VIBRATION OF PLATES & BARS

The objective of this experiment is:

- To observe the normal modes of a flat bar clamped at one end and free on the other and to observe the normal mode patterns of plates of different shapes using Chladni patterns.

APPARATUS: Function generator, linear amplifier, chladni plates.

INTRODUCTION

The equation of vibrational motion of plates involve fourth order spatial derivatives as discussed in lecture. Solution of the equation in one dimension as applied to a "long plate" (a bar) with the boundary condition that the bar is fixed at one end and free on the other end gives normal mode frequencies expressed as:

$$f_1 = \left(0.56\,\kappa/\lambda^2\right)\sqrt{Y/\rho}$$

$$f_2 = 6.27 f_1$$

$$f_3 = 17.55 f_1$$

etc.

where L = length of the bar
$\kappa = a/\sqrt{12}$ = is the radius of gyration
a = thickness of the bar
Y = Young's modulus
ρ = mass density.

In the case of aluminum, $\rho = 2.7 \times 10^3$ kg/m^3 and a typical (but can vary according to manufacturing process) value of Young's modulus is Y = 7.5 x 10^{10} N/m^2.

To solve for the normal modes of plates the fourth order equation must be solved in two dimensions. The solutions become very complicated for the free boundary condition at the perimeter of the plate. The Chladni patterns are very useful in visualizing the vibrational modes. When a normal mode is excited in the plate, small sand particles sprinkled onto the plate tend to collect at the nodal lines. These nodal line patterns were observed and studied by Chladni.

The sine wave output current of a function generator is connected to a mechanical vibrator. The vibration is induced by the Lorenz force between the current and a magnetic field.

Bars and plates to be tested can be attached to the vibrator by simply inserting the plug into the receptacle at the top. When removing plates, hold the receptacle to prevent it from coming out excessively.

Caution: If the vibrator is driven excessively, the amplifier will burn out.

On the function generator there are an amplitude control and two small "aux." out knobs. Begin by keeping Aux. knob at about 50% of maximum, but keep all other knobs turned to zero. On the audio amplifier increase the large "main" volume control cautiously.

Procedure:

I. Bar

Attach the long rectangular bar (about 50 cm length) aluminum plate to the vibrator. Measure the fundamental mode frequency of the longer side and then that of the shorter side. When you look for resonance in the longer side, you can hold the shorter side by hand to approximate the fixed boundary condition. Leave the other end free. When you look for modes in the shorted side, hold the longer side by hand. Compare the measured fundamental frequency of the longer side with the formula given above. The thickness is 1/16 inch. Measure the length with a ruler. Does the resonant frequency change according to the formula?

Look for higher harmonics and note the frequencies.

II. Plates

Change the set up slight to study the vibration of plates. There are several shapes available. The plate should be made horizontal to minimize falling sand particles .

Start with a square plate. Change the frequency slowly to look for normal modes by watching the nodal patterns develop on sprinkled sand grains. Sketch the Chladni patterns and note the corresponding normal frequency. If plates with mounting hole located at different position, try them to see the effects of drive position.

Change the plate to rectangular and triangular plates and look for interesting patterns.

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LAB REPORT FORM

NAME: ______________________________________ DATE: _____________

PARTNER(S): ____

I.

Dimensions of the sample bars. Record the units.

longer bar

L(length) =__________________, a (thickness) = _________________

Measured f_1 = _______________ ± _________________

Calculated f_1 = ______________ using Y= 7.5 x 10^{10}• N/m^2

shorter bar

L(length) =__________________, a (thickness) = _________________

Measured f_1 = _______________ ± _________________

Calculated f_1 = ______________ using Y= 7.5 x 10^{10}• N/m^2

(Observed f_1 for shorted bar)/(Observed f_1 for longer bar) =___________

expected ratio based on the change in length = ___________________ (Note that resonant frequencies are proportional to L^{-2}.)

longer bar

Observed higher mode frequencies:

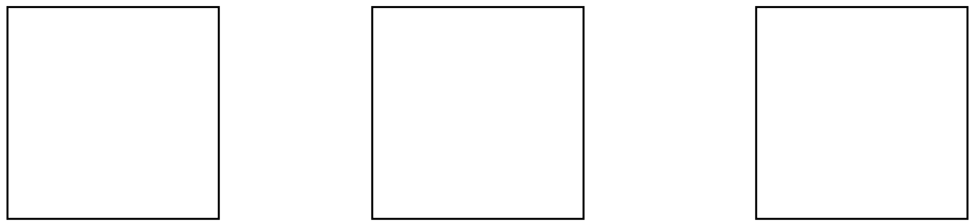
f_2 = __________________ f_3 = ___________________

Expected higher mode frequencies:

f_2 = __________________ f_3 =___________________

II. dimensions of the square plate: ________________________

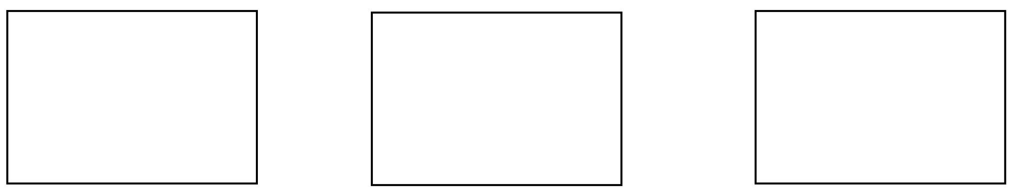
Chladni patters and frequencies observed:



f = _____ f = _____ f = _____

dimensions of rectangular plate: _____________________

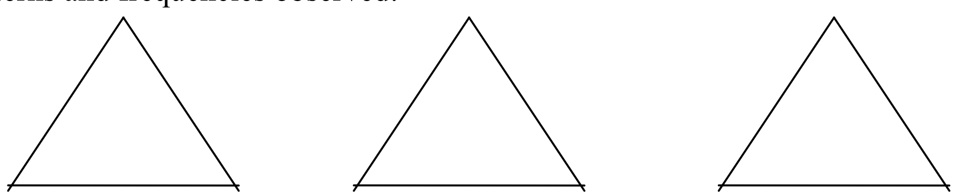
Chladni patterns and frequencies observed:



f = _____ f = _____ f = _____

dimensions of triangular plate:____________________

Chladni patterns and frequencies observed:



f = _____ f = _____ f = _____

Do the violin shape if time permits.