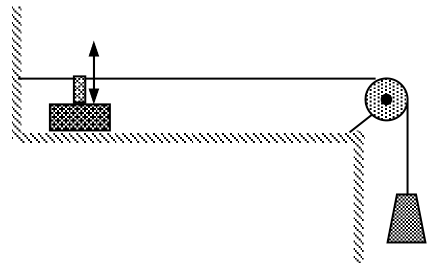
String Waves

Introduction: In this laboratory you will investigate properties of string waves.

Preliminary Questions:

1. Consider a string of density μ fixed at one end and with a mass M attached to the other end as shown in the figure. Suppose a vibrating device wiggles the string at a point near its fixed end. Explain qualitatively what happens to the waves generated by the device. What is the tension in the string?



2. Consider two traveling waves combining along the string: $y_R = A\cos[kx - \omega t]$ and $y_L = -A\cos[kx + \omega t + \varphi]$. Explain what each of these waves represent and find the overall wave that results from their combination. What principle is utilized to determine the combined wave and under what circumstances is it valid for string waves?

3. Assume the distance from the fixed end of the string to the pulley is L. For the expression you found for the net wave $y(x,t)$ in part **2** above explain why $y(0, t) = 0 = y(L, t)$. Use this condition to determine the phase angle φ and the allowed wave numbers k. What wavelengths and frequencies are associated with these wave numbers?

4. The allowed frequencies you found above are called the "normal modes" of vibration for the system. In the space below sketch the shapes of the vibrating string corresponding to the first three modes. Can you state in words a simple rule for how the wavelength of each mode is related to the length of the string?

Measurements and Observations:

1. Obtain some string (1.5m should be adequate). By taking the appropriate measurements determine the density of the string. In the space below explain your method and quote your value for μ along with its uncertainty.

2. Set up the string and oscillator as shown on the previous page. Measure the length L from the fixed end of the string to its point of contact with the pulley. Using L and your value for μ, *predict* the frequency of the lowest mode when a weight of mass 200g, 400g, 600g, 800g, is hung from the string.

3. Adjust the frequency of the oscillator so that the string vibrates maximally with *one* loop. Record the frequency in the table below and then repeat for masses 400, 600, 800g. This lowest vibrational *mode* is called the *Fundamental Harmonic* of the string. Use the split window of the chart to record your prediction and observation of the frequency.

Mass (g)				
Freq. (Hz)				

4. Hang a 250g mass from the cord's end and determine the frequency of the fundamental harmonic. Now move the oscillator so that the vibrating part of the string (between the oscillator and hanging mass) is 3/4, its original length and determine the string's fundamental frequency, repeat for string lengths 1/2, 1/4 its original length and record your results in the table below

Length (cm)				
Freq. (Hz)				

Q1: From your results how does the frequency of the fundamental mode appear to depend on the length of the string? Provide an explanation using your analysis from the previous page.

Q2: As we have mentioned in class the waveform that results on the string is the superposition of transmitted and reflected waves. In each of the cases above determine the wavelength of these waves and record them in the table below.

Wave Length (cm)				
Freq.(Hz)				

Q3: Using the fundamental result $\lambda f = v$, compare the speed of the waves traveling on the string for each of the above instances. Does it depend on the length of the string? How does it compare with the value one would expect for waves on a string of this tension and density?

5. Return the string to its largest length. If a 250 gram mass is hung from its end *predict* the first seven resonant frequencies of the string.

6. By gradually raising the frequency adjust the oscillator so that two, three,…seven, loops are present on the string and record the resonant frequency and wavelength for each mode. In the split box for frequency record your predicted and observed results for the resonant frequencies. For each frequency quote your uncertainty on the measurement.

Loops							
Freq.							
Wave length							

Q1: How do your observations compare with your predictions? Which of the three quantities λ, *f*, or v is constant for all of the above data?

Resonance:

1. With the string at its maximum length and the 250g mass connected to its end tune the oscillator so that the string oscillates in its fundamental mode. Now measure several amplitudes of vibration for the fundamental mode for different driving frequencies *near* the resonant frequency. If possible attempt to measure four different frequencies on each side of the resonance and the corresponding amplitude of vibration.

Freq.								
Amplitude								

2. Repeat **1** for the second harmonic and list your results in the table below.

Freq.								
Amplitude								

3. For both modes *on graph paper* plot the square of the oscillation amplitude versus the angular driving frequency. Measure the full width at half maximum Δω and compute the "quality factor" $Q = \omega_0/\Delta\omega$. Record your results for *Q* and Δω in the space below. How do the *Q* values for each mode compare? Staple your graph to this sheet when you submit it.