CALIFORNIA SCIENCE & ENGINEERING FAIR
2019 PROJECT SUMMARY

Name(s)

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Project Number

J1704

Project Title

Measuring Sound Speed with Acoustic Interferometry

Abstract

Objectives

The purpose of my experiment was to measure the speed of sound in gases through acoustic interferometry. Key objectives were to verify the expected temperature dependence of sound speed in air, measure the accuracy of interferometers of different lengths, and detect the change in the composition of a gas.

I used a cylindrical cavity with closed ends for my acoustic interferometer. When white noise is introduced into the cavity, resonant modes are excited. The resonant modes are those in which an integer number of half-wavelengths fit exactly within the tube. They are spaced equally in frequency, with the frequency spacing being directly proportional to the velocity.

Methods

I tested with three different tubes with lengths ranging from 0.3 m to 1.9 m. A speaker emitted white noise at one end of the tube and a microphone recorded sound at the other end. The temperature changes were monitored with a temperature logger. From each recording, I calculated a frequency spectrum and estimated the peak spacing, which yielded the sound speed.

Results

The sound speed of air increased from 333.3 to 341.1 m/sec between 280 and 291 K. My results were consistent with the expected thermodynamic behavior of an ideal gas and within 0.5% of accepted literature values. The three interferometers of different lengths yielded consistent sound speed measurements, with the longer interferometers having the best accuracy. To test if my interferometer could accurately measure the speed of sound in gases other than air, I tested with carbon dioxide. When carbon dioxide was injected into the interferometer, the sound speed decreased from 340 m/sec to 260 m/sec, close to the accepted value for carbon dioxide, and then gradually increased as air re-entered the tube.

Conclusions

In summary, I accurately measured the speed of sound in gases, including the temperature dependence, and detected the change in the composition of a gas. As an extension of my results, I would like to build an air quality monitor that could detect the presence of gaseous contaminants in air, such as carbon monoxide, by measuring the speed of sound. Because sound speed in air is sensitive to temperature, it is important to use a thermometer to compensate for thermal effects. For practical applications, I would make this device as small as possible, so I would investigate a more compact helical design.

Summary Statement

An acoustic interferometer was used to verify the expected temperature dependence of sound speed in air, measure the accuracy of interferometers of different lengths, and detect the change in the composition of a gas.

Help Received

I received advice finding spectral analysis tools from my father.