# WACO ISD EDUCATION FOUNDATION
## COVER SHEET – PART II
## Application for Grant:
## 2026-2027 Funding Cycle

**Assigned Grant Proposal #:** 46

**Project Title:** Speed of Sound and Resonance

**Grade Level(s):** 9 - 12 **# of Students DIRECTLY involved:** 120

**Subject Area(s):** Physics

**Amount Requested: $** 200

**Grant Focus Area(s):** In order to be considered, Waco Education Foundation Innovation Grant proposals must fall under one or more of the E4 focus areas: early childhood development, enhanced programming for advanced students, extended education for staff, and emphasis on student performance. NOTE: In addition to meeting one of the E4 focus areas above, grant readers are especially interested in creative and innovative grant requests that target fine arts, STEM, literacy, or enrichment.

**(check all that apply)**

- ☐ Early Childhood Development
- ☑ Enhanced Programming for Advanced Students
- ☐ Fine Arts
- ☑ Literacy
- ☐ Extended Education for Staff
- ☑ Emphasis on Student Performance
- ☑ STEM
- ☑ Enrichment

**Assigned Proposal #46**

**Project Title:** Speed of Sound and Resonance

**Project Description:** This kinesthetic acoustic physics project utilizes tuning forks and water-submerged PVC air columns to explore resonance. Students manipulate frequency and wavelength, calculating the speed of sound. Adding novelty, the project extends to investigate how varying pipe diameters and environmental temperatures impact acoustic properties. Moving beyond abstract equations, students connect their findings to real-world applications in plumbing, engineering, and environmental science, enriching their STEM experience with tactile learning and applied research.

**1. Rationale**

This project aligns directly with the Waco Education Foundation's focus areas of Enhanced Programming for Advanced Students, Emphasis on Student Performance, STEM, Literacy, and Enrichment. By investing in foundational resonance apparatuses (sturdy PVC pipes and graduated cylinders), we ensure that students can bridge the gap between abstract mathematical relationships and tactile, physical reality. Beyond the analytical rigor of calculating wave speed, this project demands high-level collaboration as students work in synchronized pairs to manipulate acoustic variables. The experimental design fosters critical thinking by requiring students to analyze how varying tube diameters and shifting environmental temperatures alter sound's physical properties. Furthermore, this project supports District and Campus Improvement Plans by elevating rigor and kinesthetic inquiry in advanced science coursework, fulfilling a distinct need for permanent, hands-on materials in the physics classroom.

**2. Goals**

- Facilitate active student participation in physical, kinesthetic physics experiments.
- Encourage deep analysis and critical thinking that extends beyond simple, laborious mathematical calculations.
- Connect classroom learning to real-world life, career, and research applications.
- Enrich the student learning experience through adaptable and personalized research extensions.
- Foster collaborative skills through synchronized group work, data collection, and the sharing of scientific findings.

## 3. Plan of Operation

**Activities & Strategies:** This project provides a hands-on exploration of acoustic physics using open-closed pipe oscillators. Students will use tuning forks to generate sound waves, adjusting the length of a water-submerged PVC air column to find resonance. They will collect physical data across varying frequencies, pipe diameters, and water temperatures to calculate the speed of sound. As a personalized extension, students will select a research track to investigate how these acoustic principles apply to real-world fields, moving from raw data to applied science.

**Timeline:** The project will be completed over the course of one week during the spring semester. This includes one to two class days dedicated to active, hands-on experimentation and data collection, with the remaining days allotted for collaborative data analysis and independent research.

**Parental & Community Involvement:** The applied nature of this lab bridges classroom physics with highly valued community skills. By exploring pipe resonance, students connect with practical engineering and plumbing concepts, highlighting direct ties to the training and careers fostered by local institutions like Texas State Technical College (TSTC) and the Greater Waco Advanced Manufacturing Academy (GWAMA). Students will be encouraged to discuss their practical research with their parents, bringing STEM conversations into the home. Finally, the research component of the lab will be displayed in the classroom and school hallways to disseminate their findings to the broader school community.

## 4. Communication & Dissemination

During the lab days, students will be invited to take pictures and videos to document their kinetic learning, and we will share these visual resources with the grant foundation. We would also welcome the opportunity to include the Foundation with an invitation to observe the lab in action. To share the results and pedagogical strategies with others in the District, the lab framework and student success metrics will be offered as a resource during district staff development meetings for science teachers.

## 5. Evaluation

The proposed project's success will be evaluated based on the students' active engagement in the comprehensive research process. Rather than solely grading the mathematical accuracy of their calculations, evaluation will focus on the students' ability to effectively collaborate in groups to gather precise physical data. Success will be measured by the completion of written laboratory reports where students thoughtfully ponder and analyze the effects of temperature and pipe diameter on resonance.

Furthermore, students will be assessed on their ability to independently research real-world acoustic applications and successfully share those findings with their peers and the school community.

**6. Long Term Implications**

The core supplies we intend to acquire—PVC piping, graduated cylinders, and a pipe cutter—are highly durable. Once purchased, these materials will supplement our current tuning forks to establish a permanent set of stable oscillators. This ensures that we can sustain this tactile exploration of acoustic physics for years to come without requiring recurring funding for this specific module. It will consistently impact between 105 to 180 9-12th grade physics and AP physics students annually.

**7. Key Personnel**

- **Physics/AP Physics Teacher:** As the instructor, this individual is highly familiar with the content and will facilitate proper lab etiquette, ensure precision in measurement and technique, and assist students with their collaborative research, data analysis, and career-application extensions.

**8. Budget and Budget Narrative/Justification**

- **Total Amount Requested:** $200.
- **Line Item 1 - Large plastic graduated cylinders:** The requested funds will be used to purchase these cylinders to hold the water and form the primary resonance apparatus.
- **Line Item 2 - PVC piping:** This serves as the physical air column that students will manipulate. By investing in these fundamental materials, we ensure that students can continue to bridge the gap between abstract mathematical relationships and tactile, kinesthetic learning.
- **Line Item 3 - PVC pipe cutter:** This tool is necessary to safely cut and prepare the PVC pipes into the specific lengths and 0.5-inch and 2.0-inch diameter segments required for the varied trial parameters.

The campus has already allocated resources in terms of tuning forks and glass thermometers.

Optional: Below is the lab report template for the lab. A modified version of this has been used for over 3 years at other locations. McGraw Hill includes a similar lab activity using tuning forks and pipes. We are unable to partake in the foundational, phenomenological lab without this equipment.

Name: ____________________ **Speed of Sound and Resonance**

**Objectives:**

1. Calculate the speed of sound based on a resonating sound wave.
2. Compare wavelength per changing frequency and device setup.
3. Compare speed of sound per changing temperature.
4. Research applications of acoustics.

**Procedure:**

1. Place a tuning fork over a tube in a graduated cylinder.
2. Place the top of the tube slightly above waterline.
3. Move the tube and tuning fork up until the sound resonates.
4. Record the length of the tube above the water level for the given frequency.
5. Repeat steps 1-4 for the remaining frequencies and pipe diameters.
6. Calculate the wavelength and the speed of sound.

**Part 1: First harmonics per frequency and pipe diameter**

| Frequency of Tuning Fork (Hertz) | Diameter of Pipe (inches) | Length of Pipe above $H_2O$ (m)<br><br>L | Wavelength (m)<br><br>4xL | Speed of Sound (m/s)<br><br>Frequency x Wavelength | Percent Error<br><br>(Accepted Value = 343m/s )<br><br>100x(Experimental - Accepted) / Accepted |
|---|---|---|---|---|---|
| 512 Hz | 0.5 | | | | |
| 384 Hz | 0.5 | | | | |
| 256 Hz | 0.5 | | | | |
| 512 Hz | 2.0 | | | | |
| 384 Hz | 2.0 | | | | |
| 256 Hz | 2.0 | | | | |

**Analysis**

1. What happened to the wavelength as the frequency decreased?

2. How is frequency limited by pipe length?

3. Does the speed of sound change with changing frequency?

4. What are the effects increasing the pipe diameter? Conceptually what might be happening with larger diameters?

**Part 2: First Harmonics per temperature**

**Procedure:**

1. Ice bath:
   a. Place the 0.5-inch pipe in an ice bath.
   b. Let the pipe equilibrate for 7 minutes.
   c. Take temperature in the tube.
   d. Repeat the procedure from part 1.
2. Hot water bath: Repeat the steps from the ice bath procedure.

| Frequency of Tuning Fork (Hertz) | Temperature (deg C)<br><br>T | Length of Pipe above $H_2O$ (m)<br><br>L | Wavelength (m)<br><br>4xL | Speed of Sound (m/s)<br><br>Frequency x Wavelength | Percent Error<br><br>(Accepted Value = 331.3 + 0.606T)<br><br>100x(Experimental - Accepted) / Accepted |
|---|---|---|---|---|---|
| 512 Hz | Ice-bath | | | | |
| 384 Hz | Ice-bath | | | | |
| 256 Hz | Ice-bath | | | | |
| 512 Hz | Hot water | | | | |
| 384 Hz | Hot water | | | | |
| 256 Hz | Hot water | | | | |

**Analysis**

1. How did the measured resonance length (L) change as the temperature of the air increased? Based on the wave equation (v = frequency x wavelength) what does this imply about the speed of sound in warmer air?

2. Using the formula v = 331.3 + 0.606T, calculate the theoretical speed of sound for your three environments. How does this compare to your experimental results (v = 4Lf)? Calculate the percent error for each.

3. Conceptually, why does heating the air allow the sound wave to travel faster? Think about the behavior of air molecules at 5 degC versus 50 degC?

4. In the hot water bath experiment, the air inside the pipe likely became more humid. Does water vapor make air more or less dense than dry air? How might this affect your speed of sound calculation compared to the dry 'room temperature' trial?

## Acoustic Resonance in the Real World

After having measured how pipe diameter and air temperature change the way sound behaves in a simple PVC pipe, it is time to research how professionals use these exact same principles to solve complex problems in medicine, engineering, and environmental science.

Select **one** of the following research tracks.

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### Option 1: Medicine & Respiratory Health

**The Connection:** The human respiratory system is essentially a series of branching pipes. Doctors use "Acoustic Percussion"—tapping on a patient's chest—to listen for resonance. A healthy, air-filled lung resonates like an open-closed pipe, but a lung filled with fluid (pneumonia) changes the medium and the effective length (L) of the cavity.

- **Research Question:** How does the presence of fluid in the lungs (pulmonary edema) change the resonant frequency heard by a doctor?
- **Data Analysis Challenge:** Based on your **Part 2** results with the ice and hot water baths, explain how a change in the *density* or *temperature* of the medium (air vs. fluid) would affect the speed of sound and the resulting wavelength ($\lambda$).

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### Option 2: Engineering & Infrastructure (Pipeline NDT)

**The Connection:** Engineers use **Acoustic Pulse Reflectometry (APR)** to find blockages (clogs) or leaks in massive underground pipes without digging them up. They send a sound wave through the pipe; when the wave hits a change in diameter, it reflects back.

- **Research Question:** How do engineers use the timing and frequency of reflected sound waves to determine the exact location and size of a "clog" in a city's water main?
- **Data Analysis Challenge:** In **Part 1**, you observed how changing the pipe diameter from 0.5" to 2.0" changed your measurements. If a pipe is partially blocked by mineral buildup, effectively narrowing the diameter, how does that change the "End Correction" and the resonance the engineer would measure?

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### Option 3: Marine Science & The SOFAR Channel

**The Connection:** The ocean has a "speed of sound sandwich" called the **SOFAR Channel**. Because the speed of sound is affected by temperature, sound waves get "trapped" in a specific layer of the ocean, allowing whale calls or submarine pings to travel thousands of miles.

- **Research Question:** What is the "SOFAR Channel," and how do temperature and pressure gradients create a "pipe" in the open ocean that prevents sound from escaping?
- **Data Analysis Challenge:** Look at your data for the speed of sound at different temperatures ($v = 331.3 + 0.606T$). If a sound wave travels from a warm tropical surface layer into a cold deep-sea layer, how does its wavelength ($\lambda$) change if the frequency of the source remains constant?

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**Option 4: Urban Planning & "Water Hammers"**

**The Connection:** Have you ever heard a loud *bang* in the walls after turning off a faucet? This is a "water hammer." Plumbers install "arrestors"—short, air-filled pipes—to act as resonators that absorb the shock wave before it damages the plumbing.

- **Research Question:** How does the length of an air-filled "stub" pipe determine which shock wave frequencies it can successfully absorb?
- **Data Analysis Challenge:** In your lab, you found that frequency is limited by pipe length. If a plumber installs a pipe that is too short, will it be able to resonate with (and thus absorb) a low-frequency shock wave? Use your data from the **256 Hz vs. 512 Hz** trials to justify your answer.

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**Option 5: Musical Instrument Design (The Luthier's Physics)**

**The Connection:** Every wind instrument—from a massive pipe organ to a tiny piccolo—is a real-world application of the experiment you just performed. Instrument makers (luthiers) must account for temperature and pipe diameter to ensure an instrument plays "in tune."

- **Research Question:** Why do wind instrument players (like flutists or trumpeters) must "warm up" their instruments to stay in tune? How does the diameter of a woodwind instrument's bore affect the richness or "timbre" of the sound?
- **Data Analysis Challenge:** In **Part 2** of your lab, you saw how temperature changes the speed of sound (v). If a concert hall warms up by 10 degrees Celsius during a performance, would the musicians need to make their instruments physically *longer* or *shorter* to keep the resonance at the correct frequency? Use your **Table 2** data to support your claim.

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**Option 6: Student Choice – "Resonance in the Wild"**

**The Connection:** Physics doesn't just stay in the classroom. Resonance occurs in car exhaust systems, the design of "whispering galleries" in famous buildings, and even in how certain animals (like elephants) communicate over long distances using low-frequency infrasound.

- **Research Question:** Identify a machine, animal, or architectural structure that relies on acoustic resonance. Describe how it uses a "pipe" or "cavity" to amplify specific frequencies.
- **Data Analysis Challenge:** Define the "effective length" (L) and the "medium" (air, water, etc.) for your chosen subject. Explain how changing one physical property (like making the cavity wider or the air hotter) would change its resonant frequency based on the patterns you observed in **Part 1 and Part 2** of this lab.

# Waco Education Foundation

## Grant Budget Form

| | |
|---|---|
| Assigned Proposal # | 46 |
| Project Title: | Speed of Sound and Resonance |
| Number of Students Served by Grant: | 120 |

| Qty | Budget Item | Verify Vendor (Y or N) | $ Requested from the WISD Foundation | Other Secured Source | $ from Other Source (if applicable) | Total Amount |
|---|---|---|---|---|---|---|
| | **Consumable Supplies** | | | | | |
| | | | | | | $ - |
| | | | | | | $ - |
| | | | | | | $ - |
| | | | | | | $ - |
| | | | | | | $ - |
| | | | | | | $ - |
| | total Consumable Supplies | | $ - | | $ - | $ - |
| | **Technology** | | | | | |
| | | | | | | $ - |
| | | | | | | $ - |
| | total Technology | | $ - | | $ - | $ - |
| | **Long-Term Supplies / Equipment** (items that will last beyond the grant year) | | | | | |
| 8 | Large plastic graduated cylinders | Y | $ 60.00 | 0 | $ - | $ 60.00 |
| 16 | PVC piping | Y | $ 108.00 | 0 | $ - | $ 108.00 |
| 1 | PVC pipe cutter | Y | $ 32.00 | $ - | $ - | $ 32.00 |
| | | | | | | $ - |
| | | | | | | $ - |
| | | | | | | $ - |
| | total Long-Term Supplies | | $ 200.00 | | $ - | $ 200.00 |
| | **Contracted Services** | | | | | |
| | | | | | | $ - |
| | | | | | | $ - |
| | total Contracted Services | | $ - | | $ - | $ - |
| | **Personnel** | | | | | |
| | | | | | | $ - |
| | | | | | | $ - |
| | total Personnel | | $ - | | $ - | $ - |
| | **Travel / Other** | | | | | |
| | | | | | | $ - |
| | | | | | | $ - |
| | | | | | | $ - |
| | | | | | | $ - |
| | total Other | | $ - | | $ - | $ - |

| **Totals** | **Total Requested from the WISD Foundation** | **Foundation Cost Per Student** | **Total from Other Sources** | **Total Cost of Project** |
|---|---|---|---|---|
| | **$ 200.00** | **1.666666667** | **$ -** | **$ 200.00** |