PROBLEM #1

a) $$\frac{\partial E}{\partial x} = -\frac{\partial B}{\partial t} \quad \& \quad -\frac{\partial B}{\partial x} = \varepsilon_0 \mu_0 \frac{\partial E}{\partial t}$$

eq 1 eq 2

DIFFERENTIATE eq 1

$$\frac{\partial^2 E}{\partial x^2} = -\frac{\partial^2 B}{\partial x \partial t} = \frac{\partial}{\partial t}\left[-\frac{\partial B}{\partial x}\right] \overset{\text{BY eq 2}}{=} \frac{\partial}{\partial t}\left[\varepsilon_0 \mu_0 \frac{\partial E}{\partial t}\right] = \varepsilon_0 \mu_0 \frac{\partial^2 E}{\partial t^2}$$

$$\Rightarrow \boxed{\frac{\partial^2 E}{\partial t^2} = \frac{1}{\varepsilon_0 \mu_0} \frac{\partial^2 E}{\partial x^2}}$$

THIS IS THE SAME FORM AS THE WAVE EQUATION, WITH

$$\boxed{v = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}}$$

THE SAME MANIPULATIONS GIVE

$$\boxed{\frac{\partial^2 B}{\partial t^2} = \frac{1}{\varepsilon_0 \mu_0} \frac{\partial^2 B}{\partial x^2}}$$

(10 pts)

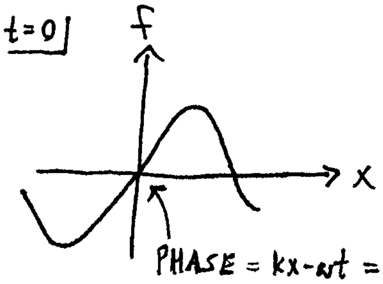
(ANY FORM $f(x,t) = F(kx-\omega t)$ WORKS!)

b) THE OBVIOUS CHOICE IS $f(x,t) = A \sin(kx-\omega t)$. PLUGGING THIS INTO THE WAVE EQUATION:

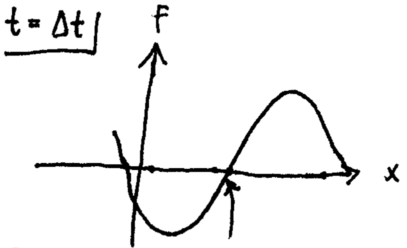
$$-\omega^2 A \sin(kx-\omega t) = -v^2 k^2 A \sin(kx-\omega t)$$

$$\Rightarrow \boxed{v = \omega/k} \quad (5\text{ pts})$$

AS t INCREASES, ωt INCREASES. (I'M USING $k, \omega > 0$.) HENCE



PHASE = $kx-\omega t = 0$ AT $x=0$



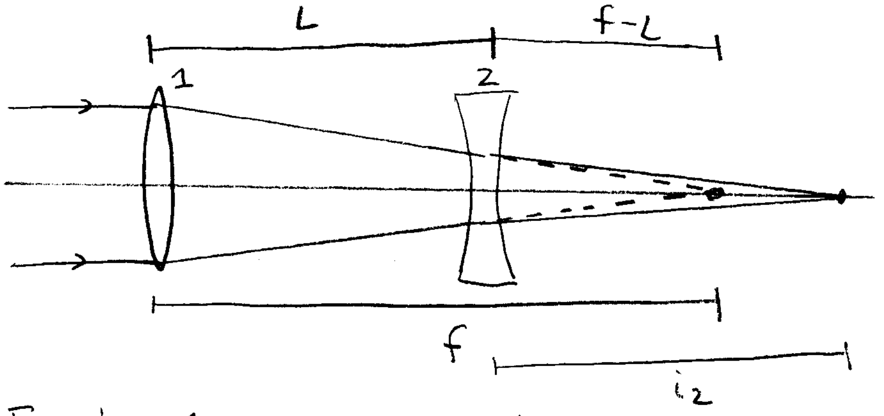
$x = \frac{\omega}{k}\Delta t = v\Delta t$, NEW PHASE = 0 POINT

THE WAVE IS MOVING TOWARDS +x. (5 pts)

Lee Sp. '06, MT 1

2a.) For lens 1, $o_1 = \infty \Rightarrow \frac{1}{i_1} = \frac{1}{f_1}$, or $i_1 = f_1$

For lens 2, $o_2 = -(f-L) \Rightarrow \frac{1}{i_2} + \frac{1}{-(f-L)} = -\frac{1}{f} \Rightarrow i_2 = \left(\frac{1}{f-L} - \frac{1}{f}\right)^{-1} = \frac{f(f-L)}{L}$,



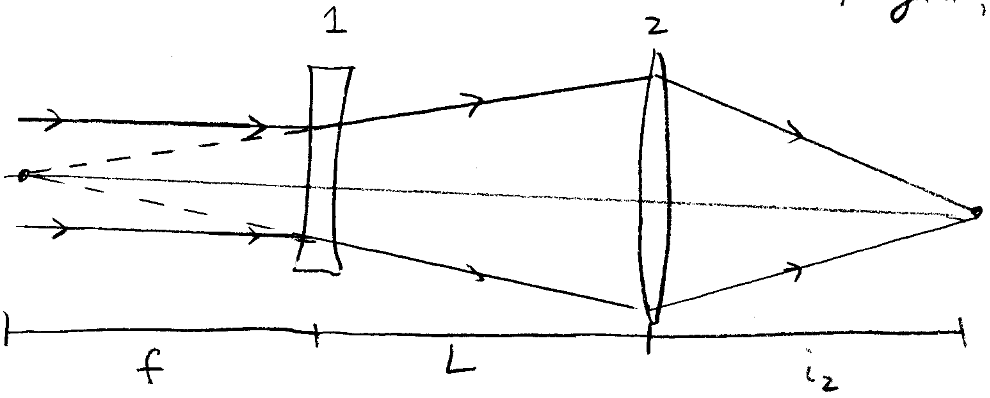
so $i_2 > 0$ for $L < f$

(+ $L > 0$ for this setup to make sense)

b.) For lens 1, $o_1 = \infty \Rightarrow \frac{1}{i_1} = -\frac{1}{f}$, or $i_1 = -f$

For lens 2, $o_2 = f + L \Rightarrow \frac{1}{i_2} + \frac{1}{f+L} = +\frac{1}{f} \Rightarrow i_2 = \left(\frac{-1}{f+L} + \frac{1}{f}\right)^{-1} = \frac{f(f+L)}{L}$,

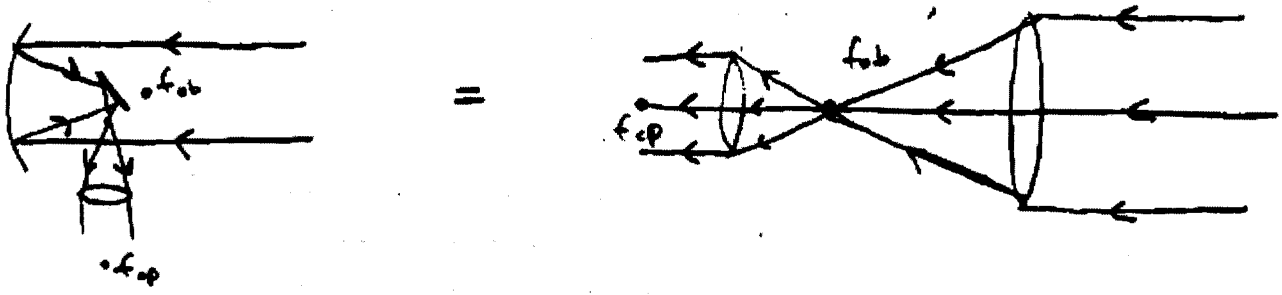
so now $i_2 > 0$ for any L (with, again, $L > 0$)



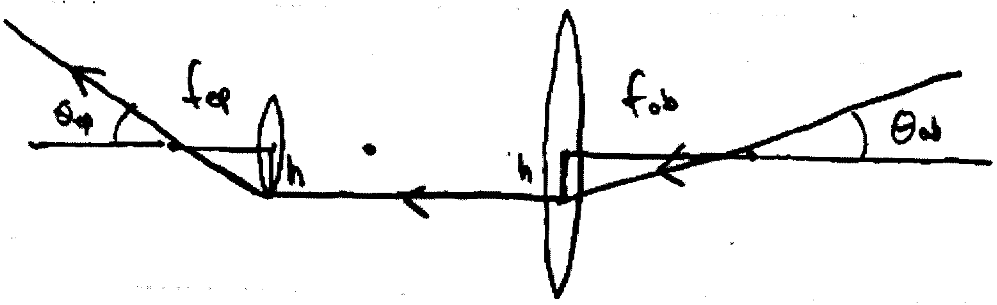
(For all $L > 0$, object distance for converging lens is larger than f, so it converges.)

c.) In both cases, $f \to \infty$ as $L \to 0$, i.e., the light comes out parallel (in effect, the 2 lenses "cancel").

Problem 3



a)



$$\theta_{ep} \simeq \tan\theta_{ep} = h/f_{ep} \qquad \theta_{ob} \simeq \tan\theta_{ob} = h/f_{ob}$$

$$M \equiv -\frac{\theta_{ep}}{\theta_{ob}} = -\frac{\cancel{h}}{f_{ep}} \cdot \frac{f_{ob}}{\cancel{h}} = \boxed{-\frac{f_{ob}}{f_{ep}}}$$

b) $f_{ob} = 16.8\ m$

$$\theta_{ob} = \frac{1\ m}{2000\ m} = 5 \times 10^{-4}$$

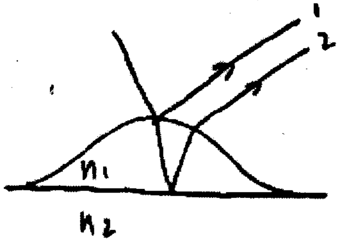
$$h = \theta_{ob} f_{ob} = (5 \times 10^{-4})(16.8\ m) = \boxed{8.4\ mm}$$

c) $r = 10\,m \Rightarrow f_{ob} = r/2 = 5\,m$

$$f_{ep} = -f_{ob}/M = -5m/-200 = \boxed{2.5\ cm}$$

Problem 4

a)



$$\Delta\varphi = k_{n_1}\Delta x_2 + \pi - \pi$$

phase change due to reflection of beam one

phase change due to reflection of beam two

$$\Rightarrow \Delta\varphi = \frac{2\pi}{\lambda_{n_1}} \times 2t = \frac{4\pi n_1 t}{\lambda_0}$$ (λ_0 is wavelength in air).

@ the edge $t=0 \Rightarrow \Delta\varphi = 0 \Rightarrow$ constructive interference b/c the beams are in phase!

$\boxed{\therefore \text{ there is a bright spot}}$

b) if a fringe is blue, $\lambda_0 = 475\times10^{-9}$ m

$\Delta\varphi = 2\pi n$ where $n = 3$.

$$\Rightarrow \frac{\overset{2}{\cancel{4}}\cancel{\pi} n_1 t}{\lambda_0} = 2\cancel{\pi}(3)$$

$$\Rightarrow t = \frac{3\lambda_0}{2n_1} = \frac{3(475\text{ nm})}{2(1.2)} = \boxed{593.75\text{ nm}}$$

c) When the oil gets thick the beam reflected off of the surface is separated from the beam that bounces ~~off of~~ the surface of the water. When this happens they do intersect to a distant observer and thus cannot interfere. Since the light source is incoherent, the phase of other nearby beams will not be in phase, and thus not contribute to any coherent interference constructive or destructive. Thus, an observer will only see white light.