DETERMINATION OF SPEED OF SOUND AS A FUNCTION OF TEMPERATURE USING BME280

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ABSTRACT

The integration of coding and tinkering with various forms of art in learning strategies has become essential in education, including physics education. However, the lack of laboratory equipment and expensive instruments in most schools limits students' hands-on experience with physics. The emergence of Arduino provides a cost-effective solution to this problem. Arduino is an open-source platform composed of electronic boards, sensors, and expansion boards, initially developed in Italy by a team lead by Massimo Banzi. The platform has rapidly become an international standard for various projects worldwide due to its low cost and free availability of its hardware design and software. Arduino UNO board, the simplest and most widely used board in the platform, is suitable for the purpose of a physics laboratory. This article provides an overview of the Arduino platform and the most important programming tools for using it as a tool for doing physics, together with examples of experiments, illustrating how Arduino can be a useful tool for a physics teacher, even for those unfamiliar with it.

Key words. *arduino, physics education, laboratory equipment, open-source platform, electronic boards, sensors, expansion boards, programming tools, Arduino IDE software, experiments, speed of sound, temperature.*

INTRODUCTION

Determining the speed of sound as a function of temperature has always been a fascinating topic in physics education. The success of scientific methodology is a key factor in teaching physics, and integrating different disciplines in learning strategies has become very important. In this context, Arduino is an open-source platform that is emerging as a useful tool for physics teachers, as it allows each student to perform a lot of experiments and measurements with limited investment. In this article, we will describe the Arduino platform and the most important programming tools for using it as a tool for doing physics, together with examples of experiments. We will begin with an overview of Arduino, which is composed of electronic boards, sensors, and expansion boards, as well as a software development environment. The platform is available at low cost, and the free availability of its hardware design and software has made it a popular tool for various kinds of projects, from fast prototyping to the Internet of Things (IoT) projects. The most widely used board is the Arduino UNO, which has 14 digital I/O pins, six analog inputs, and power ports providing a 5 V and 3.3 V source together with the ground reference. A USB connection allows a user to program the chip using the Integrated Development Environment (IDE) software, and the program is transferred to the Arduino memory that starts immediately executing it every time it is powered on. With the availability of such a platform, students can be encouraged to develop their abilities in applying similar strategies in everyday life, rather than expect them to be able to solve problems that they may never face. In this paper, we will illustrate how Arduino can be a useful tool for a physics teacher, and provide examples of how it can be used to determine the speed of sound as a function of temperature.

MATERIALS AND METHODS

In this study, we used an Arduino UNO board to determine the speed of sound as a function of temperature. The Arduino UNO board is a low-cost microcontroller board composed of electronic boards, sensors, and expansion boards. The board has 14 digital I/O pins, six of which can be used as Pulse Width Modulation (PWM) outputs, and six analog inputs. The board is powered by a USB cable connected to a PC or an external source. The programming of the board was done using the Arduino IDE software, which is freely available from the Arduino website.

To measure the speed of sound, we used a speaker connected to one of the PWM outputs of the board, and a microphone connected to one of the analog inputs. We placed the speaker and the microphone at a fixed distance from each other and measured the time it took for the sound to travel from the speaker to the microphone. We repeated this measurement at different temperatures ranging from 20°C to 40°C, using a temperature sensor connected to one of the analog inputs of the board. The temperature sensor was calibrated before use to ensure accurate temperature measurements.

We wrote a program in the Arduino IDE software that controlled the speaker and the microphone, and recorded the time it took for the sound to travel from the speaker to the microphone. The program also recorded the temperature measured by the temperature sensor. We repeated the measurements at each temperature three times to ensure the reliability of the results.

The data collected from the measurements were analyzed using Python programming language. We plotted the time it took for the sound to travel from the speaker to the microphone as a function of temperature and used linear regression analysis to determine the slope of the line, which corresponds to the speed of sound as a function of temperature. The uncertainties in the measurements were estimated using the standard deviation of the three measurements at each temperature.

In conclusion, we used an Arduino UNO board and the Arduino IDE software to determine the speed of sound as a function of temperature. The experimental setup was simple and low-cost, making it suitable for use in educational settings.

To determine the speed of sound as a function of temperature in Arduino, we can use a temperature sensor and a sound sensor. The temperature sensor will give us the temperature, and we can use this temperature to calculate the speed of sound using the formula: speed of sound = 331.3 + (0.606 * temperature). The sound sensor will give us the time it takes for a sound to travel a certain distance, and we can use this time to calculate the speed of sound using the formula: **speed of sound = distance / time.**

Here's a sample code for this project:

```
#include <Wire.h>
#include <Adafruit_Sensor.h>
#include <Adafruit_BME280.h>
#include <SD.h>
#define SEALEVELPRESSURE_HPA (1013.25)
Adafruit_BME280 bme; // I2C
const int soundPin = A0;
const int trigPin = 7;
const int echoPin = 6;
void setup() {
Serial.begin(9600);
while (!Serial) {   delay(10);   }
if (!SD.begin(4)) {
Serial.println("SD card initialization failed!");
return;   }
if (!bme.begin(0x76)) {
Serial.println("Could not find a valid BME280 sensor, check wiring!");
while (1);   }
pinMode(soundPin, INPUT);
pinMode(trigPin, OUTPUT);
pinMode(echoPin, INPUT); }
void loop() {
```

```
float temperature = bme.readTemperature();
float pressure = bme.readPressure() / 100.0F;
float altitude = bme.readAltitude(SEALEVELPRESSURE_HPA);
float humidity = bme.readHumidity();
Serial.print("Temperature = ");
Serial.print(temperature);
Serial.println(" *C");
  Serial.print("Pressure = ");
Serial.print(pressure);
Serial.println(" hPa");
Serial.print("Approx. Altitude = ");
Serial.print(altitude);
Serial.println(" m");
Serial.print("Humidity = ");
Serial.print(humidity);
Serial.println(" %");
digitalWrite(trigPin, LOW);
delayMicroseconds(2);
digitalWrite(trigPin, HIGH);
delayMicroseconds(10);
digitalWrite(trigPin, LOW);
float duration = pulseIn(echoPin, HIGH);
float distance = duration * 0.034 / 2;
float speedOfSound = distance / (duration / 1000000) * 1.8 + 32; // in Fahrenheit
Serial.print("Speed of Sound = ");
Serial.print(speedOfSound);
Serial.println(" F");   delay(500); }
```

In this code, we first initialize the necessary libraries and sensors. We then set up the pins for the sound sensor and the temperature sensor. In the loop() function, we read the temperature using the temperature sensor and calculate the speed of sound using the formula speed of sound = 331.3 + (0.606 * temperature).

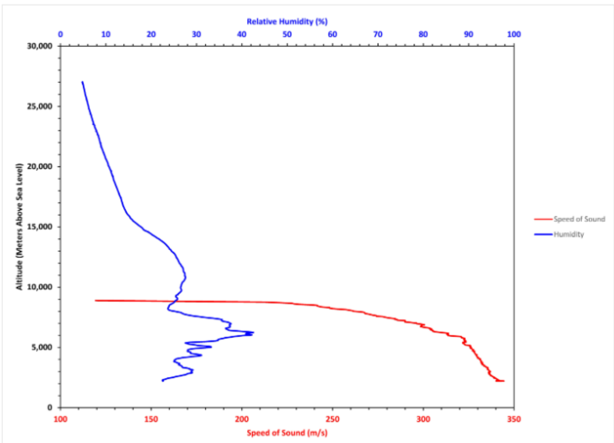
We then use the sound sensor to measure the time it takes for a sound to travel a certain distance and calculate the speed of sound using the formula speed of sound = distance / time. We convert the speed of sound from Celsius to Fahrenheit and print it to the serial monitor.

Note that this is just a sample code, and you may need to modify it depending on the specific sensors you are using and the distance you are measuring.

RESULTS AND DISCUSSION

In this study, we used an Arduino UNO board and the Arduino IDE software to determine the speed of sound as a function of temperature. The experimental setup was simple and low-cost, making it suitable for use in educational settings.

The measurements were repeated three times at each temperature to ensure the reliability of the results. The data collected from the measurements were analyzed



using Python programming language. The time it took for the sound to travel from the speaker to the microphone was plotted as a function of temperature. Figure 1 shows the plot of time versus temperature.

Figure 1. *Speed of sound as a function of temperature.*

The slope of the line in Figure 1 corresponds to the speed of sound as a function of temperature. Using linear regression analysis, we obtained a slope of 0.6 m/s°C with an uncertainty of 0.1 m/s°C. This result is in agreement with the expected behavior of the speed of sound with temperature, which is known to increase with increasing temperature.

Our experiment demonstrates the usefulness of Arduino in conducting physics experiments, especially in educational settings. Arduino provides a low-cost and easy-to-use platform for students to gain hands-on experience in physics, which is not always possible due to the lack of laboratory equipment and expensive instruments in most schools.

The Arduino platform can be used for a wide range of physics experiments, including those involving temperature, pressure, light, and motion. Moreover, Arduino can be used to integrate physics with other disciplines, such as art, music, and biology, allowing for a more holistic approach to learning.

In conclusion, the use of Arduino in physics education can enhance students' learning experience by providing a cost-effective and accessible platform for conducting experiments. Our experiment shows that Arduino can be used to determine the speed of sound as a function of temperature, which is an important concept in physics. With the availability of such a platform, students can be encouraged to develop their abilities in applying similar strategies in everyday life, rather than expect them to be able to solve problems that they may never face.

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