Experiment 1: Acoustical normal modes in basic chambers

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I. INTRODUCTION

In this experiment we sought to observe the acoustical normal modes of a steel box and cylinder, encapsulating only the surrounding air in the room. The acoustical modes being the synchronous movement of air particles such that it becomes resonant. Ultimately this experiment is done to test the current theory of air in a cavity and seeing if we can personally align with the expected results. TO conduct this experiment we had to utilize a simple speaker and microphone to both propagate and capture the excitation of the air waves. Exciting the air, allows us to then adjust to a particular frequency matching its boundaries that leads to a full wave cycle that is resonant. The speaker used a variable oscillator, to adjust its driving frequency; and allowed us to see the various eigennmodes of the air in the box. Also moving the microphone we could measure the pressure oscillations of the environment driven at at resonant frequency. This experiment yielded results within the expected theoretical ranges, for many modes, and allowed us a good mapping of the acoustical parameters inside the differing boxes.

II. THEORY

For this experiment we had to take into account several physical phenomenon to properly gauge the acoustical modes for the cube and cylinder boxes. A fairly needed measurement was the temperature, baromic pressure, and relative humidity of the day, this was to measure the speed of sound in air, though the results will be expressed later, the equation used is seen in equation 1, where R is the Gas constant, T is temperature in Kelvin, ω is the adibatic constant and M_w is the molecular weight of air. To correct our results we factor in the humidity for making part of air water into the molecular weight and heat capacity calculations given in equations 2 and 3 respectively, the the factor named X is given by $X = h*(saturatedvaporpressure/barometricpressure)$, where h is the humidity.

$$c = \sqrt{\frac{\gamma RT}{M_w}} \qquad [1]$$

$$M_w = (18*X)+(1-x)*[(.78*28)+(6.72)+(.4)] \qquad [2]$$

$$C_p = C_v+R = (X*C_v(H_2O))+((1-X)*(\frac{5*R}{2})+R \qquad [3]$$

The speed of sound in air allows us to measure the eigenmodes of the frequencies for the enclosures, as well as the dimensions of the box. We had to measure the dimensions of the boxes, this is because the expected results are dependent on the dimensions of the box, specifically the resonant modes change based on box size because the amount of air changes as well as pressures. Since the calculations are lengthy the equations of the theoretical eigenmodes for a cubical box given in equation 4 and for a cylindrical one in equation 5. Equation 4, simply shows the dimensions of the box in Cartesian coordinates effecting the differing modes and speed of sound being the base targeted by the overall equation in both 4 and 5. Equation 5 has one unique parameter, that being the Bessel function. The Bessel function being a parameter dependent on the n and m which are given by differing regions in the cylinder, we are provided the numerical results but not the derivation, so it is provided thusly.

$$f_{x,y,z} = \frac{c}{2}\sqrt{(\frac{x}{L_x})^2 + (\frac{y}{L_y})^2 + (\frac{z}{L_z})^2} \qquad [4]$$

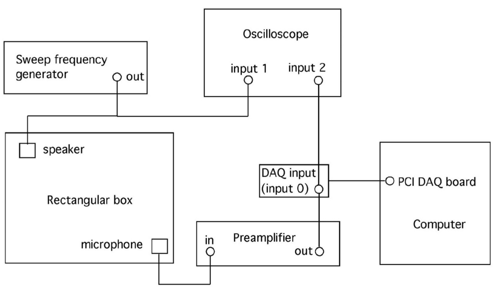
$$f_{m,n,z} = \frac{c}{2}\sqrt{(\frac{J_{mn}}{L_r})^2 + (\frac{z}{L_z})^2} \qquad [5]$$

Equation 4 and 5 both have vakues under a square root, these values can be taken as a single number known as k. To calculate the wavelength in our lab we simply take $\frac{2\pi}{k}$. To find the speed of sound from frequency and wavelength we simply use $c = \lambda f$

This gives us a full but shortened process of theoretically predicting normal modes in a box, the reason these modes exist is the dimensions of the box, which is also why the lengths of the box are accounted for, in this case we see the frequency is able to match with a node or multiple nodes in the dimensions of its space, the relative motion of the air particles become synchronous and have amplitudes that grow, thus allowing us to exploit and observe resonance. While the size of the boxes do not matter their dimesions surely do.

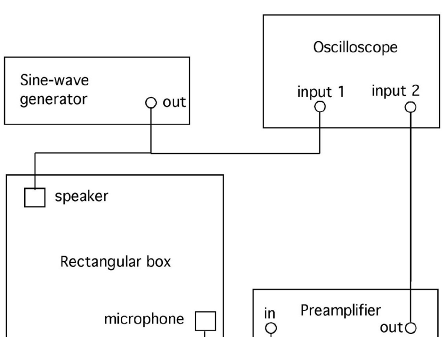
III. APPARATUS AND PROCEDURE

In this experiment we seek to accomplish 3 tasks with 2 geometries. The overall experiment required us to go through a mode selection, then to finely adjust for the modes in a box to measure the speed of sound inside the box, and the last task was to gather the eigenmode pressures of the box. To accomplish these tasks we first had our metal enclosures matching the theoretical geometry as best as possible. Then we have a Microphone collecting the air waves in the enclosures, as well as a speaker driven by a variable voltage supply, to allow for a varying frequency. We collected all the data using a computer and oscilloscope connected in series with the microphone. We typically have a frequency generator connected to power the speaker, and we have a microphone connected to a myDAQ. You can see the wire set up in figures 1 and 2.



FFT measurement set-up

Figure 1: This Diagram shows the setup used to measure the eigenmodes using a FFT (fast Fourier Transform) .



Mode mapping set-up

Figure 2: This Diagram shows our mode mapping set up, where it gives us only voltages.

To preform the experiment we take it in steps. The first procedure was the mode selection, for this we simply needed to sweep the frequencies at the corner, middle corner, and middle of the box from 50Hz to 5kHz, the purpose to find resonant modes that are good throughout the box's displacement, to preform we simply took our Speaker and placed it in the proper hole in the Cube or Cylinder, and let the sweep continue, we capture the sweep on a computer and wait for it to stabilize. The next activity we had to do was measure the precise resonant frequencies of the boxes, this was to gather the speed of sound, and we based our measurements off the first task for both portions of the experiment. To preform the task we simply placed the Speaker in the corner of the box and the microphone in the other corner and we manually adjusted using a knob on a precise wave generator to find the resonant frequencies. The last segment of the experiment had us measure the Eigenmode pressures of the boxes. For the cube, we simply placed a Speaker at the corner at a resonant frequency and moved .5cm a time across the entire dimension for all x,y, and z, a similar measurement was made for the Cylinder except the parameters being the degrees of rotation, height, and position in chamber. This experiment was fairly simple to conduct and no sophisticated equipment was used.

IV. DATA AND ANALYSIS

One of the first things we did in this lab was measuring the internal dimensions of the boxes that we were analyzing. We gathered the dimensions of the cubical box in Cartesian coordinates and the Cylindrical in Cylindrical coordinates, so that we could have a description of the wavelength, as well as a way of calculating the theoretical modes, initially using a speed of sound of 345 m/s, then more precise later. The values for the dimensions we got can be seen in the following table.

Dimensions			
X_{Final}	$203 \pm .1mm$	L_R	$241.7 \pm .1mm$
Y_{Final}	$161.6 \pm .1mm$	L_z	$44.5 \pm .1mm$
Z_{Final}	$140.8 \pm .1mm$		

Table 1: This table shows the dimensions of the Rectangular and Cylindrical Box.

To display the Theoretical values we calculated for the modes we expect, I present another table below, table 2. This table basically shows a imprecise way of measuring the modes since we use a speed of sound of 345 without consideration of the actual speed of sound though gives us more understanding in mode selection later, we use equation 4 for the calculation along with presented values. In table 3 we present the same data the frequency and wavelength from the gathered values and using the cylindrical box. Examples of frequency calculations are shown below.

$$f_{x,y,z} = \frac{345}{2}\sqrt{(\frac{1}{203})^2 + (\frac{0}{L_{161.6}})^2 + (\frac{0}{140.5})^2} = 850$$

$$f_{m,n,z} = \frac{345}{2}\sqrt{(\frac{J_{02}}{241.7})^2 + (\frac{0}{44.5})^2} = 1741$$

Nx	Ny	Nz	Lx	Ly	Lz	kx	ky	kz	k	wavelength	frequency
1	0	0	0.20305	0.16159	0.14082	15.46417	0	0	15.46417	0.4061	850.0369
0	1	0	0.20305	0.16159	0.14082	0	19.4319	0	19.4319	0.32318	1068.135
0	0	1	0.20305	0.16159	0.14082	0	0	22.29797	22.29797	0.28164	1225.678
2	0	0	0.20305	0.16159	0.14082	30.92834	0	0	30.92834	0.20305	1700.074
1	1	1	0.20305	0.16159	0.14082	15.46417	19.4319	22.29797	33.37572	0.188161	1834.602
2	0	1	0.20305	0.16159	0.14082	30.92834	0	22.29797	38.12823	0.164707	2095.838
0	2	0	0.20305	0.16159	0.14082	0	38.86379	0	38.86379	0.16159	2136.271
1	2	0	0.20305	0.16159	0.14082	15.46417	38.86379	0	41.82744	0.150141	2299.177
2	1	1	0.20305	0.16159	0.14082	30.92834	19.4319	22.29797	42.7944	0.146748	2352.329
0	0	2	0.20305	0.16159	0.14082	0	0	44.59594	44.59594	0.14082	2451.356
3	0	0	0.20305	0.16159	0.14082	46.39251	0	0	46.39251	0.135367	2550.111
1	2	1	0.20305	0.16159	0.14082	15.46417	38.86379	22.29797	47.39973	0.13249	2605.476
0	1	2	0.20305	0.16159	0.14082	0	19.4319	44.59594	48.64562	0.129097	2673.96
1	1	2	0.20305	0.16159	0.14082	15.46417	19.4319	44.59594	51.04446	0.12303	2805.82
3	0	1	0.20305	0.16159	0.14082	46.39251	0	22.29797	51.47295	0.122006	2829.373
2	2	1	0.20305	0.16159	0.14082	30.92834	38.86379	22.29797	54.44406	0.115348	2992.69
3	1	1	0.20305	0.16159	0.14082	46.39251	19.4319	22.29797	55.01875	0.114143	3024.279
2	1	2	0.20305	0.16159	0.14082	30.92834	19.4319	44.59594	57.64511	0.108942	3168.645
0	3	0	0.20305	0.16159	0.14082	0	58.29569	0	58.29569	0.107727	3204.406
1	3	0	0.20305	0.16159	0.14082	15.46417	58.29569	0	60.31192	0.104125	3315.235
1	2	2	0.20305	0.16159	0.14082	15.46417	38.86379	44.59594	61.1419	0.102712	3360.858
4	0	0	0.20305	0.16159	0.14082	61.85669	0	0	61.85669	0.101525	3400.148
1	3	1	0.20305	0.16159	0.14082	15.46417	58.29569	22.29797	64.30184	0.097664	3534.554
2	2	2	0.20305	0.16159	0.14082	30.92834	38.86379	44.59594	66.75144	0.09408	3669.203
0	0	3	0.20305	0.16159	0.14082	0	0	66.89391	66.89391	0.09388	3677.035
3	1	2	0.20305	0.16159	0.14082	46.39251	19.4319	44.59594	67.22099	0.093423	3695.014
2	3	1	0.20305	0.16159	0.14082	30.92834	58.29569	22.29797	69.65737	0.090156	3828.937
0	1	3	0.20305	0.16159	0.14082	0	19.4319	66.89391	69.65912	0.090153	3829.033
1	1	3	0.20305	0.16159	0.14082	15.46417	19.4319	66.89391	71.35499	0.088011	3922.252
0	4	0	0.20305	0.16159	0.14082	0	77.72758	0	77.72758	0.080795	4272.542
1	2	3	0.20305	0.16159	0.14082	15.46417	38.86379	66.89391	78.89442	0.0796	4336.681
0	0	4	0.20305	0.16159	0.14082	0	0	89.19188	89.19188	0.07041	4902.713

Table 2: This Table shows the Theoretical expected modes, from dimensions of the cubical box as well the wave lengths and frequencies expected.

m	n	nz	Jmn	Frequency
0	2	0	3.8317	1741.968
1	1	0	1.8412	837.0467
2	1	0	3.0542	1388.501
2	2	0	6.7061	3048.729
3	1	0	4.2012	1909.95
4	1	0	5.3176	2417.488
4	2	0	9.2824	4219.967
1	2	0	5.3314	2423.762
0	3	0	7.0156	3189.434
5	1	0	6.4156	2916.661
6	1	0	7.5013	3410.243
1	3	0	8.5363	3880.774
7	1	0	8.5778	3899.641
3	2	0	8.0152	3643.872
1	1	1	1.8412	3969.157
2	1	1	3.0542	4120.861
0	0	1	0	3879.892

Table 3: This Table shows the Theoretical expected modes, from dimensions of the cylindrical box.

The next set of data that is presented is the raw data of the mode selection used on the cubical box in the corner, corner center, and center of the box. This was us sweeping frequencies and capturing them through a fast Fourier Transform. We also indicate the peaks that were close to the frequencies and put in error. Below the Table of peaks we see, we will present the graphs of the raw data as well, where they strictly graph the raw data of the frequency vs voltage, and we can see clear peaks where resonant modes occur but we also pick up random data that skew our idea of what a mode is, though because our theoretical calculations and taking multiple scans we can find the modes that work.

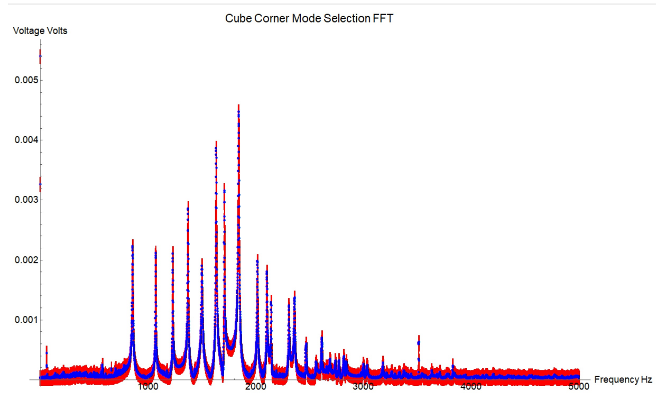


Figure 3: This Graph shows the results of the fast Fourier transform on the Corner of the box, the blue is the point captured, the red is possible error.

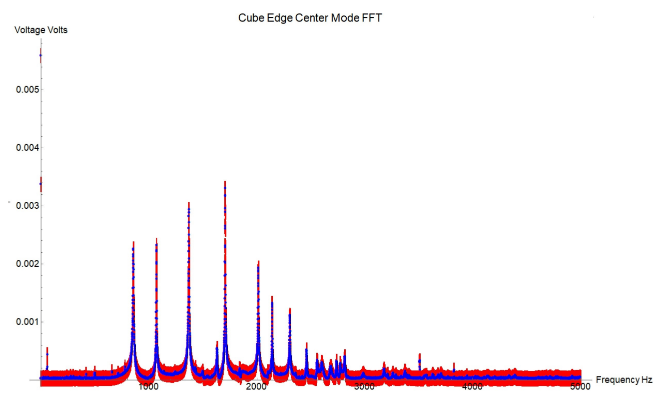


Figure 4: This Graph shows the results of the fast Fourier transform on the Corner center of the box .

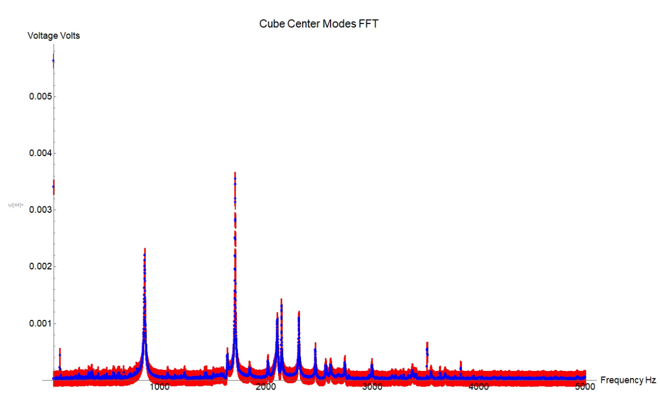


Figure 5: This Graph shows the results of the fast Fourier transform on the Center of the box.

The next set of data that we took was the precise resonant frequencies of the boxes which allows us to calculate the speed of sound as well, since we can acquired the wavelengths with the modes we match, and we know which modes we match since we have a theoretical set that closely resembles the peaks that we acquired. To find the resonant frequencies we simply tuned to them, we then matched the theoretical mode it resembled acquired the digits and were able to find the k by plugging into the mode for the values under the square root in equations 4 and 5, then applied the wavelength and frequency together to find the speed of sound, though we compare our results later; we shows the results for both the cubical and cylindrical cases

measured	measured	measured	uncertainty range
857	857	857	-1
1072	1072		-0.6
1375	1372		-0.4
1633	1709	1708	-0.6
1841			-0.6
2015	2016	2104	-1.2
2103	2144	2144	-0.8
2307	2307	2307	-0.4
2358			-0.9
2466	2462	2461	-4
2558	2558	2559	-3.8
2612	2603	2605	-1.4
2689	2740	2739	-3
2817	2817		-2
2840			-102.5
3000	2987	2994	-2.5
3032			-1.4
3180	3180		-3
3214	3260		-0.8
3329			-3.5
3374	3373	3374	-2.4
3440			-1.6
3512	3509	3512	-3.7
3632	3630	3634	-2.3
3678	3680	3682	-3.9
3708	3709		-2.1
3828			-8
3840	3829	3829	
3948	3949	3949	-1.3
4205	4939		-3.7
4540	4390		-3.1
4770	4922	4923	-3.7

Table 5: This Table shows the Mode selection from a slow movement to all the peak positions for precise analysis, for the cubical box.

Frequency	Measured Frequency
1741.9682	1708
837.04672	857
1388.501	1341
3048.7286	2993
1909.9504	1869
2417.4884	2461
4219.9666	4205
2423.7622	2557
3189.4335	3149
2916.6614	2876
3410.2426	3370
3880.7745	3840
3899.6412	3859
3643.8719	3603
3969.1573	3929
4120.8612	4145
3879.892	3839

Table 6: This Table shows the Mode selection for a cylindrical box where we tuned to precise modes.

The last set of raw data we had to deal was the eigenmode pressure map, where we can map the pressure voltages of particular points in the box when we place the box at a resonant frequency. To map we had to move the box in a dimension coordinate and slowly gather the voltages through the oscilloscope, we present the tables of what we gathered below, as well as the graphs of there representation, for both the Cylindrical and Spherical Coordinates. We had to take two sets of data for both boxes as well, we did this at the 1841.8 Hz and 2359.6 Hz for the cubical and 857 and 2993 Hz for the Cylindrical.

CM	x	y	z
0	228	260	360
0.5	256	284	440
1	260	278	448
1.5	264	264	456
2	264	252	448
2.5	250	248	432
3	236	232	424
3.5	232	200	400
4	206	170	368
4.5	190	140	336
5	176	120	288
5.5	156	96	248
6	144	74	200
6.5	124	58	152
7	106	40	44
7.5	92	20	16
8	74	0	72
8.5	54	24	120
9	46	50	160
9.5	28	70	200
10	16	86	236
10.5	14	104	268
11	28	142	288
11.5	44	160	328
12	64	188	400
12.5	84	210	424
13	102	220	432
13.5	124	236	464
14	154	240	472
14.5	172	252	
15	190	254	
15.5	212	256	
16	236		
16.5	252		
17	266		
17.5	274		
18	282		
18.5	268		
19	258		
19.5	242		

Table 7: This is Eigenmode pressure voltage for the 1841.8 Hz run for Cubical box .

CM	x	y	z
0	63	64	92
0.5	62	62	110
1	54	62	112
1.5	43	60	116
2	31	60	112
2.5	21	59	110
3	15	55	106
3.5	10	47	100
4	8	42	90
4.5	0	36	78
5	8	28	70
5.5	15	23	58
6	17	17	44
6.5	25	12	25
7	35	8	14
7.5	49	0	18
8	60	4	31
8.5	62	8	42
9	60	13	56
9.5	59	18	66
10	58	21	80
10.5	63	24	88
11	60	30	98
11.5	52	35	108
12	38	41	114
12.5	28	46	122
13	21	50	126
13.5	17	52	124
14	13	55	128
14.5	8	57	
15	0	58	
15.5	8	60	
16	16		
16.5	20		
17	29		
17.5	40		
18	53		
18.5	58		
19	59		
19.5	58		

Table 8: This is the eigenmode pressure voltage for the 2359.6 Hz run for the Cubical box.

r	v	angle	v
0	7.4	0	10.2
0.5	7.22	20	10.2
1	6.88	40	10.4
1.5	6.08	60	10.4
2	5.6	80	10
2.5	5.36	100	10.4
3	4.8	120	10.4
3.5	4.7	140	10
4	4.32	160	10.8
4.5	4.8	180	10.6
5	5.36	200	10.6
5.5	5.6	220	10.8
6	6.4	240	10.2
6.5	7.44	260	10.4
7	8	280	10.2
7.5	8.6	300	11
8	9	320	10.4
8.5	9.4	340	10
9	9.6	360	10.2
9.5	10		
10	10.2		
10.5	11		
11	10.6		
11.5	10.6		
12	10.2		
12.5	9.6		

Table 9: This is the eigenmode pressure voltage for the 857 Hz run.

r	v	angle	v
0	5.4	0	4.4
0.5	5.6	20	4.7
1	5.44	40	4.8
1.5	5.28	60	4.6
2	5.12	80	4.8
2.5	4.96	100	4.8
3	4.56	120	4.6
3.5	4.08	140	4.6
4	3.9	160	4.6
4.5	4.16	180	4.8
5	4.32	200	5
5.5	4.64	220	4.8
6	4.8	240	4.8
6.5	4.96	260	5
7	4.96	280	4.8
7.5	4.72	300	5
8	4.24	320	4.8
8.5	4	340	4.6
9	3.46	360	4.6
9.5	4.24		
10	4.56		
10.5	4.72		
11	5.04		
11.5	5.36		
12	4.64		
12.5	4.48		

Table 10: This is the eigenmode pressure voltage for the 2993 Hz run.

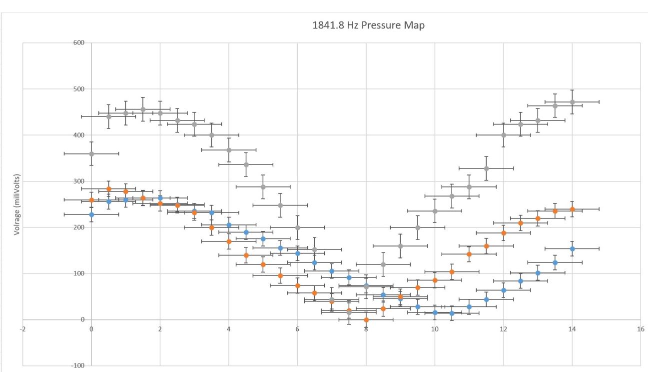


Figure 6: This Graph shows the Eigenmode pressure map for 1841.8 Hz run, where grey is z, orange is y, and blue is x.

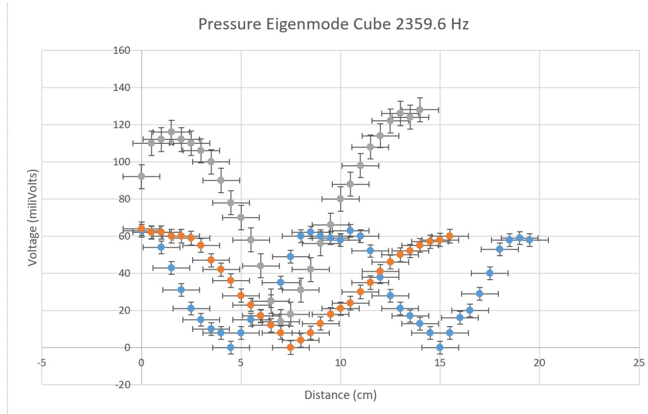


Figure 7: This Graph shows the Eigenmode pressure map for 2359.6 Hz run for the Cube Box, the colors match figure 6.

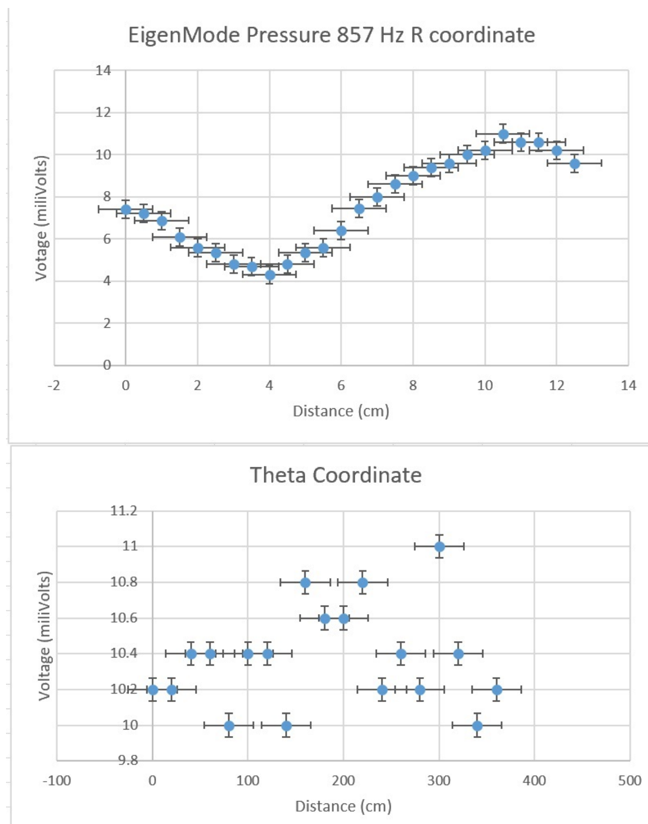


Figure 8: This Graph shows the Eigenmode pressure map at 857 Hz for the Cylindrical box.

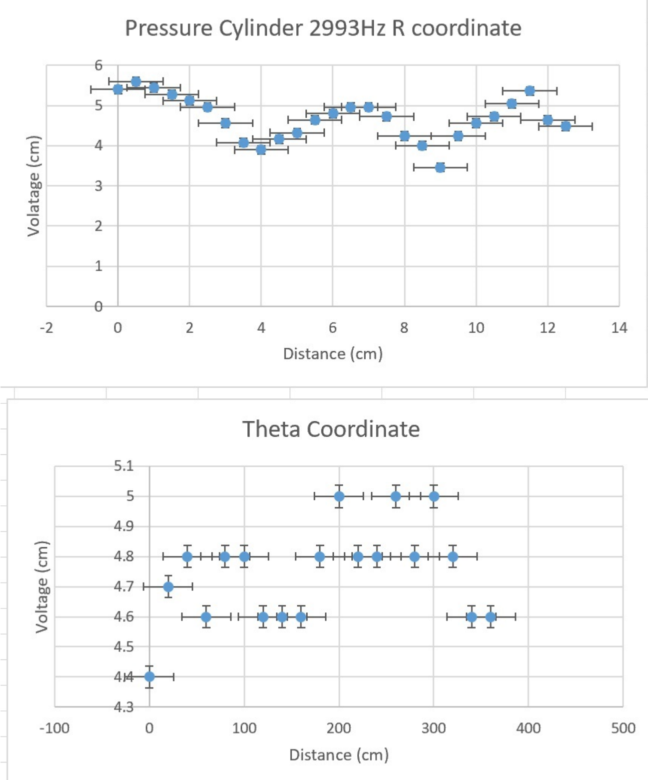


Figure 9: This Graph shows the Eigenmode pressure map at 2993 Hz for the Cylindrical box.

Thus far we have only provided raw data now a more thorough analysis will ensue. First we are asked to talk about our mode elimination. If you look back on to figures 3,4 and 5 you can get a glimpse of how the resonant modes reduced in number but that particularly strong peaks remained, we used these peaks, the strongest one for the cubical being at 1841.8 Hz and the Cylindrical at 857 Hz. This helped us in selecting modes that we thought were most assuredly occurring in the box, other notable modes were noted in our tables as well. So looking at our graphs we can see the spectra of modes decline, modes that are seen throughout all 3 graphs can safely be assumed to be real modes and other abnormalities can be canceled as well.

The next part of our analysis actually has us using equations 1-3 as we had to measure the exact scientific value for the speed of sound that day, note we will include error analysis later. The temperature our day was 23.6 degrees Celsius, the humidity was about 65% and the barometric pressure was about 29.97 Hg, and using the humidity relation with X we find that the value of X is about .6 and plugging that into equation 2 we find that the molecular weight due to water is 21.384, that then leads us to find the speed of sound is about 350 with error of about plus or minus 4. Lastly we can find the heat capacity, in equation 3, this yielded us about 17.9.

Afterwards we began to compare the speed of sound with our calculations using pressure, mass, and humidity with the ones we found using the wavelengths of the modes for each enclosure we present tables of the observed resonances and uncertainties with the speed of sound in tables, as well as present graphs of the speed of sound vs frequency afterwards. We include our thermodynamic calculation on our graphs we found our speed to be 350 ±4 m/s and then for the cylinder we oddly found a speed of sound exactly at $345 \pm 3.5 m/s$ and for the cube we had a varying but speed of sound of about $350 \pm 3.5 m/s$, though we did take the measurements for the cylinder in a different day, so our data correlated strongly with our theoretical expectations the tables and graphs are below for both cube and cylinder.

Nx	Ny	Nz	Lx	Ly	Lz	kx	ky	kz	k	wavelength	Theoretical	measured f	Error	Speed	Error
1	0	0	0.20305	0.16159	0.14082	15.46417	0	0	15.46417	0.4061	850.0369	857	± .1 Hz	348.0277	3.480279
0	1	0	0.20305	0.16159	0.14082	0	19.4319	0	19.4319	0.32318	1068.135	1072	± .1 Hz	346.449	3.464491
0	0	1	0.20305	0.16159	0.14082	0	0	22.29797	22.29797	0.28164	1225.678	1375	± .1 Hz	387.255	3.872551
2	0	0	0.20305	0.16159	0.14082	30.92834	0	0	30.92834	0.20305	1700.074	1633	± .1 Hz	331.5807	3.315807
1	1	1	0.20305	0.16159	0.14082	15.46417	19.4319	22.29797	33.37572	0.188161	1834.602	1841	± .1 Hz	346.4039	3.46404
2	0	1	0.20305	0.16159	0.14082	30.92834	0	22.29797	38.12823	0.164707	2095.838	2015	± .1 Hz	331.8853	3.318854
0	2	0	0.20305	0.16159	0.14082	0	38.86379	0	38.86379	0.16159	2136.271	2103	± .1 Hz	339.8238	3.398238
1	2	0	0.20305	0.16159	0.14082	15.46417	38.86379	0	41.82744	0.150141	2299.177	2307	± .1 Hz	346.3745	3.463746
2	1	1	0.20305	0.16159	0.14082	30.92834	19.4319	22.29797	42.7944	0.146748	2352.329	2358	± .1 Hz	346.0322	3.460323
0	0	2	0.20305	0.16159	0.14082	0	0	44.59594	44.59594	0.14082	2451.356	2466	± .1 Hz	347.2621	3.472621
3	0	0	0.20305	0.16159	0.14082	46.39251	0	0	46.39251	0.135367	2550.111	2558	± .1 Hz	346.2679	3.46268
1	2	1	0.20305	0.16159	0.14082	15.46417	38.86379	22.29797	47.39973	0.13249	2605.476	2612	± .1 Hz	346.0644	3.460645
0	1	2	0.20305	0.16159	0.14082	0	19.4319	44.59594	48.64562	0.129097	2673.96	2689	± .1 Hz	347.1416	3.471417
1	1	2	0.20305	0.16159	0.14082	15.46417	19.4319	44.59594	51.04446	0.12303	2805.82	2817	± .1 Hz	346.5755	3.465755
3	0	1	0.20305	0.16159	0.14082	46.39251	0	22.29797	51.47295	0.122006	2829.373	2840	± .1 Hz	346.4965	3.464966
2	2	1	0.20305	0.16159	0.14082	30.92834	38.86379	22.29797	54.44406	0.115348	2992.69	3000	± .1 Hz	346.0432	3.460433
3	1	1	0.20305	0.16159	0.14082	46.39251	19.4319	22.29797	55.01875	0.114143	3024.279	3032	± .1 Hz	346.0813	3.460813
2	1	2	0.20305	0.16159	0.14082	30.92834	19.4319	44.59594	57.64511	0.108942	3168.645	3180	± .1 Hz	346.437	3.46437
0	3	0	0.20305	0.16159	0.14082	0	58.29569	0	58.29569	0.107727	3204.406	3214	± .1 Hz	346.2335	3.462335
1	3	0	0.20305	0.16159	0.14082	15.46417	58.29569	0	60.31192	0.104125	3315.235	3329	± .1 Hz	346.6333	3.466333
1	2	2	0.20305	0.16159	0.14082	15.46417	38.86379	44.59594	61.1419	0.102712	3360.858	3374	± .1 Hz	346.5499	3.465499
4	0	0	0.20305	0.16159	0.14082	61.85669	0	0	61.85669	0.101525	3400.148	3440	± .1 Hz	349.246	3.49246
1	3	1	0.20305	0.16159	0.14082	15.46417	58.29569	22.29797	64.30184	0.097664	3534.554	3512	± .1 Hz	342.9973	3.429973
2	2	2	0.20305	0.16159	0.14082	30.92834	38.86379	44.59594	66.75144	0.09408	3669.203	3632	± .1 Hz	341.6999	3.416999
0	0	3	0.20305	0.16159	0.14082	0	0	66.89391	66.89391	0.09388	3677.035	3678	± .1 Hz	345.2906	3.452907
3	1	2	0.20305	0.16159	0.14082	46.39251	19.4319	44.59594	67.22099	0.093423	3695.014	3708	± .1 Hz	346.4132	3.464132
2	3	1	0.20305	0.16159	0.14082	30.92834	58.29569	22.29797	69.65737	0.090156	3828.937	3828	± .1 Hz	345.1155	3.451156
0	1	3	0.20305	0.16159	0.14082	0	19.4319	66.89391	69.65912	0.090153	3829.033	3840	± .1 Hz	346.1887	3.461887
1	1	3	0.20305	0.16159	0.14082	15.46417	19.4319	66.89391	71.35499	0.088011	3922.252	3948	± .1 Hz	347.4661	3.474661
0	4	0	0.20305	0.16159	0.14082	0	77.72758	0	77.72758	0.080795	4272.542	4205	± .1 Hz	339.743	3.39743
1	2	3	0.20305	0.16159	0.14082	15.46417	38.86379	66.89391	78.89442	0.0796	4336.681	4540	± .1 Hz	361.3842	3.613842
0	0	4	0.20305	0.16159	0.14082	0	0	89.19188	89.19188	0.07041	4902.713	4770	± .1 Hz	335.8557	3.358557

Table 11: This is the table showing the speed with the error and the cubical encapture .

m	n	nz	Jmn	Frequency	Measured Frequency	Error	Wavelengtl	Speed	Error
0	2	0	3.8317	1741.9682	1708	±.1 Hz	0.621883	345	±3.5
1	1	0	1.8412	837.04672	857	±.1 Hz	1.294193	345	±3.6
2	1	0	3.0542	1388.501	1341	±.1 Hz	0.780194	345	±3.7
2	2	0	6.7061	3048.7286	2993	±.1 Hz	0.355328	345	±3.8
3	1	0	4.2012	1909.9504	1869	±.1 Hz	0.567188	345	±3.9
4	1	0	5.3176	2417.4884	2461	±.1 Hz	0.44811	345	±3.10
4	2	0	9.2824	4219.9666	4205	±.1 Hz	0.256708	345	±3.11
1	2	0	5.3314	2423.7622	2557	±.1 Hz	0.44695	345	±3.12
0	3	0	7.0156	3189.4335	3149	±.1 Hz	0.339653	345	±3.13
5	1	0	6.4156	2916.6614	2876	±.1 Hz	0.371418	345	±3.14
6	1	0	7.5013	3410.2426	3370	±.1 Hz	0.317661	345	±3.15
1	3	0	8.5363	3880.7745	3840	±.1 Hz	0.279145	345	±3.16
7	1	0	8.5778	3899.6412	3859	±.1 Hz	0.277795	345	±3.17
3	2	0	8.0152	3643.8719	3603	±.1 Hz	0.297294	345	±3.18
1	1	1	1.8412	3969.1573	3929	±.1 Hz	0.272929	345	±3.19
2	1	1	3.0542	4120.8612	4145	±.1 Hz	0.262882	345	±3.20

Table 12: This is the table showing the speed with the error and the cylinderical encapture.

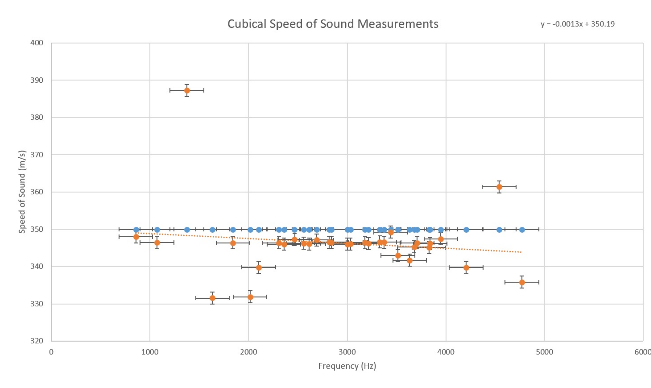


Figure 10: This Graph shows Speed of sound vs frequency compared to the steady frequency of 350,

Orange is the Cube blue is the thermodynamic value.

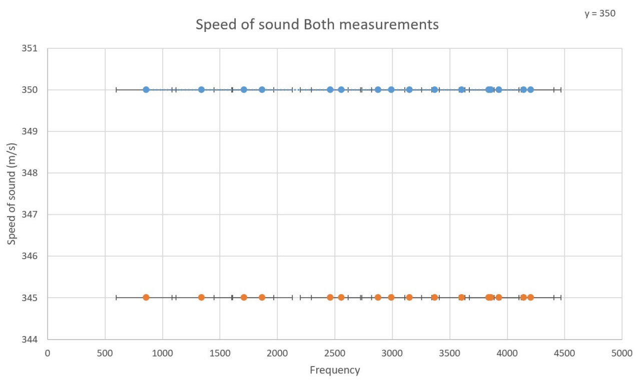


Figure 11: This Graph shows Speed of sound vs frequency compared to the steady frequency of 350, Orange is the cylinder blue is the thermodynamic value.

Earlier when presenting the raw data I drew graphs and presented the values calculated in tables 7-10 and figures 6-9. The theory on these curves is that the graphs should be the absolute value of the pressure amplitudes in theory. They follow so for the most part some are poorer graphs though the expressions are following what we would expect, that the pressure at anti nodes are small and at nodes large following the particle velocities typical movement, as what would be expected for air to follow since it is moving in a wave like manner.

V. ERROR ANALYSIS

In this experiment we have calculation and experimental error. I will present the calculation error first and then the experimental error in my conclusion. The first thing to note is the error equation used and the areas where error propagated in calculations. The error formula is presented in equation 6.

$$\delta F = \sqrt{(\frac{dF}{dx})^2(\delta x)^2 + \frac{dF}{dy})^2(\delta y)^2} \qquad [6]$$

In our raw data we present error, though we did not have many instances of calculation besides the thermodynamic and acoustical ways we acquired the speed of sound. This would be the only time where error propagated and when making that calculation error was included in the table. Though to present a rundown of that calculation for the acoustical instance we use equation 6 because to calculate the error we take the wavelength and multiply by frequency in the equation c=$\lambda f, sothecalculationissimplyexpressedasbelow.$

$$\delta F = \sqrt{(f^2(.1)^2 + .01^2(\lambda)^2} = \pm 3.49$$

The next section of propagating error was the thermodynamic condition, this was in equation 1, this again is simple since it is a division of two errors which can be treated similarly to the one above though the are relatively different.

$$\delta F = \sqrt{((T/2^2(.1)^2 + .01^2(h/2)^2} = \pm 4$$

That is all for error propagation.

VI. CONCLUSION

This experiment sought to observe the acoustical eigenmodes of a cubical and cylindrical enclosure. To achieve this we used a speaker and microphone and drove waves at differing frequencies and observed the pressure changes and voltage changes associated with the box. The results were great in reality, they correlated to the theoretical expectations well, there was error as that cannot be avoided entirely and results that were expected to be skewed were. A notable example is the cylindrical speed of sound was precisely 345 m/s for all the measured frequencies, and the pressure mode map successfully achieved a proper mapping of the channel. we also were able to successfully narrow our modes from our graphs and we achieved proper error propagation and had thermodynamic results correlate to our acoustical results as well. A note to be made is that the precision sine-wave generator was not working well when we were making adjustments, this can be attributed to the electronics of the machine, this lead to some minor error when capturing the proper resonant frequencies that would match. Another source of error was due to the fact talking and other outside noise would bleed into our results. Though the outside sources of error are not to horrible, to better preform the experiment it would be ideal to be in a isolated environment, as well as having a box that has no holes in it and can be firmly cemented in place, filled with a single gas, that way we can have complete experimental control over the environment of the boxes we are observing, though this did not prevent us from achieving accurate results. This experiment has lead to the conclusion that the theory affirming acoustical modes is correct, and that the Bessel functions associated with the cylindrical system work as well, though we did not learn anything the thoroughness of is never complete.