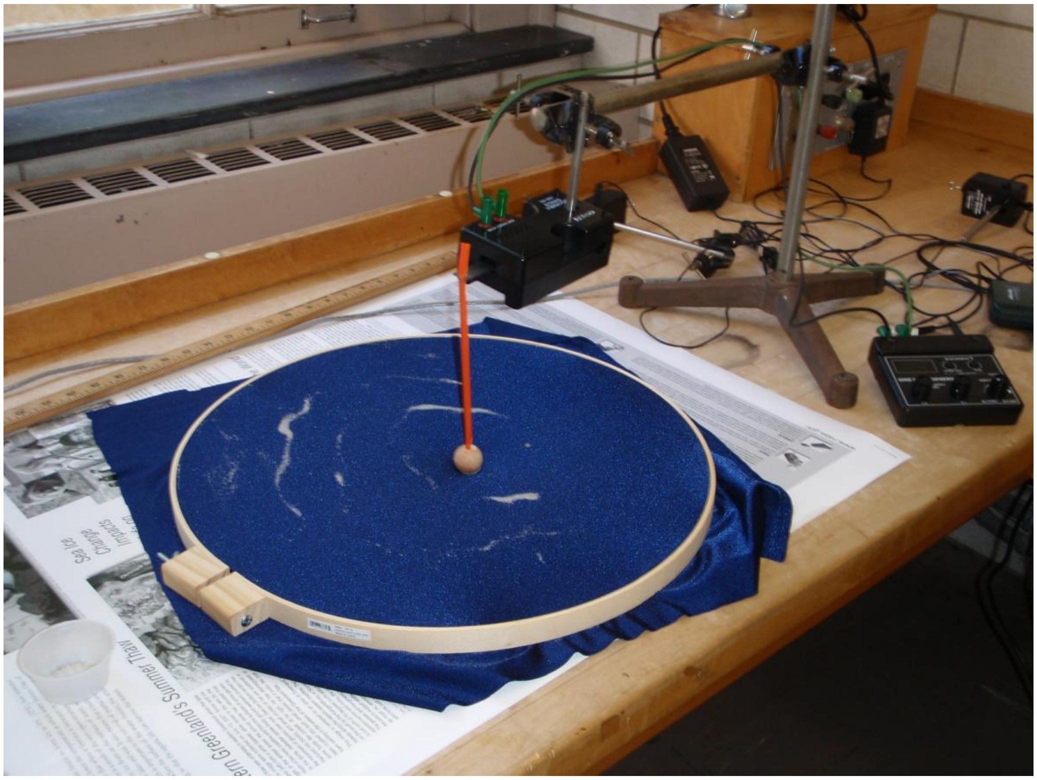
Waves on a Membrane PH1140



Overview

In this lab we study transverse standing waves on the two dimensional surface of an elastic cloth, termed the “membrane”, stretched over a wooden frame. Whereas waves on a string can travel in only one of two directions, waves on a surface can travel in any direction along the surface. On a string, a wave front is simply a point. But on a surface, wave fronts form lines and curves, and standing waves form a variety of geometrical patterns reflecting the symmetries of the surface boundaries (edges). The nodes of standing waves on a circular membrane form concentric rings. The next time you have a cup of tea, thump the table next to the cup and you will see the standing wave!

Water waves are a familiar form of surface waves, but where have you seen waves on a membrane? A flag flapping in the wind is an example of waves on a membrane. Drumheads and soap bubbles are other common examples of membranes, but their waves are not easily seen. Like a guitar string, the ratio of tension to mass is great, therefore wave speed is great. Traveling waves dart across the surface, and standing waves vibrate in a blur. We shall use sand to help us “see” the standing waves.

Setup

Stretch the cloth over the outer ring of the circular frame, taking care to stretch evenly in all directions. Insert the inner frame and tighten the wing nut to secure the membrane. Place the frame on the lab bench and attach the vibrator to the stand as shown in the figure. Connect the sine wave generator to the vibrator. Attach the plastic wand to the vibrator tongue, center the tip of the wand over the membrane, and bring the tip of the wand in contact with the membrane, allowing the tip to depress the center of the membrane slightly. Spread a pinch of sand over the surface of the membrane.

Procedure

Set the generator amplitude to minimum, turn on power and adjust the amplitude to create a standing wave on the membrane. The locations of the ring shaped nodes and anti-nodes of the standing wave are revealed by the sand, which collects at the nodes. Vary the frequency in the range of 50 to $200\ Hz$ to create standing waves of various wavelengths. Avoid excessive amplitudes, which may cause a miniature but messy sand storm.

1) Why does the sand collect at the nodes?

2) Record the frequency and measure the wavelength of the standing wave. Calculate the wave speed associated with the standing wave.

3) Using $m = 55\ g$ as the mass of the membrane, and diameter $d = 18\ in$, determine the tension F per unit length in the membrane.

Now repeat steps (2) and (3) for two other frequencies.

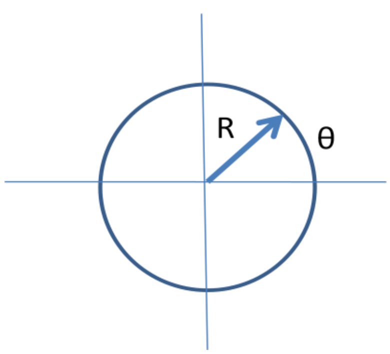
4) How does the mass of the sand affect the determination of tension?

You may have noticed various types of irregularities in the shapes of the nodes, which prevent the nodes from forming perfect rings. A number of physical features of the experimental setup contribute to the formation of these irregularities.

5) Sketch some of the irregularities.

6) Identify physical features of the setup and offer explanations of how these features cause the observed irregularities.

The sand reveals concentric ring-shaped nodes. The amplitude is said to have radial dependence, meaning the amplitude of the wave varies with radius R measured from the center of the membrane (see figure below). You may have noticed periodic variations in the shape of the node rings that have angular dependence, meaning the amplitude of the wave varies with angle θ.



7) Sketch the angular variations, and offer an explanation for the presence of these variations in the node rings.