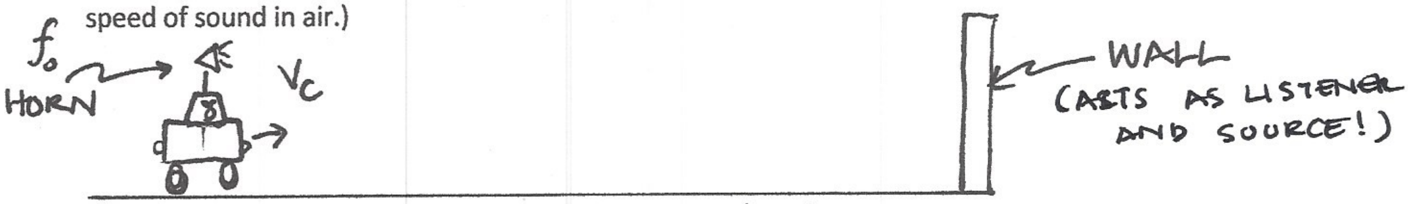
Physics 4C – Spring 2017 Name______________________________

EXAM 2

Show all your work for full credit. No electronic devices, scratch papers or note cards are allowed. You have one (1) hour for the exam.

1. (15 points) A car approaches a sound reflecting wall. The horn is stuck and the frequency of the horn is f_o. If the speed of the car is V_c, **what is the beat frequency heard by the driver?** (Please use V for the speed of sound in air.)



WHAT f_{BEAT} DOES THE DRIVER HEAR?

$$f_{beat} = |f' - f_o|$$

The wall "hears" $f_{wall} = f_o\left(\frac{V \pm \cancel{V_L}^{\,0}}{V \pm V_s}\right)$ $\quad f_{wall} \uparrow \quad V_s$ is moving toward (−) sign.

The driver hears $f' = f_{wall}\left(\frac{V \pm V_L}{V \pm \cancel{V_s}^{\,0}}\right)$ $\quad f' \uparrow \quad V_L$ is moving toward (+) sign

$$f' = f_{wall}\left(\frac{V + V_c}{V}\right)$$

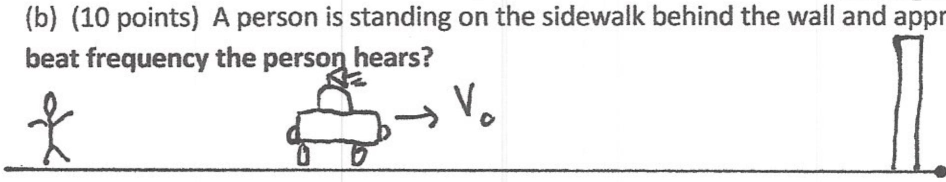
$$f' = f_o\left(\frac{\cancel{V}}{V - V_c}\right)\left(\frac{V + V_c}{\cancel{V}}\right)$$

$$f_b = f' - f_o = f_o\left(\frac{V + V_c}{V - V_c} - 1\right)$$

$$f_b = f_o\left(\frac{\cancel{V} + V_c - (\cancel{V} - V_c)}{V - V_c}\right)$$

$$\boxed{f_b = \frac{2 f_o V_c}{V - V_c}}$$

(b) (10 points) A person is standing on the sidewalk behind the wall and approaching car. **What is the beat frequency the person hears?**



WHAT f_{BEAT} DOES THE PERSON HEAR?

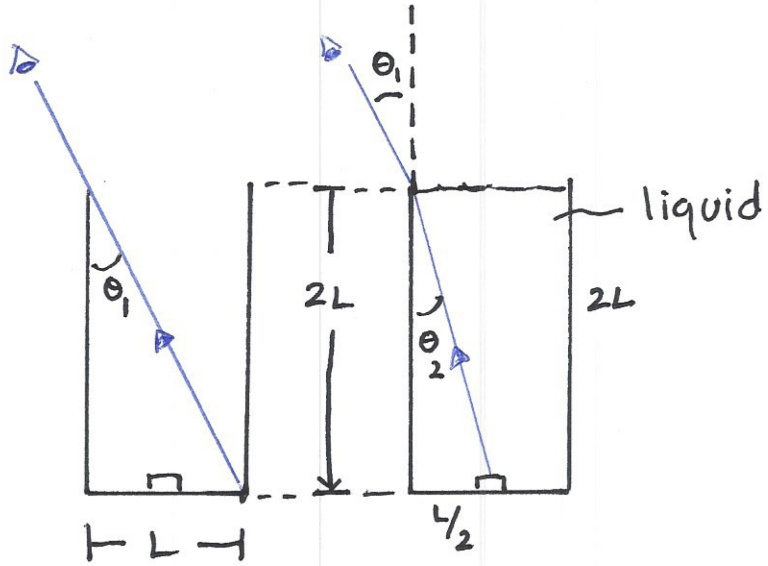
$$f_{\substack{person\\beat}} = \left|f_{wall} - f_{\substack{car\\receding}}\right|$$

$$f_{car\ receding} = f_o\left(\frac{V \pm \cancel{V_L}^{\,0}}{V \pm V_s}\right)$$ now V_s is away, choose (+)

$$f_{person} = \left|f_o\left(\frac{V}{V - V_c}\right) - f_o\left(\frac{V}{V + V_c}\right)\right| = f_o\left(\frac{\cancel{V^2} + V_c V - (\cancel{V^2} - V_c V)}{V^2 - V_c^2}\right)$$

$$\boxed{f_{person} = 2 f_o \frac{V_c V}{V^2 - V_c^2}}$$

2. A person looking into an empty container is able to see the far edge of the container's bottom as shown. The height of the container is *2L* and its width is *L*. When the container is completely filled with a fluid, the person can see the center of a coin in the middle of the container's bottom. Find *n*, the index of refraction of the liquid.



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

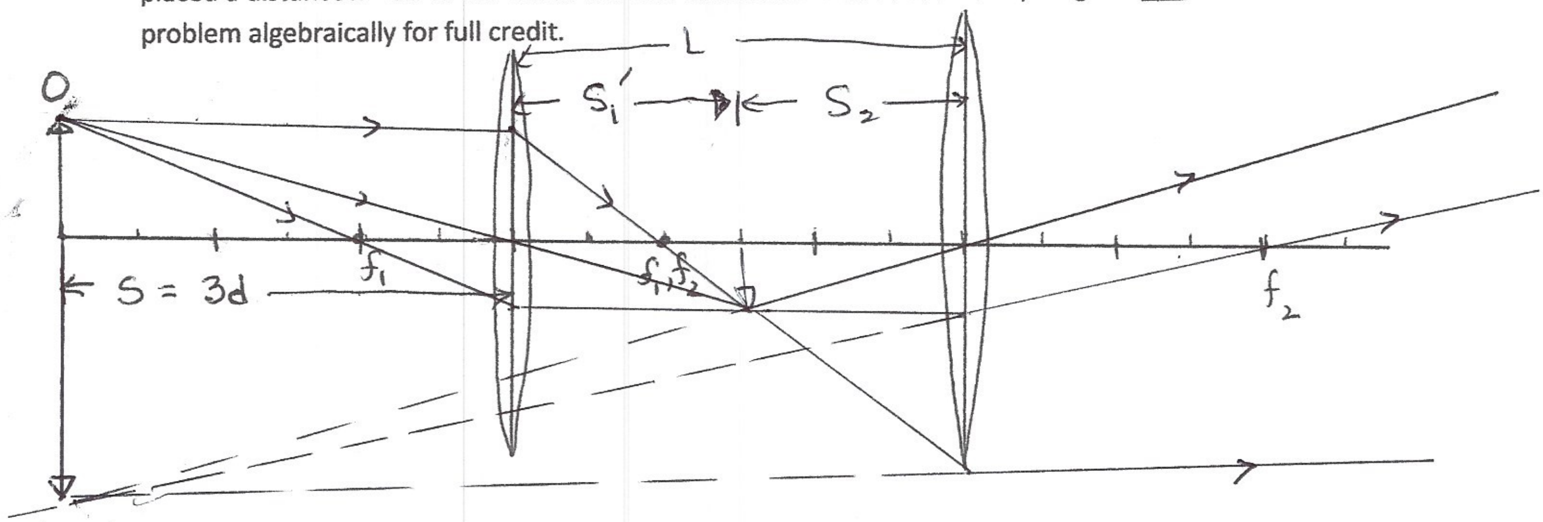
$n_1 = 1$ for air
$n_2 = n$

$$\frac{L}{\sqrt{L^2 + (2L)^2}} = n\left(\frac{L/2}{\sqrt{(L/2)^2 + (2L)^2}}\right)$$

$$n = \frac{\dfrac{L}{\sqrt{5L^2}}}{\dfrac{L/2}{\sqrt{\frac{L^2}{4} + 4L^2}}} = \frac{\dfrac{1}{\sqrt{5}}}{\dfrac{L/2}{\sqrt{\frac{17}{4}L^2}}} = \frac{\dfrac{1}{\sqrt{5}}}{\dfrac{\cancel{1/2}}{\cancel{\frac{1}{2}}\sqrt{17}}}$$

$$\boxed{n = \frac{\sqrt{17}}{\sqrt{5}} = \frac{\sqrt{85}}{5}}$$

3. **Find** the position of the **final image, S',** for the two lens system shown **and the** overall **magnification M.** The first lens is a double convex lens of focal length $f_1 = d$. The second lens is a double convex lens with focal length $f_2 = 2d$ and is located a distance $3d$ to the right of the first lens as shown. The object is placed a distance $x = 3d$ to the left of the lens as shown. Please draw a ray diagram and solve the problem algebraically for full credit.



$$\frac{1}{S} + \frac{1}{S_1'} = \frac{1}{f_1}$$

$$\frac{1}{S_1'} = \frac{1}{f_1} - \frac{1}{S}$$

$$\frac{1}{S_1'} = \frac{3 \cdot 1}{3d} - \frac{1}{3d}$$

$$\frac{1}{S_1'} = \frac{2}{3d}$$

$$S_1' = \frac{3}{2}d$$

$$m_1 = \frac{-S_1'}{S} = \frac{-\cancel{3}/2\,\cancel{d}}{\cancel{3d}} = \frac{-1}{2}$$

$$S_2 = L - S_1'$$

$$S_2 = 3d - \frac{3}{2}d = \frac{3}{2}d$$

$$\frac{1}{S_2} + \frac{1}{S'} = \frac{1}{f_2}$$

$$\frac{1}{S'} = \frac{1}{f_2} - \frac{1}{S_2}$$

$$\frac{1}{S'} = \frac{1}{2d} - \frac{1}{\frac{3d}{2}}$$

$$\frac{1}{S'} = \frac{3}{6d} - \frac{4}{6d}$$

$$\frac{1}{S'} = \frac{-1}{6d}$$

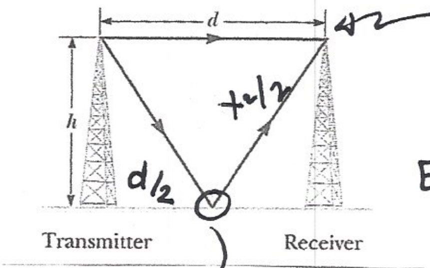
$$\boxed{S' = -6d}$$ as shown

$$m_2 = \frac{-S'}{S_2} = + \frac{\cancel{6}^{2}\cancel{d}}{\frac{\cancel{3d}}{2}} = 4$$

$$M = m_1 m_2 = \frac{-1}{2} \cdot 4 = -2$$

inverted as shown

4. The figure shows a radio-wave transmitter and a receiver separated by a distance *d* and both a distance *h* from the ground. The receiver can receive signals both directly from the transmitter and indirectly from signals that reflect from the ground. Assume the ground is level between the transmitter and receiver. **What is the longest wavelength that interferes constructively? What is the longest wavelength that interferes destructively?**



$E_1 = E_0 \sin(kx_1 - \omega t)$

$E_2 = E_0 \sin(kx_2 - \omega t - \pi)$

$E = E_1 + E_2 = 2E_0 \cos\frac{1}{2}(k(x_2 - x_1) - \pi)\sin\frac{1}{2}(k(x_2 + x_1) - 2\omega t - \pi)$

inversion Amplitude $\cos\frac{1}{2}(k(x_2 - x_1) - \pi) = 1$ max

$= 0$ min

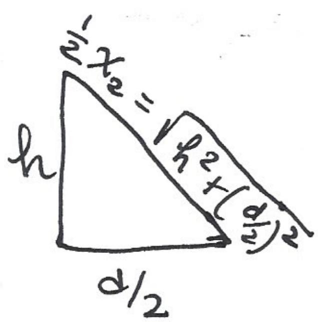
or $\frac{1}{2}\left(\frac{2\pi}{\lambda}(x_2 - x_1) - \pi\right) = n\pi$

$\frac{2\pi}{\lambda}(x_2 - x_1) - \pi = 2n\pi$

$\frac{2\pi}{\lambda}(x_2 - x_1) = 2n\pi + \pi = (2n+1)\pi$

$x_2 - x_1 = (2n+1)\pi \cdot \frac{\lambda}{2\pi}$

$x_2 - x_1 = (n + \frac{1}{2})\lambda$ max ;



$2\sqrt{h^2 + \frac{d^2}{4}} - d = (n + \frac{1}{2})\lambda$

$\lambda_{longest} \to n = 1$ constructive

$\frac{1}{2}\lambda = \sqrt{4h^2 + d^2} - d$

$\boxed{\lambda = 2\sqrt{4h^2 + d^2} - 2d}$

Destructive $\Delta x = m\lambda$ here $m = 1$ for $\lambda_{longest}$

$\boxed{\lambda = \sqrt{4h^2 + d^2} - d}$

too easy ... oh well