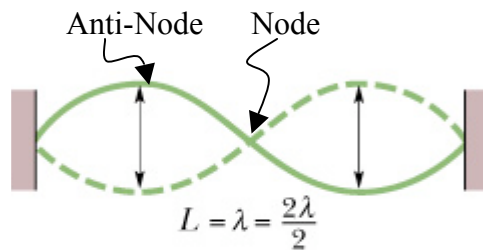
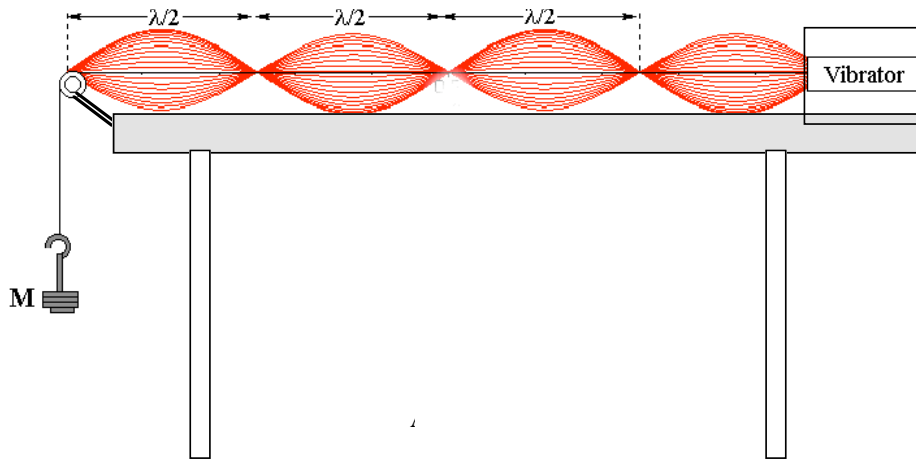
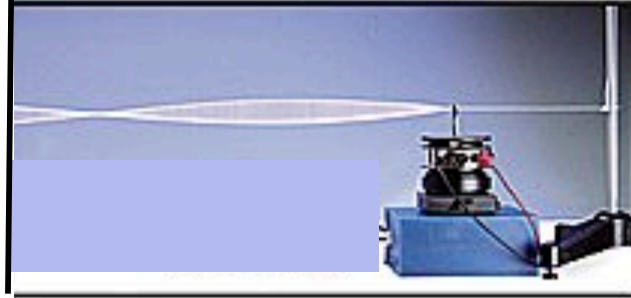


Waves on a String

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Purpose:

To study the properties of standing waves on a string by obtaining an experimental frequency value and comparing it to the driving frequency.



Equipment:

signal generator, string vibrator, set of weights, meter stick, digital balance, pulley, desk clamp, string (white/green, white/red, etc.), leads

Theory:

A fundamental equation of wave motion is $v = \lambda f$ (equation 1)
where v = velocity, f = frequency and λ = wavelength of the wave.

The velocity of a transverse wave traveling along a string is given by the equation

$$v = \sqrt{\frac{T}{\mu}} \quad (\text{equation 2})$$

where T is the tension in the string and μ is the mass per unit length of the string.

If one end of the string is held fixed (on a pulley) and the other end is attached to a vibrator so that its direction of vibration is perpendicular to the string. Proper adjustment of the string's frequency of vibration can produce stationary waves on the string, yielding an integral number of half wavelengths on the string. The distance between adjacent nodes is $\frac{\lambda}{2}$. Note that the *harmonic number* corresponds to the *number of anti-nodes*.

Procedure:

For purposes of error propagation, be sure to record your uncertainty in each measured value you record (e.g. string mass, length of string with known mass, distance from vibrator to pulley, hanging mass).

1. Measure and record the length (l) and the mass (m) of a piece of string (**green/white**) sufficiently long for the experiment. These values will be used to calculate μ , the mass per unit length, of the string. Contemplate whether the above measured length (l) will be the same length as from fixed end to fixed end of the string as measured in step .
2. Attach one end of the string to the vibrator and the other end over the pulley to the weight hanger (containing a total mass, M).
3. Plug the vibrator into the signal generator. If you need
4. Depress the signal generator button next to the picture of a "sinusoidal" wave function and depress the 100 Hz button.
5. Pull the *frequency adjust* knob of the signal generator out and turn it all of the way counterclockwise then **push it back in. Do not pull it out again for the remainder of the experiment.**
6. To adjust the frequency of the mechanical vibrator, turn the *frequency adjust* knob.

PART I:

7. Set the vibrator to 60 Hz.
8. While the string (**green/white**) is vibrating; adjust the tension (and **length**, if necessary, **keeping it as large as possible**) so that the string vibrates with one anti-node, i.e. the first harmonic. It will probably be necessary to do a rough calculation of the length necessary for a given tension, by using equations 1 and 2 along with the relationship between wavelength and string length (from fixed end to fixed end) for the first harmonic. Once you view the first harmonic, record the tension, the number of half-wavelengths and the length of the string from the pulley to the vibrator.
9. DO NOT ADJUST THE LENGTH of the string again until PART II. Adjust the tension to increase the number of anti-nodes by one and record the tension, the number of anti-nodes, and the length of the string from the pulley to the vibrator.
10. Repeat step 9 until the third harmonic is viewed. Record the tension, the number of anti-nodes, and the length of the string from the pulley to the vibrator.

PART II:

11. Now set the vibrator to 120 Hz (still using the **green/white** string) and repeat steps 9 & 10 above, however you only need to observe & take data for two consecutive harmonics.
12. Now use another string of different linear density (e.g. **red/white**) and repeat steps 9 & 10. View and take data on two consecutive harmonics. (NOTE: You will most likely be able to see only the 2nd, 3rd & maybe 4th harmonics if using the white/red string.)

Analysis:

1. Calculate the linear mass density, μ (mass per unit length) for all strings used in the experiment.
2. Calculate the tensions used for each run in *Part I* and *Part II*.
3. For *Part I*, calculate the frequencies of the 1st, 2nd and 3rd harmonics using equations 1 & 2 along with the relationship between wavelength and string length (from fixed end to fixed end) for each harmonic. Average them to get an experimental frequency for Part I. Compare the experimental frequency with the actual frequency of the signal generator (i.e. string vibrator).
4. For the 120 Hz Green/White string in *Part II*, calculate the frequencies of the two consecutive harmonics using equations 1 & 2 along with the relationship between wavelength and string length (from fixed end to fixed end) for each harmonic. Average them to get an experimental wave frequency and compare the experimental frequency with the actual frequency of the signal generator (i.e. string vibrator).
5. Apply step 4 (above) to the Red/White string

Question:

1. Does the speed of a wave on a string depend upon frequency? Why or why not? (Hint: Try calculating the wave speed for the 1st, 2nd and 3rd harmonics in *Part I*.) If not, what dictates the frequency of a wave on a string?