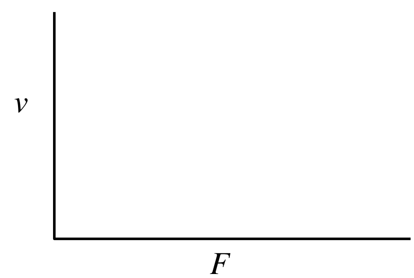
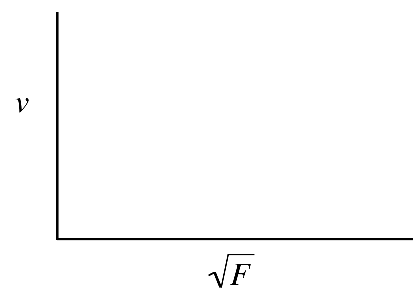
Lab B. Waves

Pre-Lab Assignment

1. The theoretical speed v of a transverse wave in a flexible cord of length density (mass per unit length) μ under tension F is $v = \sqrt{F/\mu}$. Suppose a particular cord does not elongate under tension. If, in an experiment, you pull the cord to different tensions F and measure the speed v of transverse waves in the cord at those different tensions, what should (theoretically) a graph of v vs. F look like? A graph of v vs. $\sqrt{F}$? Sketch both predictions in the axes provided.





2. Suppose that the cord does elongate under tension, like a bungee cord. How should length density μ change as tension F increases?

3. Qualitatively, how would elongation under tension affect the appearance of graphs of v vs. F or v vs. $\sqrt{F}$?

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MECHANICAL WAVES

Problem

- How can we measure the velocity of a wave?
- How are the wavelength, period, and speed of a wave related?
- What types of behavior do waves exhibit?

Equipment

electronic frequency generator, vibrator, elastic cord, hanging weight for tension, table-mounted pulley

Apparatus

In this lab, you a mechanical vibrator, frequency generator, stretchable string, clamp, pulley, and hanging weights, as shown schematically in Figure 1. This system will be used to generate standing waves on the string.

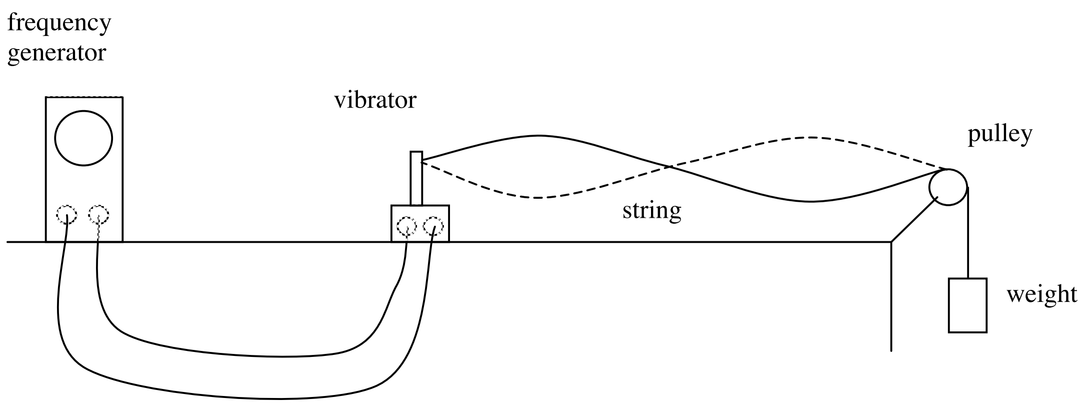

Figure 1. Diagram of a mechanical vibrator and string.

Background

Consider what happens when you toss a pebble into a still pond. The pebble disturbs the surface of the water, creating ripples. Picture the pattern of the ripples. Suppose a leaf is floating on the water's surface some distance away from the spot where you threw in the pebble. After the stone is tossed into the pond, the leaf bobs up and down as the ripples pass the leaf's position. Why did the leaf move up and down? How is this example different from the case of a leaf that is pushed down a river by flowing water?

A wave is a propagation of energy. Electromagnetic waves (light, radio, etc.) can propagate through vacuum; other types of waves need a medium to pass through. The wave is a disturbance in that medium.

Any wave shape that repeats is called periodic. The distance between successive crests, successive troughs, or any other pair of identical points on the wave is called the *wavelength*, λ. The maximum displacement of any point from the equilibrium position is called the wave *amplitude*, A.

The number of complete waves that pass a single position in a unit of time, such as a second, is the wave *frequency*, *f*. The time a complete cycle of a wave takes to pass that position is the wave *period*, *T*. The period is related to the frequency by $T = 1/f$. The speed at which the wave travels through its medium is its *propagation speed*.

Waves may be either transverse, longitudinal, or a combination. In a transverse wave, the motion of individual points in the medium is perpendicular to the direction of propagation of the wave (i.e., up-down or left-right as the wave moves forward). In a longitudinal wave, the individual points move parallel to the direction of propagation (i.e., forward-backward as the wave moves forward). Instead of having crests and troughs, longitudinal waves have regions of compression and rarefaction. Many waves in nature, such as ocean waves, are complex combinations of these two limiting types.

INVESTIGATION: WAVELENGTH AND FREQUENCY OF A STANDING WAVE

You will use the mechanical vibrator to move one end of an elastic string up and down. The string is held under tension by a weight on a pulley as shown in Figure 1. The frequency at which the vibrator oscillates is controlled electronically by the frequency generator. The wavelength of the standing waves can be measured by using a ruler or meter stick.

1. The cord may have knots in it when you receive it. Untie the knots and measure the length and mass of the slack cord. Calculate its length density μ.

   Length _________ m   Mass _______ kg   Length density _________ kg/m

2. Tie a knot in one end of the cord to anchor the cord between the prongs of the reciprocating rod of the vibrator. Run the cord form the vibrator over the pulley. Tie a loop in the cord beyond the pulley to hook the hanging weight.

3. While the cord is still slack, tie two short lengths of yarn to the cord a known distance apart. Record the distance. Hook the weight on the cord, making sure that the hanging weight does not touch the ground. Now that the cord is stretched, measure the distance between the yarn markers. Determine and record the length density of the stretched cord.

4. Turn on the frequency generator. Experiment with frequencies ranging from a few hertz to a few hundred hertz. Does any frequency create steady standing waves on the string?

5. Find a frequency at which a steady standing wave develops. Record this frequency in Table 1.

6. Measure the wavelength of the standing wave with a meter stick. Note that the distance between adjacent nodes (stationary positions) equals *half* a wavelength. Also keep in mind that the vibrator is not located exactly at a node.

7. Change the frequency to create a different standing wave. Repeat steps 5 and 6 for the new standing wave.

8. Repeat steps 5 and 6 again with two more frequencies, for a total of four sets of data. Try to get a wide range of frequencies and wavelengths!

9. Repeat step 3–8 with three different tensions in the cord, for a total of four different resonant frequencies at each of four different tensions.

Table 1. Standing Waves in a String

Tension _______ N; Slack length ______ m; Stretched length ________ m

Length density _______ kg/m

Frequency (Hz)	Wavelength (m)	Speed (m/s)	$\sqrt{F/\mu}$

Tension _______ N; Slack length ______ m; Stretched length ________ m

Length density _______ kg/m

Frequency (Hz)	Wavelength (m)	Speed (m/s)	$\sqrt{F/\mu}$

Tension _______ N; Slack length ______ m; Stretched length ________ m

Length density _______ kg/m

Frequency (Hz)	Wavelength (m)	Speed (m/s)	$\sqrt{F/\mu}$

Tension _______ N; Slack length ______ m; Stretched length ________ m

Length density _______ kg/m

Frequency (Hz)	Wavelength (m)	Speed (m/s)	$\sqrt{F/\mu}$

10. Calculate the speed (speed = distance/time = wavelength/period = wavelength · frequency) of each standing wave. Record the values in Table 1.

11. The theoretical speed of a wave in a string is $v = \sqrt{F/\mu}$, where v is wave speed, F is tension, and μ is length density.

(a) Verify the units in this formula. Show your work.

(b) Compare v to $\sqrt{F/\mu}$ for the different waves you observed. Does the formula apply?

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Post-lab Assignment

1. For some types of waves, the speed of the wave is different for different frequencies. This phenomenon is known as *dispersion*. Do the transverse waves in the stretched cord show dispersion? Justify your answer.

2. Using a spreadsheet or the Vernier software, make a plot of v vs. $\sqrt{F}$ for the transverse string waves. Fit it with a $y = Ax$ curve. Is the fit fairly good? Explain how it meets or does not meet your standard of a good fit.

3. Now plot v vs. $\sqrt{F/\mu}$ using the length densities μ you determined for each F. Fit the plot with a $y = Ax$ curve. Is the fit any better or worse than the fit to v vs. $\sqrt{F}$?