Applet Exercise 4: 2D Modes and the Rectangular Cavity

Objectives:

1. Understand how 2 dimensional modes are the same and different from 1 dimensional modes.
2. Learn how to export data to a spreadsheet and graph the results.
3. Learn how to interpret a spectrum of a cavity and assign modes.
4. WARNING: It will take roughly an hour to collect the data from the Virtual Lab. You can keep using your computer for something else – the applet will run on its own. Just don't be surprised by the amount of time it takes. The analysis will also take some time. This lab will be challenging!

Preface:

In a 1D cavity, the open-open, open-closed, and closed-closed tubes, the modes are simple waves with nodes at the open ends and anti-nodes at the closed ends. The overtone series' are either harmonic or partial harmonic.

In 2D cavities, like a rectangle, there are some similarities, but also some important differences. In a 2D cavity, 1D modes are still possible along each direction, separately. We will consider rectangular cavities which are closed all the way around. Assume that the lengths of the sides of the rectangle are A and B. Then, we will have a normal closed-closed overtone series given by $f_n = n(v/(2A))$ in one direction and $g_m = n(v/(2B))$ in the other direction. You will find these frequencies in the spectrum of the cavity. Notice that there are two series and so we need two numbers to specify the modes, n and m.

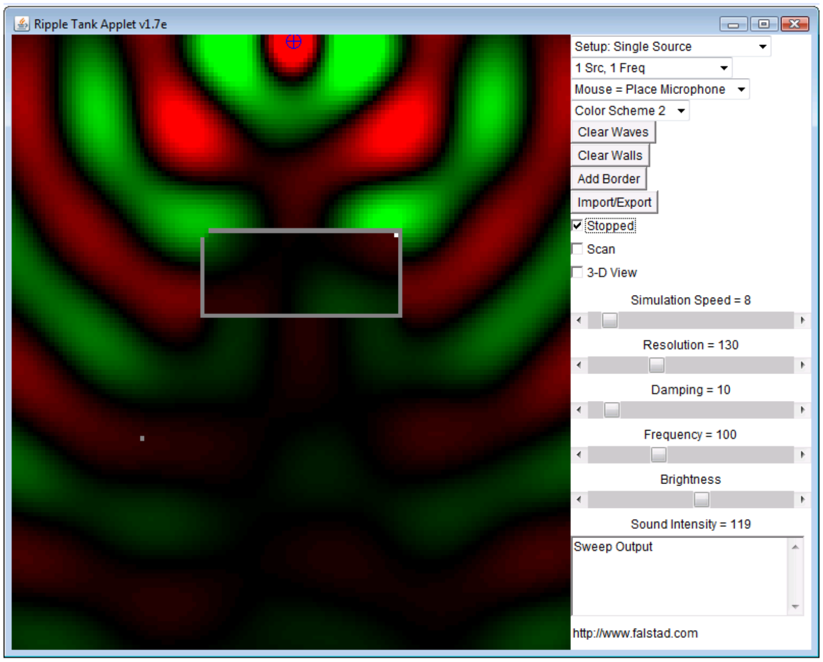
However, what is new about 2D waves is that there are modes consisting of combinations of the two series, for example the 2nd mode in one direction and the third mode in the other, which would label the (2,3) mode. The frequency of the (2,3) mode ends up being related to the frequency of the individual modes according to the Pythagorean theorem: $(F_{2,3})^2 = (f_2)^2 + (g_3)^2$. Or, in general, $(F_{n,m})^2 = (f_n)^2 + (g_m)^2$. This makes for a lot of possible frequencies. And, it also means that they do not form a nice harmonic series. As a result, 2D instruments, like drums and cymbals are percussion instruments, as they do not have a strong sense of pitch. (A lot of work goes into making a tympani have a reasonable sense of pitch).

The other big difference between 1D and 2D modes is how we describe the shape of the mode. In 1D, all that we really needed to do is specify the locations of the nodes and antinodes along a line. In 2D, the modes fill a plane. More importantly, the nodes, which in 1D are points, become lines – nodal lines – in 2D. Specifying the nodal lines are all that is needed to describe a 2D mode.

Finally, we will use the method to find the resonances of the cavity that was introduced in Lab #3 – i.e. scanning. In Lab #3, scanning might not have seemed so useful, but for this lab it is critical.

Instructions:

1. Initial settings: Simulation speed = 8, Resolution = 130, Damping = 2, Frequency = 100.
2. Choose Mouse = Edit Walls. Draw a rectangle roughly 20 by 45 cm. Choose your own values, but don't make the ratio exactly 2:1. Of course, if the rectangle is completely closed, no sound waves will enter the cavity, so we need to place an opening in one corner of the rectangle. Just remove the 3 pixels at the upper left or right corner.
3. Change the mouse menu to Mouse = Place Mic and place the microphone on of the corners. You're screen will look something like this:



4. Now set the Frequency to 1 Hz and the Simulation speed to 99. Clear the waves and make sure the simulation is running (Stopped is unchecked). Finally, click Scan. At this point, the Virtual Lab will run on its own, increasing the frequency one Hz at a time and recording the sound intensity in the cavity. *Depending on your computer this could take over an hour, so just be sure you have all the parameters set correctly.* The scan will stop automatically at the maximum frequency of 299 Hz. In the meantime, you can fill in Table 1.
5. Table 1 will contain your predicted values of the resonance. In the first row, enter the harmonic series you expect in the horizontal direction. In the first column, enter the expected harmonic series in the vertical direction. You don't need to enter any values over 300 Hz (that's as high as we can measure). Then, fill in the rest of the table by finding combinations according to the Pythagorean Theorem. Again, don't enter values above 300 Hz.
6. When the scan has finished running, open an Excel spreadsheet. Then, click in the text box in the lower right hand corner of the Virtual Lab. Press ctrl+a (select all) and then ctrl+c (copy). Go over to the new Excel document, click in the upper left hand corner and click ctrl+v (paste). The first line should read Sweep output. Below that, there will be two columns – the left is the frequency and the right is the sound intensity at that frequency.
7. Highlight the two columns of data. Then click >Insert on the menu bar, >Chart, >XY (Scatter), >Straight lines with symbols (lower left option), >Next, >Finish. This should produce a graph of your

data. You will see a series of peaks. Each peak corresponds to a particular mode (either a simple or combination mode) of the cavity. You job now is to identify all of the peaks. *It is possible.*

8. From you Excel graph, record all of the peaks in the data. If you hold the mouse over a data point, it will display the coordinates – you can use that to read off the frequency of each peak. Enter these values in to Table 2. Note that there will be some peaks below 30 Hz which are from a different effect, so ignore those. The same thing happens in the physics labs!
9. So far, the directions have been relatively straight forward, if a little complicated. Now comes the more creative part. You must match up the predicted frequencies in Table 1 with the measured frequencies in Table 2. Things won't match up perfectly, but there should be a unique way of associating the measured and predicted frequencies. Once you make this connection, you know the mode of a given resonance from Table 1, which you should enter into Table 2. Finally, you can determine how far of the measured and predicted frequencies are by taking the ratio. The ratio should be between 0.9 and 1.1 if the assignments are correct.
10. You have a different way to check the association between the modes and the frequencies that you don't have in the physical lab. If you are not sure what mode a frequency corresponds to, go back to the Virtual Lab and set the frequency to the one in question. Then let the applet run at that frequency, for awhile. Don't scan. Eventually, you will see a mode pattern start to develop. It might not be very stable because there might be other modes at a nearby frequency which affect the mode pattern. However, you should be able to see and count the nodal lines in each direction. This will identify the mode for you. Even if you are pretty sure about a frequency, it is worth checking the mode.

Questions

A. Why put the microphone in the corner of the rectangle? What would be the problem with putting it somewhere in the middle?

B. How close were the measured frequencies to the predicted frequencies? What are some reasons that they would not agree?

Table 1 – Predicted frequencies

Length in horizontal direction:

Fundamental in horizontal direction:

Length in vertical direction:

Fundamental in vertical direction:

n/m	0	1	2	3	4	5	6	7
0								
1								
2								
3								
4								
5								

Table 2

Measured frequency	Predicted frequency from Table 1	Mode (n,m)	Measured/Predicted frequency