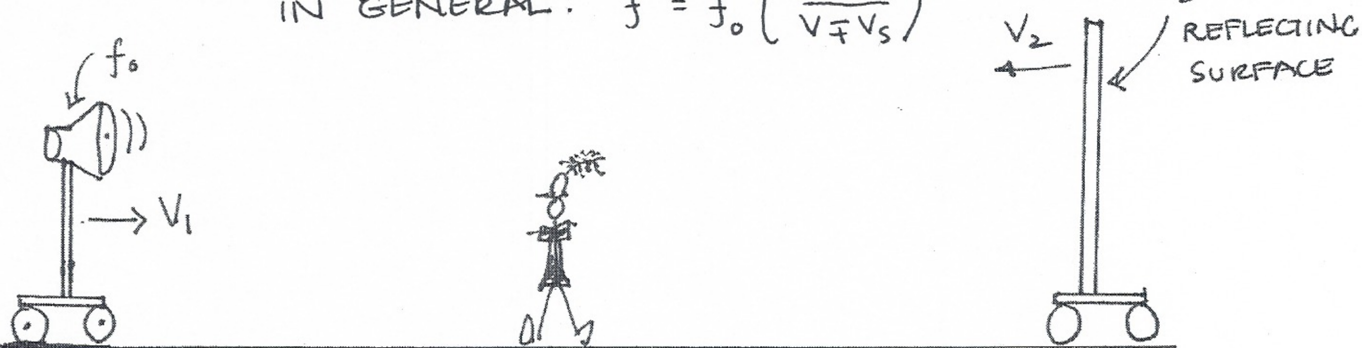
Physics 4C – Spring 2018 Name $\underline{\text{SOLUTIONS}}$

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. A source of sound waves of frequency f_o moves to the right (in the positive x-direction) with speed V_1 relative to the ground. To the right is a sound reflecting surface moving to the left (in the negative x-direction) with speed V_2. Let the speed of sound in air be V. A stationary listener is standing between the source and the moving reflecting surface. **What is the beat frequency, f_b, heard by the stationary listener?** (Your answer should be in terms of f_o, V, V_1, and V_2)

IN GENERAL: $f' = f_o\left(\frac{V \pm V_L}{V \mp V_S}\right)$



shifted sound source → Listener

$$f' = f_o\left(\frac{V \pm V_L}{V \mp V_S}\right) \quad V_L = 0 \text{ (AT REST)},\ V_S = V_1,\ (-)\text{ app.}$$

$$f' = f_o\left(\frac{V}{V - V_1}\right)$$

Sound from source → wall

$$f'' = f_o\left(\frac{V \pm V_L}{V \mp V_S}\right) \quad V_S = V_1\ (-),\ V_L = V_2\ (+)$$

$$f'' = f_o\left(\frac{V + V_2}{V - V_1}\right)$$

This is the frequency reflected. Now the wall acts like a moving source

Sound from wall → listener

$$f''' = f''\left(\frac{V \pm V_L}{V \mp V_S}\right) \quad V_L = 0,\ V_S = V_2\ (-)$$

$$f''' = f''\left(\frac{V}{V - V_2}\right)$$

$$f''' = f_o\left(\frac{V + V_2}{V - V_1}\right)\left(\frac{V}{V - V_2}\right)$$

$$f_b = |\Delta f|$$

$$f_b = f''' - f' \quad \{f''' > f'$$

$$f_b = f_o\left[\frac{(V + V_2)V}{(V - V_1)(V - V_2)} - \frac{V}{V - V_1}\right]$$

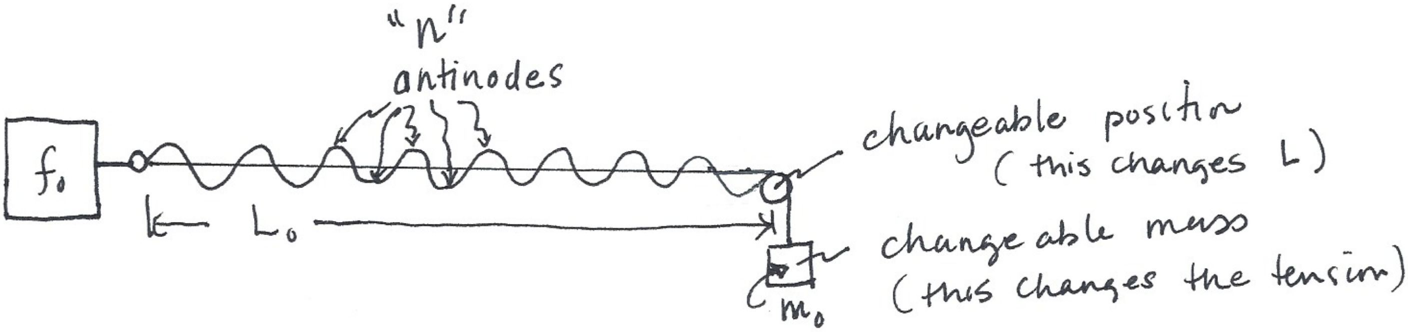
$$f_b = f_o\left[\frac{V^2 + VV_2 - [V(V - V_2)]}{(V - V_1)(V - V_2)}\right]$$

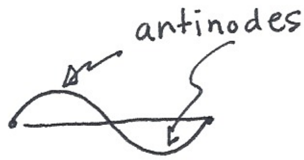
$$f_b = f_o\left[\frac{V^2 + V_2V - V^2 + V_2V}{(V - V_1)(V - V_2)}\right]$$

$$\boxed{f_b = f_o\left(\frac{2VV_2}{(V - V_1)(V - V_2)}\right)}$$

YIKES!

2. A standing wave is set up in a string of variable length and tension by a vibrating source of variable frequency. Both ends of the string are fixed and μ, the mass per unit length, is constant. Originally, it is observed that frequency f_o under tension F_{to}, with length L_o, n antinodes are set up in the string. If the frequency is tripled, $f' = 3f_o$, the length of the string is halved, $L' = \frac{1}{2} L_o$, and the number of antinodes is doubled, $n' = 2n$, **by what factor must the force of tension, F_t, change?** (Your answer should be a number.)





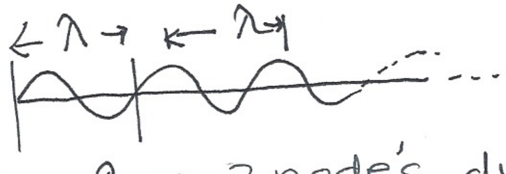
$$v_o = \sqrt{\frac{F_{To}}{\mu}} = f_o \lambda_o$$

$$v' = \sqrt{\frac{F_T'}{\mu}} = f' \lambda'$$

$$F_{To} = f_o^2 \lambda_o^2 \mu \xleftrightarrow{\text{Compare}} F_T' = f'^2 \lambda'^2 \mu$$

$$\frac{F_T'}{F_{To}} = \frac{(3 f_o)^2 \left(\frac{1}{4}\lambda_o\right)^2 \cancel{\mu}}{\cancel{f_o^2} \cancel{\lambda_o^2} \cancel{\mu}}$$

but what is λ?



each $\lambda \rightarrow$ 2 node's distance

also! $\lambda \rightarrow$ 2 × antinode distance

$$\boxed{\frac{F_T'}{F_{To}} = \frac{9}{16}}$$

$$\frac{\lambda}{2} = \frac{L}{n}$$

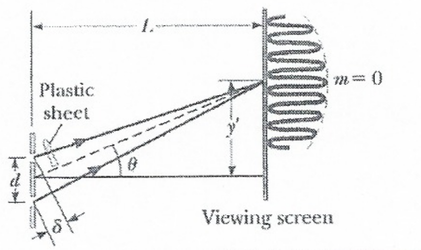
$$\lambda' = \frac{2L'}{n'}$$

$$\lambda_o = \frac{2L_o}{n}$$

$$\lambda' = \frac{2\left(\frac{1}{2} L_o\right)}{2n} = \frac{1}{4}\left(\frac{2L_o}{n}\right)$$

$$\lambda' = \frac{1}{4}\lambda_o$$

4. A double slit of separation, d, is illuminated with coherent light of wavelength λ. The distance from the slit to the screen is L. A sheet of transparent plastic with an index of refraction n and thickness t is placed over the upper slit. As a result, the central maximum of the interference pattern moves upward as shown. **Find y'**, the distance on the screen the central maximum moves. (Your answer should be in terms of L, t, n and d)

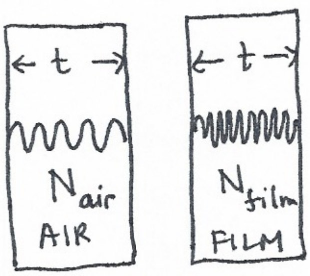


The change in the number of waves in the space t is what causes the interference pattern to move upward.

$$t = N_{air}\,\lambda_{air}$$

$$t = N_{fiem}\,\lambda_{film}$$

$$t = N_{fiem}\,\frac{\lambda}{n}$$



$N_{air} \Rightarrow$ # of waves in air of thickness t

$N_{fiem} \Rightarrow$ # of wave in fiem of thickness t.

The condition for constructive interference from 2 slits is usually $d\sin\theta = m\lambda$

Here $m = 0$!

Now!

$$d\sin\theta = \delta = (\text{\# of extra waves due to fiem})\,\lambda$$

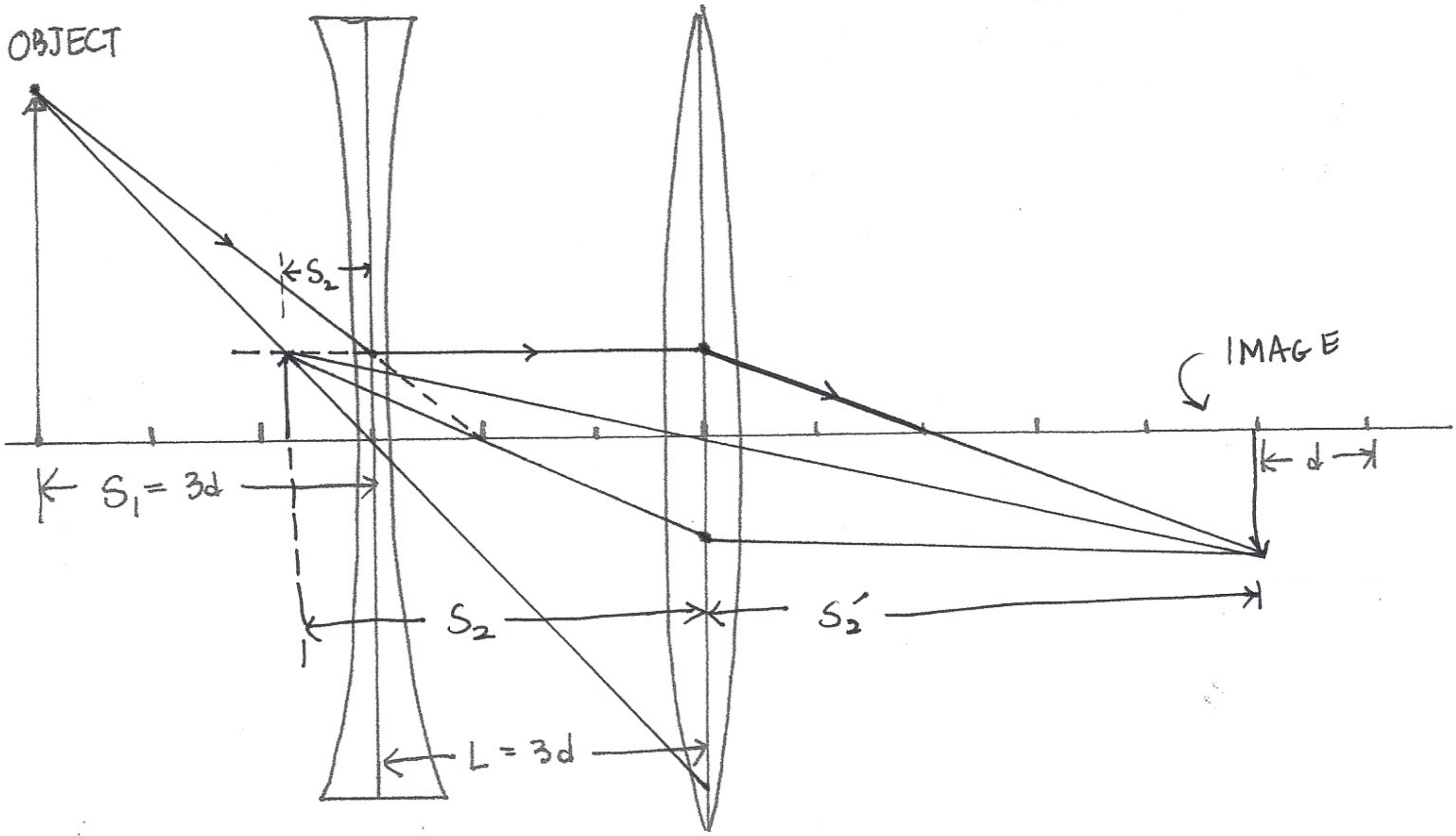
$$d\sin\theta = \left(N_{fiem} - N_{air}\right)\lambda$$

$$d\sin\theta = \left(\frac{tn}{\cancel{\lambda}} - \frac{t}{\cancel{\lambda}}\right)\cancel{\lambda}$$

$$\frac{y'}{\sqrt{L^2 + y'^2}} = \frac{t}{d}(n-1) \qquad \begin{cases} \sin\theta \ll 1 \\ L^2 \gg y^2 \end{cases}$$

$$\boxed{y' \approx \frac{Lt(n-1)}{d}}$$

3. A luminous object is placed a distance *3d* to the left of diverging lens of focal length $f_1 = -d$. A converging lens of focal length $f_2 = 2d$ is located a distance $L = 3d$ to the right of the first lens as shown in the drawing. **Find the position and magnification of the final image** for this two lens system. A ray diagram must accompany an algebraic solution for full credit. (Your answer should be in terms of *d* for the position and a number for the magnification.)



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

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

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

$$\frac{1}{S_1'} = \frac{-4}{3d}$$

$$S_1' = \frac{-3d}{4}$$

$$S_2 = L - S_1'$$

$$S_2 = 3d - \frac{-3d}{4}$$

$$S_2 = \frac{12d}{4} + \frac{3d}{4} = \frac{15d}{4}$$

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

$$\frac{1}{S_2'} = \frac{1}{2d} - \frac{1}{\frac{15d}{4}}$$

$$\frac{1}{S_2'} = \frac{15}{30d} - \frac{8}{30d}$$

$$\frac{1}{S_2'} = \frac{7}{30d}$$

$$\boxed{S_2' = \frac{30d}{7}}$$ from lens 2

$$M = m_1 m_2$$

$$\boxed{M = -\frac{S_1'}{S_1} \cdot -\frac{S_2'}{S_2} = +\frac{\left(\frac{\cancel{3d}}{4}\right)}{\cancel{3d}} \cdot -\frac{\left(\frac{\cancel{30d}^{\,2}}{7}\right)}{\frac{\cancel{15d}}{\cancel{4}}} = \frac{-2}{7}}$$