Physics III
Experiment I
Vibrating Strings

Purpose

To study standing waves on a vibrating string and to investigate the dependence of the wave length, nodal separation, and amplitude on the variables of the system.

Introduction

For our purposes, a string will be defined as a one dimensional system, capable of transverse deflection, which can support a fixed tension $\boldsymbol{T}$ and has a density per unit length $\boldsymbol{\rho}$. We will excite vibration in the string using an electrical oscillator and an electrically driven vibrator connected to one end of the string. The other end of the string will be constrained not to move, and tension will be maintained in the string using calibrated masses. Relations between the applied frequency $\boldsymbol{f}$, the wave length $\boldsymbol{\lambda}$, the tension, and the mass density will be explored experimentally. The phenomenon of resonance will also be explored.

Procedure

When a string under tension is vibrated from one end and fixed at the other there will be standing waves (the superposition of the incident and the reflected wave from the fixed end) established on the wave. For certain frequencies, called *resonant frequencies*, the oscillations of the string will attain large amplitude. Observations of the standing waves are easiest to do under resonance conditions, but so long as the vibrations have stable nodes (positions on the string where the amplitude of oscillation is zero) measurements of the half-wavelength (distance between adjacent nodes) can be performed. The wavelength will be measured as a function of applied frequency for different strings (ie string mass density) and tension. An oscilloscope will be used to measure the applied frequency. Mass densities for each string will be measured directly and compared to the value derived from wave measurements.

Suggested Problems

1) In principle, the waves on the string should have a dispersion relation:

$$f\lambda = v = \sqrt{\frac{T}{\rho}}$$

This means that a plot of $\boldsymbol{f}$ vs $\mathbf{1/\lambda}$ should produce a straight line with slope equal to the wave propagation speed $\boldsymbol{v}$**.** Observe the degree to which this is true.

Given a measured wave propagation speed and a known tension, the mass density of the string should be given by:

$$\rho = \frac{T}{v^2}$$

The validity of this relation can be verified for each string by directly measuring the mass of a fixed length of string and by comparing the density to the ratio of the tension to the square of the propagation speed. This relation can be checked further by changing the magnitude of the tension.

2) For musical instruments it is important that the resonance frequencies of the string be harmonically related. This means that

$$f_n = n * f_0$$

where

$$f_0 = \frac{v}{2L}$$

and L is the length of the vibrating string. Thus, the musical string has nodes at each end and has an integer number of half wave lengths on the string at resonance. This will normally be true for a string that is rigidly fixed at both ends. Because of the way that the string is excited and tensioned in this experiment the resonances may follow a different relation. Discover this relation experimentally and attempt to explain it.

3) Create a hybrid string by connecting two different strings. Under what conditions do you expect resonance? Check your theory.