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# PHYSICS 133 SPRING 2006 EXPERIMENT NO. 8

## STANDING WAVES

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### Introduction

In this experiment we study standing waves on a long rubber band stretched between fixed supports. These standing waves are similar to those produced in a guitar string when it is plucked, except that in the present experiment, we will continuously drive them so that they will not die out.

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

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

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

Waves reflecting off the far end of the rubber band interfere with incident waves, and for certain driving frequencies a stable pattern emerges, characterized by fixed points of destructive interference (nodes) and constructive interference (anti-nodes). The condition for this to occur is

$$L = n \lambda/2, \text{ with } n = 1, 2, 3, \dots \text{ (integer)} \quad (2)$$

This tells us that only certain wavelengths (and thus only certain frequencies) can exist as stable patterns of excitation. These stable patterns are known as the “normal modes” of vibration of the system. We say that the system is “quantized.” [This happens all the time in the atomic world, described by quantum mechanics, where particles have wave properties.]

### Measurement

The rubber band is stretched over a pulley, and the tension  $T$  is provided by a weight. The *total* (not just the part between the supports) mass of the rubber band is recorded on a label on the small motor for each apparatus, so you can calculate the linear mass density by measuring the rubber band’s *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 period of the oscillations is determined by a photogate and an electronic timer, the operation of which your TA will explain.

If computers are available, use the “Precision Timer” program, choose “miscellaneous timing modes” from the main menu, and then choose “strobe timer.” This mode will measure the time from one interruption of the photogate to the next. When you start the measurement by pressing the “enter” key, a series of numbers will appear on the screen, each of them equal to the period  $T$  of the vibration. When 10 or 20 of these numbers have appeared, stop the program (by pressing “enter” again), go to “display table of data” and take the average of the displayed numbers (this is given at the bottom of the list of data). The reciprocal of the average will be the frequency of vibration in Hertz.

1. Find the series of frequencies which produce standing waves and record all relevant experimental parameters. Place the photogate so it will be interrupted by the tab on the shaft of the drive motor. Produce the lowest frequency and at least 7 sequential overtones. Make a plot of frequency versus  $1/\lambda$ .
2. Adjust the position of the motor support rod to make the vibrating part of the rubber band shorter by 20 - 30%, and repeat the experiment. Add these data points to your graph. Do these points fall on the same line as the points from step 1? Explain why they do or do not.
3. As time permits, repeat the above steps, using different weights to change the tension.

## 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).

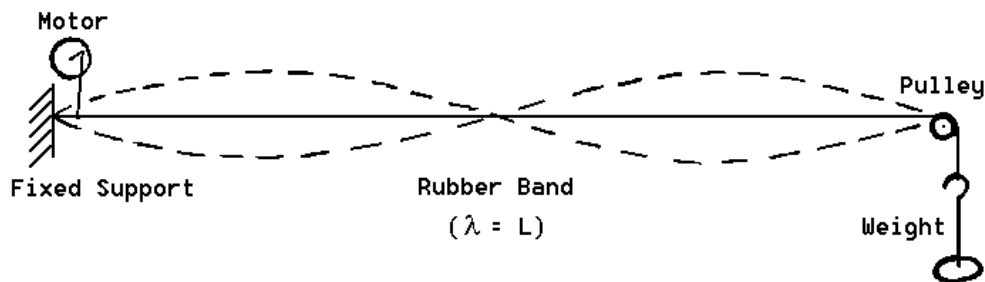


Figure 1: Standing wave (case  $\lambda = L$ ) on a rubber band. This corresponds to  $n=2$  in Eq. (2). It is the “second harmonic” or “first overtone.”