Sound

The Doppler Effect

Overview

Have you ever noticed how the **sound** of a passing car or train changes as it moves closer to you and then farther away? This change in sound is caused by the **Doppler effect**, a fascinating phenomenon that affects all types of waves, including **sound and light**.

Background

The Doppler effect is the change in **frequency** or wavelength of a wave in relation to an observer who is moving relative to the wave's source. It occurs because the motion of the source compresses or stretches the **sound waves** as they travel through a medium like air.

When the source of the sound is moving toward the observer, the sound waves are compressed, resulting in a higher frequency and pitch. Conversely, when the source is moving away, the sound waves are stretched, causing a lower frequency and pitch. This is why a siren sounds higher-pitched as it approaches and lower-pitched as it moves away.

The Doppler effect is not limited to sound, it also applies to light and is used by astronomers to measure the movement of stars and galaxies. On Earth, the Doppler effect is applied in technologies like radar, medical imaging (Doppler ultrasound), and even weather forecasting to track storms. By exploring this phenomenon, you'll gain a deeper understanding of how motion influences waves and how we use this knowledge in everyday life and science.

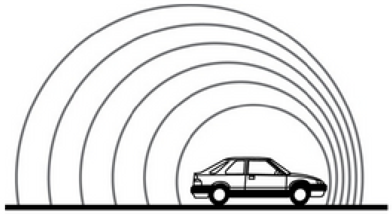
Grades: Middle School
Time: 45 Minutes
Subject: Physical Science
Topics: Doppler effect, Sound, Sound Waves, Speed of Sound

What You Will Need/Prep

- databot with sound and distance sensor
- IOS/Android Smart Device
- Install Vizeey™ on your Smart device.
- Tuning Fork
- Ruler or measuring tape

- Test your databot™ connection.
- You will be prompted to select and connect to databot™ each time you launch an experiment.
- If there are two or more databot™'s listed, the one closest to your device will be highlighted in blue.
- Study the background information and terms and prepare to explore!

In this activity, you will investigate the Doppler effect and learn how motion influences the frequency and pitch of sound. Using a databot's sound sensor and simple experiments, you'll observe and analyze how sound waves behave when their source or the listener is in motion.



Learning Objectives

By completing this lab, students will:

- Understand the principles behind the Doppler effect and its relationship to wave frequency, wavelength, and relative motion.
- Identify and explain how motion of a sound source or observer affects the perceived pitch of sound.
- Observe and measure changes in sound frequency using databot's sound sensor during motion experiments.
- Analyze recorded data to identify patterns in frequency shifts caused by the Doppler effect.
- Connect experimental observations to theoretical principles of wave behavior in moving systems.
- Visualize and interpret changes in sound wave data using graphs to deepen their understanding of how the Doppler effect works.

Important Terms

Doppler Effect: A change in the observed frequency of a wave caused by the relative motion between the source of the wave and the observer.

Frequency: The number of wave cycles passing a point per second, measured in hertz (Hz). Determines the pitch of sound.

Pitch: The perceived highness or lowness of a sound, directly related to the frequency of the sound waves.

Relative Motion: The movement of the wave source, the observer, or both, which affects the observed frequency due to the Doppler effect.

Sound Sensor: A device used to detect and measure sound waves, often used to observe changes in frequency and intensity.

Sound Wave: A vibration that travels through a medium (e.g., air) as a longitudinal wave, compressing and rarefying particles in the medium.

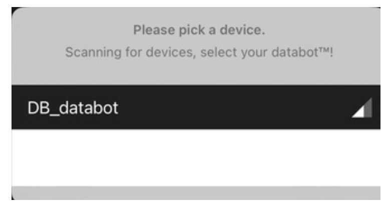
Using Vizeey

In order to work with the experiment you need to launch the Vizeey application and click on + in the upper right corner.

Then select "Add experiment from QR code" and scan the QR code prepared for this experiment. Your experiment will appear in the list.

Once in the Experiment

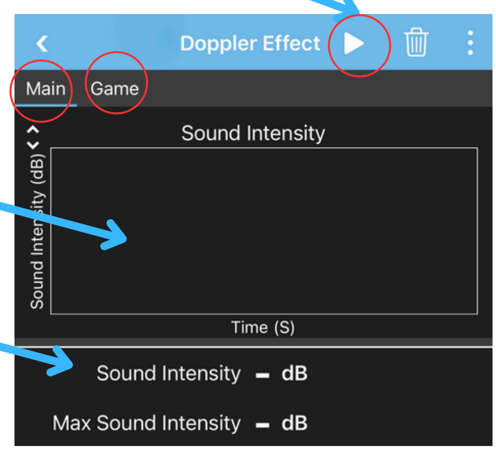
When you start the experiment you will be immediately offered to connect to your databot. Make sure that databot is turned on and in Vizeey mode with a blue blinking light.



Press this button to start the experiment.

This lab work investigates the Doppler effect

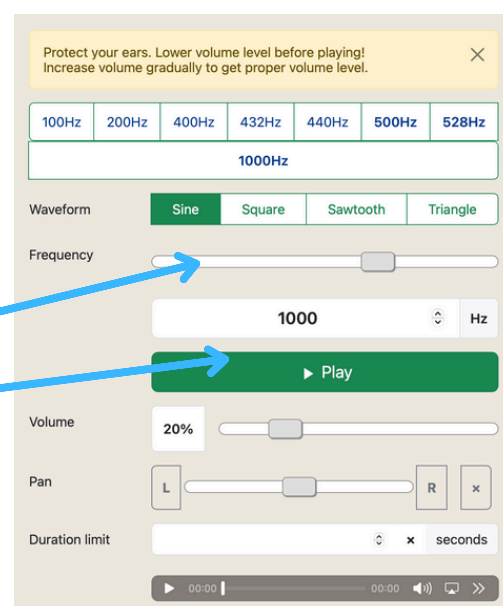
- The experiment contains several tabs.
- Graph showing the sound level
- Sound intensity value in real-time.
- Maximum sound value



The lab work will involve generating a sound source of different frequencies. To do this, scan the qr code with your phone.

Set the frequency

Start the sound



Part 1: Initial Observations and Discussion Questions

Why do sirens on emergency vehicles sound different as they approach and then move away? ____

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Can the Doppler effect occur with waves other than sound, such as light?

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If the source and the observer are moving at the same speed in the same direction, will the Doppler effect still occur? Why or why not?

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Part 2: Hypothesis

Based on your understanding of sound waves and motion, propose a hypothesis about how the Doppler effect could be observed and measured using a databot sound sensor. Consider how changes in frequency might occur when the sound source or observer is in motion, and how this data could be used to confirm the principles of the Doppler effect. Predict the relationship between the speed of motion and the observed change in sound frequency.

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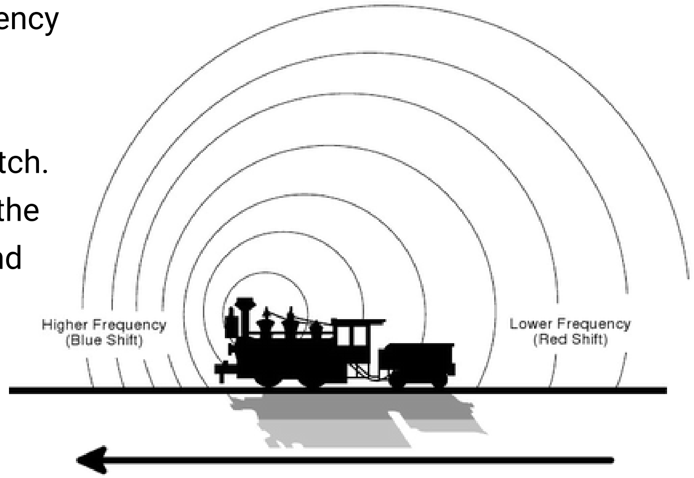
Part 3: Experiment Procedure

The Doppler effect is a change in the frequency or pitch of a wave. When a source moves toward the observer, the waves compress, resulting in an increase in frequency and pitch. Conversely, when the source moves away, the waves stretch, decreasing the frequency and pitch of the tone. This phenomenon is commonly observed with the sound of a passing siren. It illustrates the relationship between motion and wave behavior.

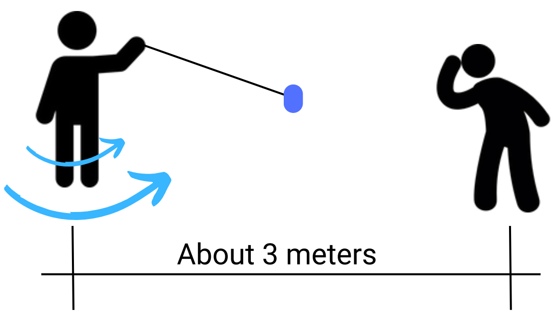


Part 3: Experiment Procedure

The Doppler effect is used in various real-life applications:

- Radar and Speed Measurement: Doppler radar is used by police to measure the speed of vehicles by detecting the frequency shift of radio waves reflected from moving cars.
- Medical Imaging: In ultrasound technology, the Doppler effect helps to measure blood flow by detecting changes in the frequency of sound waves bouncing off moving blood cells.
- Astronomy: Astronomers use the Doppler effect to determine the speed and direction of stars, planets, and galaxies by observing shifts in the frequency of light or radio waves they emit.
- Weather Forecasting: Doppler radar is also used in meteorology to track storms and precipitation, as it detects the movement of rain or snow particles through frequency shifts in radio waves.

<u>Demonstration of the Doppler effect using available materials and minimal space.</u>



Sound Generator

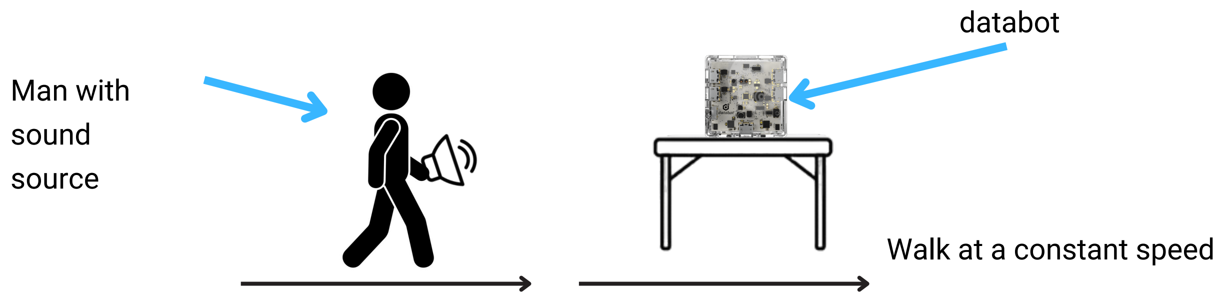
- Scan the provided QR code with your smartphone to access the sound generator.
- Choose a constant frequency (e.g., 440 Hz, or any other of your choice).
- Securely attach the smartphone to one end of the string. Ensure it is tightly fastened to avoid slipping.
- Play the selected tone on the smartphone.
- One student stands in the center of the classroom, holding the other end of the string, and begins rotating the smartphone in a circular motion above their head.
- The rest of the students stand at a safe distance, listening carefully as the smartphone moves closer to and farther from their position.
- Pay attention to how the sound changes as the phone moves. When the phone approaches, the pitch will rise when it moves away, the pitch will drop.

Ensure the rotating area is clear, and students maintain a safe distance to avoid accidents.

Part 3: Experiment Procedure

Effect Observed:
As the phone moves closer to the listeners, the pitch of the sound becomes higher. When it moves away, the pitch becomes lower.

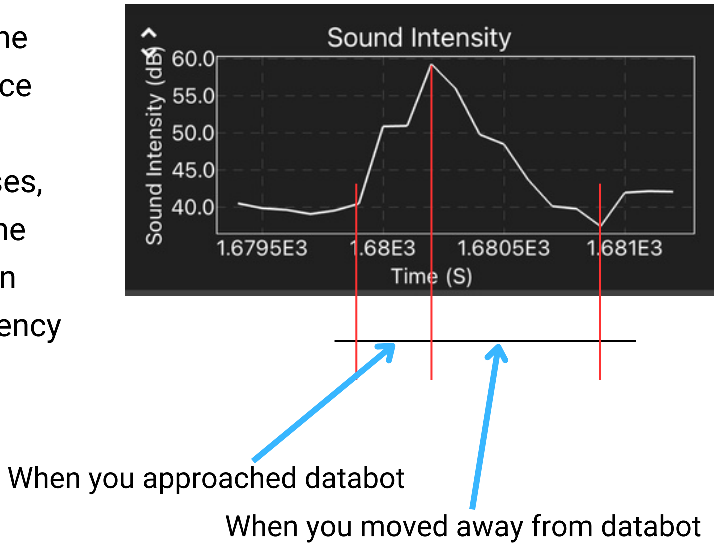
Why It Happens:
This occurs due to the Doppler effect: the motion of the sound source compresses sound waves when approaching, increasing their frequency (higher pitch), and stretches them when receding, decreasing their frequency (lower pitch).



- Open the Vizeey app on your smart device.
- Turn on databot (using the small button on the left side)
- Tap on **"The Doppler Effect"** in Vizeey to load the experiment.
- You will be prompted to connect to databot.
  - Hint- if there is more than one databot in use, the one closest to you will be in blue!
  - A solid blue light on databot means you are connected.
- Start your experiment using:
  - Use these icons at the top of the screen in Vizeey to start and to pause the experiment.
- Place databot on a flat surface, such as a table, in a space where sound can travel freely.
- Set up a sound source (any speaker generating a frequency around 7000 Hz, which is optimal for the databot's sensor)
- Begin playing the sound at a steady frequency, ensuring the sound is continuous and stable.
- Move with the Sound Source: Walk at a constant speed while holding or carrying the sound source, passing by the databot

Part 3: Experiment Procedure

Observe the Graph: Watch the graph on the databot's screen as you move. You'll notice that as you approach the databot, the frequency detected by the sensor increases, and the distance between the peaks on the graph becomes smaller. Conversely, when moving away from the databot, the frequency detected decreases, and the distance between the peaks becomes larger.

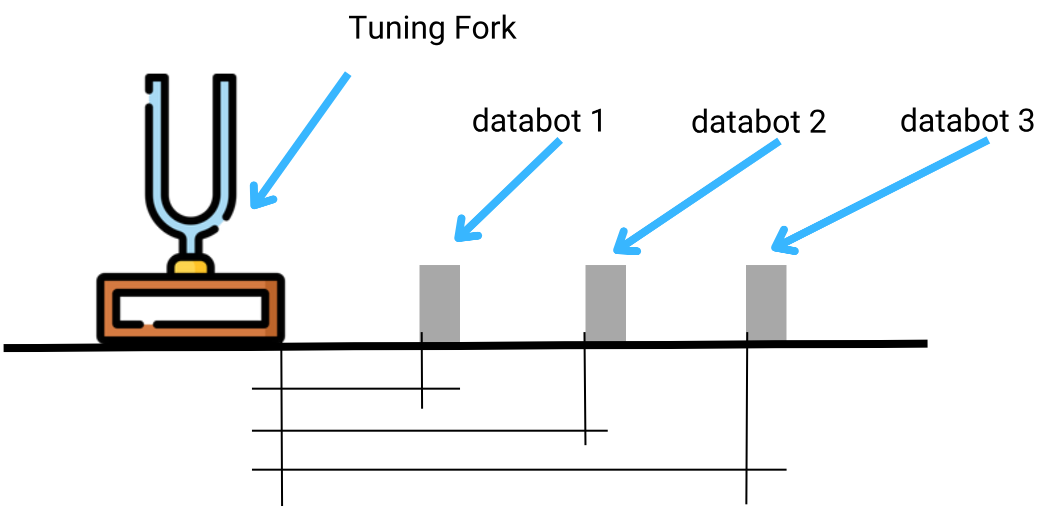


If you don't succeed the first time, repeat this experiment.

Effect of Distance on Sound

Sound intensity and the Doppler effect are related indirectly

The intensity of sound decreases as the distance between the sound source and the observer increases. This happens because sound energy spreads over a larger area as it travels, and less energy reaches a specific point the farther it moves.
The intensity of sound is inversely proportional to the square of the distance from the source. This is known as the inverse square law. For example, doubling the distance reduces the sound intensity to one-fourth.



Part 3: Experiment Procedure

- Begin by preparing the tuning fork for the experiment. Ensure that it's in good condition and ready to produce a steady tone when struck.
- Gather several databots and place them at varying distances from the tuning fork. Position the sound sensors of the databots facing the tuning fork to ensure accurate sound.
- Open **"The Doppler Effect"** experiment in the Vizeey app, which is designed to record and analyze sound intensity and start your experiment using
- Strike the tuning fork gently to produce a consistent sound.
- Watch the graphs.
  - While the sound emitted from the tuning fork remains constant, the data will show a clear pattern. The further databot is from the tuning fork, the lower the recorded sound intensity. This demonstrates how sound intensity decreases with distance.

Fill in the table indicating the distance from the tuning fork to the databot as well as the maximum sound value

	Distance Between databot and tuning fork (cm)	Maximum sound intensity (dB)
databot 1		
databot 2		
databot 3		

Make a histogram of the resulting values

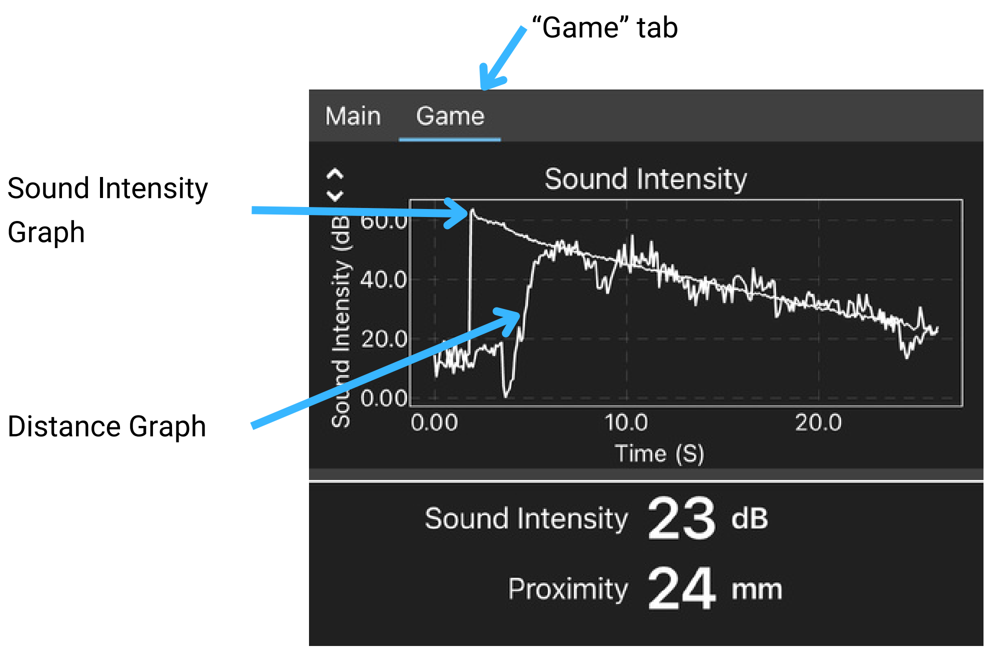
Part 3: Experiment Procedure

Now, let's turn this into a fun game of skill and understanding!

In the Vizeey app, navigate to the *"Game"* tab to begin the experiment.

- Position the databot as close as possible to the tuning fork to capture the maximum sound intensity.
- Initiate the experiment using ▶ and striking the tuning fork. A sound wave of a certain intensity will be generated, and it will appear on the graph in white.
- Gradually move the databot away from the tuning fork. As you do, the graph of the sound intensity will change, showing a decrease in intensity as the distance increases.
- At the same time, the distance sensor graph will show the change in distance as you move the databot.

- The Challenge: Your task is to adjust the movement of databot so that the sound intensity graph and the distance graph align as closely as possible. Try to make them match!



Did you manage to realize it?

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Part 5: Concept Questions

Data Interpretation:

- What happens to the frequency of a sound wave as the source moves towards the observer? ______________________________

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- How does the Doppler effect explain the change in pitch that we hear when a moving vehicle passes by?

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- In what real-life scenarios can the Doppler effect be applied (e.g., medical imaging, radar)? ______________________________

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Part 6: Reflection

1. What additional experiments or observations could you make to further explore the Doppler effect?

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2. How would you modify this experiment to study the Doppler effect with light waves instead of sound?

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3. How would the results of this experiment change if the sound source were moving in a circular path instead of in a straight line?

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4. Could the Doppler effect be observed with objects moving at constant speed? How would the shift compare to objects accelerating or decelerating?

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