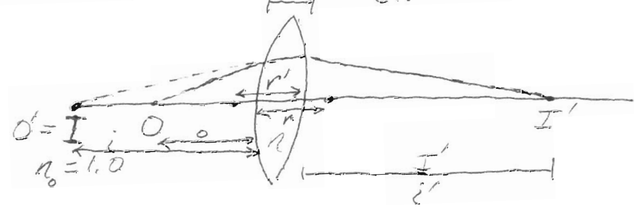
Thin Lenses

l = lens thickness



At first surface

$$\frac{n_0}{o} \quad \frac{n}{i} = \frac{n-n_0}{r} \qquad (1)$$

The image from first surface is the source, or object, for the 2nd, O'

$$\frac{n}{(i+l)} + \frac{n_0}{i'} = \frac{n_0-n}{r'}$$

If lens thin enough, we can ignore "l" in this relation, & get

$$\frac{n}{i} + \frac{n_0}{i'} = \frac{-(n-n_0)}{r'} \qquad (2)$$

Adding (1) + (2) gives

$$\frac{n_0}{o} + \frac{n_0}{i'} = (n-n_0)\left(\frac{1}{r} - \frac{1}{r'}\right)$$

which can be written for a thin lens in air or vacuum

$$\frac{1}{o} + \frac{1}{i} = (n-1)\left(\frac{1}{r} - \frac{1}{r'}\right)$$

where "i" is the image distance for the lens

Thin lenses (cont.) Focal length + Magnification

If we consider paraxial rays, $o \to \infty$

$$\frac{1}{i} = \boxed{(n-1)\left(\frac{1}{r} - \frac{1}{r'}\right) = \frac{1}{f}}$$

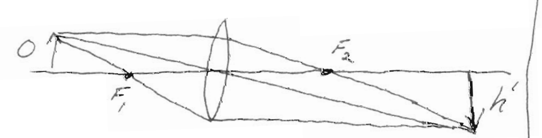
↳ Lens Maker's Eq.

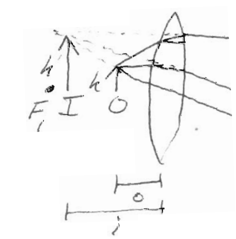
This then allows us to write a general relation

$$\boxed{\frac{1}{o} + \frac{1}{i} = \frac{1}{f}} \quad \text{Thin lens Eq.}$$

→ 2 focal points - one for each direction thru

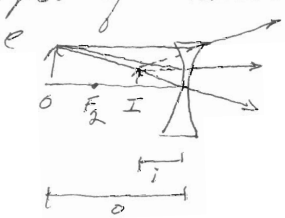
(h)





$$M = -\frac{i}{o}\left(\frac{h'}{h}\right)$$

→ for all types of lenses, including concave



Problem 28

Contact lens has $n = 1.5$ and radii of curvature $+2.0$ cm and $+2.5$ cm. What is focal length?

Note both radii are >0 →

$$\frac{1}{f} = (n-1)\left[\frac{1}{r} - \frac{1}{r'}\right]$$

$$= (1.5-1)\left[\frac{1}{0.02m} - \frac{1}{0.025m}\right] = 0.05m^{-1}$$

$\boxed{f = 20cm}$

29) biconvex lens → left side $|r| = 12$ cm
→ right side $|r'| = 18$ cm

so $r > 0$ and $r' < 0$

a) focal length? $\frac{1}{f} = (n-1)\left(\frac{1}{r} - \frac{1}{r'}\right)$

$$= 0.44\left(\frac{1}{0.12m} - \left(-\frac{1}{0.18m}\right)\right)$$

$f = 16.4$ cm

b) turn it around

$$\frac{1}{f} = (n-1)\left(\frac{1}{r'} - \frac{1}{r}\right)$$ but now $r<0$, $r'>0$

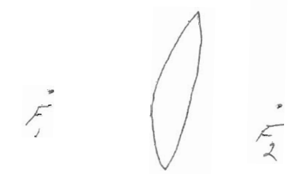
$$= (0.44)\left(\frac{1}{0.18m} - \left(-\frac{1}{0.12m}\right)\right)$$

$\boxed{f = 16.4cm}$ again

Problem 31

Thin lens w/ $f = 25$ cm

a) describe image when $o = 26$ cm



$$\frac{1}{i} = \frac{1}{f} - \frac{1}{o} = \frac{1}{0.25m} - \frac{1}{0.26m}$$

$\boxed{i = +6.5m}$

$$M = -i/o = -\frac{6.5m}{0.25m} = \boxed{-26 < 0}$$

image real, inverted an elarged

b) $o = 24$ cm

$$\frac{1}{i} = \frac{1}{0.25m} - \frac{1}{0.24m} \Rightarrow \boxed{i = -6.0m}$$

$$M = -i/o = -\frac{(-6.00)}{0.25} = \boxed{+24 > 0}$$

(neg sign)

image virtual, upright and enlarged