Project Plan – Emmanuel Zeta

Acoustic metamaterials are materials which can manipulate waves which are bound by Newton's law of motion [1] and are utilised for many things such as research in seismic waves or even for creation of acoustic meta-equalizers. Different materials, each with its own resonant frequency, can be utilised as acoustic metamaterials as each material would allow certain frequencies to transmit more than others.

In this experiment we will use a method inspired by an experiment carried out by Jong Jin Park et al [2]. A long tube with a speaker connected to a signal generator on one side and a receiver on the other side. The metamaterial made out of a material of our choice will placed in the tube and transmission of the sound waves will be measured for varying frequencies. We will also vary the size and number of holes in each metamaterial to see how that affects the transmission and the frequency.

As a side project, we could carry out a similar experiment where we analyse the electric circuit model as done by B. Edwards et al [3]. We would carry out the experiment using a metamaterial with a specific electric permittivity and magnetic permeability so that microwaves can pass through. By varying the frequency, we will test for the transmittance of the microwaves and will use these results to compare with acoustic metamaterials to see whether the results are concordant with the theory.

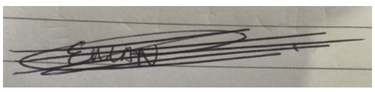
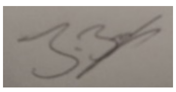
Project Timetable:
Week 3: I will configure the apparatus and test that the apparatus works as expected.
Week 4: I will create the data acquisition code with my partner using MATLAB. Once completed, I will start data acquisition for 2 materials. If time permits, I will vary the size of the holes and start data acquisition.
Week 5: I will continue with varying the size of the holes and continue with data acquisition.
Week 6: I will repeat the test using another material.
Week 7: Using a metamaterial with another number of holes, I will collect data to see how it affects the physics of the system.
Week 8: I'll continue with what I started in week 7.
Week 9: [Calculate expected results and then start calculating actual results – spot any errors.]
On this week I will calculate the expected results and then start processing the data to calculate real results. I will look out for any random or systematic errors in the experiment. If an error is significant and requires me to repeat data acquisition, I will plan to reacquire data.
Week 10: On this week, I'll continue with the data processing and graphing.
Week 11: This week we will compile everything.

Bibliography

[1] G. Ma and P. Sheng, "Acoustic metamaterials: From local resonances to broad horizons," *Science Advances,* vol. 2, no. 2, p. e1501595, 26 February 2016.

[2] J. J. Park, K. J. B. Lee, O. B. Wright, M. K. Jung and S. H. Lee, "Giant Acoustic Concentration by Extraordinary Transmission in Zero-Mass Metamaterials," *Physical Review Letters,* vol. 110, no. 24, p. 244302, 2013.

[3] B. Edwards, A. Andrea, M. E. Young, M. Silveirinha and N. Engheta, "Experimental Verification of Epsilon-Near-Zero Metamaterial Coupling and Energy Squeezing Using a Microwave Waveguide," *Physical Review Letters,* vol. 100, no. 3, p. 033903, 2008.


Emmanuel Zeta | Josbin Jacob | Anthony Kent **(supervisor)**

(To assist in the completion of this form, notes are available by positioning the cursor in each heading box that has a red marker in the top right corner)

RISK ASSESSMENT FORM

BRIEF DESCRIPTION OF ACTIVITY	Conducting an experiment with a signal generator, long hollow tube, loud speaker and receiver. I will be placing the acoustic metamaterials		**SCHOOL/ DEPARTMENT**		Physics and Astronomy	**LOCATION**	
ASSESSOR (Name/Signature)	Emmanuel Zeta		**DATE**	6/10/20	**COUNTERSIGNATURE (Responsible Person/ Supervisor)**		

ASSOCIATED HAZARD/S	**TYPE OF POSSIBLE INJURY**	**EXISTING RISK-CONTROL MEASURES**	**HAZARD RATING (SEVERITY OF HARM)**	**RISK FACTOR (LIKELIHOOD OF EVENT)**	**EXTENT (NUMBER OF PEOPLE AFFECTED)**	**RISK RATING**	**FURTHER REMEDIAL MEASURES REQUIRED FOR RISK RATINGS >3**
List the significant hazards associated with each subject (e.g., electricity, petrol, fumes, noise, dust, etc.)	Give a brief statement for each hazard (e.g., cut hand, eye damage, chronic illness)	List for each hazard the control procedures, equipment and devices currently used. (e.g. specific PPE, systems of work etc.)	Enter for each hazard 1(Slight) to 3(Major)	Enter for each hazard 1(Low) to 3 (High)	Enter for each hazard 1(1-10 persons) to 3(whole department)	Enter for each hazard (Hazard Rating x Risk Factor x Extent)	Give brief statement of further remedial actions taken. Risk Rating > 3 - Assessor to action Risk Rating > 6 - Safety Officer to be consulted
Speaker	Hearing loss due to prolonged exposure to high volumes.	Use sound meters to track decibel levels and ensure that sound isn't too loud. Ensure the usage of ear plugs or noise cancelling headphones if high frequencies are used. Have breaks to reduce ear fatigue.	2	1	1	2	
Risk of COVID-19	Coronavirus have serious symptoms such as coughing, lack of taste and fever. This can cause death if you are vulnerable.	Wear masks for the duration of the lab experiment. Wipe surfaces with wipes after use. Minimise contact with other people unless necessary. If you have symptoms, inform supervisor and lab partner then isolate. Lab partners will come in on alternating days to reduce spread and video cam will be used if both lab partners need to work together on data processing or calculations.	2	1	1	2	

CONTINUATION SHEET

ASSOCIATED HAZARD/S	TYPE OF POSSIBLE INJURY	EXISTING RISK-CONTROL MEASURES	HAZARD RATING (SEVERITY OF HARM)	RISK FACTOR (LIKELIHOOD OF EVENT)	EXTENT (NUMBER OF PEOPLE AFFECTED)	RISK RATING	FURTHER REMEDIAL MEASURES REQUIRED FOR RISK RATINGS >3
List the significant hazards associated with each subject (e.g., electricity, petrol, fumes, noise, dust, etc.)	Give a brief statement for each hazard (e.g., cut hand, eye damage, chronic illness)	List for each hazard the control procedures, equipment and devices currently used. (e.g. specific PPE, systems of work etc.)	Enter for each hazard 1(Slight) to 3(Major)	Enter for each hazard 1(Low) to 3 (High)	Enter for each hazard 1(1-10 persons) to 3(whole department)	Enter for each hazard (Hazard Rating x Risk Factor x Extent)	Give brief statement of further remedial actions taken. Risk Rating > 3 - Assessor to action Risk Rating > 6 - Safety Officer to be consulted
Faulty electronics	Electrocution	Inspect cables and wires before use. Ensure it's been tested beforehand. Ensure no liquid is around the apparatus at any time.	1	1	1	1	

Transmission of Sound waves in hollow tube with acoustic metamaterial – Week 3 (Thursday) – Emmanuel Zeta

08 October 2020 14:35

Aim:
I will set up the apparatus and will carry out preliminary tests to ensure that everything is working accordingly.
If time permits, I will start on creating code for the data acquisition.

Methods:
Create data acquisition code for the experiment and configure apparatus.

My Comments:
I've attempted to get MATLAB to read and acquire data from the microphone using the computers built in sound card but for whatever reason, MATLAB isn't actually displaying the soundcard as a 'vendor' in order for me to create a session. I've attached a link to the MATLAB help I've been using so that Josbin can attempt too.

https://www.mathworks.com/matlabcentral/mlc-downloads/downloads/submissions/47593/versions/20/previews/examples/acoustic/html/AcquireSoundCardDAQExample.html

Additionally, I've attempted to get MATLAB to work with the signal generator but to no avail. I've attached a link to the manual for the signal generator too.

http://ecelabs.njit.edu/student_resources/33220_user_guide.pdf

Update: Matt has sent me an example MATLAB code for how to use the microphone to receive a signal (in volts) so it's worth figuring out how to convert that voltage from volts to decibels.

Finishing configuration of Equipment and Trial runs-Week 4 Tuesday- Josbin Jacob

13 October 2020 10:47

Aim:
The aim of this session will be to finish integrating MATLAB code with the oscilloscope and take initial readings with the set up.

Method:
Use the code to automate data collection. The data will be collected for some membrane with the same methodology as described in the research paper.
Our microphone will be connected to the computer's soundcard instead of the DAQ board, this ensures a better resolution.
The signal generator will be connected to the computer via a DAQ board. It will generate a range of frequencies. Each frequency will play for a fixed amount of time and the amplitude received will be measured. Then a MATLAB program will plot average amplitude over that fixed amount of time against frequency, hopefully showing the characteristic curve indicating coupling.

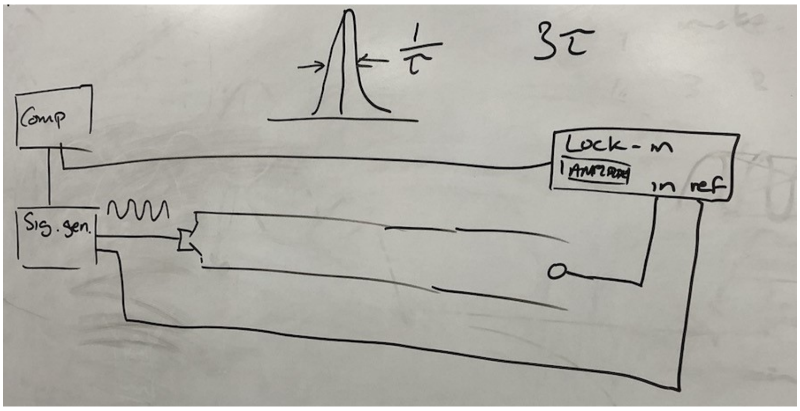
Experiment:
The audio input program is essentially the same as given in the example. No need to change the y-axis values because we are not interested in how loud the speaker is, just the intensity. (Intensity will corelate with loudness). We will adjust time values so they match the time values of the frequency sweep. Using the manufacturer's webpage [1], the recording frequencies are between 30Hz – 18 Khz. Since this is the case, we can't use frequency values over 9Khz, due to anti-aliasing. This is a limitation for our experiment as the human ear can hear up to 22Khz, locking us out of potential membrane materials. We could also get a better microphone.

Reference:
[1]: https://uk.rs-online.com/web/p/lavalier-wired-microphones/2428911/

Finishing Data Acquisition code -Week 4 Thursday-Emmanuel Zeta

15 October 2020 10:22

Aim:
To finish microphone input and data acquisition code.
Method:
I have read the manual for the signal generator to find the required commands needed to generate a signal at specific frequencies and amplitudes. I have also automated the process of signal generation by utilising for loops in MATLAB. The apparatus has been altered so instead of feeding the microphone's signal directly into the computer, the signal will be fed into a lock-in amplifier with a time constant of a third of a second. This will allow for a bandwidth of 3Hz around the signal allowing for quick but precise data acquisition. A diagram for the apparatus is given below:



The speaker will output each frequency for 1 second.
Experiment:
Everything has worked as planned. The only issue now is that we need to alter the code so that the computer can communicate with the lock-in amplifier so that it can receive the microphone signal.

Here is a link to the manual for the lock-in amplifier
https://www.thinksrs.com/downloads/pdfs/manuals/SR830m.pdf

(Page 85 of the the pdf is useful)
(Chapter 5 part 1)

Finishing Data Acquisition code -Week 4 Thursday- Josbin Jacob

15 October 2020 14:27

Aim
Finish data acquisition code
Method
By reading the locked in amplifier code, finish data acquisition code.

During our experiment I finished up the code. During testing it was shown that the lock in amplifier required a bit of time to settle down so the pulse of each frequency was set to 5 seconds

Results
These are the very first results for frequencies between 1-2 Khz. These don't represent anything, it's just proof that our code works.

Frequency (KHz)	Amplitude(arbitrary units) (10^-4)
1.00	2.1
1.25	1.2
1.50	-4.5*
1.75	2.4
2.00	1.4

These results need to be repeated with the proper set up. Some values could be higher than others because the sound waves could be forming standing waves. No repeats were taken, these are just trial runs to ensure the code is executing correctly. It might be useful to find the different harmonics formed in the pipe as this could explain why certain frequencies peak even without the membrane. This could be done by measuring the tube length and assuming room temperature conditions.
Next week onwards I think we can set up membranes and do the actual tests.

Collecting Data – Emmanuel Zeta (week 5 Thursday)

22 October 2020 10:42

Aim:
To carry out the experiment with the nitrile gloves and to collect data.
Method:
By using the apparatus outlined earlier in the lab report, I will collect data for the transmission of sound waves through an acoustic metamaterial.

The size of the hole in the baffle used is 11mm.

Today, I will use nitrile gloves as the material to test its permittivity of sound waves in a frequency range.

We have decided to use the entirety of the microphones range (30Hz to 18kHz)

Experiment:
After running the program with the baffle and the nitrile glove, I've come to these main conclusions:

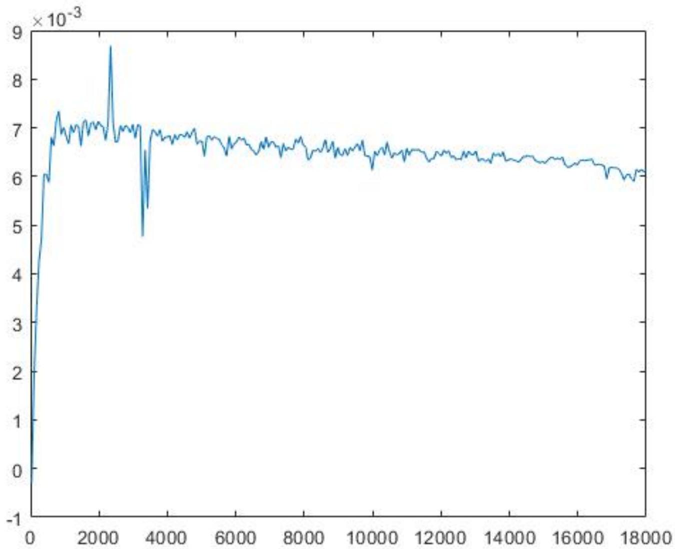
1) We need to lower the time for each pulse. The time constant is 300ms therefore in order to ensure maximum precision, 5 time constants is all we need for the pulse. Therefore I've now lowered the pulse time to 1.5 seconds.

2) We need to lower the number of actual data points collected and if we notice anything special in the data, we can redo the experiment at a smaller frequency range. I've lowered it from 500 data points to 250 data points.

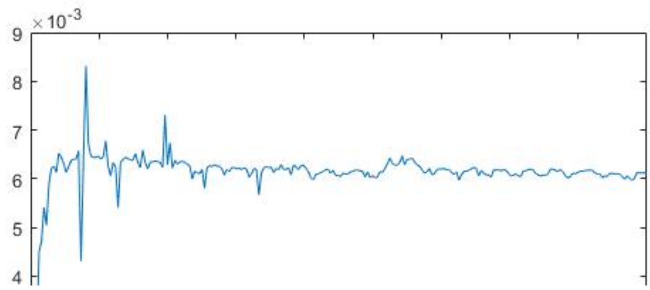
By making these changes, it shortens the data acquisition time to approx. 6 minutes per test which is much more ideal.

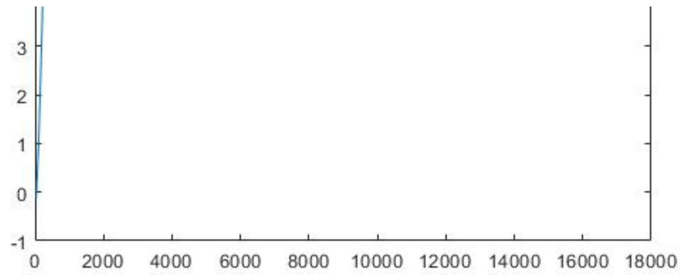
Now, I will carry out the experiment to get the transmission of sound waves without the baffle , with the baffle (without glove) and with the baffle with glove. By doing this, we can compare the results under each of these conditions and identify areas of interest to 'zoom in' on so we can rerun the experiment with a smaller frequency range if required.

Results:
Without baffle:

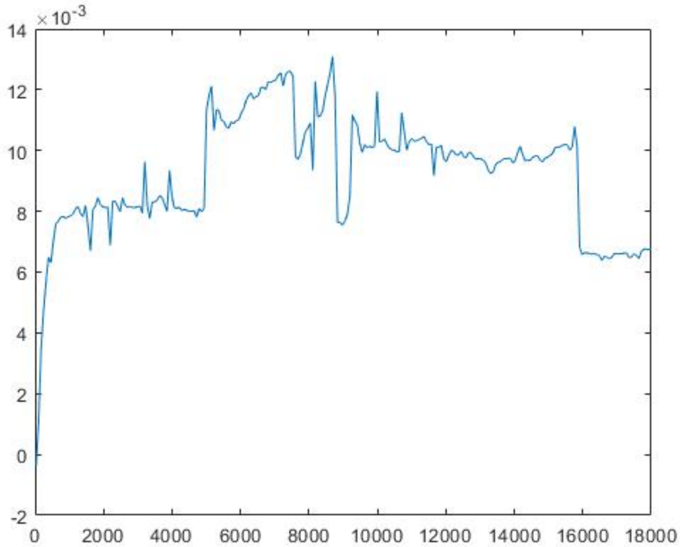


With baffle **– No Glove:**





With baffle **– With Glove:**



I've forgotten to label the axis on MATLAB as frequency in Hz. The y axis is an arbitrary unit which represents amplitude.

My comments:
I've realised now that I didn't take repeat results. This is due to time constraints. Repeated results will be taken later by Josbin.

Repeats for 11mm hole sizes using Nitrile Gloves – Thursday Week 5- Josbin Jacob

22 October 2020 14:31

Background
When a sound wave is passed through an aperture much smaller than the wavelength, it will diffract very little if at all through the medium. However when certain materials are placed at the aperture certain frequencies will resonate with the metamaterial and will transmit almost all the soundwaves. There are optimal frequencies for each metamaterial but certain frequencies could be over represented. This occurs because the pipe the sound is travelling through is closed, hence standing waves can be produced. Certain frequencies could be the harmonic frequencies within the pipe.
For closed tubes harmonic frequencies are given by:

$$F_n = \frac{nv}{4L} . \qquad (1)$$

Where F_n is the harmonic frequency, n is a positive integer, v is the speed of sound and L is the effective length of the pipe.

Experiment
Part 1: Measuring fundamental frequency and subsequent harmonics

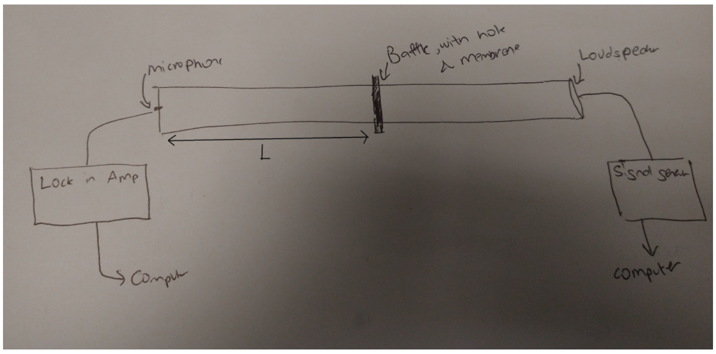


Figure 1: Experimental set up with L clearly displayed.

During the experiment the value of L was 88.2 cm. This is the value from the microphone to the baffle. Using this value and the speed of sound in air (343 m/s), the fundamental frequency as calculated by equation (1) is: 97.2 Hz.
There are errors on this value because speed of sound changes with temperature and humidity and I measured neither. Also the L value could be slightly off because we have encased the microphone in a foam to limit external audio inputs.
This means that all multiples of 97.2Hz are harmonics of the pipe.

Part 2: Carrying out repeats on Emmanuel's Data
I tried to use matlab to automate collecting 5 sets of results but accidentally deleted hours' worth of results. I then decided just to save the data sets in between to complicate things less. In the meantime while experiments were running I built the electronic circuit which represents the same phenomenon but using electric current instead of sound waves.
Data was collected and stored in a folder.
When I collected the data there is a sharp increase and then a plateau, I think this is because the very low frequencies have amplitudes so small compared to the higher frequencies that all interesting characteristics are dwarfed.

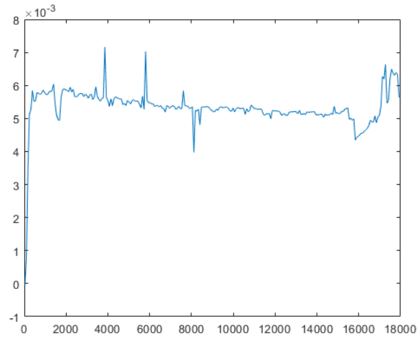
Analysis of initial results –Tuesday Week 6- Josbin Jacob

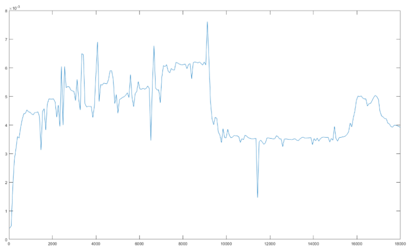
27 October 2020 10:23

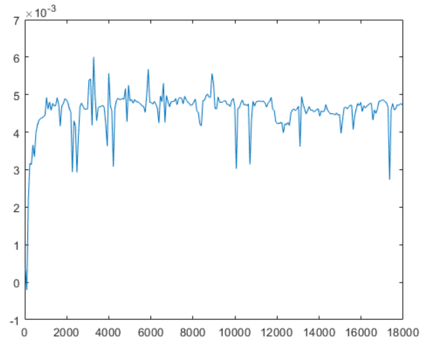
Objectives
Since our initial data was collected, I will analyse and find regions displaying this coupling effect. Then we will proceed to narrow our search region to these frequencies and display the resonance effect. We could then switch out our material, change hole size or switch materials.
Last week in between the tests I built the electric circuit which models the same behaviour but using an electricity instead of sound waves.

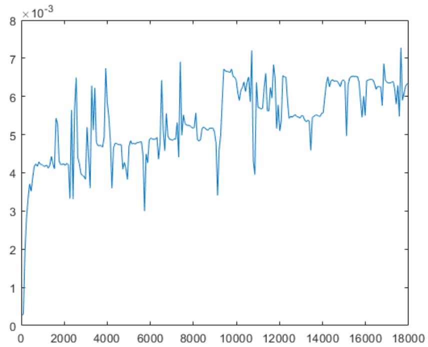
Results

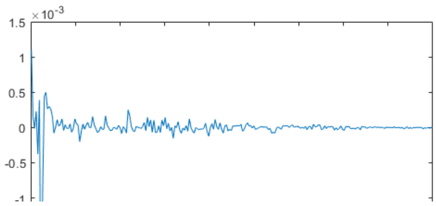
I didn't upload my results last week. I think something went wrong for most of my results. This probably occurred due to a loose connection between the equipment.

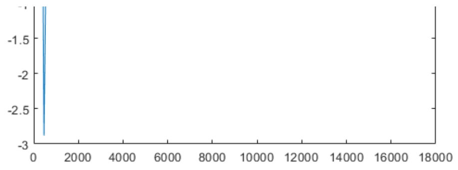


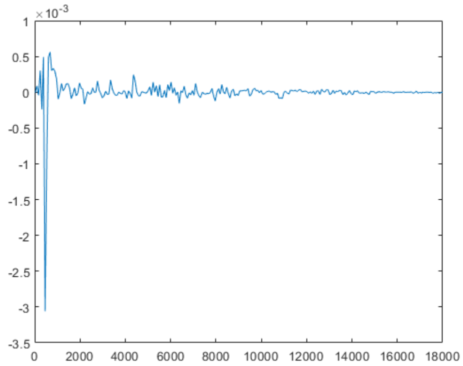












I forgot to label the axis on MATLAB but the x axis is frequency in Hz. The y axis is an arbitrary unit indicating amplitude.

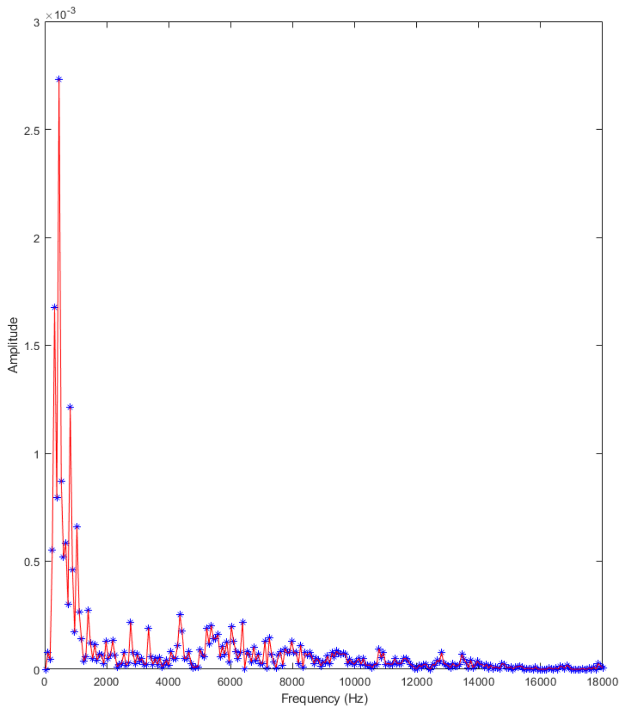
The first 4 graphs have no consistency between them, leading me to think they are just amplified noise. The only consistent graphs are graphs 5 & 6. This leads me to believe they are the only correct values. I am going to repeat this test again but for frequency going up to only 8000Hz. If the same peak occurs around 500 Hz, it should be correct.
I was extremely bothered by the negative results because amplitude should not have a negative result. When I consulted the manual for the lock in amplifier, I discovered that I am only recording part of the signal by recording Y output.
Specifically within the lock in amplifier:

$X = V_{signal}$* cos(theta)   In phase component

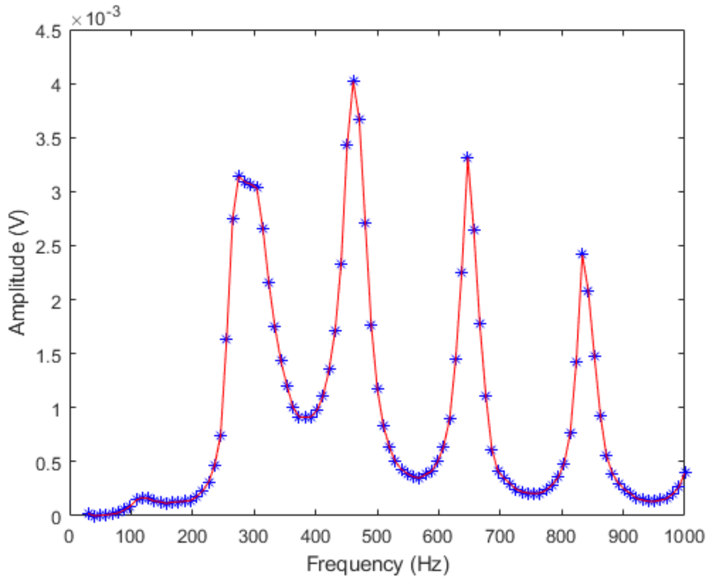
$Y = V_{signal}$* sin(theta) Quadrature Component

I am not too sure of exactly what this means but these represent the signal as vectors, so to get the magnitude of the signal R (amplitude):
R = sqrt(X^2 + Y^2).

When I did our experiment again, I once again I found the familiar peak around 500Hz.



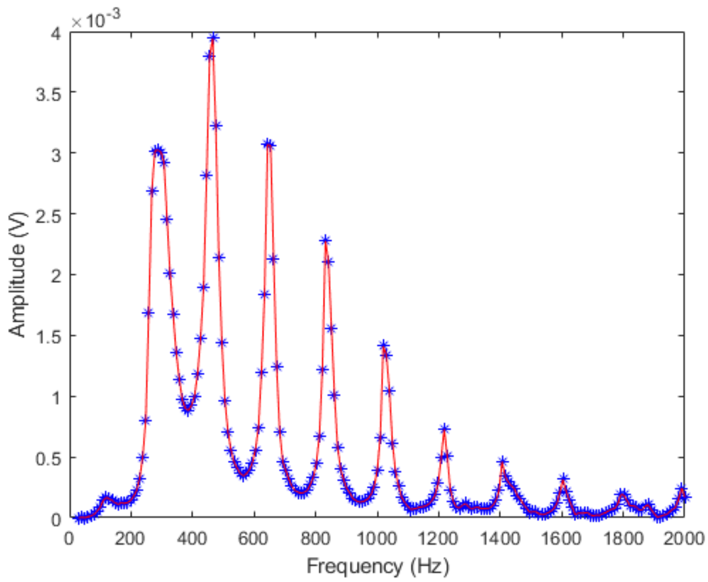
This shows data from 0Hz to 18000 Hz, the full range of our microphone. This data has a peak around 500 Hz. This also shows that the effect harmonics have on the amplitude is completely dwarfed by the acoustic coupling. I thought that perhaps this coupling effect could be found in frequency multiples but that is clearly not the case. We should only observe 1 peak throughout the data.



When I zoomed in to the 500 Hz region it doesn't show a clear 1 peak as I expected but instead numerous smaller peaks. I calculated the fundamental frequency as 97.2 Hz but that peak isn't very prominent. Using the MATLAB max function the maximum frequency occurred at 461.1 Hz.

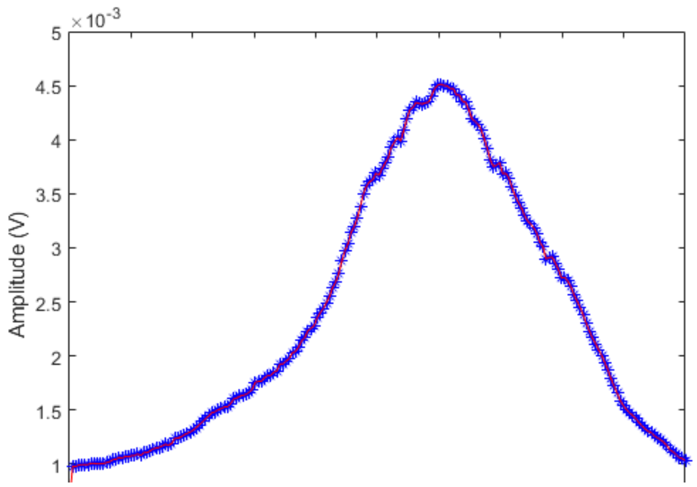
During measurements I measured the phase shift that the lock in amplifier was recording, I expected this to be zero because the Lock in was using the signal generator for its reference. I discovered that this was not the case when I asked a technician they said it most likely occurred due to background noise.

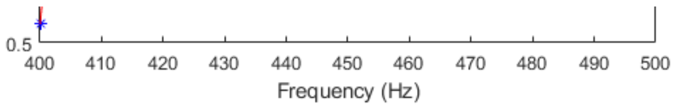
I decided to take this reading again to 2000 Hz to see if there were any patterns I could observe.



Here once again the maximum Frequency value occurred for 465.6 Hz. These peaks have some periodicity (in that the intervals are around 200Hz) occurring every 200 Hz or so and they decay fairly quickly.

Just to be clear here is the result showing the resonant behaviour from 400-500 Hz.





Max amplitude occurs at frequency 460.3

Conclusion

While I was unable to do tests with the electric circuit all our equipment is now ready to go and we have a good set of results. Next session Emmanuel can change the material and play around with other material. We could change baffle size and determine its effect on the overall graph and the resonant frequency.

Collecting Data (Week 6) – Emmanuel Zeta

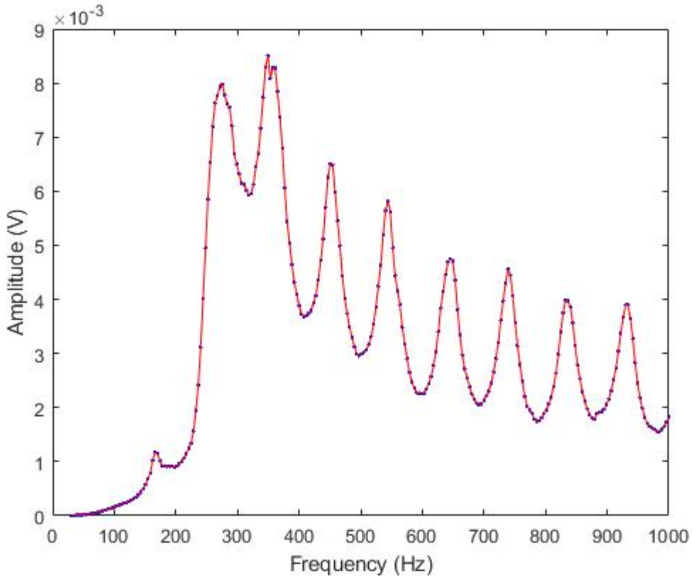
29 October 2020 14:47

Aim:
To collect data values for the following conditions for 11mm:
- Without the baffle
- With the baffle but not glove
- With the glove

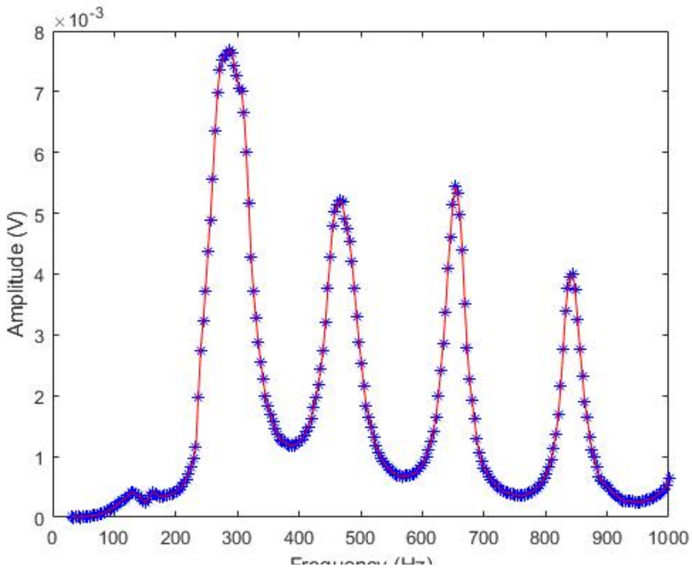
Method:
By using the apparatus outlined earlier in the lab report, I will collect data for the transmission of sound waves through an acoustic metamaterial.
The code has been updated to record R values ie: the actual signal.
I will start by sweeping through the entirety of the frequency range and I'll 'zoom' into areas of interest if necessary.

Experiment:
I used the entire frequency range and collected 250 pieces of data.
I zoomed into the 30Hz to 2000Hz range for the next set of data as it was the area of interest. For this frequency range I will also collect 250 pieces of data.
I zoomed again into the 30Hz to 1000Hz range for the next set of data.

Results:
I collected data for all conditions and was able to generate 3 graphs for each condition - 1 graph for each frequency range.
When the baffle with the glove was inserted, there was a peak at approx 450Hz so I zoomed in around that range for each condition so it can be compared. Below are the 'zoomed' in graphs:
<u>No Baffle:</u>

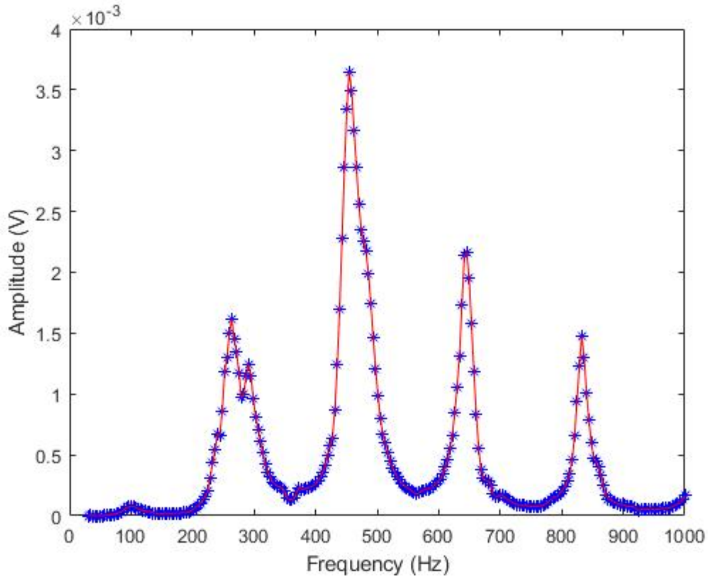


<u>Baffle (no glove):</u>



Frequency (Hz)

Baffle (glove):



Data collection Week 7 –Josbin Jacob -Tuesday

03 November 2020 10:18

Objectives:

Emmanuel's data could explain why I observed periodic peaks in my data. His data for without baffle and with baffle also has some periodic peaks every 200 Hz or so.
Last week I came up with a method for analysing a practical use of acoustic coupling. I proposed a plan to play a wave composed of multiple different frequencies, with one being a resonant frequency. I then would play this resonant frequency into the tube. The audio we record at the end should have a much lower amplitude because the material wouldn't couple very well with certain frequencies. Then by doing a fast Fourier transform, we could see the frequency peaks which was most prominent in our results. I expected that the frequencies other than the resonant would be cut out, but this is not quite what happens. This plan doesn't work very well in our acoustic set up due to noise. As I discovered last week, when I checked the phase shift recorded by the lock in amp, it wasn't zero as expected. Noise, which can be any frequency or have a relative phase was entering the mic too, this caused a phase shift. These noise frequencies would also appear on our Fourier transforms. Furthermore any reflections or standing waves created within the tube (like the periodic peaks we saw last week) would also show up. This would make it very hard to analyse. However this method could work very well for our electronic set up. We could send short pulses made up of various frequencies and fft those results. There would be very minimal noise, and I could once again use the lock in amp, to make sure that the phase shift between the oscilloscope and the data recorded is very close to zero, which would indicate very little stray frequencies entering our set up. Or along with plotting the real part of the fft, which shows frequency space, I could also plot phase space, which should hopefully show a very small phase shift.
Today I will carry on with recording data for numerous baffle sizes, I will attempt to find the main source of systematic and random errors. During the tests I will try and get some results for my electronic circuit too.

Figure 1: Diagram showing electrical circuit

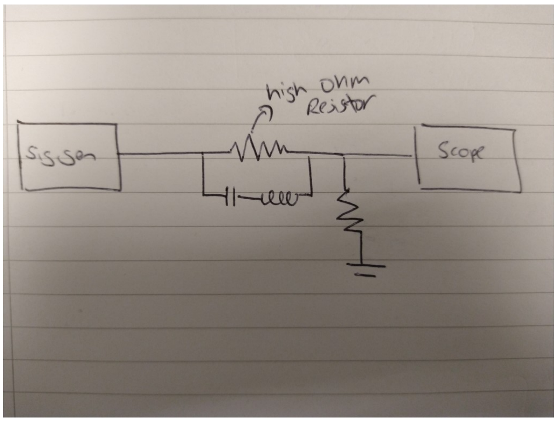


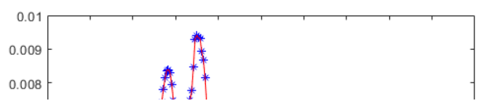
Fig 1: Diagram showing electrical circuit. The high ohm resistor is in the region of ~ 1kΩ. The capacitor and inductor represent 'stiffness' and the spring constants of the materials within the tube. The high ohm resistor represents the baffle.

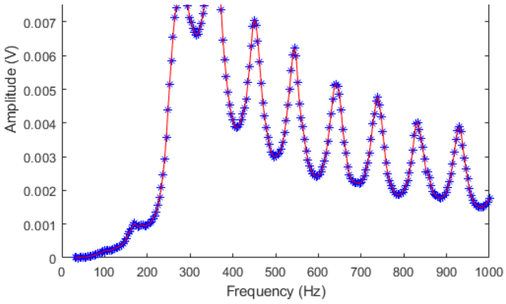
Method

I will take results by initially recording with no baffle, save this data, then record with only baffle, save this data and then use the metamaterial as well. I don't know if I should just subtract the results for no baffle and just baffle from the final data, but hopefully the periodic peaks could be explained by those data points.
When doing this, it's also important to make sure our meta material is tightly fitted over our baffle. A looser metamaterial, especially a material like latex glove, behaves like a string. If it is very loose, the natural frequency could easily overlap with the signal generator, whereas tighter materials have a higher natural frequency.

Results
We have determined that it is probably best to take noise readings at the start of every session. Saving both amplitude and frequencies used.
My results today will be carried out using 18.7mm baffle, once again using nitrile gloves as the material.

The results for no baffle:

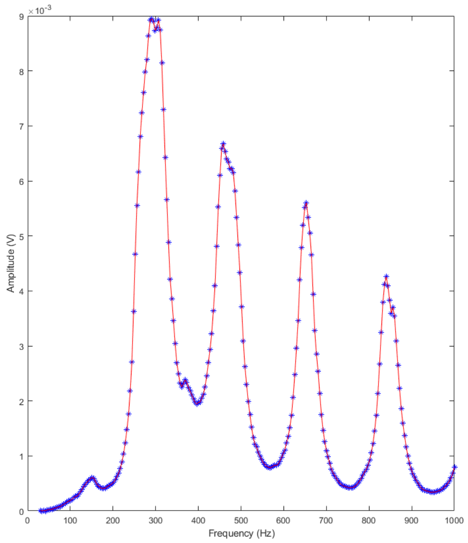




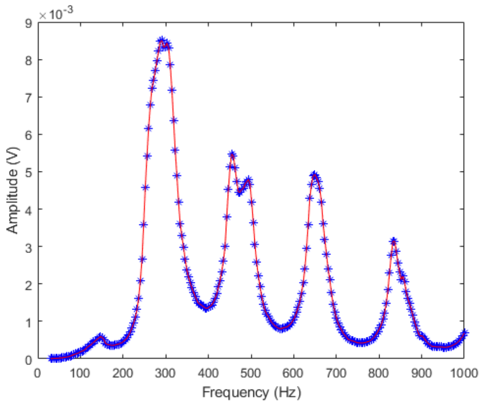
This shows the 200 Hz peak intervals but I don't know why it does form these.

When we place our baffles, it's important to note that even if the baffle isn't completely perpendicular to the tube, it shouldn't make much of a change as this coupling should be independent of geometry.

Results with just baffle:

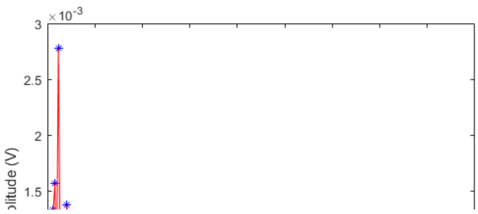


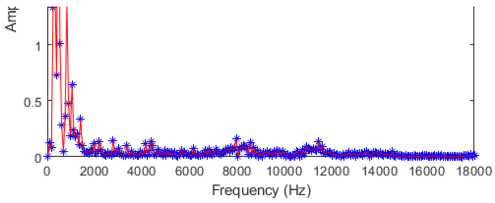
Once again the amplitudes with the baffle is smaller than the amplitudes with no baffle. However it remains quite similar, which is surprising, considering that the wavelength of 300 Hz should be about 1m yet it is still passing through the baffle unaffected. This indicates that the sound wave could be 'leaking'. I will run this again to make sure nothing is going wrong.



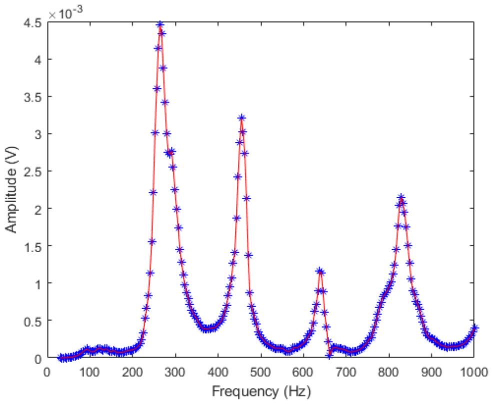
Now I will record the results for baffle with gloves. In order to make sure the gloves were tightly held in place, we are using a copper tube which tightens the glove.
I made an error here. I should have recorded data between 30 – 18 Khz again to determine the true resonant peak. I just assumed that since the last resonant frequency was around 460 Hz last time, it would be similar this time too. I will run this again for ranges from 100Hz to 15000 Hz. It is very unlikely the same material will have a resonant frequency so much higher than the value expected.

Results with baffle and glove:





Amp
1
0.5
0
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Frequency (Hz)



×10^-3
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Amplitude (V)
0
100
200
300
400
500
600
700
800
900
1000
Frequency (Hz)

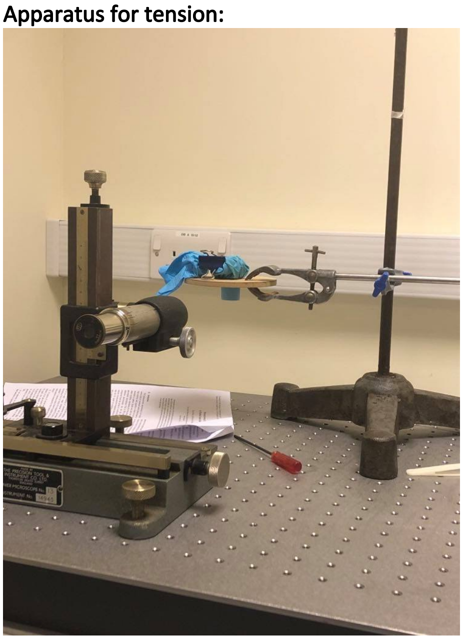
Collecting Data (Week 7) - Emmanuel Zeta - Thursday

05 November 2020 14:27

The apparatus works exactly as we want it to however we forgot to take into account the tension of the nitrile glove over the baffle. The higher the tension of the glove, the higher the resonant frequency. In order to take this extra factor into account, I will use ball bearings and a travelling microscope to measure the deflection of the surface.

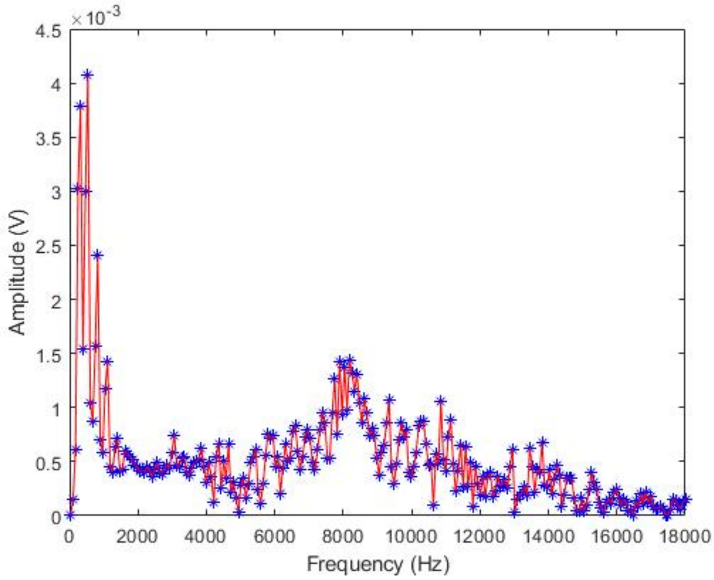
Aim:
To collect data for the 15.6mm Baffle.
To collect data for the deflection of the surface of the nitrile glove.

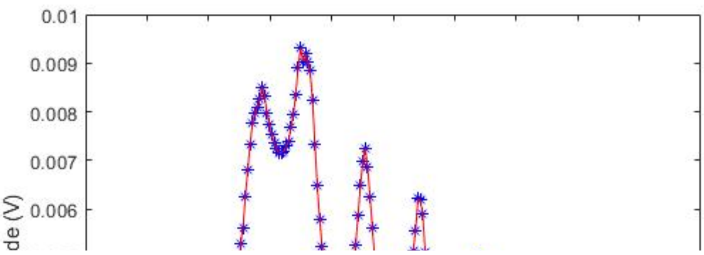
Apparatus for tension:

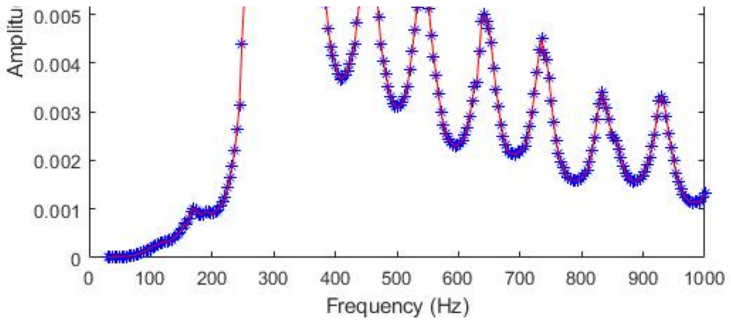


I will use a travelling microscope and a clamp stand to measure the deflection of the surface when a ball bearing of mass 1 gram is inserted.

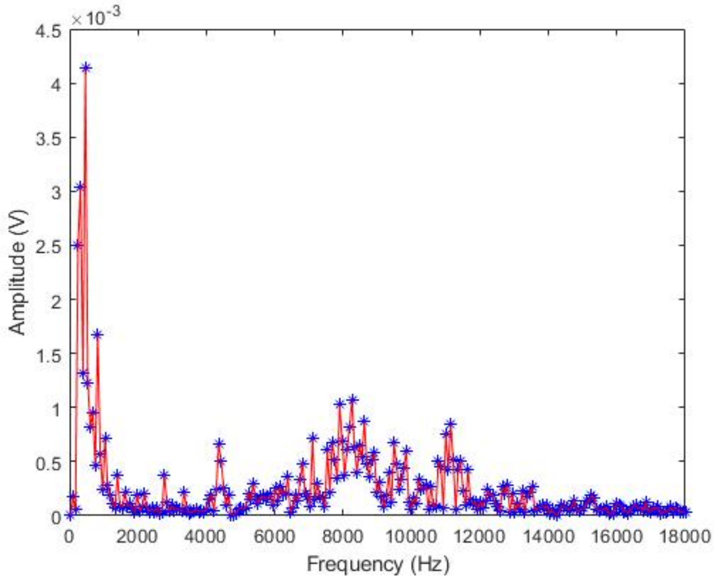
Results:
No baffle

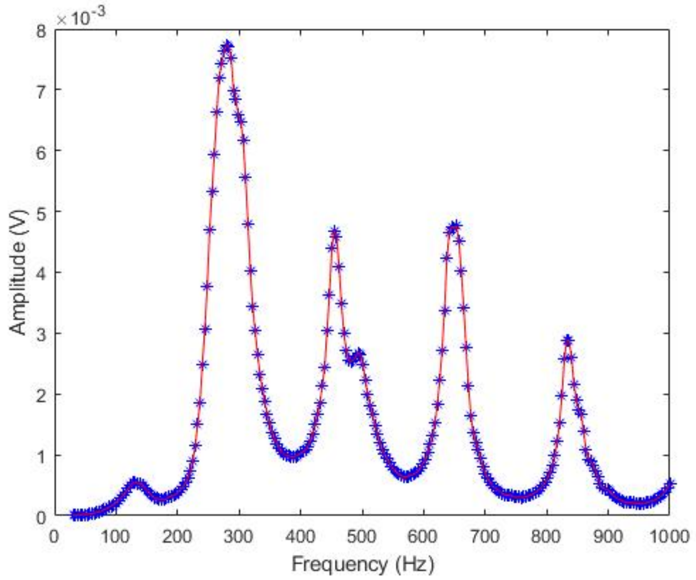




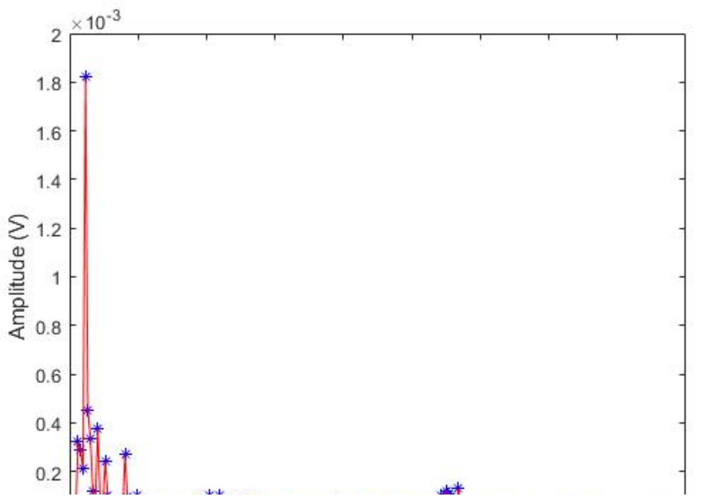


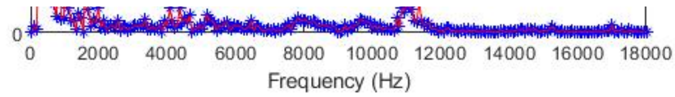
Baffle without glove

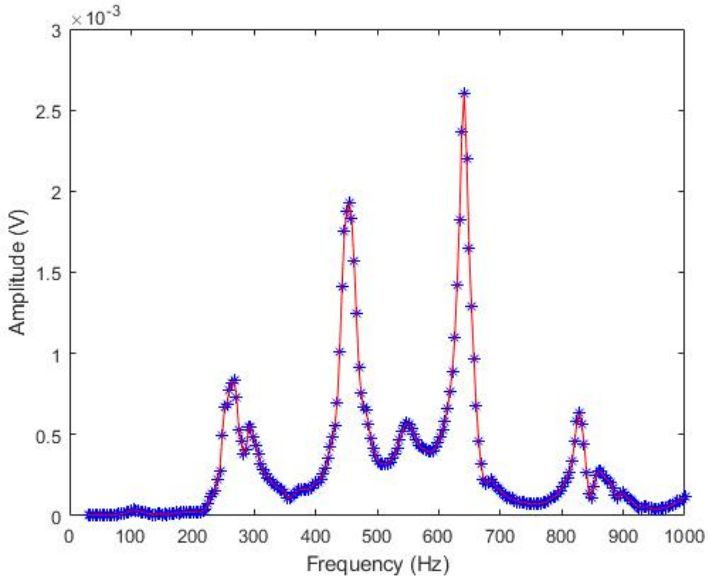




Baffle with glove







Discussion:

I ran out of time before being able to get results for the tension of the glove over the baffle holes however next session I will carry out these measurements.

The graphs for the transmission of sound waves with the baffle and nitrile is supposed to resemble that for without the baffle however the peak of the transmission is at around the 600 to 700Hz range. This is very interesting.

Tension on Nitrile Gloves – Josbin Jacob – Week 8 Tuesday

10 November 2020 10:17

Plan
Last week Emmanuel discussed the importance of working out tension on the gloves. This is important to ensure repeatability of our experiment. In this session I aim to find tension values baffle/without baffle for 11mm and 18.6mm.
Method
The method for collecting frequency has not changed, we will be using a travelling microscope as discussed by Emmanuel last week to measure displacement.
For some reason my code stopped working. When running instrwinfo on the matlab console, it states the secondary address has changed from 7 to 8. No idea why this happened as NI max still says it's at secondary address 7.
Code issues are fixed, now I will measure tension on the gloves.
After seeing the lack of movement per ball bearing I've decided to do multiples of 3 ball bearings.

Ball Bearing	Deflection(μm)	
		difference(μm)
0	94	0
3	92	2
6	91	3
9	89	5
12	87	7

I tried seeing if using my phone would help me take better readings but that didn't help. Using Hook's law, we can now derive the spring constant

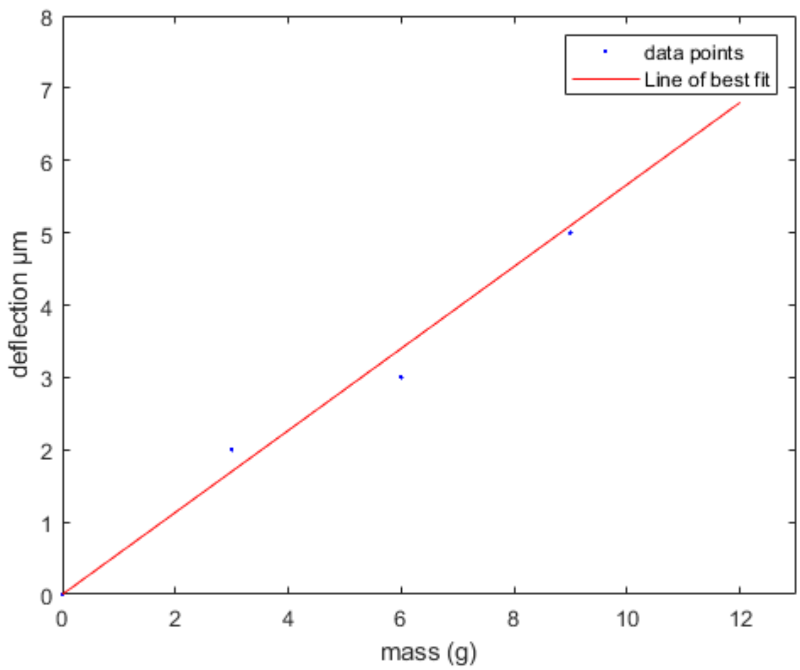


Fig 1: Graph showing deflection against mass for measuring spring

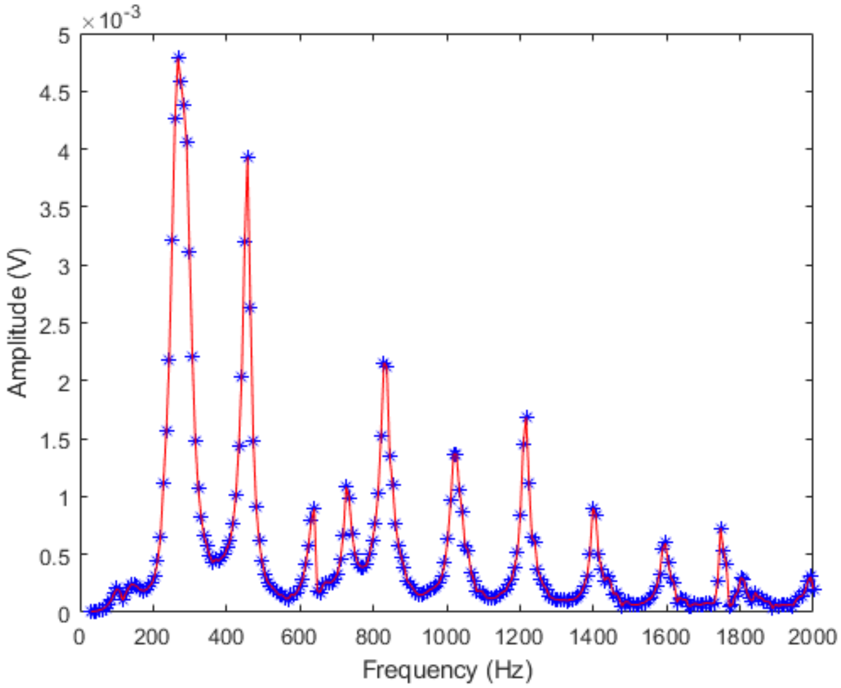
constant. The baffle width was 18.6mm.

The gradient (m) as worked out by cftool is 0.57 µm/g. Using Hooke's law, I worked out k as equal to (1/m) * g *10^-3 * 10^6.

17000 Nm^-1.

These results are only so high because I used masses of 3-12grams. At higher masses, plastic deformation would occur, tearing the nitrile gloves.
The main problem is that the deflection is so small reading it with the travelling microscope is no easy feat. Also, the nitrile gloves don't stretch uniformly over its surface. I noticed that when the ball bearings were dropped, the nitrile gloves have certain 'points' on their surface which stick out more than the neighbouring areas. I think for smaller widths this shouldn't be a problem as it is easier to localise the ball bearings so only the deflection of these 'points' is measured. However larger diameters, there is a certain degree of randomness on where the ball can land. I tried getting over this by adding 3 balls at a time. 3 balls were roughly enough to cover the whole surface. I hoped that since no more new 'points' could be formed, the load would be evenly distributed across the glove.
Due to the difficulty in reading the travelling microscope and all the other factors as mentioned above, I can't justify giving a greater accuracy than 2 sig fig.

Maximum frequency recorded = 267 Hz.



Data - Emmanuel Zeta (Week 8)

12 November 2020 14:06

Aims:
After talking with my lab partner and supervisor, we've come to the conclusion that the apparatus and methodology could be improved in order to generate better results. Today, I will be outlining the improved methodology and I will be collecting a new data set for when the Nitrile glove is on a given baffle and for just the baffle itself.

Method:
Prior to this, the way in which the metamaterial was inserted into the baffle was by stretching an entire glove over the baffle hole by pressing a tube of corresponding diameter through the glove and into the baffle.
This has been changed because the excess glove is unnecessary and could've messed with the results. Now, I have cut 3 square pieces of the Nitrile glove big enough to be stretched over each baffle.

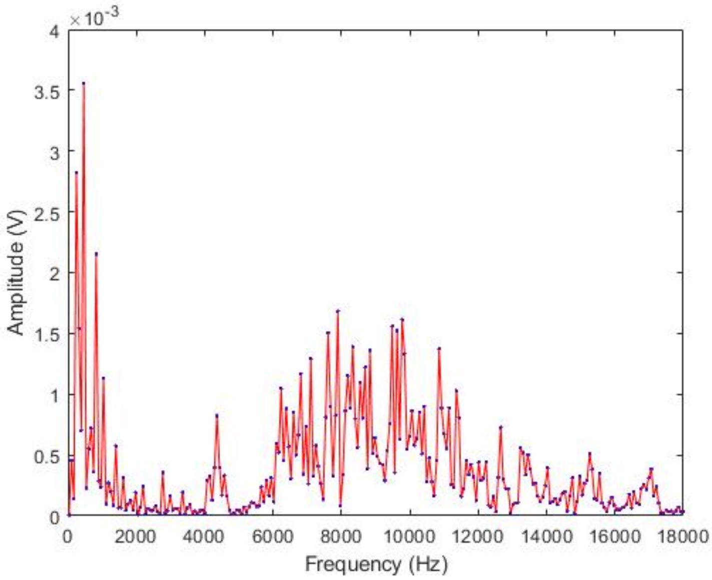
Furthermore, when recording values for with the baffle on its own, prior to this, the tube was not present but this would affect the data results since we're testing for the material on its own not the material in combination with the tube. For this reason, I will rerecord the data for the baffle on its own but with its corresponding tube inserted.

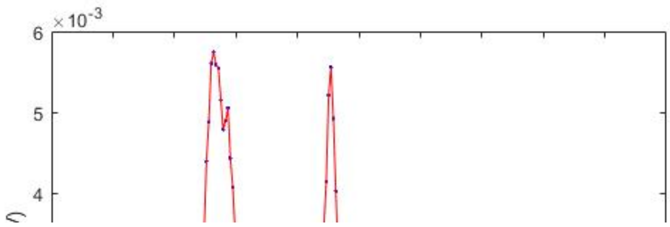
Before recording the data for each baffle, I'll measure the tension on the Nitrile Gloves for the sake of reproducibility using the method outlined last week

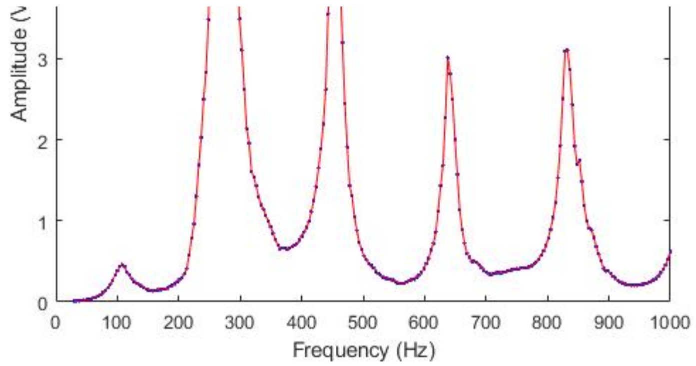
Results:

18.7mm Baffle			
No. Of Ball Bearings	Zoomed	Difference (µm)	Deflection
0	76	-	0
3	63	13	13
6	55	8	21
9	45	10	31
12	39	9	40
15			

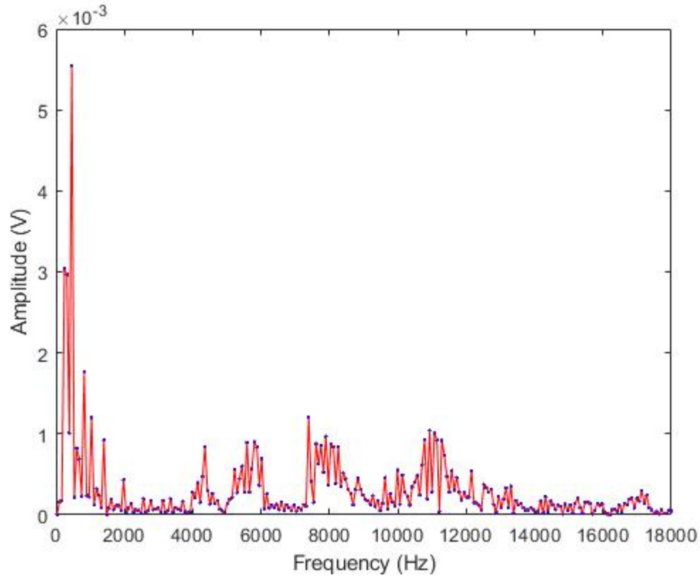
No membrane (18.7mm)

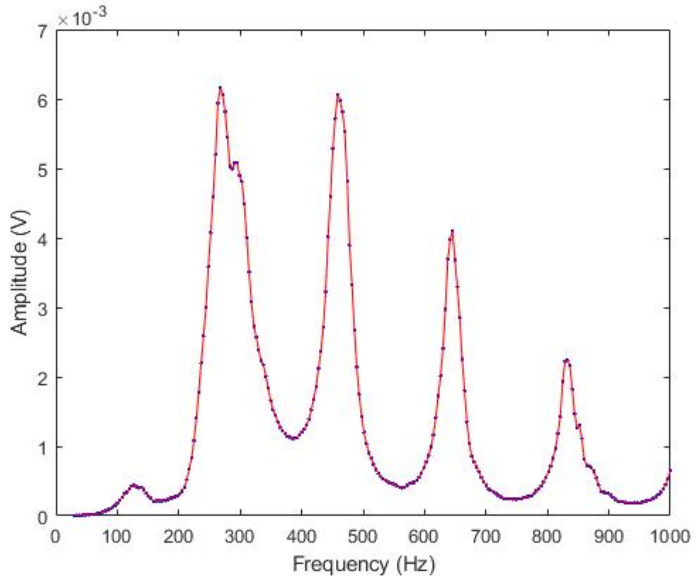




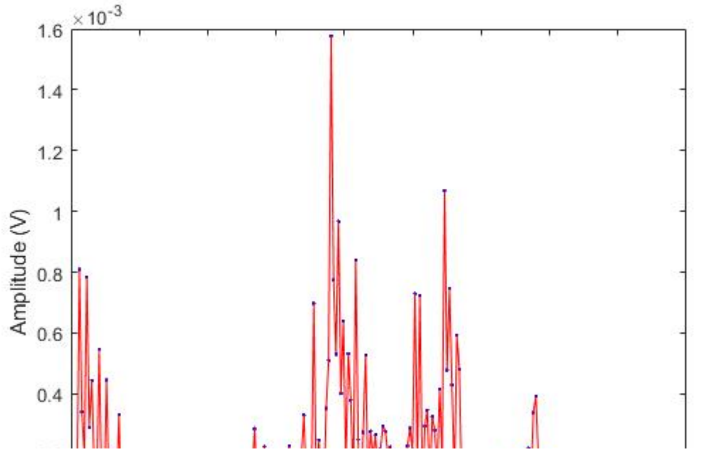


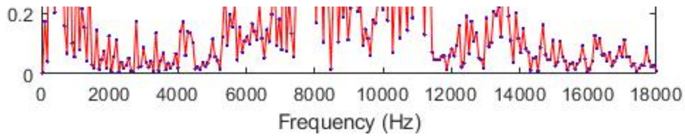
No membrane (15.6mm)

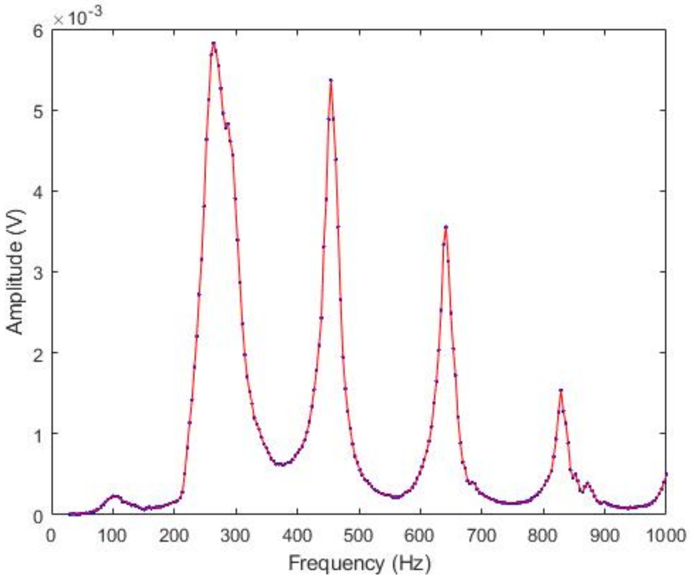




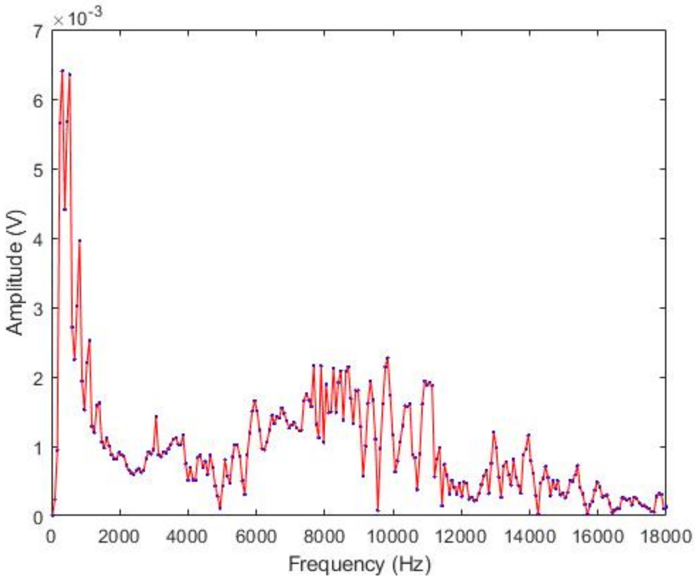
No membrane (11mm)

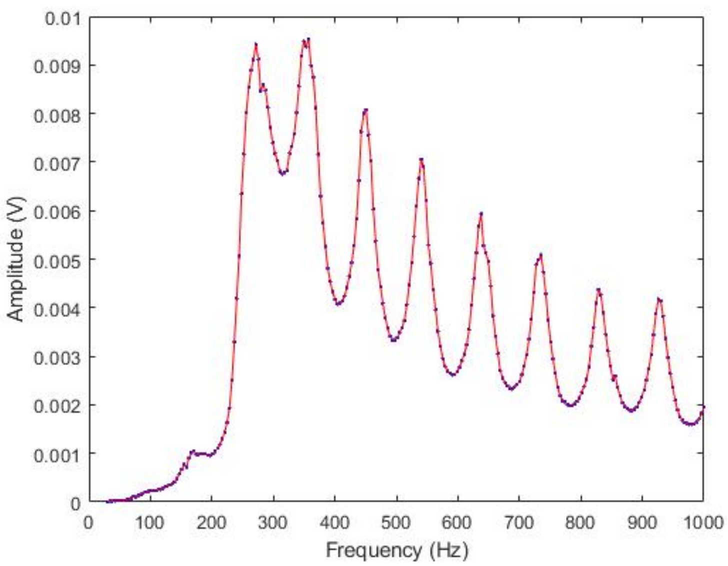



0.2
0
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Frequency (Hz)


$\times 10^{-3}$
6
5
4
3
2
1
0
Amplitude (V)
0
100
200
300
400
500
600
700
800
900
1000
Frequency (Hz)

Empty tube


$\times 10^{-3}$
7
6
5
4
3
2
1
0
Amplitude (V)
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Frequency (Hz)


0.01
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
Amplitude (V)
0
100
200
300
400
500
600
700
800
900
1000
Frequency (Hz)

Data - Emmanuel Zeta (Week 9)

17 November 2020 10:48

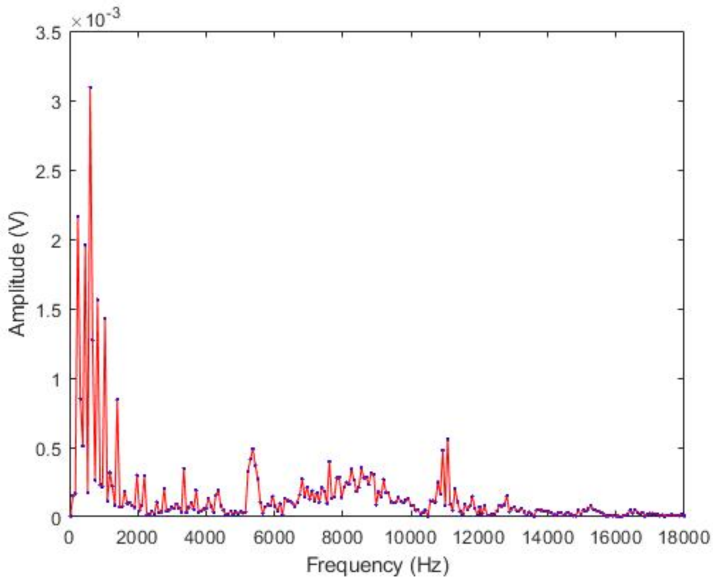
Aims:
To continue with what I started last week:
- Find tension values
- Finish recording transmission data

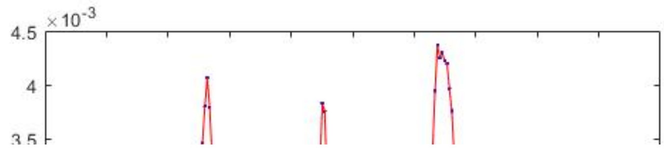
I think the values recorded last week for the deflection for the 18.7mm baffle was good but requires more points so it's more clear.

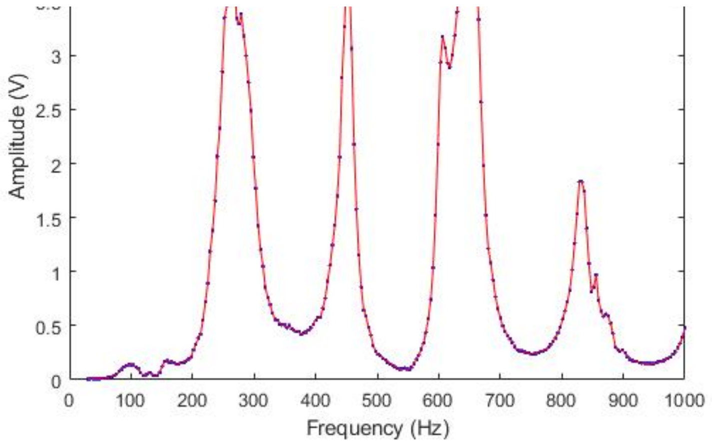
18.7mm Baffle	1g ball bearing		
No. Of Ball Bearings	Measurement	Difference (µm)	displacement
0	66	0	0
2	55	11	11
4	45	10	21
6	38	7	28
8	31	7	35
10	25	6	41
12	18	7	48

15.6mm Baffle	1g ball bearing		
No. Of Ball Bearings	Measurement	Difference (µm)	displacement
0	83	0	0
1	61	22	22
2	56	5	27
3	51	5	32

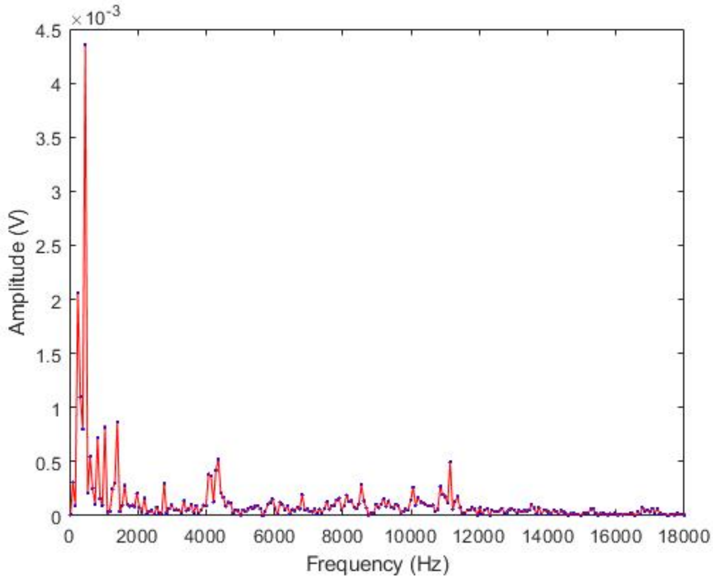
With membrane (18.7mm)

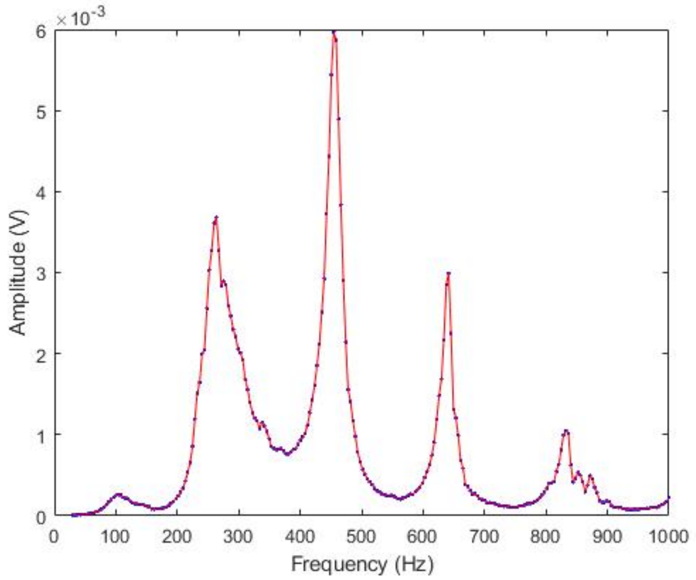






With membrane (15.6mm)





Discussion:
I ran out of time so I didn't record readings for the 11mm baffle. However, by looking at this set of data and comparing it to that with no baffle, it doesn't seem to exhibit the behaviour we are looking for. This suggests that there is an issue with our experimental setup and methodology. I have sent an email to Anthony for guidence.

Week 9 – Carrying on with Tension and Resonant Frequency collection

19 November 2020 10:32

We've decided it's best to record the amplitude of the lock in amplifier with our results. While the amplitude of the lock in doesn't affect the characteristic curve, we've decided that in order to have better clarity especially between mine and Emmanuel's results, it's better to record both.

Amplitude on lock in = 1.352 V

Mass of large ball bearing – 4.1g
Mass of medium ball bearing –2.0g

After consulting Dr Kent, numerous improvements were made on our experiment. This includes isolating the pipe from the desk by using foam, ensuring that excess nitrile glove is trimmed and ensuring gloves are tightly stretched out over the pipe.

Drum Skin modes:

When the nitrile glove is stretched out over the pipe, it behaves like a drumskin. The fundamental frequency of the skin is similar to fundamental mode on a string. The fundamental mode on an ideal drumskin is solved by solving the wave equation on a 2D surface. This results in Bessel equations being used for part of the solution. Since we are only interested in the fundamental frequency, we use $J_m = 0$. When this is done the equation becomes:

$$f_1 = 0.766 \frac{\sqrt{T/\sigma}}{D}$$

T = membrane tension in Newtons/meter

σ = density in kg per square meter

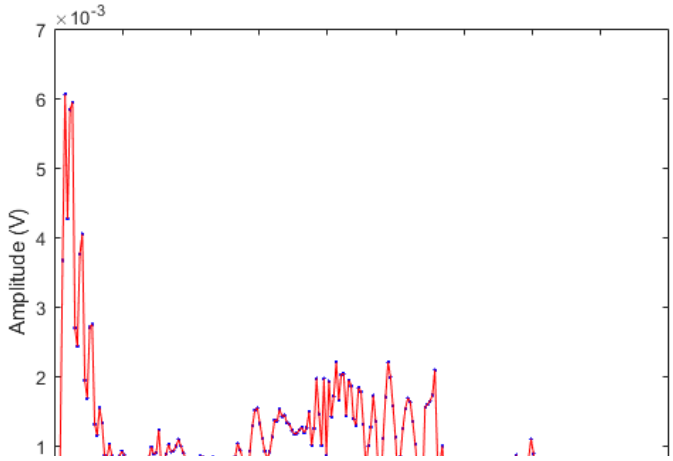
D = diameter of membrane in meters

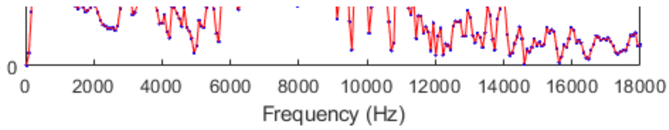
Large ball bearings were used

# of ball bearings	Distance (micrometres)	Deflection	Total Deflection
0	56	0	0
1	51	5	5
2	49	2	7
3	47	2	9
4	43	3	12
5	48*	2	14
6	46	1	15
7	47*	1	16

*The micrometre would sometimes jostle slightly up or down, changing the scale value, I worked around this by taking readings just before the ball dropped and then after. This way I didn't have to repeat measurements each time.

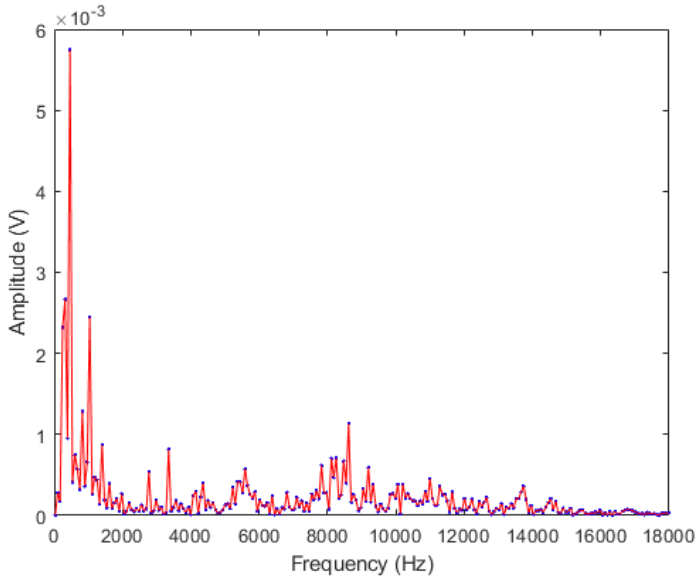
With our improvements in place here are the results for no baffle:





Here the max amplitude recorded was around 6.1x10^-3

Now with improvements, here is the result for with baffle:



Here max amplitude occurred at around 5.7 x 10^-3

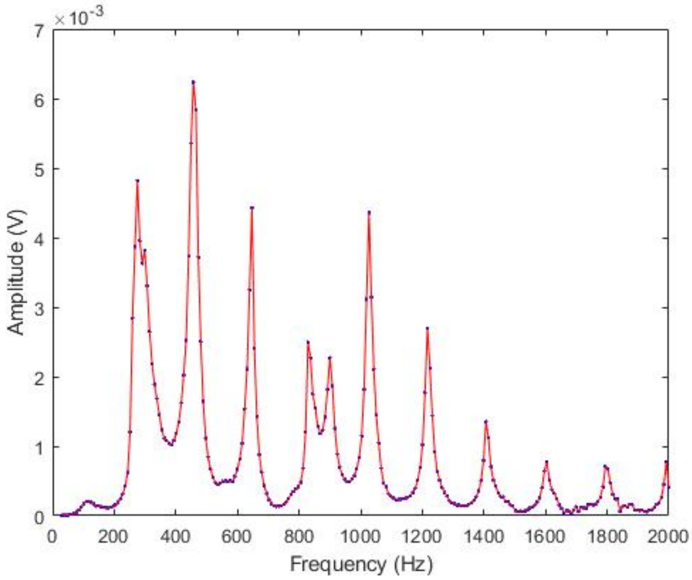
Data Collection Week 9 – Emmanuel Zeta

19 November 2020 14:34

We have discussed our method with Anthony and Josbin has made the changes necessary in order for us to get the results we need. Firstly, we have the entire tube raised above the table on dampening material in order to decouple the apparatus from the table. Secondly, we have the membrane secured more tightly on the baffle. Thirdly we have the metal clamp that holds the two tubes together secured more tightly when running the tests, reducing the sound leakage. These improvements enabled us to get data which actually shows what we're looking for which is that when a membrane is present, the transmission of sound through it is similar to the transmission without a membrane at all.

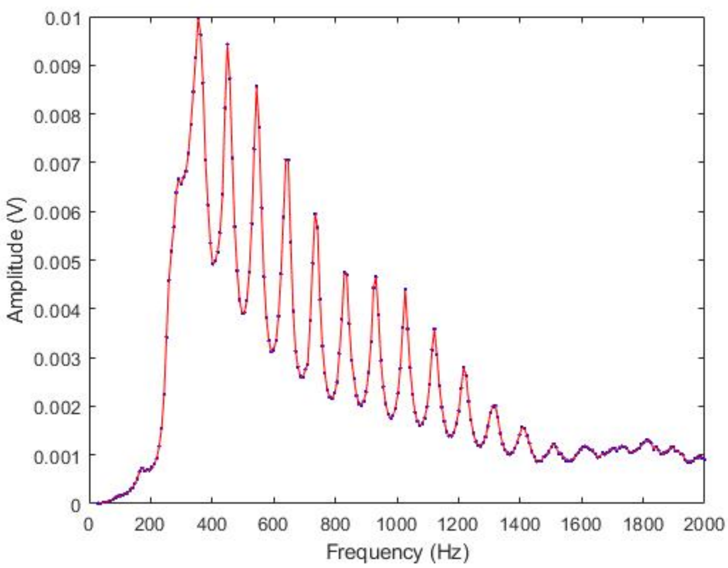
Aim:
Today I will carry out the experiment again as Josbin did but zoomed into the area of interest.
I will also cut the membrane out of the baffle and I will run the experiment again in order to get data for when there is no membrane present.

Result:
Baffle with Membrane:



The maximum amplitude is 6.2x10^-3 V and is at the 400 to 500Hz range.

Without Baffle and Membrane:



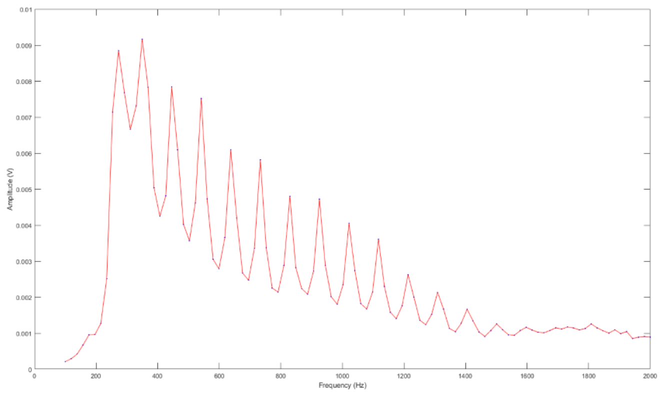
Week 10 – Collecting results- Josbin Jacob

24 November 2020 11:13

We have collected results enough to know that the peak frequencies for nitrile gloves occur within the 2000 Hz range.

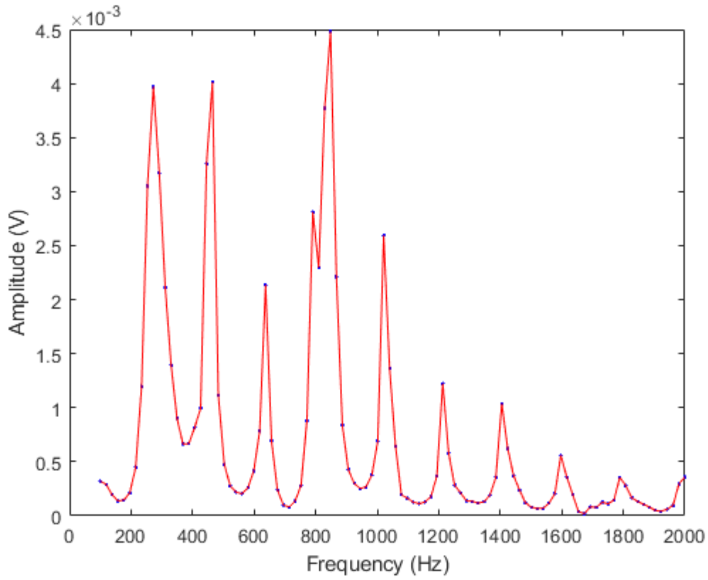
The smallest ball bearings were measured to have a mass of 0.13g (on average).

The empty tube readings are:



As expected standing waves form every 100 Hz or so.

Then for our 18.6mm the results are:



After reading the paper which originally demonstrated this effect, here is how to relate the spring constant of the material to its resonant frequency.

$$\omega_0 = \sqrt{k/(M_{\text{air}} + M_{\text{mem}})},$$

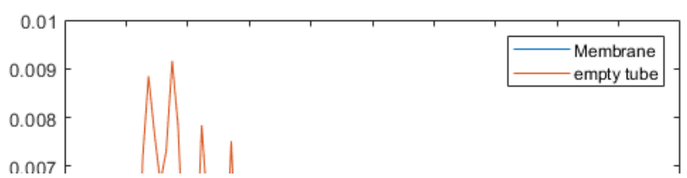
Where $\omega_0 = 2*pi*f_0$

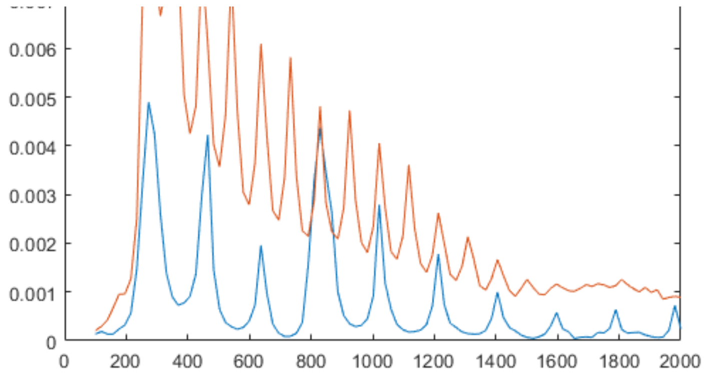
K = spring constant of membrane

M_{air} & M_{mem} = Mass of air & mass of membrane.

We can solve for f0 (resonant frequency) by working out all these parameters.

The coupling effect can't easily be observed so here is a graph with both membrane and no membrane, around 850 Hz almost all the sound wave travels through, in line with what we should observe for resonant frequencies.





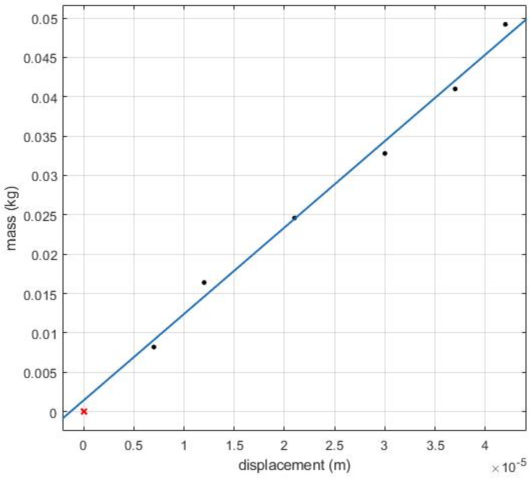
There are less harmonics being formed because I think the membrane essentially acts as a speaker halfway through the tube. This would effectively halve the length of the tube causing harmonic intervals to be doubled.

Week 10 - Emmanuel

24 November 2020 14:30

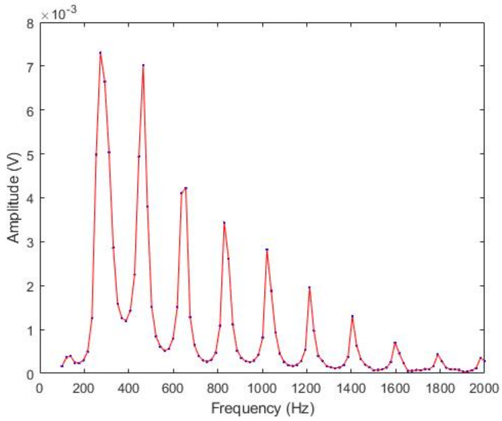
Aim:
Calculate the displacement when ball bearings are added to the 18.6mm baffle.

No. Of ball bearings	Reading	Difference	Displacement
0	67	0	0
2	60	7	7
4	55	5	12
6	46	9	21
8	37	9	30
10	30	7	37
12	25	5	42

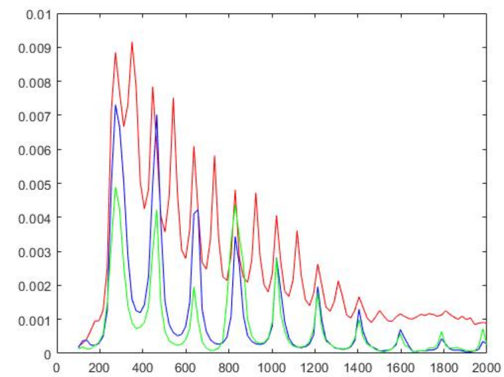


Using this graph, I worked out the gradient and therefore the spring constant.
I calculated a value of 1119kg/m for the spring constant.

Below is the graph for the transmission of sound when only the baffle and the copper tube is present.



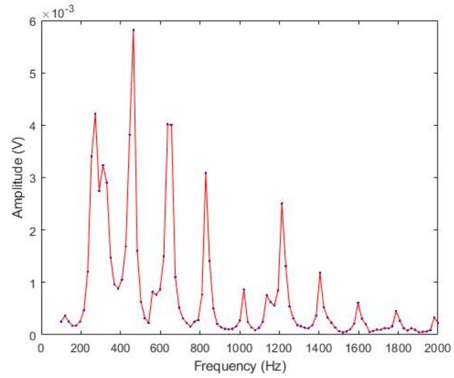
Below is a graph which compares all the data.



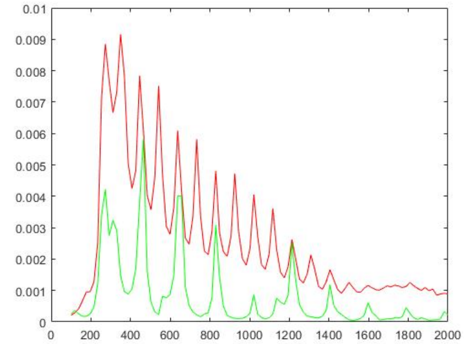
The red line represents the transmission when the tube is empty.
The blue line represents the transmission when the just the baffle (with the copper tube is inserted) is present.
The green line represents the transmission when the membrane is present.

The transmission is near the same for when the membrane is present as for when the tube is empty for approx 850Hz. This is good because this is the effect we've been looking for.

Below is a graph for the transmission of sound waves for a 15.6mm baffle with the membrane present.



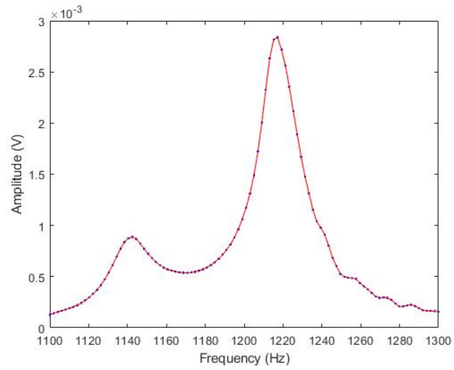
Below is a graph which compares the data to the empty tube data.



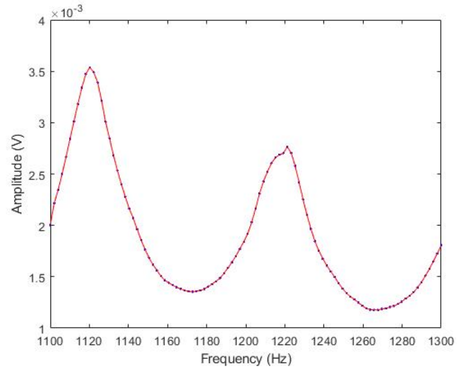
As you can see, the transmission of the sound is more or less the same at around 1200Hz. I'm 'zooming' into the area of interest: 1100Hz to 1300Hz in order to further examine this.

Note: I should've done this for the 18.7mm baffle but I had already cut the glove out of the baffle.

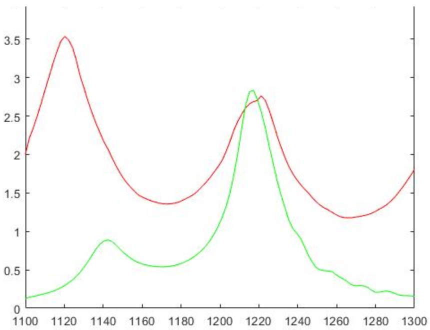
Zoomed in with 15.6mm baffle and membrane.



Zoomed in Empty tube:



Graph which compares data:



3.5
3
2.5
2
1.5
1
0.5
0
1100
1120
1140
1160
1180
1200
1220
1240
1260
1280
1300

Week 10 Thursday- Collecting Data- Josbin Jacob

26 November 2020 10:19

The work done by both me and Emmanuel shows promising results. The formula discussed by the literature for resonant frequency is:

$$\omega_0 = \sqrt{k/(M_{\text{air}} + M_{\text{mem}})},$$

Where ω_0= 2*pi*f_0

K = spring constant of membrane

M_{air} & M_{mem} = Mass of air & mass of membrane.

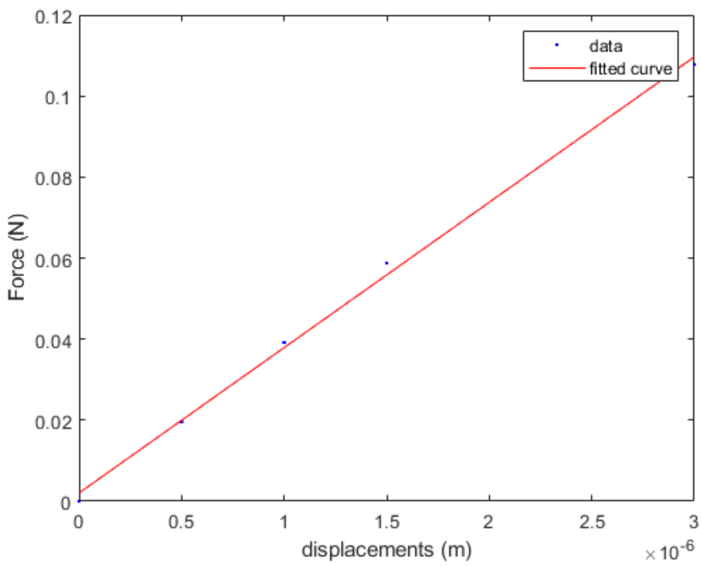
We can solve for f0 (resonant frequency) by working out all these parameters.

Calculating spring constant for 15.6 mm Baffle:

Medium ball bearings 2.0g were used

Mass	Total displacement	Displacement
0	0	0
2	0.5	0.5
4	1	0.5
6	1.5	0.5
11	3	1.5

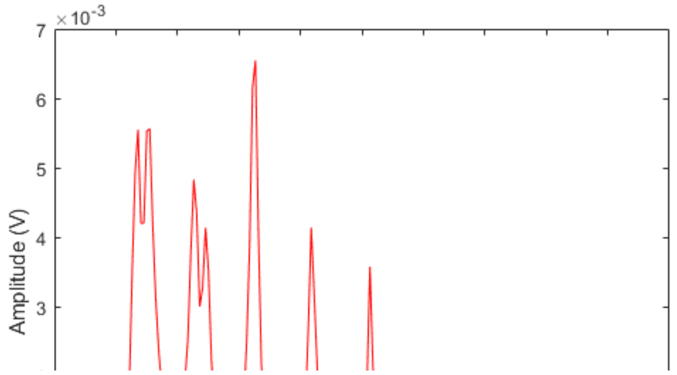
I couldn't find suitable ball bearings for all the readings so I used a different set of small masses. This could have limited my results somewhat as they aren't all of uniform shape and size.

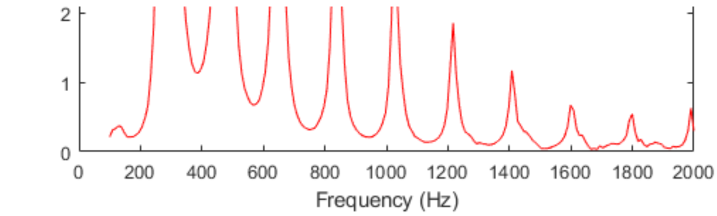


From this data the spring constant k is 3.6x10^4 Nm^-1.

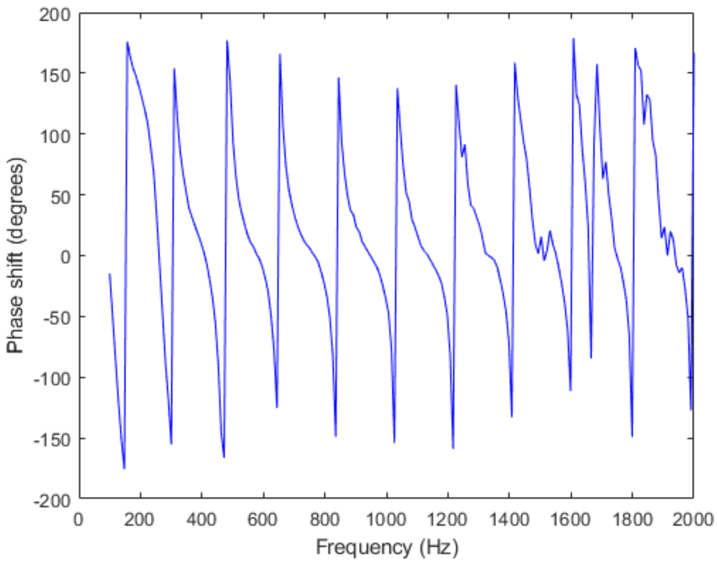
Here are the phase shift and amplitudes for 15.6mm with only baffle, no membrane.

Amplitude:





Phase:



We devised a method for working out mass of membrane, we would cut out the exposed parts of the membrane and also the whole membrane, this would give us an estimate of the upper and lower bounds the frequency should fall under.

Week 10 Thursday – Emmanuel

26 November 2020 14:36

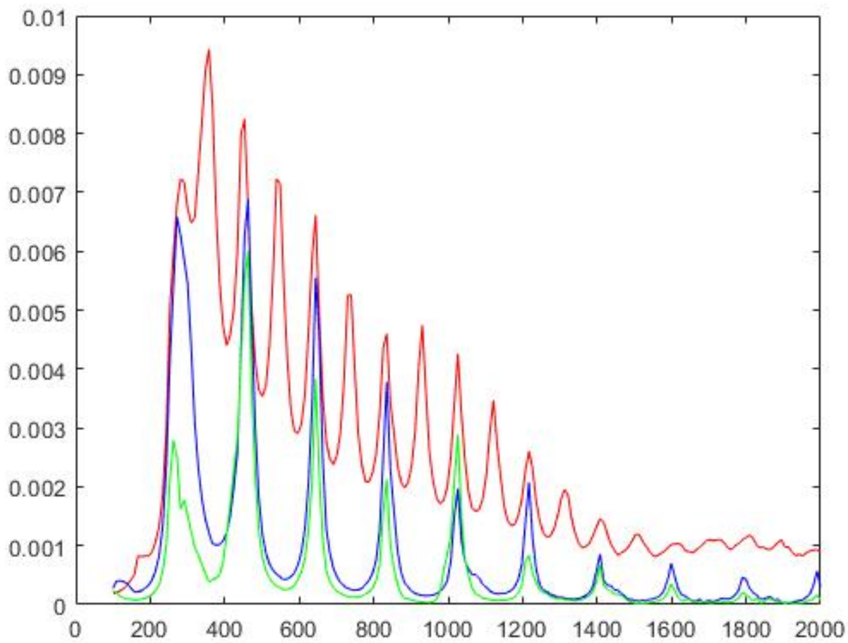
Displacement for 15.6mm membrane

No. Of ball bearings	Reading	Difference	Displacement
0	82	0	0
2	72	10	10
4	60	12	22
6	52	8	30
8	44	8	38

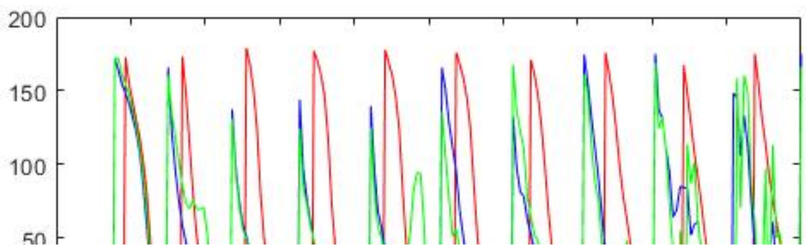
To do list:
- Record transmission for 15.6mm no membrane zoomed
- Plot comparison graphs for full and zoomed data

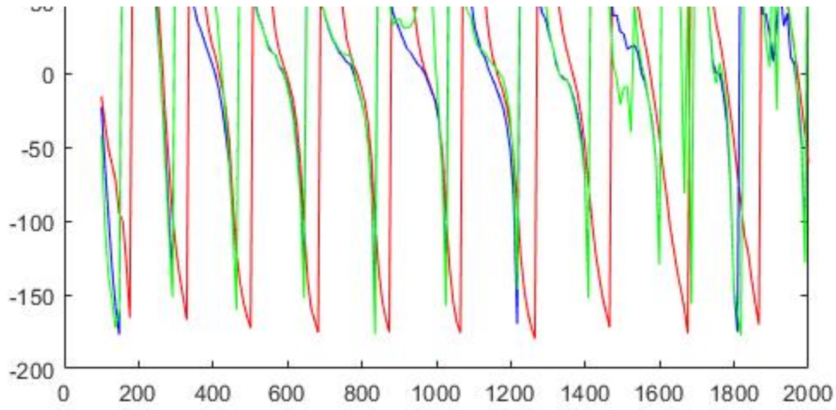
Results:

Below is a graph which shows the transmission of sound waves. The red line represents the empty tube, the blue represents with just the baffle and the green represents with the membrane.



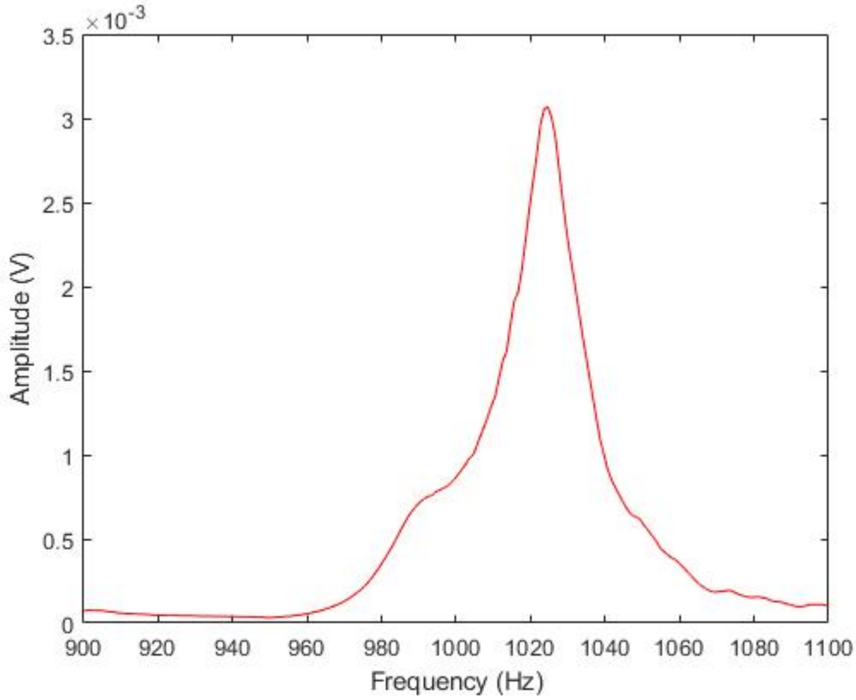
Below is a graph which shows the corresponding phase.



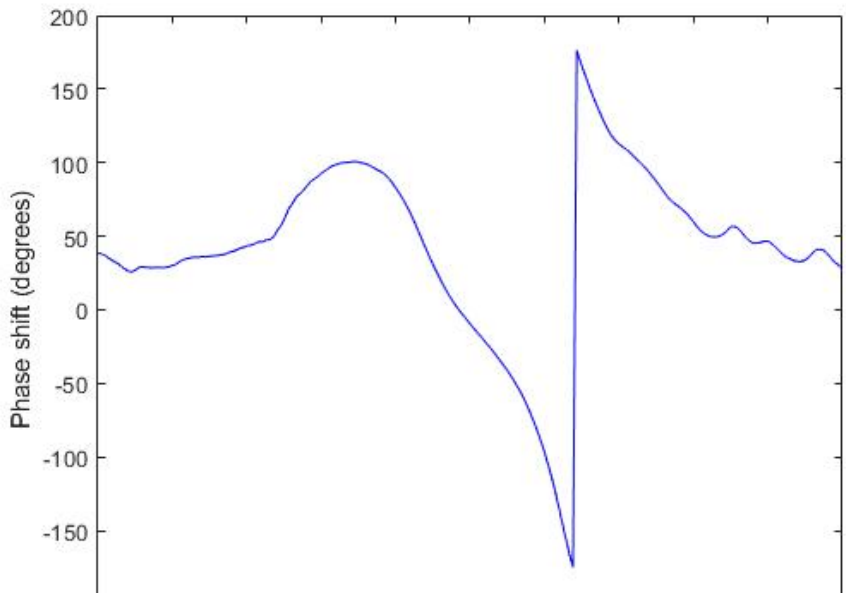


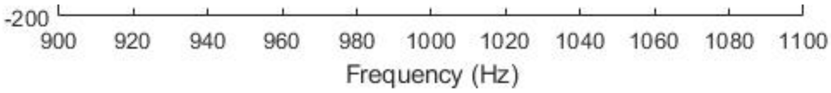
It's obvious to see that extraordinary transmission occurred at approx 1000Hz. This frequency range needs to be zoomed into.

Below is a graph which shows a graph zoomed into the 950 to 1100Hz range and showcases the transmission of sound waves

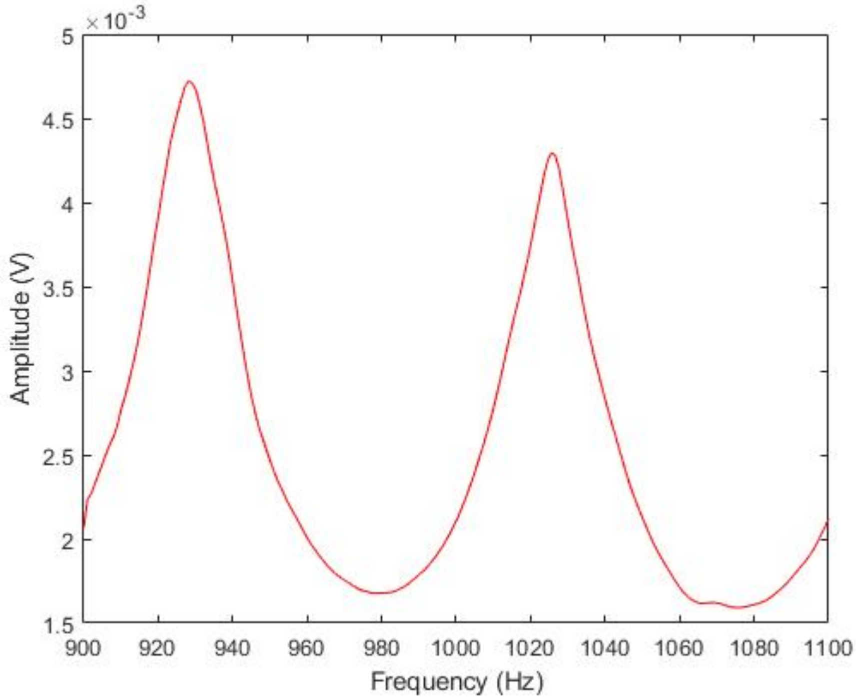


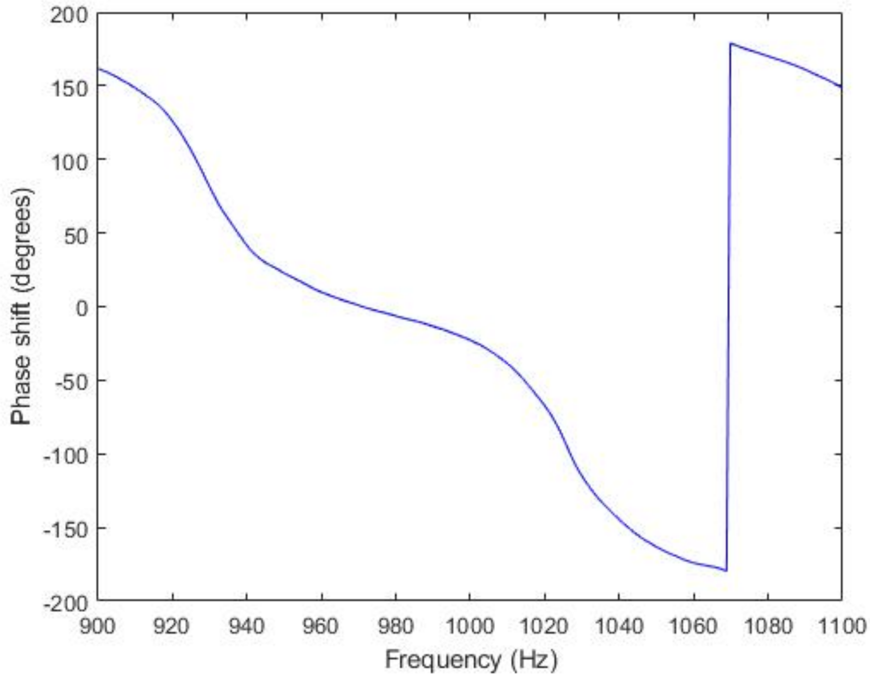
Below is a graph which shows the corresponding phase of the transmitted sound waves





Below is the transmission of the empty tube zoomed into the same frequency range and the corresponding phase





Week 11 – Data acquisition- Josbin Jacob - Tuesday

01 December 2020 10:31

We now have a good system in place for collecting amplitude and phase for each of our tube. We also have a theoretical expectation value we can use to compare the results to. I will take readings for the 11mm baffle today, find regions of interest and calculate the spring constant as well. The phase diagram around the resonant frequency should hopefully show a phase of zero at resonance.

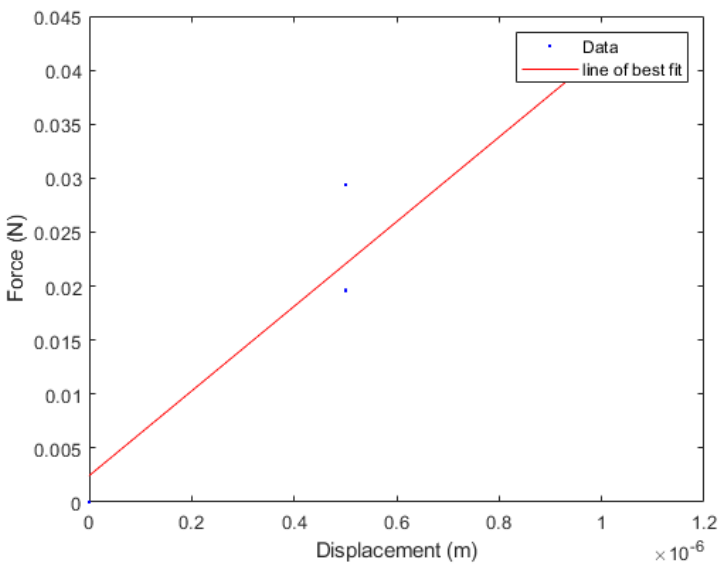
I will take empty tube readings for a range of 100-2000 Hz as all our membranes so far have only displayed interesting results around this range. At higher frequencies I believe other resonances, such as resonant frequencies from tables, or even the metallic tube can play a part. This is most likely where the small peaks in frequencies for the higher frequencies in work from our earlier weeks comes from. At frequencies below 100 Hz, our results show almost nothing, leading me to believe that the speaker doesn't work at lower frequencies. With this empty tube reading I will superimpose this with baffle only and completely empty tubes. These should hopefully give a clear indication of where the resonant frequency is.

11mm Baffle spring constant:

Mass (g)	Micrometre readings(micrometre)	Total deflection
0	91	0
2	90.5	0.5
3	90.5	0.5
4	90	1

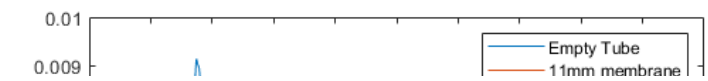
I am severely limited in how much I can measure deflection due to how many masses I can place into the tube. This problem though is not as bad as it looks as our equation could probably only give us a predicted f0 to the same order of magnitude. In general we expect that as the mass of the membrane decreases, the resonant frequency should increase. We also expect that as the tightness increases, resonant frequency increases. The reason for this is that the spring constant for a 2d membrane is a function of its membrane tension. If the tension across the membrane is low, the membrane will deflect more at lower forces and vice versa at higher frequencies. Within our tube, if the tension across the membrane is low, it would correspond to a lower frequency.

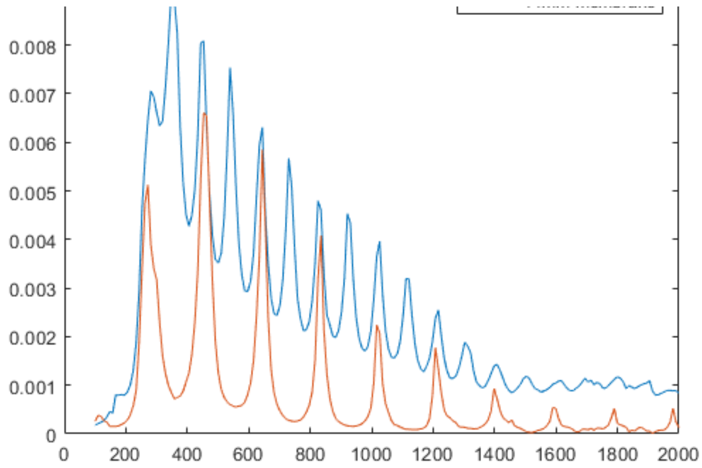
From our graph the spring constant is: 3.9 * 10^4 Nm^-1



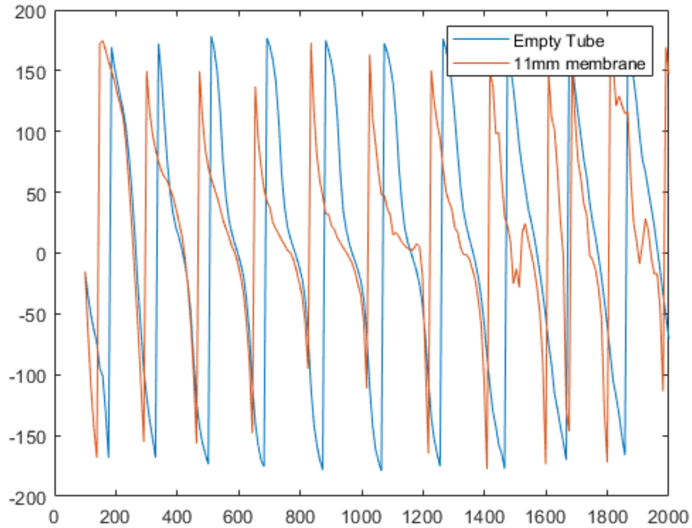
As expected spring constant is similar to the spring constants recorded for the higher diameters previously. This makes sense as we are trying to ensure that the membrane is as tight as possible around the copper tube as possible for all our tubes, and so a similar membrane tension should be present for all of them.

I can't do the just baffle reading until I have found the region of interest.





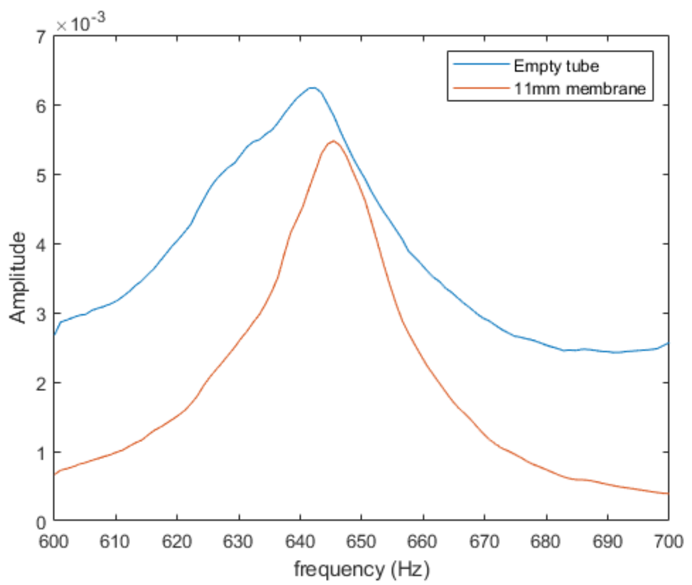
Here the x axis is frequency in Hz, the y axis is amplitude.

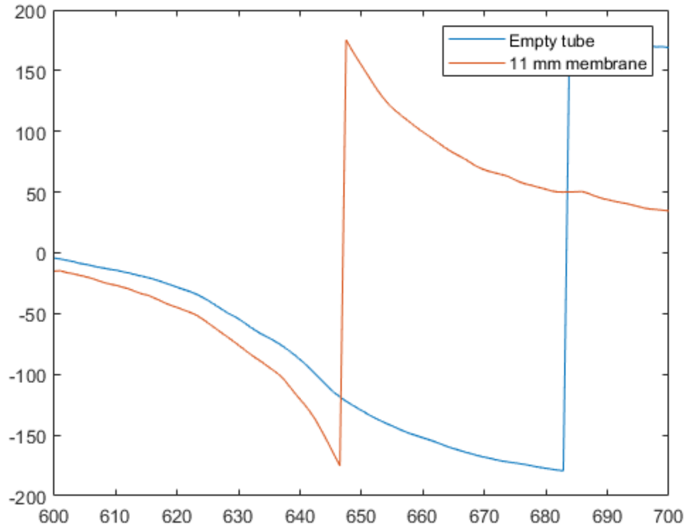


This third graph shows the phase diagram. The y axis is phase shift in degrees, the x axis is frequency in Hz.

The 600 Hz and 800 Hz region results seem to show an interesting effect. The phase shift here is close to zero and almost all the amplitude is being transferred through. I will run phase and amplitudes again between 600-700Hz and 800-900Hz. I think the resonance is around 600 Hz just from looking at the graph as close to the resonant frequency, the tube may have 'opened up', and could be behaving almost like nothing is present there.
There is also a small blip at around the 100 Hz mark. This blip has consistently formed in all our graphs and could be an interesting phenomena at lower frequencies.

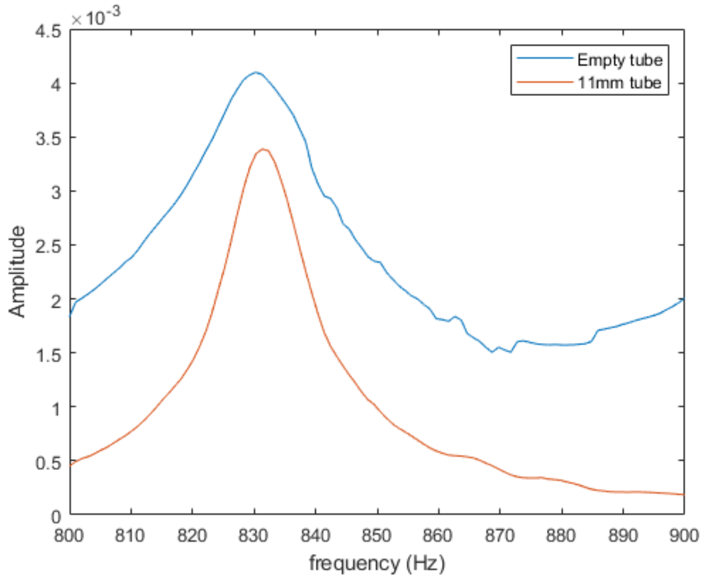
Here are the combined graphs for 11mm membrane phase and amplitude compared to an empty tube.

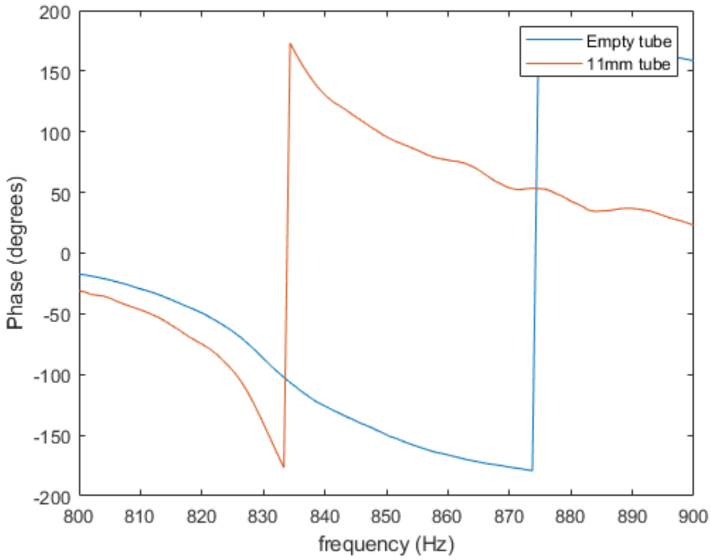




As expected the phase change at the resonant peak is zero. The phase change for the empty tube is shifted because that is where the harmonics would form.

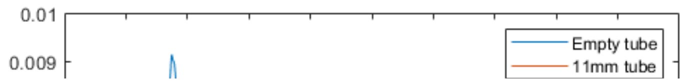
For the 800-900Hz region:

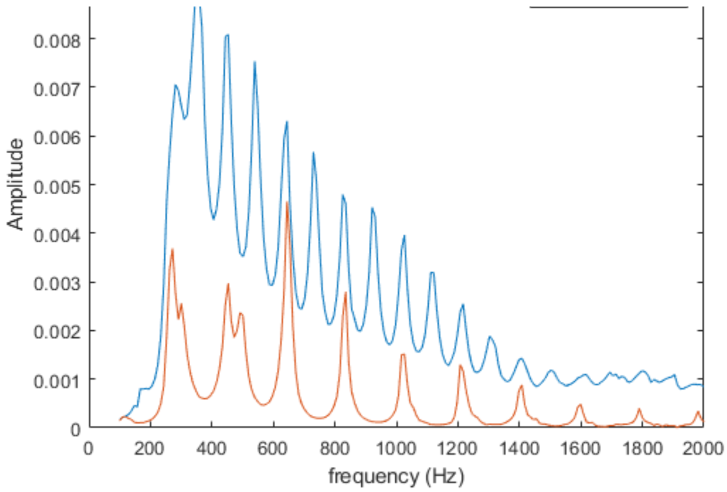


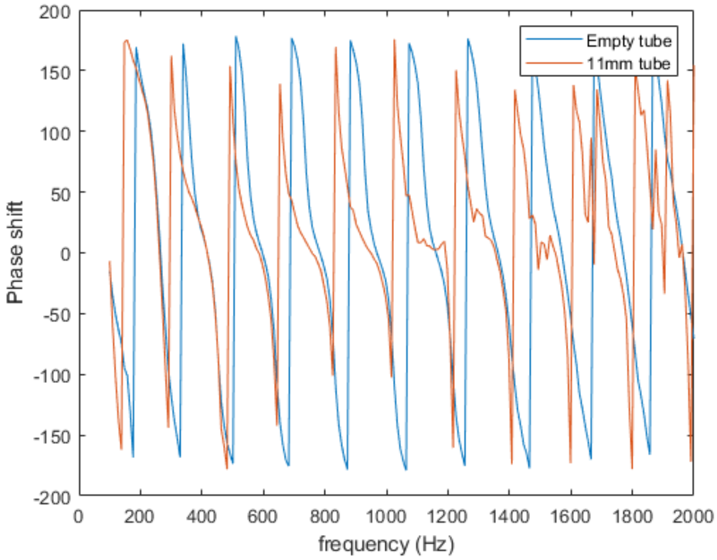


Once again as expected the membrane resonances match up.

These results bothered me so I redid the experiment over the 2000Hz region. My new results are consistent with a 600 Hz max amplitude







Some new features are present. In my new combined amplitudes image there are small peaks forming around 300Hz and 500 Hz. This lends credibility to the idea that the tube is opening up. The small peaks at 300 Hz and 500 Hz is where the tube essentially acts like the membrane is not present at all. Before when we introduced the membrane, the length of the tube is effectively halved, doubling the harmonic frequencies. This should mean that we should be missing the 100Hz, 300Hz, 500Hz and so on as I calculated the resonance of the whole tube to be around 100Hz. This is also what we see at frequencies past the resonant frequencies. However close to the resonant peak, this coupling occurs and so the tube behaves as if the membrane is not present.
I am not too sure of why such a drastic change in my results occurred. This data though isn't consistent though as I expected this result to be much larger as the mass of the membrane used has decreased. This could indicate that the membrane tension has decreased. In order to test this, I will test for the membrane's spring constant once more.

Mass of membrane: 0.075g

Mass(g)	Micrometre reading	Total Deflection(micrometre)
0	50	0
2	46	4
4	44	6
6	41	9

The deflections have increased dramatically. This explains why the lower frequencies are more prominent. The membrane tension has decreased. I was able to find smaller ball bearings and this time I tensioned the membrane with a smaller mass and found a region where the mass stuck out. I then zoomed in on the indentation and measured the total deflection. The mass of the membrane I used is also really small and looked stretched out. It could be that the membrane was stretched during the experiment. This could explain the drastically different amplitude graphs. As the membrane stretches, its integrity reduces, probably decreasing spring constant.

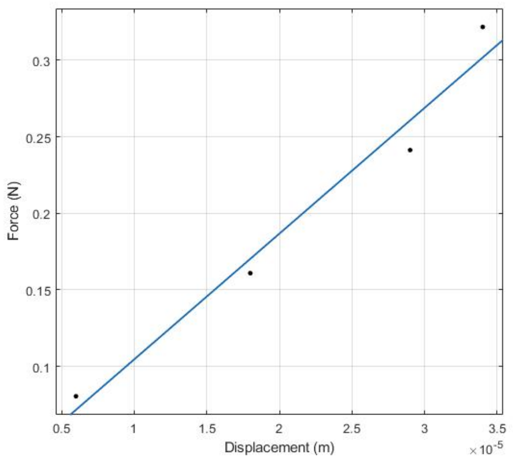
Week 11 Tuesday - Emmanuel

01 December 2020 14:23

Aim: Today my aim is to carry out measurements for the 18.6mm baffle.

I will use the empty tube data collected earlier by Josbin and will compare it with values measured when the membrane is present and not present. First I will measure the spring constant of the membrane.

No. Of ball bearings	Reading	Difference	Displacement
0	77	0	0
2	71	6	6
4	59	12	18
6	48	11	29
8	43	5	34



Using this graph, I calculated the spring constant to be 8222 N/m.

I carried out the experiment and got the following data:

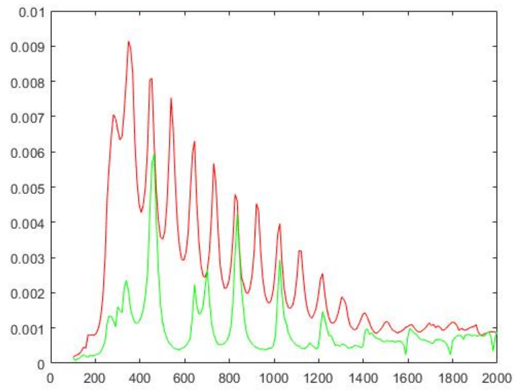
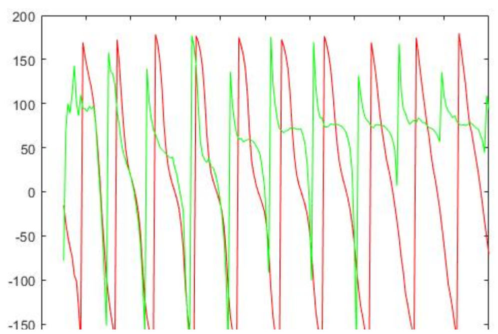


Figure 1: Voltage against Frequency graph which represents the transmission of sound waves through a tube with a membrane.



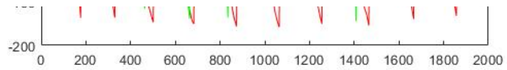


Figure 2: Phase against Frequency graph for sound waves through a tube with a membrane.

where the red line represents the transmission and phase for the empty tube and green line represents that for when the membrane is present.

As we can see in figure 1, there is near maximum transmission at approx 820Hz. In order to inspect this closely, I have zoomed into the 750 to 900Hz region. I suspect that when I reached 1400Hz, the microphone battery either died or was really low hence creating this deformity at the end.

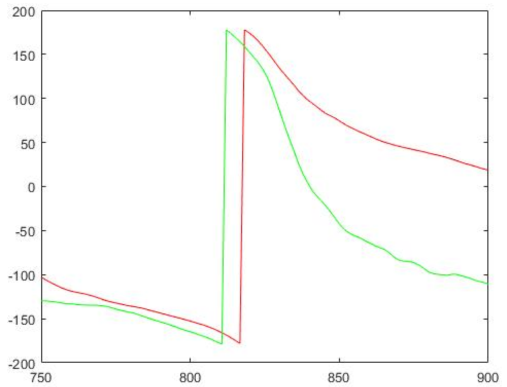


Figure 3: Zoomed Voltage against Frequency graph which represents the transmission of sound waves through a tube with a membrane.

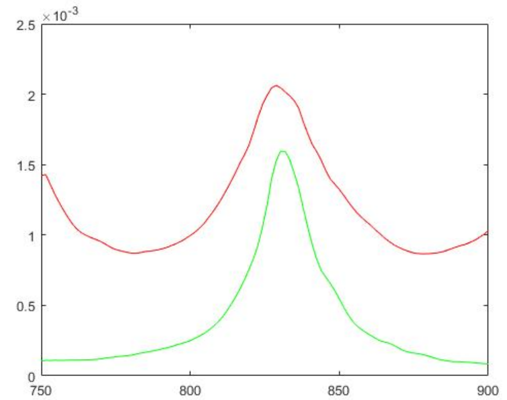


Figure 4: Zoomed Phase against Frequency graph for sound waves through a tube with a membrane.

As you can see the transmission is at it's maximum at 830Hz. However, the maximum amplitudes when zoomed in are different in comparison to when It's zoomed out. I'm not sure as to why the magnitude is lower. This is something that needs to be discussed.

The mass of just the 18.7mm membrane is 0.038g
The mass of the entirety of the nitrile glove piece is 0.0476

Week 11 Wednesday- Emmanuel

02 December 2020 14:36

Aim: To continue to record data for the 18.7mm baffle and record data for the 15.6mm baffle.

To start this experiment today, I've ran a new empty tube test to give the following:

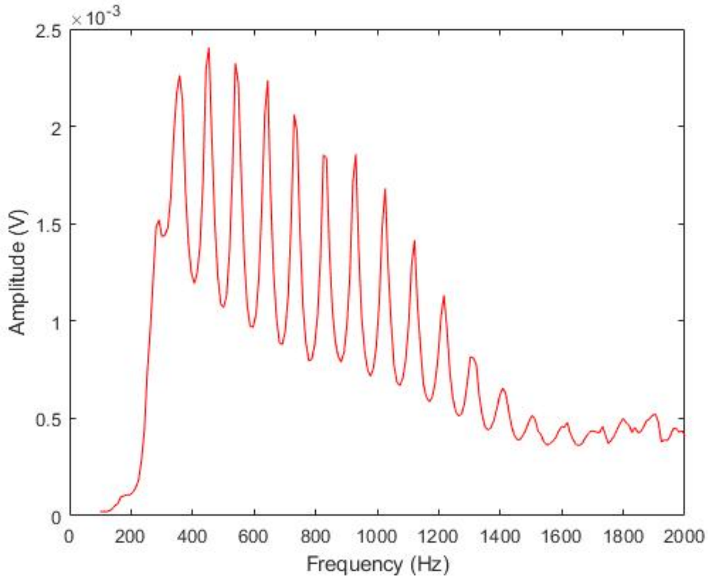


Figure 1 – Transmission of sound waves for an empty tube.

As you can see the magnitude of sound waves received now is much smaller than that for last.

The maximum amplitude shown in the empty tube is much lower for today's run in comparison to yesterday's run. Using matlab, I worked out how much smaller today's magnitudes are and it is 3.0620 times smaller today than it was yesterday. This is fine though because I can scale up the magnitudes to be compared with yesterday's results since we're not looking for absolute magnitudes but we're in face looking for the percentage of transmission given certain circumstances.

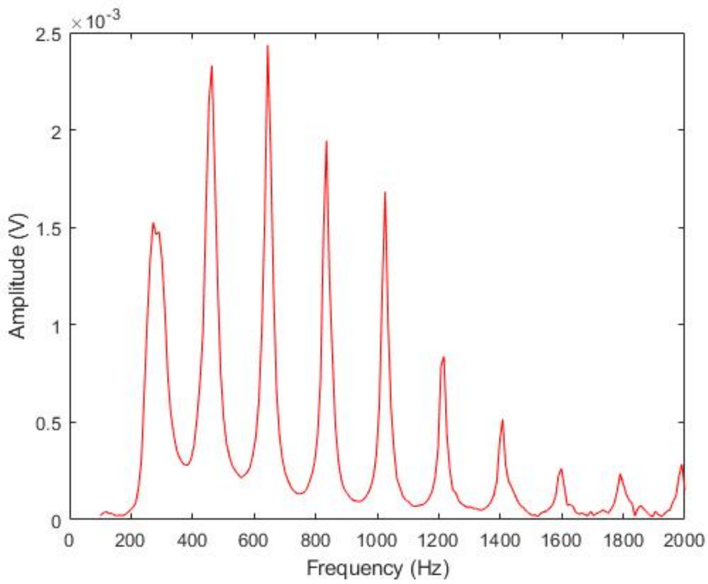
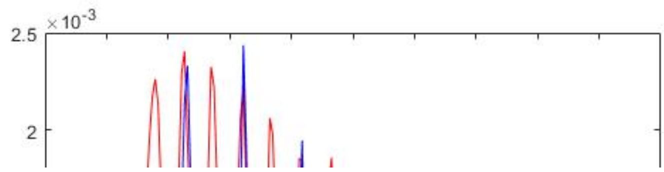


Figure 2 – Transmission of sound waves for the tube with just the baffle.

As you can see, the period of the max peaks has doubled in size as expected.



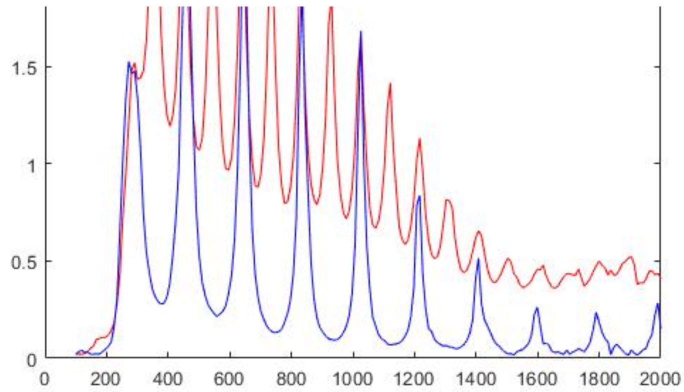


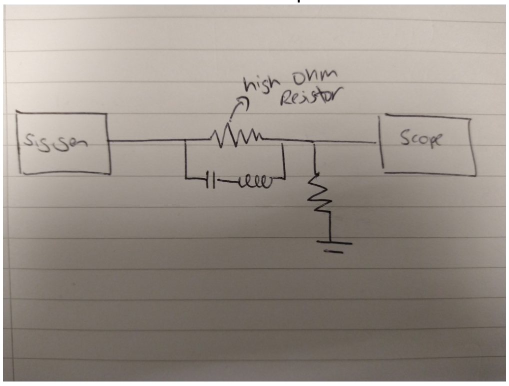
Figure 3 – Comparative graph (Figure 2 and Figure 1). Red represents empty tube, Blue represents tube with just baffle.

I scaled up the just baffle graph and plotted it on top of the full range comparative graph from yesterday but the data didn't quite make sense because some of the peaks are bigger than that for the empty tube. So we decided to use these graphs collected today as graphs to explain the phenomena occurring rather than to compare the scenarios.

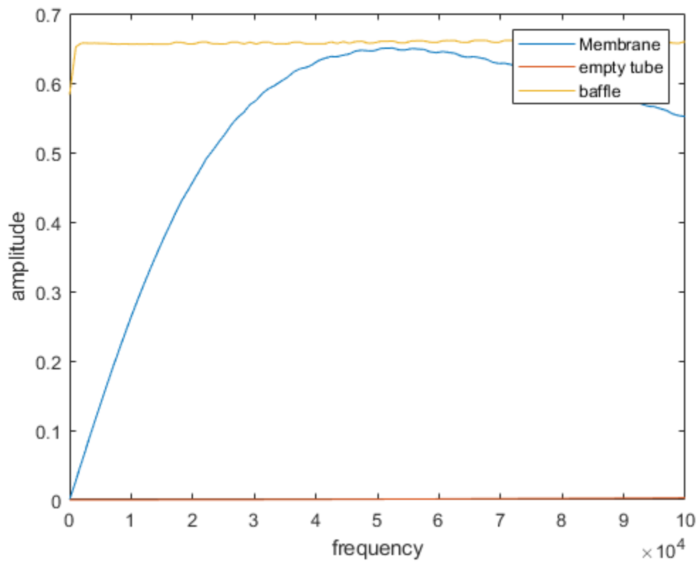
Week 11- Thursday – Josbin Jacob

03 December 2020 10:24

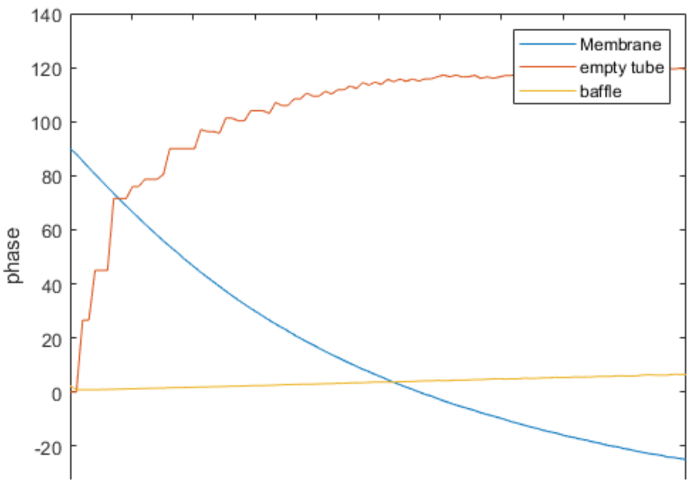
Objective:
Today's objective will be to use the electronic circuit to simulate the acoustic effect. I will write a program capable of picking up the signals and also plotting phase/ amplitude graphs as we have for the acoustic phenomenon.
The method was to connect up a circuit as shown below:

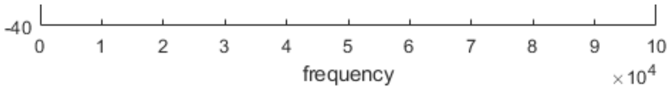


Experiment:
I couldn't connect up the oscilloscope directly to the computer for signal processing so instead I used the Lock-in amplifier for signal processing. This also had the added benefit of me requiring to change no parts of my code.
In this experiment the inductor and capacitor act as the membrane and baffle effectively. For the case of no membrane or baffle, the inductor and capacitor were removed. Then for simulating just baffle, a resistance much higher than the second resistance was used.



The resonance has a much wider peak than we expected. However we were limited by how much range the lock in amplifier had, it could only go up to 99.9 Khz. The resonance is around 50 Khz as the phase plot drops of to zero in that region the amplitude also is closest to the maximum value in that region.





The low resistance resistors were 47 Ohms.
The high resistor for just baffle was 1M Ohms.
The inductor used was 100nH
The capacitor used was 0.1 microfarads.
These results are consistent with our previous results. I unfortunately also used a 47Ohm resistor for the high ohm resistor too. If I had more time I would have redone the experiment with a higher ohm resistor.

Week 11 Thursday - Emmanuel

03 December 2020 14:15

Today I will be rerecording data for the 15.6mm baffle
Firstly I will record an empty tube reading which is shown below:

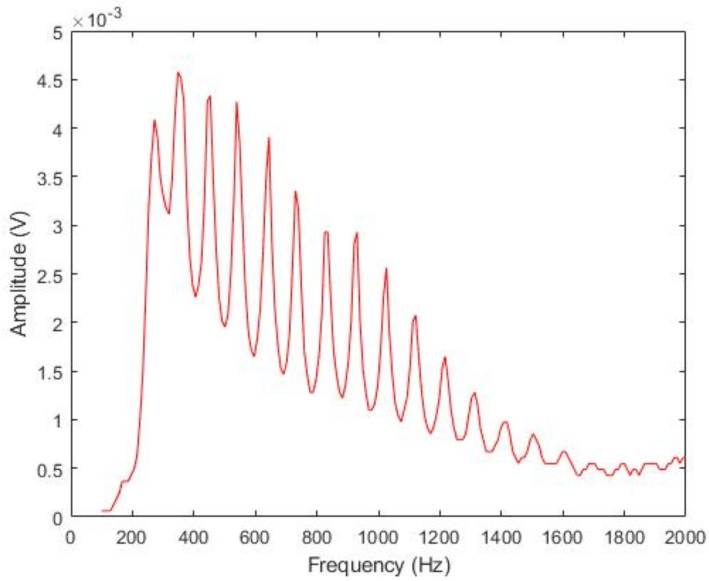


Figure 1 – Transmission of sound waves in an empty tube.

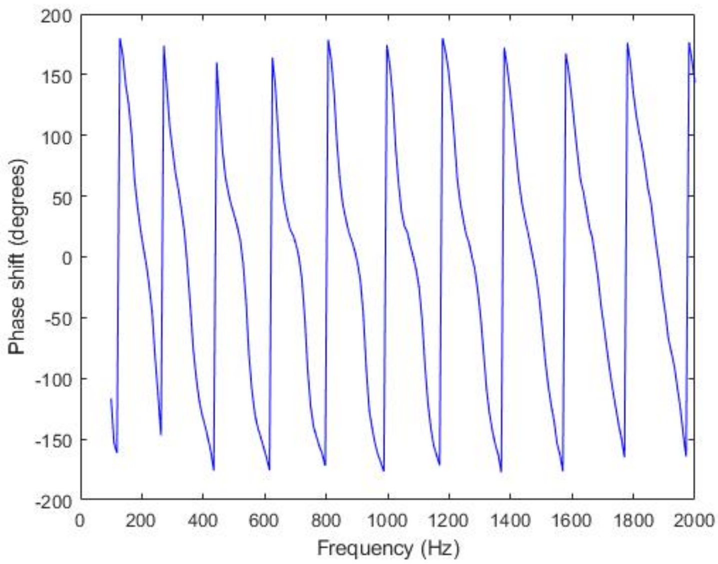


Figure 2 – Corresponding phase diagram for sound waves in an empty tube.

Now I will work out the spring constant of the membrane using 4.1g ball bearings.

No. Of ball bearings	Reading	Difference	Displacement
0	92	0	0
2	87	5	5
4	76	11	16
6	66	10	26
8	58	8	34

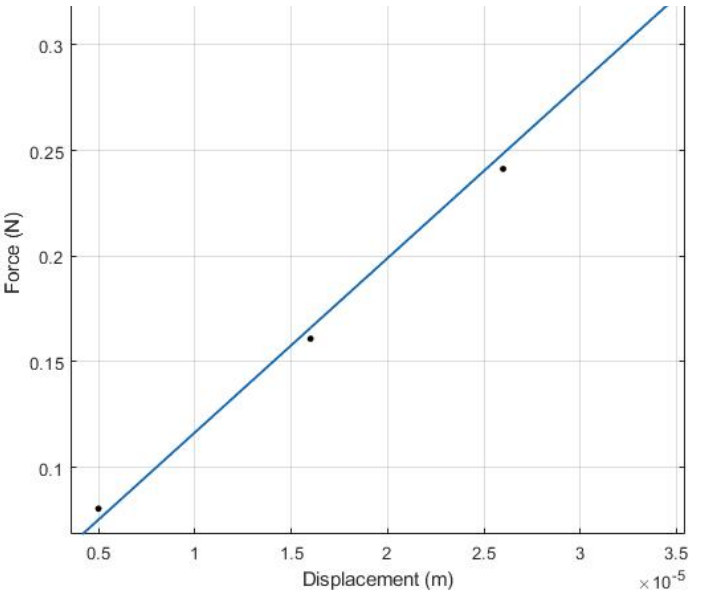


Figure 3 – Spring constant graph for the 15.6mm membrane.

Using this graph, I calculated the gradient and therefore the spring constant to be 8253N/m.

I've now measured the transmission through the membrane and plotted the transmission graph on top of that for the empty tube but it didn't look like there was any extraordinary transmission so I've decided to rerecord transmissions for the empty tube and for the membrane. I also noticed that on the Lockin amplifier, the sensitivity was set to volts and not to milivolts so i changed it back and I think that should fix everything.

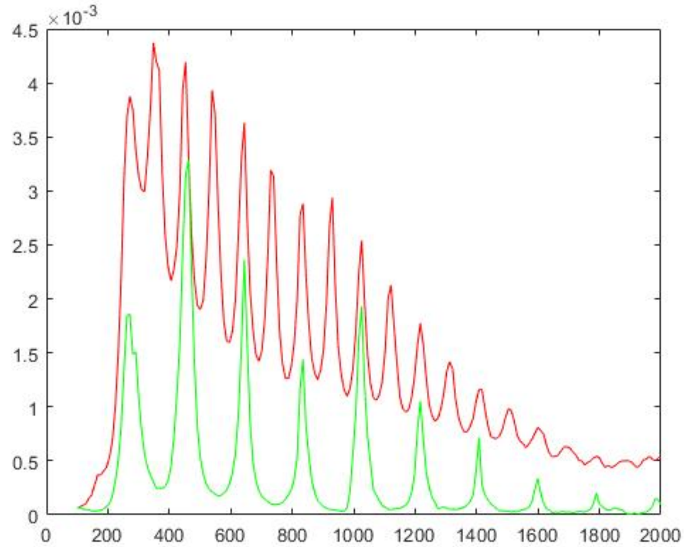


Figure 4 – Comparative graph for transmission of sound waves

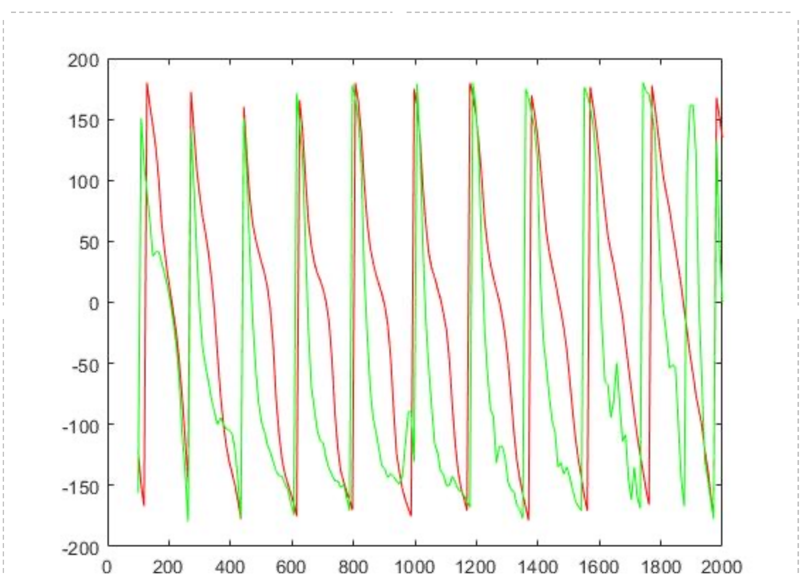


Figure 5 – Comparative graph for phase of sound waves.

Red represents the empty tube
Green represents when the membrane is present

Now, I'm going to zoom into 950 to 1100 Hz range because the resonant frequency seems to be approx 1000Hz.

These are the comparative graphs:

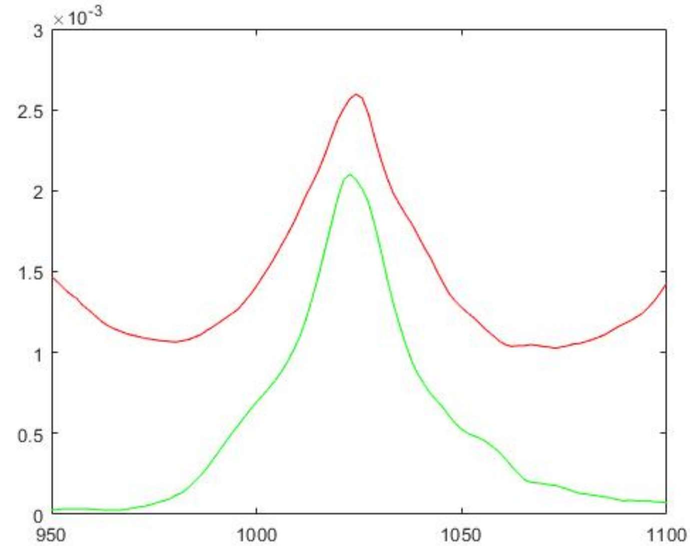


Figure 6 – Comparative graph for the transmission of sound waves within the 950 to 1100Hz range

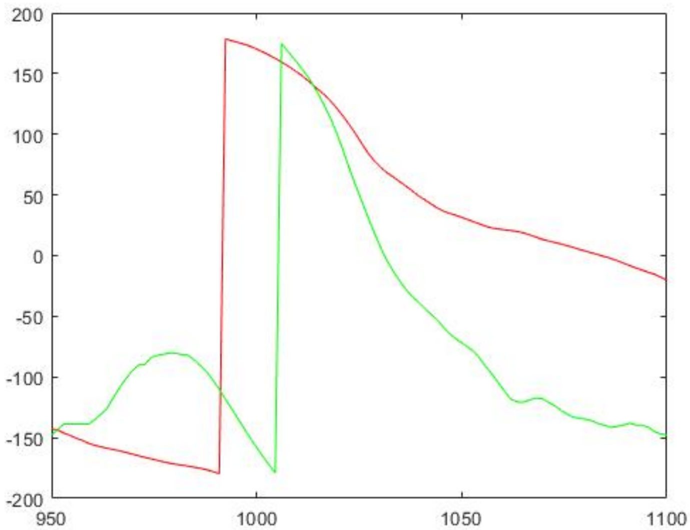
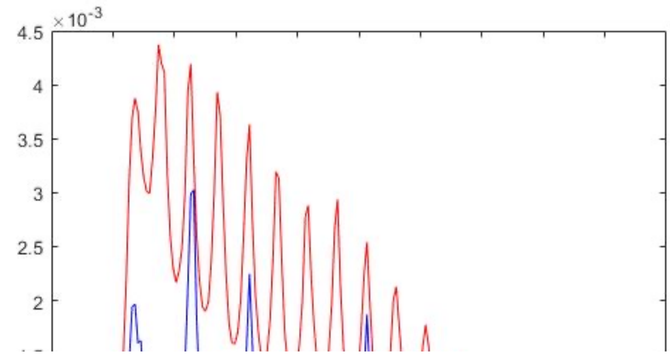


Figure 7 – Comparative graph for the phase of sound waves within the 950 to 1100Hz range.

Now to cut out the membrane and to measure the transmission and phase for just the baffle.

The mass of the circular membrane is 0.010g and the mass of the entirety of the nitrile glove piece is 0.196g.



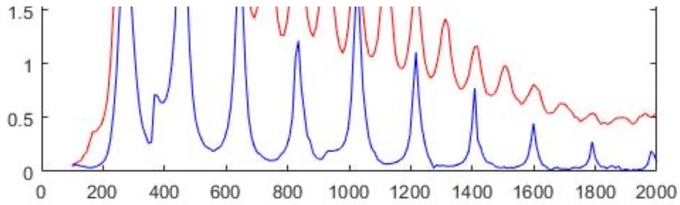


Figure 8 – Comparative graph for 15.6mm (empty tube and just baffle) for the transmission of sound waves

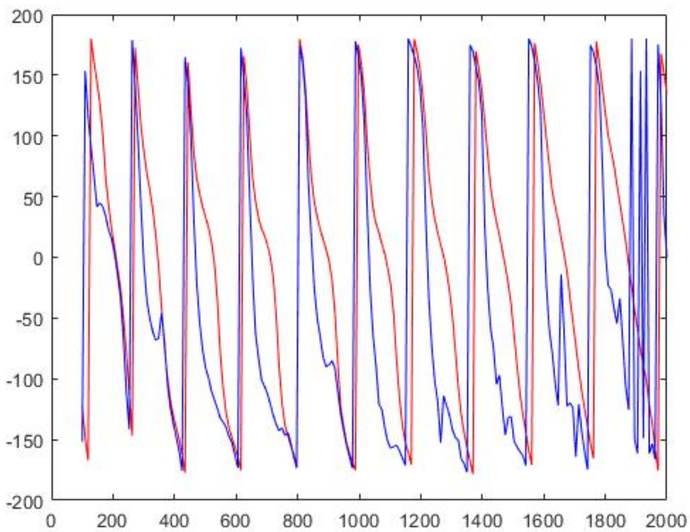


Figure 9 – Comparative graph (empty tube and just baffle) for the phase of sound waves

Josbin didn't have enough time to record the transmission of sound for just the 11mm baffle so I did that for him and got this:

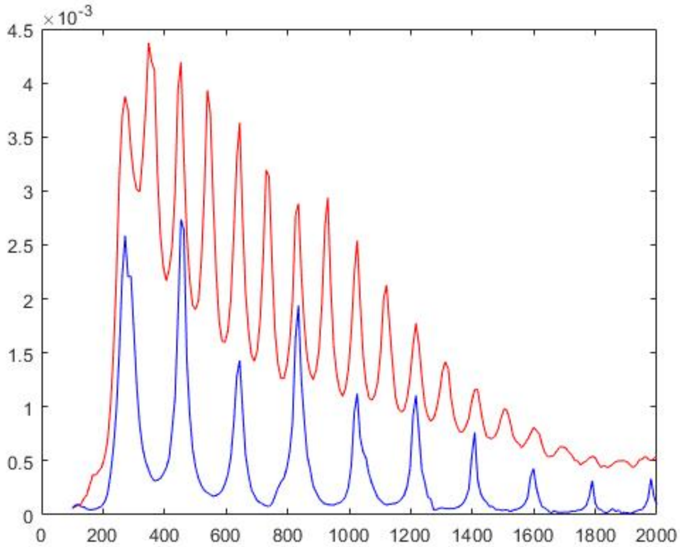
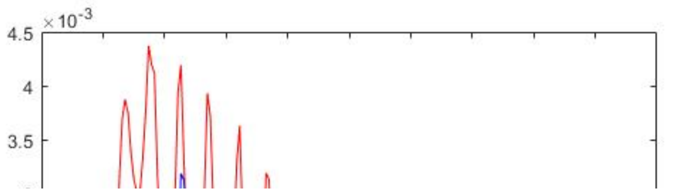


Figure 10 – Comparative graph for 11mm (empty tube and just baffle) for the transmission of sound waves

I've decided to redo the empty tube and 18.7mm baffle comparison since the amplitudes I got yesterday don't follow the same trend as the others ie: for some reason the max amplitude for yesterday's result is approx the same as that for the empty tube as it is for just the baffle whereas today, there has been a decrease in the maximum amplitude.



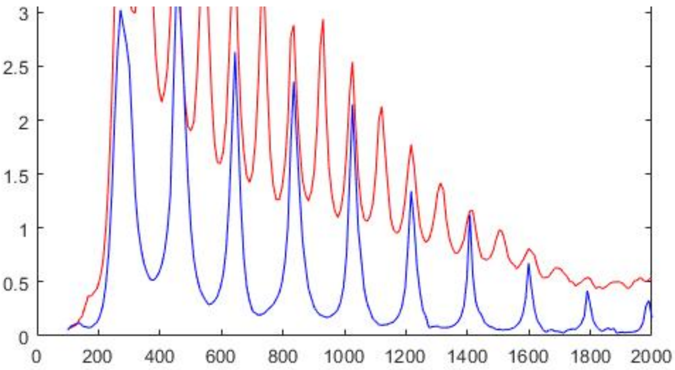


Figure 11 – Comparative graph for 18.7mm (empty tube and just baffle) for the transmission of sound waves

This looks much better.

```
clc
clear all;
clearinst  %this function detects and closes any open connections
% Initialises the Signal Generator

siggen = visa('ni', 'USB0::0x0957::0x0407::MY43002016::INSTR'); %makes visa
object siggen
% Open the connection, now the object is connected to the instrument
% Initialises the Lock-in Amplifier and microphone

lockin = gpib('ni',0,7); %makes a GPIB object reads it froma location 0, 7.
Make sure this location is correct
%for some reason this is now 8.

% Open the connection
fopen(lockin);
fopen(siggen);

set(lockin, 'EOSMode','read')
set(lockin,'EOSCharcode','LF');

it = 200;
frequency = linspace(100,10000,it);

for w = 1:it
    fprintf(siggen, ['APPL:SIN ',num2str(frequency(w)),' HZ, 3.0 VPP, 0 V'])
    pause(1.5); %determines how long sound is played for
    fprintf(lockin,['OUTP? 3']) %lets the lock in amplifier know to start
recording amplitude (R), NOTE: if OUTP? 1 was used x axis will be recorded
    %output 3 records R so that should be actual signal. X and Y are vector
    %components of output R
    y(w) = str2num(fscanf(lockin)); %converts char to num after scanning
lockin for output 3
    fprintf(lockin, ['OUTP? 4']) %records phase data
    phase(w) = str2num(fscanf(lockin));
end

fprintf(siggen, 'APPL:SIN 0 KHZ, 3.0 VPP, 0 V')

fclose(siggen); delete(siggen);
fclose(lockin);

plot(frequency,y,'r');
xlabel("Frequency (Hz)")
ylabel("Amplitude (V)")

figure
plot(frequency,phase,'b')
xlabel("Frequency (Hz)")
ylabel("Phase shift (degrees)")
```