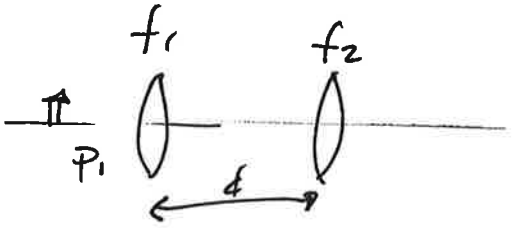
Ph 102
Spring 2015
Exam 4

1.a) upper: L passes low, C shorts high around speaker
⇒ low freq speaker

lower: C passes high, L shorts low around speaker
⇒ high freq speaker

b) top: L shorts low, C passes high ⇒ high freq speaker
bott: C shorts high, L passes low ⇒ low freq speaker
mid: does both - comb. low + high pass ⇒ mid range speaker

2.



$f_1 = 2\text{cm}$ $f_2 = 5\text{cm}$ $d = 10\text{cm}$ $p_1 = 3\text{cm}$

$\frac{1}{p_1} + \frac{1}{q_1} = \frac{1}{f_1}$ $\quad q_1 = \frac{p_1 f_1}{p_1 - f_1}$ $\quad$ if $q_1 < d$, $p_2 = d - q_1$ $\quad q_1 = 6 < d$ ✓

$\frac{1}{p_2} + \frac{1}{q_2} = \frac{1}{d - q_1} + \frac{1}{q_2} = \frac{1}{f_2}$

$\frac{1}{d - \frac{p_1 f_1}{p_1 - f_1}} + \frac{1}{q_2} = \frac{1}{f_2}$ $\quad \frac{1}{q_2} = \frac{1}{f_2} - \frac{p_1 - f_1}{d(p_1 - f_1) - p_1 f_1}$

$$\frac{1}{q_2} = \frac{d(p_1 - f_1) - p_1 f_1 - f_2 p_1 + f_1 f_2}{f_2 d(p_1 - f_1) - p_1 f_1 f_2}$$

$$q_2 = \frac{f_2 d p_1 - f_1 f_2 \, d - p_1 f_1 f_2}{d p_1 - d f_1 - p_1 f_1 - p_1 f_2 + f_1 f_2 - f_1(d + p_1) + p_1(d - f_2) + f_1 f_2} = \frac{d p_1 f_2 - f_1 f_2 (d + p_1)}{p_1(d - f_1 - f_2) + f_1(f_2 - d)}$$

$q_2 = -20\text{cm}$ from L_2, or -10cm from L_1

$$M = M_1 M_2 = \frac{q_1 q_2}{p_1 p_2} = \frac{p_1 f_1}{p_1 - f_1} \cdot \frac{q_2}{p_1(d - q_1)} = \frac{f_1}{(p_1 - f_1)(d - q_1)} \left(\frac{d p_1 f_2 - f_1 f_2 (d + p_1)}{p_1(d - f_1 - f_2) + f_1(f_2 - d)} \right)$$

$M = -10$

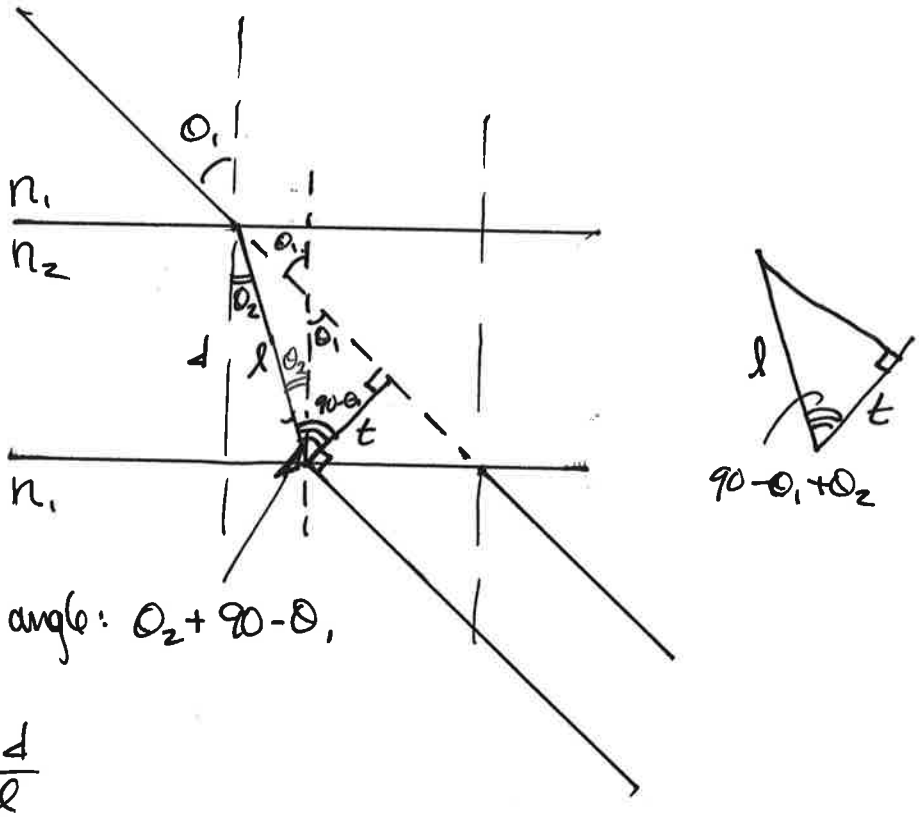
3.

a) top interface: $n_1 \sin\theta_1 = n_2 \sin\theta_2$

bottom interface: $n_2 \sin\theta_2 = n_1 \sin\theta_3$

$\Rightarrow n_1 \sin\theta_1 = n_1 \sin\theta_3 \Rightarrow \boxed{\theta_1 = \theta_3}$ (since all θ's are less than 90°)

b)



total angle: $\theta_2 + 90 - \theta_1$

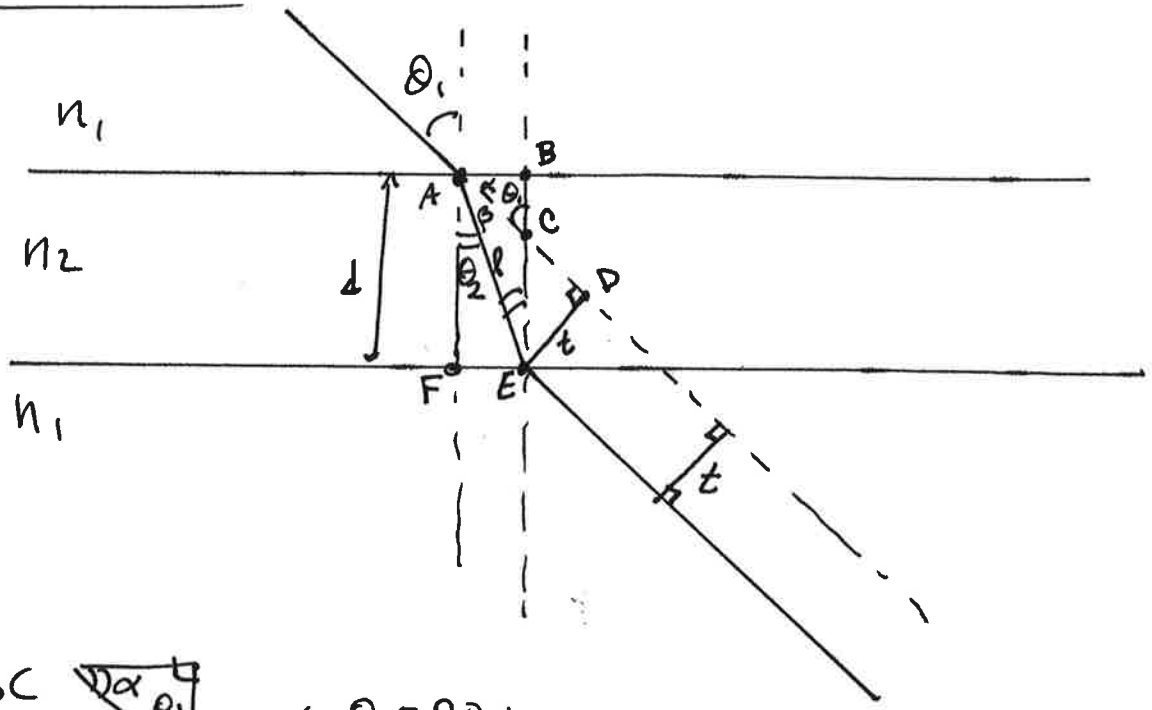
$\cos\theta_2 = \frac{d}{l}$

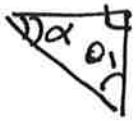
$\cos(\theta_2 + 90 - \theta_1) = -\sin(\theta_2 - \theta_1) = \sin(\theta_1 - \theta_2) = \frac{t}{l} = \frac{t}{d}\cos\theta_2$

$\Rightarrow \boxed{t = \frac{d\sin(\theta_1 - \theta_2)}{\cos\theta_2}}$

check: $n_1 = n_2 \Rightarrow \theta_1 = \theta_2 \Rightarrow t = 0$

3b, alt method



ΔABC 

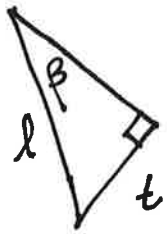
$\alpha + \theta_1 = 90$

$\Rightarrow 90 - \alpha = \theta_1$

$\angle BAF$ 

$\alpha + \beta + \theta_2 = 90$

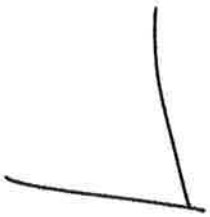
$\Rightarrow \beta = 90 - \theta_2 - \alpha = \theta_1 - \theta_2$

ΔAED 

$\sin\beta = \sin(\theta_1 - \theta_2) = \frac{t}{l}$

ΔAEF 

$\cos\theta_2 = \frac{d}{l}$

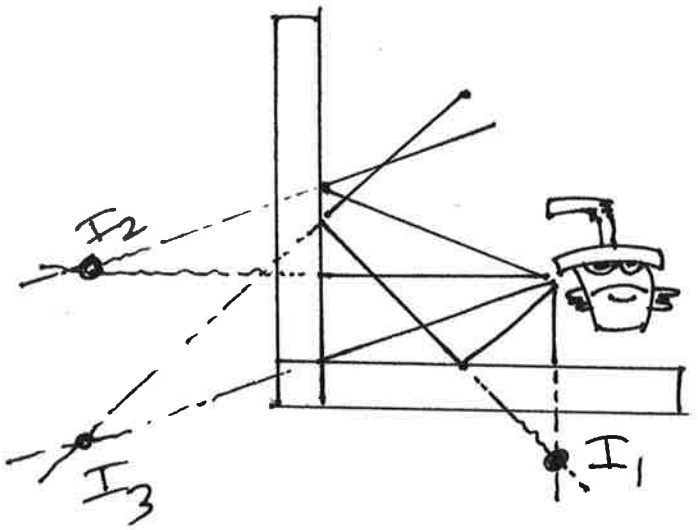


$\sin(\theta_1 - \theta_2) = \frac{t}{d}\cos\theta_2$

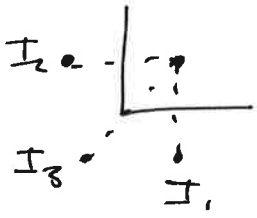
$$\Rightarrow t = \frac{d\sin(\theta_1 - \theta_2)}{\cos\theta_2}$$

4a) 3 images

two images from from light that reflects off only 1 mirror
a third comes from light that reflects off both



I_3 is 45° from horizontal if drawn correctly



4b) $R = 2f = 20\text{cm}$

image at $q = 110\text{cm}$

$$\frac{1}{p} + \frac{1}{q} = \frac{1}{f} = \frac{2}{R} \qquad \frac{1}{p} = \frac{2}{R} - \frac{1}{q} = \frac{2q - R}{Rq}$$

$$\Rightarrow p = \frac{Rq}{2q - R} = 11\text{cm}$$

pylochstands 11cm from mirror

$$M = \frac{-q}{p} = \frac{-110}{11} = -10$$

image is 10x larger, inverted, and real