**Q12: This question pertains to WLO3. <u>Main task</u>:** Write an introduction (including a couple references) that follows the WLO3 dimensions. Assume that you are writing a report detailing the characterization of the acoustic wave response of a newly discovered and synthetically produced gas, *magnetoanisotropium*, that was reported to behave anisotropically (direction dependent) under the presence of a magnetic field. **Note that this gas is fictitious, and we are creating this scenario purely for technical writing practice.** Assume for your experiment that a magnetic field, consistent with the reported field strength, is aligned with the x-axis of your scanning stage, and the reported sound speed was 340 m/s in the direction of the magnetic field, and 280 m/s perpendicular to it. **<u>Purpose</u>:** to gain practice accurately conveying the context and novelty of your work.

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A newly discovered gas magnetoanisotropium has many unknown properties and features that could be studied by scientists. Characterizing time taken for sound waves to travel (speed of sound) in this medium is the physical phenomena being explored. This will aid improving accuracy of sensitive film properties in microelectromechanical systems (MEMS) as the gas can be used instead of air or other gasses for specific procedures [1]. Furthermore, the gas can be used in place of conventional gasses such as Argon, or Air if it's less dangerous to the overall manufacturing process [2].

In order to study the effects of this gas, this research paper will cover the characterization and response of sound waves under magnetic anisotropy within a magnetic field. By looking into the response of sound waves, we can predict the expected speed of sound in the x-direction and y-direction. In summary, studying the effect of magnetic field strength on the sound waves in this new medium will prove whether or not the gas is truly anisotropic, and its efficacy. To accomplish this, we will utilize a magnetic field strength that will be calibrated to achieve desired effects on our gas sample. Currently, the reported sound speed achieved in this medium is 340 m/s in the direction of the magnetic field, and 280 m/s perpendicular to it. To measure this, we will explore changes in wave propagation: first along the x-axis (perpendicular to speaker), and then along the y-axis (parallel to the speaker).

[1] https://ieeexplore.ieee.org/document/6527578

[2] https://www.nj.gov/health/eoh/rtkweb/documents/fs/0151.pdf

**Q13: This question pertains to WLO1. <u>Main task</u>:** Write a results section (observations) followed by a discussion section (interpretations) that describes the data contained in the figure you created as part of, **at least**, [**Q4 or Q6] and Q7**. The results section should also describe how the data was collected, **and reference a figure containing a schematic that you will create detailing your experimental setup (that should satisfy WLO2)**. **<u>Purpose</u>:** To gain experience with making observations and providing supported interpretations of experimental data.

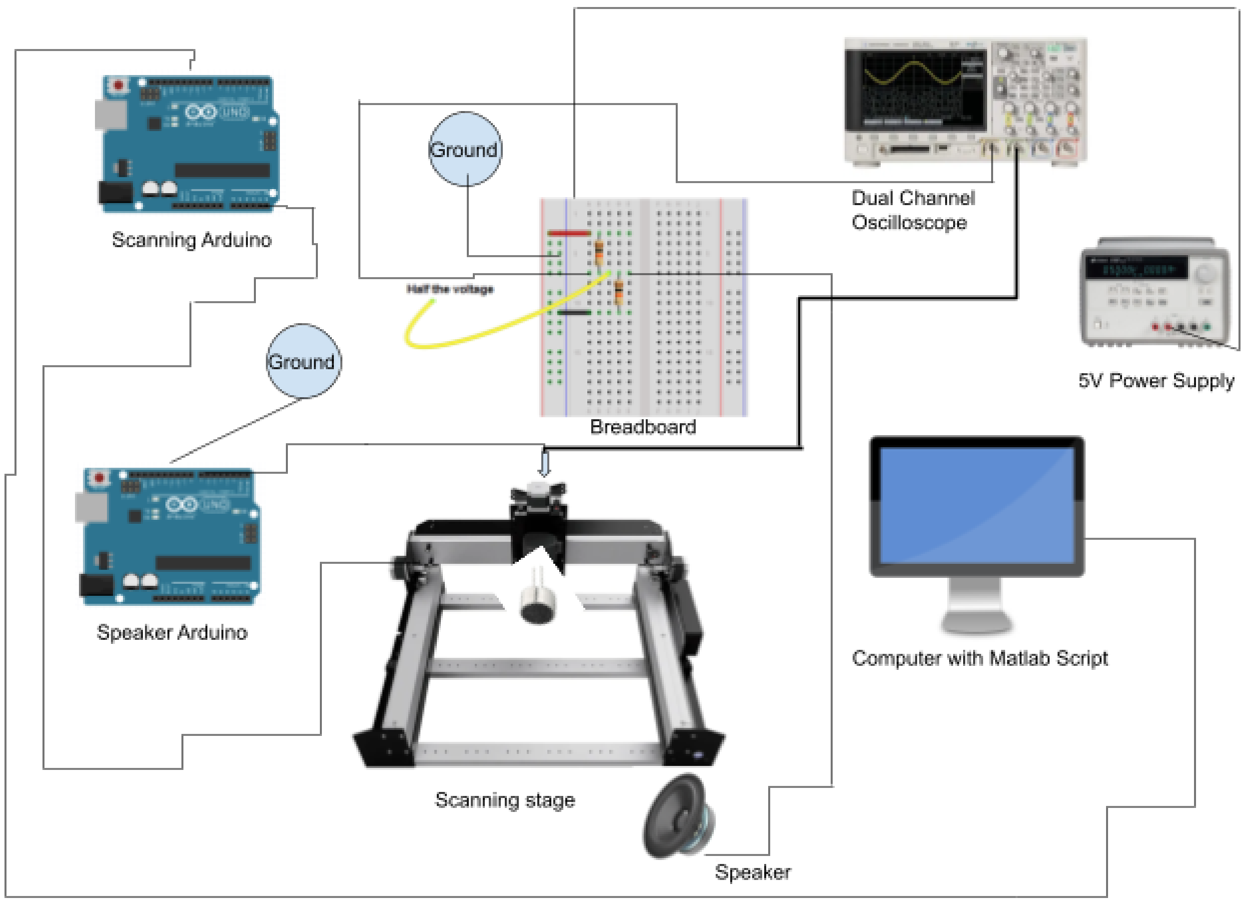


**Fig.6.** *Wiring diagram of circuit elements and components used in the experiment. Connections are approximate, and intended to show usage of devices in experiment rather than exact wiring requirements.*

To validate this experiment, A spatiotemporal sound field of 15 cm x 30 cm was scanned in front of the speaker using a microphone, which were connected using Arduino UNO R3's as shown in Figure 6. A signal of constant frequency was output from the speaker while the scanning stage measured each location. A Matlab script is used to control the scanning stage, drive the speaker, and extract data from the two oscilloscopes which was plotted to visualize sound waves propagating.

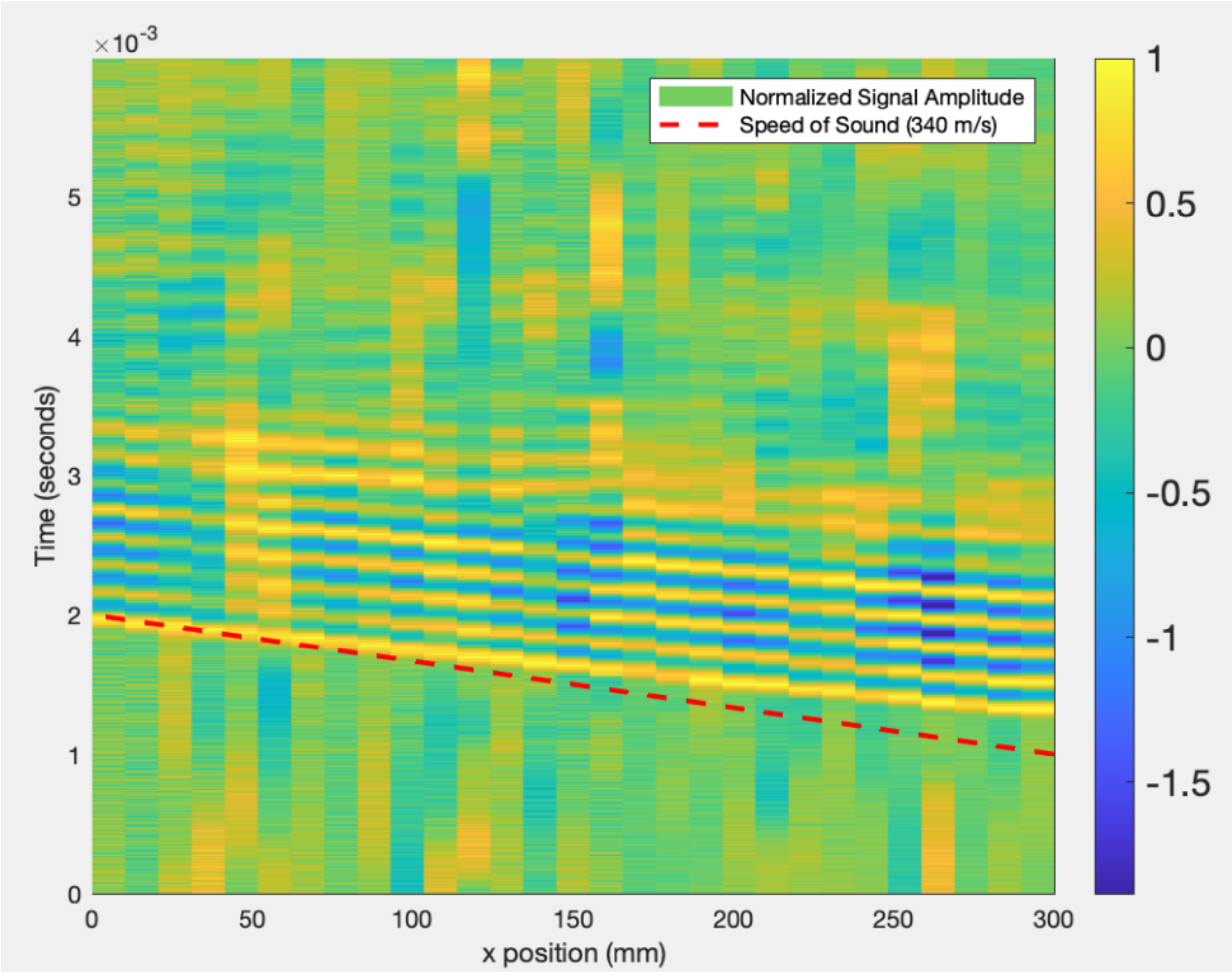


**Fig.3.** *Plot shows position along the scanning x-axis for the plot's x-axis, time as the y-axis, and color corresponds to the normalized amplitude of the signal. A line showing the speed of sound (in terms of its gradient) is depicted by a dashed red line. This line indicated the slope expected for a 340 m/s speed of sound, and the lines on the normalized signal amplitude show what was measured as speed of sound (gradient = 300 m/s).*

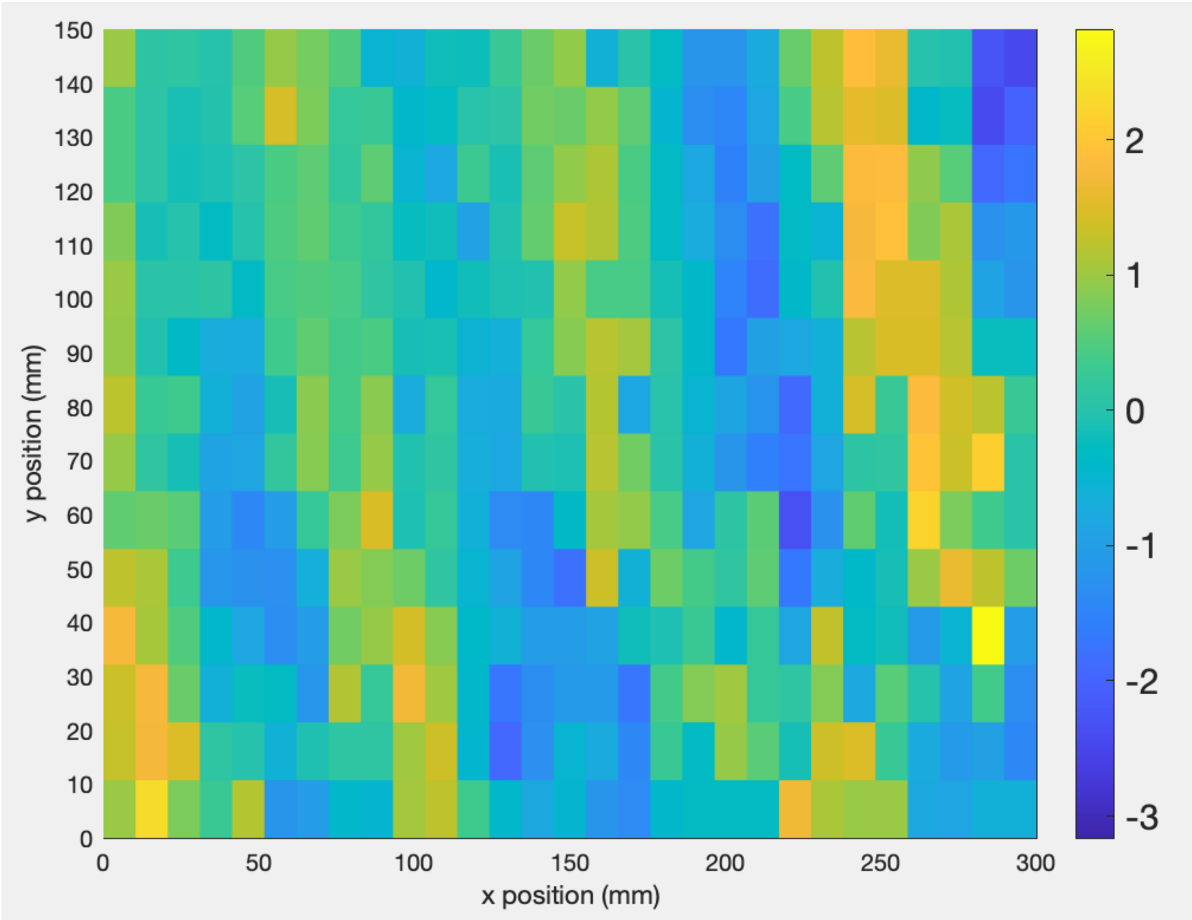


**Fig. 4.** *Plot shows the sound field at time t = 2 ms, where the total time of the data acquisition was 6 ms. The x- and y-axes correspond to the scanning system's x- and y-axes. Color bar depicts the change in amplitude along the plot, showcasing the sound waves being emitted from the speaker.*

The matlab function 'pcolor' [3] is used to create visual depictions of the data by plotting the x- position with respect to time (seconds) delay of the sound wave from being output by the speaker, to being recognised by the microphone sensor. Another plot of x- position with respect to y- position was also made to represent wave propagation along the scanning stage. Figure 3 represents the data collected when measuring along the y-axis (perpendicular to speaker), and Figure 4 shows how the wave changed in normalized amplitude along the scanning stage. In theory, the data should produce the exact same slope for both measurements assuming the gas is isotropic.

Data along the x-axis was approximated by creating a line of similar slope to the data points shown, and was estimated to a slope of -0.0032 (320 m/s). Data along the y-axis was calculated to a slope of -0.0030 (300 m/s). As shown in Fig.4. The normalized amplitude's color pattern represents a wave pattern whereby yellow shows high amplitude and blue represents lower amplitudes. However, there are more irregular patterns towards the start, and end points of measured results. The majority of the normalized amplitudes measured are 0.25 at 2ms suggesting the beginning of a wave propagation.

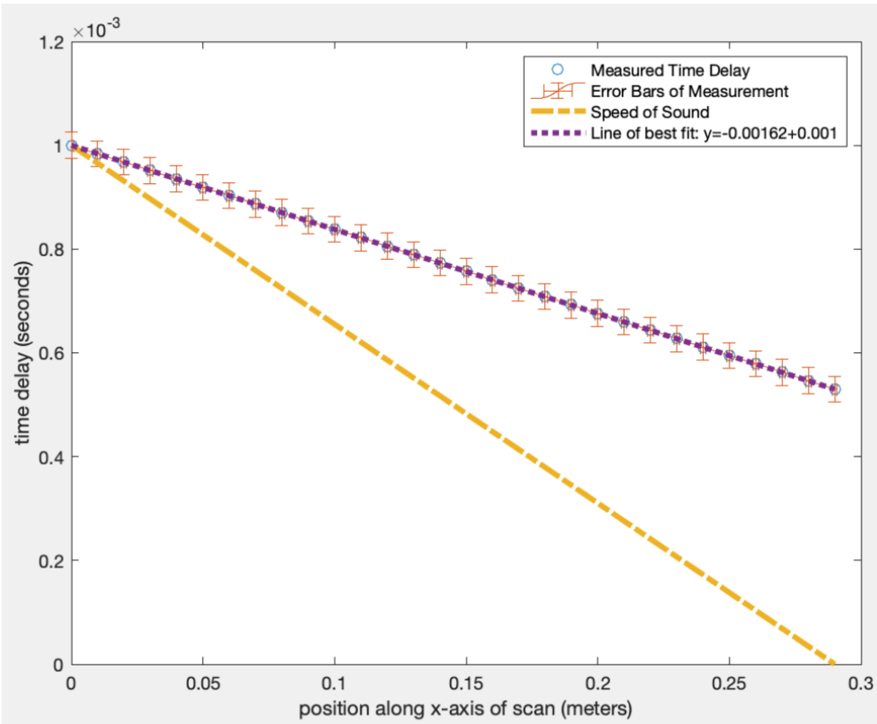


***Figure 2.*** *Plot describing the time delay of the sound pulse arrival for points along the scanning x-axis, where position (in meters) is on the x-axis of your plot and time (in seconds) is on the y-axis of your plot. Measured Time delay is represented using blue circles. Error bars of measured data were calculated and plotted based on accuracy of measurement tools. Speed of sound (-. yellow signal) was calculated using the scientific speed of sound (340 m/s). Line of best fit was approximated by plotting a line (purple dashed line) and fitting it to all the data points. Using this line, the gradient was extrapolated to give a measured speed of sound of 162 m/s.*

The measured sound of speed was 162 m/s from the slope of Figure 2 for data along the x-axis (parallel to the speaker). Error bars were based off an error of 0.001m for distance measurement (x-axis) since the apparatus used (meter rule) has an approximate error of plus/minus 0.1cm. Approximation errors when plotting/calculating using Matlab were accounted for by using a y-axis error bar to maintain accuracy of the lines and line-of-best-fit generated. Y-intercepts of each graph were left out since our experiment is only interested in the speed of sound measured (slope).

Measurement errors were easily viewable through the color plots, where abrupt changes or random color changes indicated error in measurement technique. The errors at start/end points might suggest further measurement of larger intervals to reduce the impact of the error on the overall results. A possible explanation for this artifact could be loading errors caused by the components chosen (e.g. Arduino), however this can be accounted for in the results by determining the appropriate amplitude shift.

Another source of potential error was the environment chosen to conduct the experiment. One possible explanation was the sound control in this room being limited due to the nature of 3rd year mechanical engineering students, and their chicanery. To eliminate this error, future experiments could be conducted in quiet rooms containing sound detonating foam to prevent reverberations or any additional sound waves generated. Changing this should greatly reduce the impact of our original assumption used to measure time delay.

Lastly, the changes in color show the need for greater resolution and measurement of smaller intervals to understand smaller changes within areas. Currently, it can be approximated that the gas is anisotropic given the changes shown in Figure 5 along the scanning axis. However, this could be made more quantifiable using equipment with greater resolution, and thus more detail. Magnetoanisotropium is significantly less isotropic than air, and may be used by scientists if further characterization and research is conducted on the new gas.

[3] https://www.mathworks.com/help/matlab/ref/pcolor.html