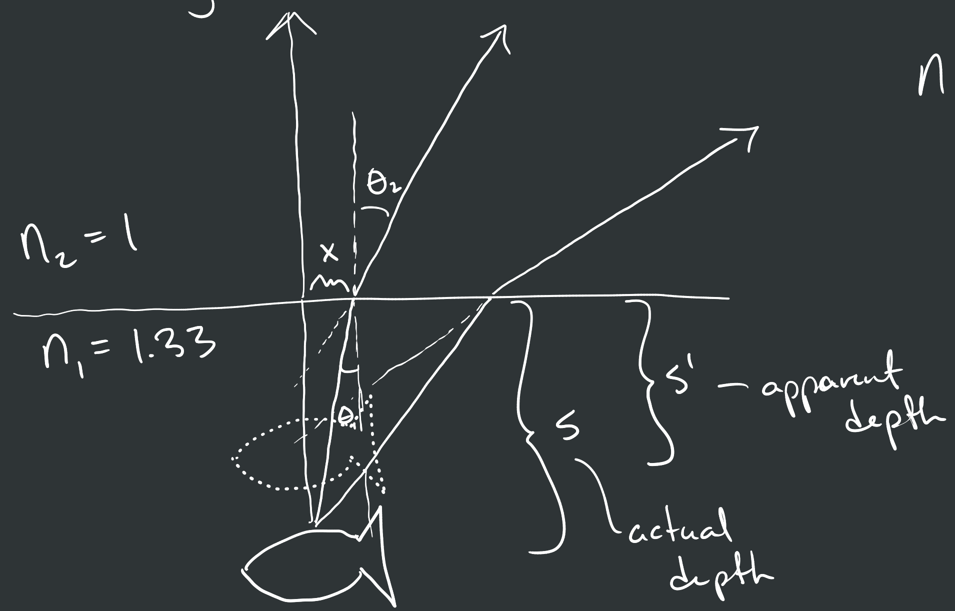
Law of Refraction (Snell's Law)

$$n_1 \sin\theta_i = n_2 \sin\theta_t$$

$$\hookrightarrow n_1 \sin\theta_1 = n_2 \sin\theta_2$$

---

fishing



$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

for small θ, $\sin\theta \approx \tan\theta \approx \theta$

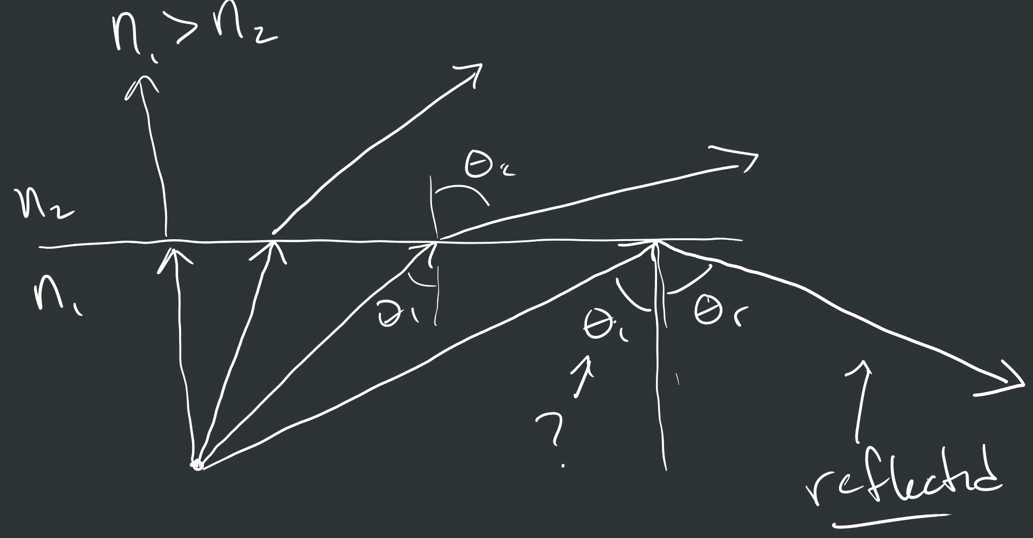
$$n_1 \tan\theta_1 = n_2 \tan\theta_2$$

$$\frac{n_1 \cancel{x}}{s} = \frac{n_2 \cancel{x}}{s'}$$

$$\frac{s'}{s} = \frac{n_2}{n_1} = \frac{1}{1.33} \approx 0.752$$

$s' = 0.752 \cdot s$

critical angle



$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$\sin\theta_2 = \frac{n_1}{n_2}\sin\theta_1$$

$$\theta_2 = \sin^{-1}\left(\frac{n_1}{n_2}\sin\theta_1\right)$$

what θ_1 causes θ_2 to be 90°

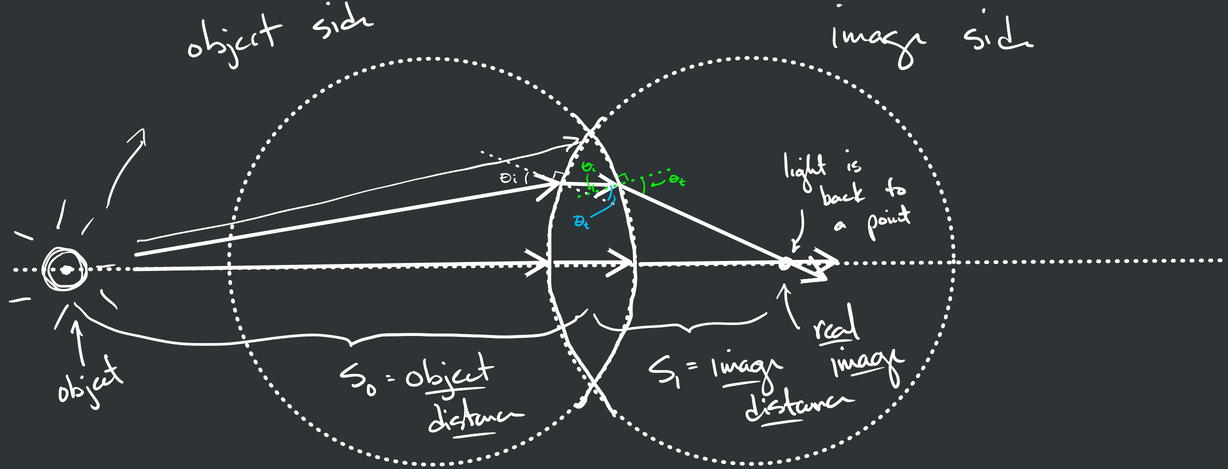
$$\underbrace{\sin\theta_2} = \underbrace{\frac{n_1}{n_2}\sin\theta_1}_{\text{when this is } \geq 1}$$

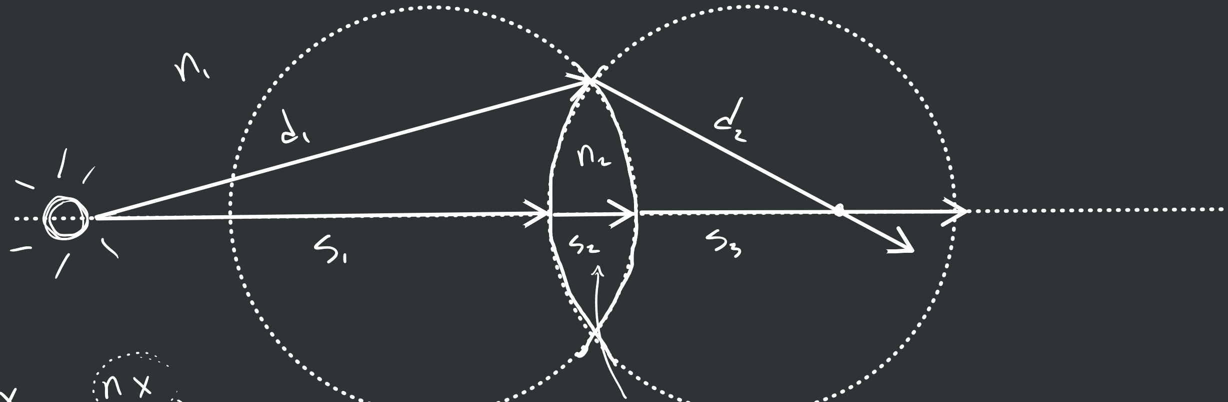
$$1 = \frac{n_1}{n_2}\sin\theta_1$$

critical angle $\longrightarrow$ $\theta_1 = \theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$

< 1

HW: Chapter 4: 6, 7, 8, 21, 24





$$t = \frac{x}{v} = \frac{n x}{c}$$ → optical path length

$$v = \frac{c}{n}$$

$$\frac{n_1 d_1}{\cancel{c}} + \frac{n_1 d_2}{\cancel{c}} = \frac{n_1 s_1}{\cancel{c}} + \frac{n_2 s_2}{\cancel{c}} + \frac{n_1 s_3}{\cancel{c}}$$

$$n_1 d_1 + n_1 d_2 = n_1 s_1 + n_2 s_2 + n_1 s_3$$ } optical path lengths are the same!

perfect images

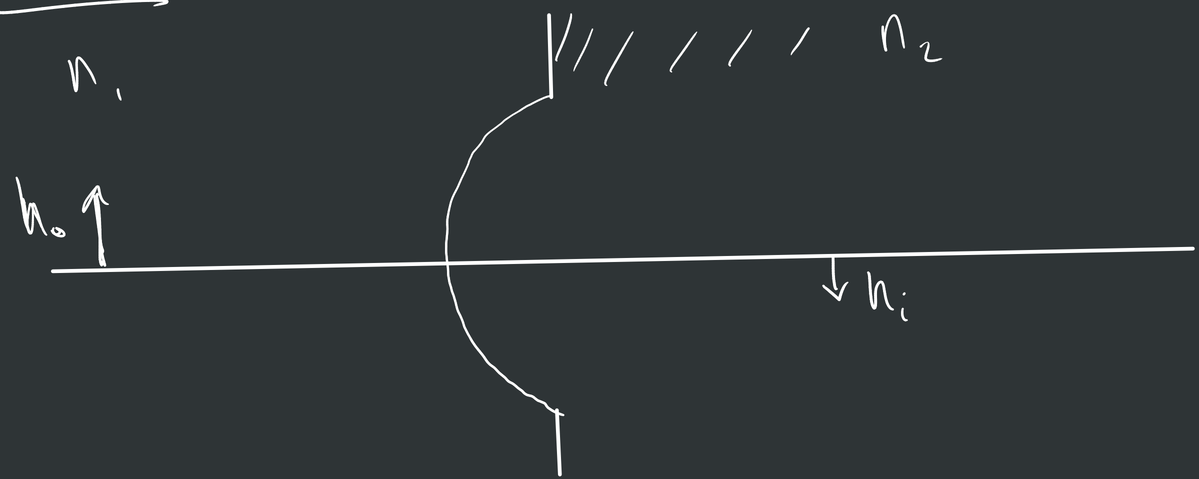
reflection

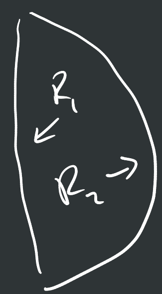
- ellipsoid
- hyperboloid
- parabola

refraction

- ellipsoid
- hyperboloid
- cartesian oval

Refraction





Thin lens

$$\frac{n_1}{S_o} + \frac{n_2}{S_i} = \frac{n_2 - n_1}{R}$$

object distance (S_o)

image distance (S_i)

thin lens (Lens Makers Equation)

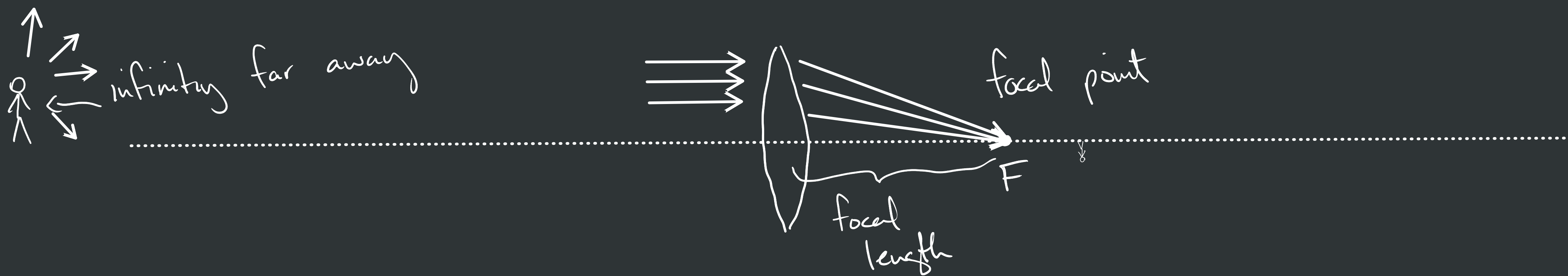
$$\frac{1}{S_o} + \frac{1}{S_i} = (n_\ell - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

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

focal length (f)

(Thin Lens Equation)

$$\frac{1}{S_o} + \frac{1}{S_i} = \frac{1}{f}$$



	+	−
s_o	real object	virtual object
s_i	real image	virtual image
f	converging lens	diverging lens
y_o	upright object	inverted object
y_i	upright image	inverted image

Optics Lab:

Conjugate Points: $$\frac{1}{s_o} + \frac{1}{s_i} = \frac{1}{f}$$

Focal Length Exp: $$\overset{\to 0}{\cancel{\frac{1}{s_o \to \infty}}} + \frac{1}{s_i} = \frac{1}{f}$$

$$\frac{1}{s_i} = \frac{1}{f} \Rightarrow s_i = f \quad \text{for } s_o \to \infty$$

Diverging Lens: $$\frac{1}{S_o} + \frac{1}{S_i} = \frac{1}{-f}$$

$$\frac{1}{S_i} = \frac{1}{-f} - \frac{1}{S_o}$$

$$S_i = \frac{1}{\frac{1}{-f} - \frac{1}{S_o}}$$

Finding a virtual image:

$$\frac{1}{S_o} + \frac{1}{S_i} = \frac{1}{f}$$

$$\frac{1}{S_i} = \frac{1\,S_o}{f\,S_o} - \frac{1\,f}{S_o\,f} = \frac{S_o - f}{f\,S_o}$$

$$S_i = \frac{S_o \cdot f}{S_o - f}$$

MINE: $S_o = 27\ \text{cm}$

$f = -15\ \text{cm}$

$$S_i = \frac{27(-15)}{27+15} = -9.60\ \text{cm}$$

Now for the check:

$$\frac{1}{s_o} + \frac{1}{s_i} = \frac{1}{f}$$

$s_i = 16.2$ cm

$f = 10$ cm

$$s_o = \frac{s_i \cdot f}{s_i - f}$$

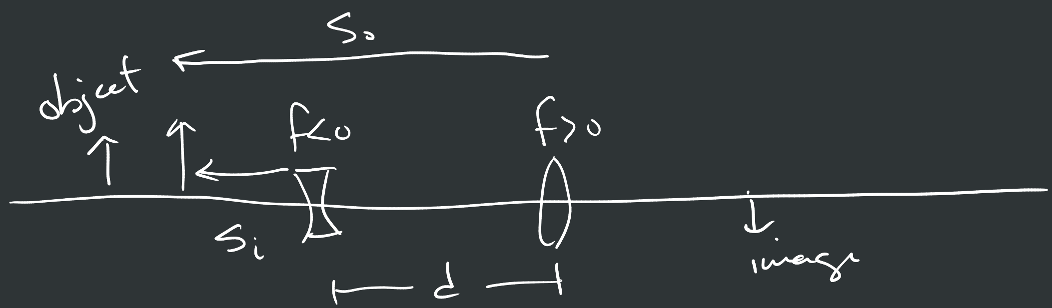
$$s_o = \frac{16.2 \cdot 10}{16.2 - 10}$$

$s_o = 26.13$

$s_o = 26.13$

So now we need to compare

$$s_o = d - s_i$$



$26.13 = d - (-9.6)$

$16.53 = d$

17.3 <u>measured</u>