PHYSICS 252 EXPERIMENT NO. 5
VIBRATION SPECTRUM OF ONE-DIMENTSIONAL WAVE

Introduction

In this experiment we study standing waves on a long rubber band stretched between fixed supports. These standing waves are analogous to the wave functions of a particle in an infinitely deep potential well.

If one end of a long rubber band is subjected to forced periodic vibrations, traveling waves will propagate down the rubber band with velocity

$$v = \sqrt{(T/\mu)} \qquad (1)$$

where T is the tension in the band and μ is the mass per unit (stretched) length of the rubber band. The wavelength λ is related to the frequency ν of the driving force and the velocity of propagation v as $\lambda = v/\nu$.

Waves reflecting off the far end of the rubber band interfere with incident waves, and for certain driving frequencies a stable pattern emerges, with fixed points of destructive interference (nodes) and constructive interference (anti-nodes). If the rubber band is very long, the wave is dissipated by friction before it reaches the far end, and no interference occurs. If this is not the case, then the wave can reflect back towards the initial point where it can again be reflected, etc.. For certain wavelengths the reflected wave will be in phase with the next incident wave, resulting in constructive interference. The condition for this to occur is

$$L = n\,\lambda/2, \qquad \text{with } n = 1, 2, 3, \ldots \ (\textit{integer}).$$

This condition ``quantizes" the system, so that only certain wavelengths (and thus only certain frequencies) can excite these ``normal modes" of the system (analogous to eigenvalues in energy).

Measurement

The rubber band is stretched over a pulley, and the tension T is provided by a weight. A set of scales is provided to be able to measure the weights and the mass of the rubber band, so you can calculate its linear mass density by measuring its *total* stretched length. (Note: this length will vary with the weight applied!) Start with the rubber band as long as possible (about 2 m). A small electric motor driven by a variable power supply produces the oscillatory driving force near one end of the rubber band. The frequency is measured by a photo-gate and counter.

1. Find the series of frequencies which produce standing waves and record all relevant experimental parameters. place the photo-gate so it will be interrupted by a tab on the shaft of the drive motor. Produce the lowest frequency and at least 5 sequential overtones. Make a plot of frequency versus $1/\lambda$.
2. Adjust the position of the end support to make the vibrating part of the rubber band shorter by 20 - 30%, and repeat the experiment. Add these data points to your graph.
3. Observe the standing waves on a rubber band stretched in a circular form. There is one setup for this at the front of the room. Observe and record the successive patterns and frequencies.

Analysis

1. How does the frequency of the lowest mode depend on the length L of the rubber band?
2. From your graph determine the velocity v of waves on the rubber band for the two sets of measurements. Compare with the value calculated from equation (1).
3. Explain the standing wave modes you observed on the circular rubber band, and comment on their frequency dependence. Discuss their analogy with wave functions in the Bohr atom.

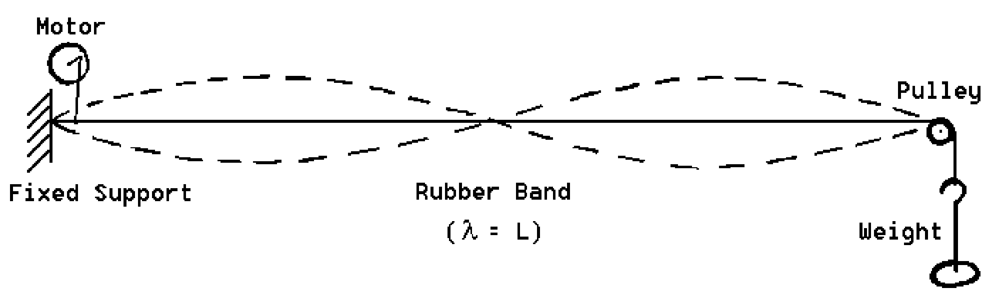

Figure 1: Standing wave (case $\lambda = L$) on a rubber band.

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