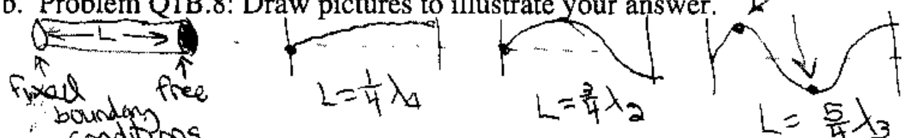
H133: 1094 Session 1 SOLUTIONS

Write your name and answers on this sheet and hand it in at the end.

There are a variety of activities today; watch the time and try to get through them all. Work with others at your table on these activities. Argue about the answers but work efficiently!

1. Q1: Group Problems [15 min.]

a. Introduce yourself to the other students at your table.
b. Problem Q1B.8: Draw pictures to illustrate your answer.

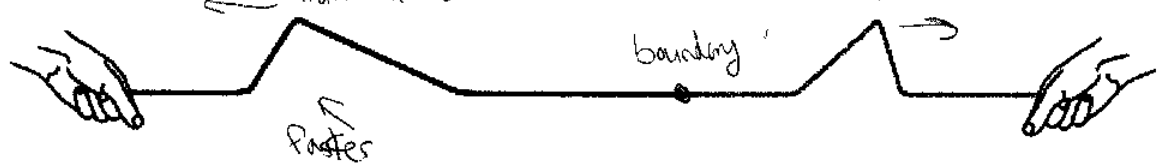


So $\lambda_3 = \frac{1}{5}\lambda_1$ but $v = \lambda f$ is the same, so $f_5 = 5 \times f_1 = 5 \times 230\,Hz = 1150\,Hz$

c. Problem Q1S.5 (Note: The pitch of a sound you hear is determined by its frequency):
The resonant frequencies in your sinuses are higher if you mix helium with air since $V_{He} \simeq 3V_{air}$ and $\lambda f = v$. So higher frequencies are emphasized, which is heard as higher pitch.

d. Hint: you might find the animated images of colliding and reflecting pulses on the H133 webpage of use!

The diagram below represents a snapshot of two springs at an instant *after* a pulse has reached the boundary between them.



a. **On the diagram, clearly label which spring has the *larger* wave speed. Explain how you could tell from the diagram.**
The wave on the left has gotten further from the boundary ⇒ faster.

b. **Is the reflection at the boundary between the springs more like reflection from a fixed end or a free end? Explain how you can tell from the diagram.**
Like a free end, because the pulses are on the same side (not inverted)

c. **On the diagram, label which pulse is the *reflected* pulse and which is the *transmitted* pulse. Explain your reasoning.**
Greater speed on left means "lighter" spring (lower μ). So pulse starts from right in order that it is reflected upright ("heavier" spring means that the boundary is more like a free end).

2. Fourier Transforms and Guitar Physics [15 min.]

Start up the PhET applet "Fourier: Making Waves" (Start->Programs->PhET, choose "Sound & Waves" from the left menu, and click once on the Fourier icon).

- You can set the amplitudes of sine wave to add together by dragging the bars with the mouse or changing the numbers under A1, A2, etc. The "Sum" graph shows the net result. Try some different amplitudes to get a feel how the waves combine.

- Now reset A1 = 1 and figure out the coefficients needed to build up a square wave according to equation (Q1.14). What values did you set for A2 and A3? A2 = 0.0
  A3 = 0.33

  The Fourier transform theorem says that these coefficients are unique! You only have low frequencies available; what parts of the square wave are not reproduced?  ← the corners (sharp parts) are not reproduced.
- Try the "Wave Game" (middle tab). Start at Level 1, where you have one amplitude to adjust. Then try Level 4. (And then move on!)

The sound from a plucked guitar string results from a superposition of the fundamental vibration and various harmonics. The relative weighting of these vibrations determines the tonal "color" of the note, and is fixed by how you pluck the string. *Support your answers to the following questions with an observation from a demo in class, a Q1 discussion or homework problem, or the PhET simulation.*

a. The strings on a guitar are all the same length. Why do they play different notes?
   The length determines the fundamental wavelength. But the note corresponds to the frequency, which is $f_1 = v/\lambda_1$. The speed v varies for the strings because their mass per length (μ) (and possibly tension F_T) differ. [See Q1S.10]

b. If you want a sound with more high-frequency harmonics, should you pluck the string so that it initially has a sharp or rounded bend? Should you pluck it in the middle or toward one end?
   To make a sharper square wave required more high harmonics, so plucking with sharp bend will excite more high frequency harmonics.
   If you pluck in the middle only half the harmonics (even or symmetric about middle) will be excited, so pluck toward the end.

c. Invent a way to start a string vibrating at *only* the fundamental frequency.
   - Start the string initially in precisely the shape of a half-cycle of a sinewave.
   - Use a tuning fork at the fundamental frequency to excite the string by resonance (they could be "coupled" by air or more directly).

3. Q2: Wave Interferenece and Diffraction [15 min.]

Start up the "Wave Interference" PhET applet (also under "Sound & Waves") and switch to the "Light" tab. The simulation shows a light wave. Click on "Show Screen" and "Intensity Graph". You have control of the wavelength and amplitude of the wave, and of one or two slits.

a. With No Barrier, what does the intensity graph show?
   Uniform intensity.

b. Now select "One Slit". Compare the simulation to Figures Q2.1 and Figure Q2.10. What is the width of the intensity plot? Predict what will happen if you decrease the wavelength. What actually happens if you change to purple light? Diffraction minimum at $\theta_{1d} = \sin^{-1}\frac{\lambda}{a} \approx \frac{\lambda}{a}$ so decreasing λ decreases the angle ⇒ width decreases. And it does! Note that the effect is not really large because the wave length difference is less that a factor of 2.

c. Now switch to "Two Slits" and answer two-minute problem Q2T.2 using your observations of the applet (i.e., play with the controls!). Let h be the distance between adjacent bright spots. ⇒ $h \approx \frac{\lambda L}{d}$
   a) $\lambda\uparrow$ h (A)   c) I↑ h same (C)   e) L↑ h↑
   b) d↑ h↓ (B)   d) width↑ h same (C)   f) n↑ h↑ slightly because $\sin\theta \lesssim \theta$

d. At Prof. Furnstahl's house, his small stereo speakers ("tweeters") are carefully positioned but the big subwoofer is hidden behind the couch. How can he get away with that? "Slit size" a is roughly speaker size.
   For tweeter, high frequency waves means $\lambda \ll a$ ⇒ not much diffraction spreading.
   For the subwoofer, $\lambda > a$, so spreads equally in all directions.