Physics 121 - Assignment #1

Include your name, Student ID number, T.A. name, and tutorial section number (e.g. D108) on the first page of your assignment.

Show all your work for full credit.

Do the following problems from *Physics for Scientists and Engineers Second Edition - A Strategic Approach* by Randall Knight.

1. 20.26

2. 20.40

3. 20.48

4. 20.50

5. 21.24

6. 21.50

7. 21.72

20.26 (a)The speed of light in a material is given by Equation 20.29 in your text:

$$n = \frac{c}{v_{mat}} \rightarrow v_{mat} = \frac{c}{n}$$

The refractive index is also

$$n = \frac{\lambda_{vac}}{\lambda_{mat}} = \frac{670nm}{420nm} = 1.60$$

Plugging this into the first equation above

$$v_{mat} = \frac{3.00 \times 10^8 m/s}{1.60} = 1.88 \times 10^8 m/s$$

b) The frequency is

$$f = \frac{v_{mat}}{\lambda_{mat}} = \frac{1.88 \times 10^8 m/s}{420nm} = 4.48 \times 10^{14} Hz$$

20.40 The function D(x,t) represents a pulse that travels in the positive x-direction without changing shape.

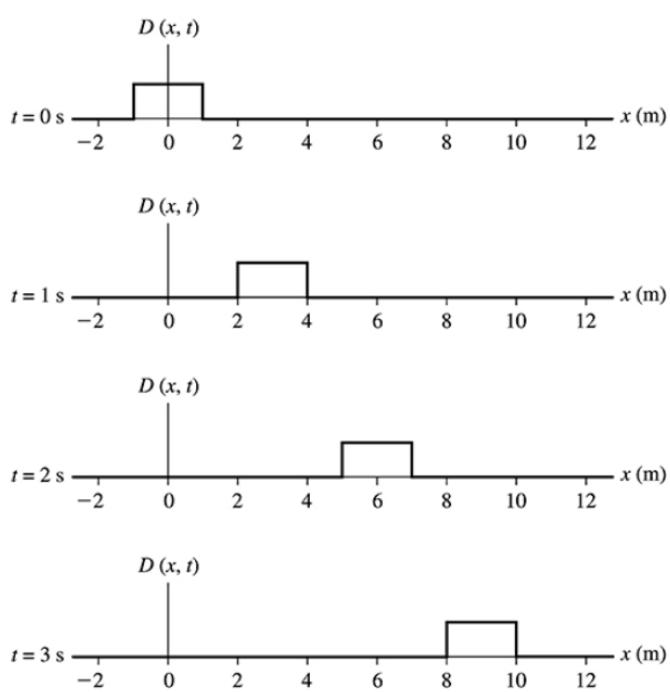
As an example, consider $t = 1s$, where is that graph equal 0? The equation for $D(x,t) = 0$ is

$$|x - 3t| > 1$$

The absolute value sign means I have 2 solutions:

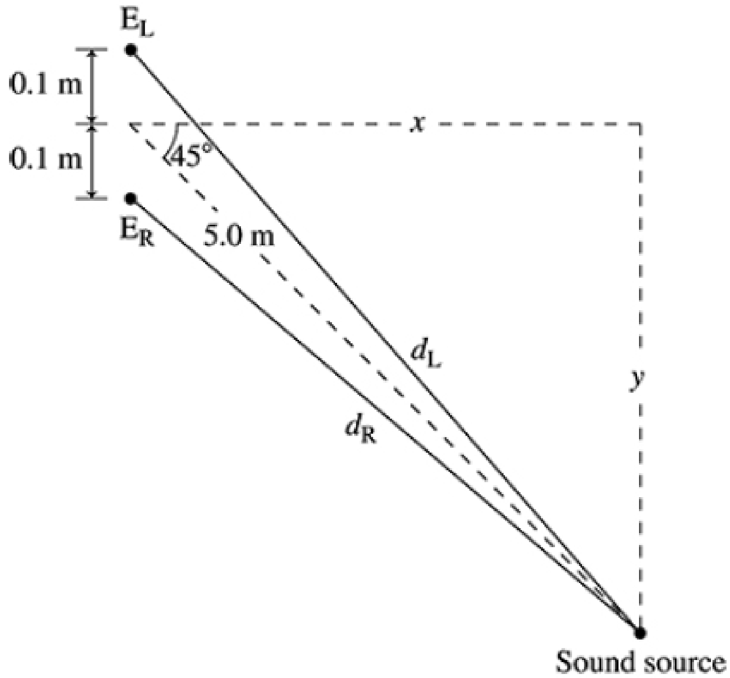
$$\begin{aligned} x - 3 > 1 &\quad \rightarrow \quad x > 4 \\ -x + 3 > 1 &\quad \rightarrow \quad -x > -2 \rightarrow x < 2 \end{aligned}$$

Everywhere else, the displacement is 1cm. The for graphs are drawn below.



b) The leading edge of the pulse moves forward 3m each second. Thus, the wave speed is 3m/s.
c) $|x - 3t|$ is a function of the form D(x-vt), so the pulse moves to the right at 3m/s.

20.48 Assume the sound is traveling through air at room temperature.



We know the speed of sound in rooom-temperature air is 343m/s. So, all we need is to calculate the path difference between the waves traveling to the left and right ears. OK, so what is the distance from the source to the left ear (E_L)?

$$\begin{aligned} d_L &= \sqrt{x^2 + (y + 0.1m)^2} \\ &= \sqrt{(5.0m \cos 45^\circ)^2 + (5.0m \sin 45^\circ + 0.1m)^2} = 5.0712m \end{aligned}$$

We can do a similar calculation for the right ear, yielding 4.9298m. Therefore the difference is

$$d_L - d_R = \Delta d = 0.1414m$$

Using the known sound speed, we can turn this into a time difference

$$\Delta t = \frac{\Delta d}{343m/s} = \frac{0.1414m}{343m} = 410\mu s$$

20.50 Assume water and air at room temperature ($20^\circ C$) for which the speed of sound is 343m/s in air and 1480m/s in water.
Firstly, we know that when a wave changes medium the frequency does not change. Therefore the first question is easy:

$$\frac{f_{water}}{f_{air}} = 1$$

Now, what about the wave speed? Well, we know that already too

$$\frac{v_{water}}{v_{air}} = \frac{1480m/s}{343m/s} = 4.31m/s$$

Finally, what is the ratio of the wavelengths? For that let's do a couple of extra steps and actually calculate the wavelength in each medium:

$$\begin{aligned} \lambda_{air} &= \frac{343m/s}{256Hz} = 1.340m \\ \lambda_{water} &= \frac{1480m/s}{256Hz} = 5.781m \end{aligned}$$

The ratio of these is clearly just 4.31, since that is the known ratio of the speeds in the numerators above. So, again the answer is 4.31.

21.24 Reflection is maximized if the two reflected waves interfere constructively. The film thickness which causes constructive interference is given by equation 21.32 in your text:

$$\lambda_c = \frac{2nd}{m}$$

where d is the thickness we wish to calculate, n is the index of refraction of the film, λ_c is the wavelength for constructive interference and $m = 1$ will give us the thinnest film. So, rearranging we get

$$d = \frac{\lambda_c m}{2n} = \frac{500 \times 10^{-9}m(1)}{(2)(1.25)} = 200nm$$

21.50 Particles of the medium at the nodes of a standing wave have zero displacement. The cork dust settles at the nodes of the sound waves. The separation between the centers of two adjacent piles is $\lambda/2$. Therefore

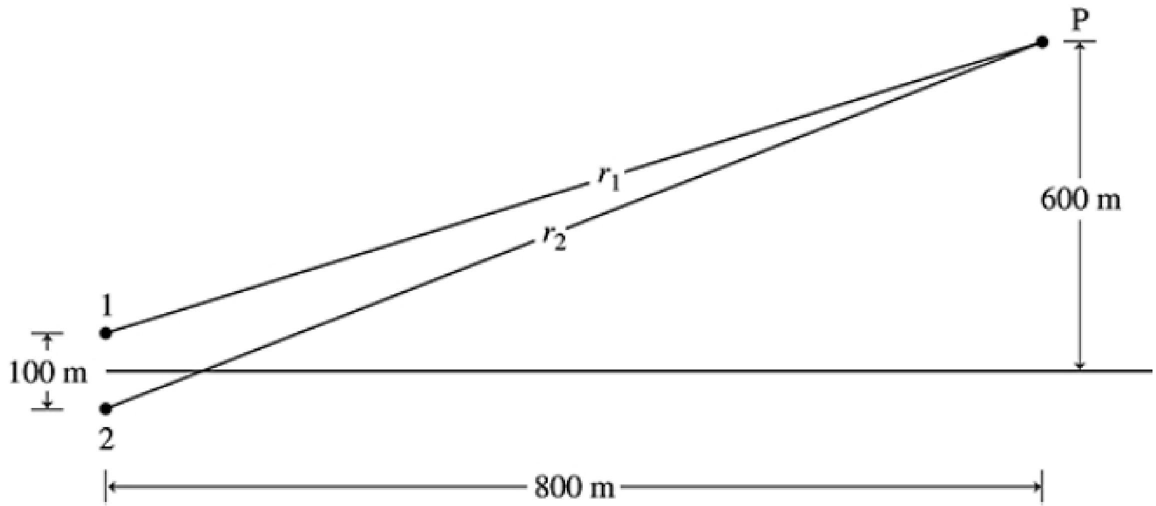
$$\frac{123cm}{3} = \frac{\lambda}{2} \rightarrow \lambda = 82cm$$

We know that the piston is driven at a frequency of 400Hz. Therefore, the speed of sound in oxygen is

$$v = f\lambda = (400Hz)(0.82m) = 328m/s$$

Which is pretty close to the speed of sound in air, which is a mixture dominated by nitrogen but with a significant oxygen component.

21.72 The two antennas are sources of in-phase waves. the overlap of these waves causes interference.



The phase difference between the two waves at point P is given by

$$\Delta\phi = 2\pi \frac{\Delta r}{\lambda} + \Delta\phi_0$$

The sources are identical, so $\Delta\phi_0 = 0$. The wavelength of the radio wave is easy to calculate

$$\lambda = \frac{c}{f} = \frac{3.0 \times 10^8 m/s}{3.0 \times 10^6 m} = 100m$$

We do need to calculate the Δr:

$$\Delta r = \sqrt{(800m)^2 + (650m)^2} - \sqrt{(800m)^2 + (550m)^2} = 59.96m$$

Now we have everything we need in order to calculate the phase difference:

$$\Delta\phi = 2\pi \left(\frac{59.96m}{100m}\right) + 0rad = 1.2\pi \ rad$$

b) Somewhere in between. Constructive would be an even number multiplied by π $(2\pi, 4\pi, 6\pi)$, destructive would be an odd number multiplied by π $(\pi, 3\pi, 5\pi, \ldots)$. This is in-between.
c) As you walk further north the phase difference will grow. It will go from something close to 1π to something closer and closer to 2π. So, you begin to walk closer to complete constructive interference and the strength will increase.