

Doppler Ball

Demonstration

Participants will learn how the doppler effect works through an interactive and physical activity.

Number of Participants: 2-10

Audience: Elementary (ages 5-10) and up

Duration: 5-10 mins

Difficulty: Level 1

Materials Required:

- Foam ball (6" or greater)
- 9V battery
- Tone Generator (400 - 2000 Hz)
- 9V battery connector



Figure 1: a complete doppler ball

Setup:

1. Solder (or otherwise connect) the 9V battery connector to the tone generator. Electrically isolate the bare wires with electrical tape or heat shrink sheaths.
2. Cut the foam ball with an exacto knife (see *Figure 1*). Make the incision as small as possible. It's recommended that the buzzer remain as close to the center of the ball as possible.
3. When ready for the demonstration, attach the battery to the buzzer and place it inside the foam ball. Test to make sure the buzzer is secure inside the ball when thrown. Wrapping the buzzer and battery in masking tape or even rubber bands can help it remain in the ball.
4. Have the students throw the ball back and forth between each other. Ask students to describe the difference in sound, or pitch. The ball can also be dropped from a ladder, if available.

Presenter Brief:

Be familiar with the doppler effect and real world examples of the doppler effect (e.g. ambulances, airplanes, trains, car sounds). Understand how the doppler effect can be applied to different situations- GPS, light, and astronomy (redshift and blueshift).

Vocabulary:

- Wave - A disturbance that can transmit energy and information while not transporting the medium.
- Longitudinal Wave - Propagation of a wave through a material through expansion and compression (see *Figure 2*)
- Frequency - How many cycles per time an oscillation happens, measured in Hz or cycles/second.
- Sound Wave - A longitudinal wave that propagates through air.
- Pitch - The highness or lowness of sound.
- Wavelength - The distance between two corresponding points, such as peak to peak, on sequential waves.

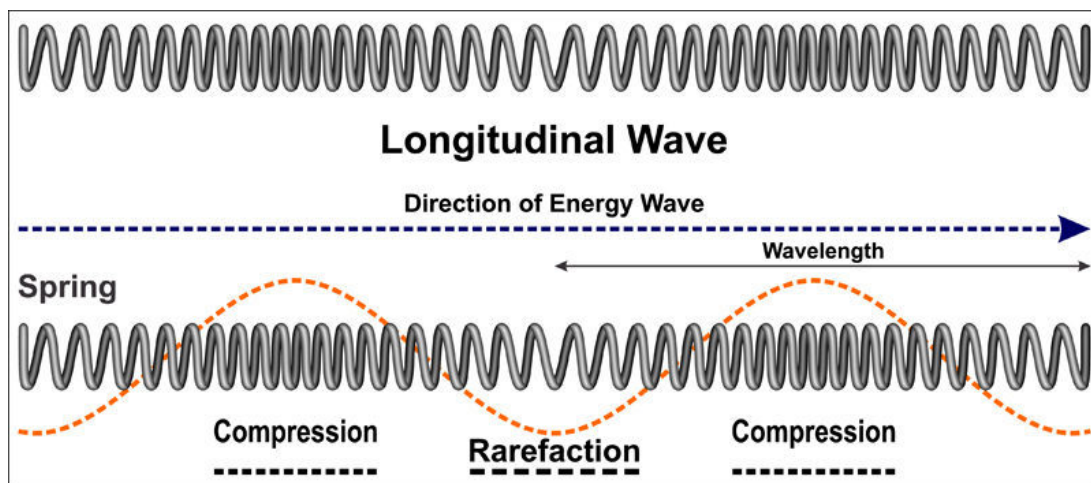


Figure 2: a diagram showing the components of a longitudinal wave via a spring (Source: Gobbler¹)

Physics & Explanation:

Elementary (ages 5-10):

Sounds are little vibrations that reach our ear. The sound travels to us by making the air wiggle. Think of a speaker and how when the speaker is playing music, the speaker is vibrating (see video linked additional resources below). This is because the speaker needs to create sound waves by moving the air around it. When something moves back and forth very quickly, it moves the air and creates sound.

The doppler effect happens when there is a moving object that is creating sound, such as the ball in this demo. When the object is moving towards you, the sound

sounds higher in pitch, and that is why when the ball is thrown towards you it sounds higher in tone or pitch when compared to stationary. When the object moves away from you, the sound will be lower. This is why when you throw the ball to someone else, the ball sounds lower to you. A very common example of this is an ambulance when it drives by you. The signature sound profile: higher pitch followed by a rapid shift to a lower pitch.

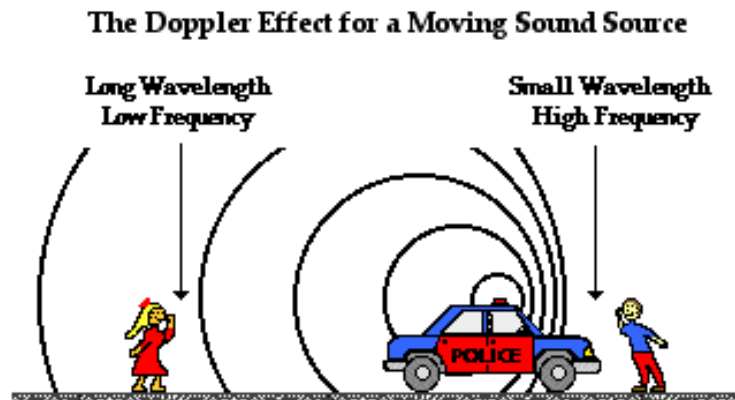


Figure 3: an illustration showing the doppler effect (Source: Physics Classroom²)

Middle (ages 11-13) and general public:

Sound is the vibration of air. A good example of this is a speaker used at home or in a concert. You can see how the speaker vibrates. The speaker vibrating causes the air around it to also vibrate, hence creating the sound that we hear.

Sound is a longitudinal wave, or a pressure wave. You can think of sound as areas of higher and lower density air, as seen in *Figure 2*. When a sound wave is moving fast, the sound we hear has a high pitch or tone. When the wave is traveling slower, the sound we hear has a lower pitch. This is how we make music and why people have different voices.

When an object is moving towards you that is making a sound, such as an ambulance, the waves are traveling faster towards you. When the object is moving away the waves are traveling slower. This is called the Doppler effect. The pitch as an object approaches you is higher than when an object is moving away from you.

High School (ages 14+):

Sound is just air vibration. This means that they are waves, similar to waves in the ocean. When sound waves move through air they cause things to vibrate, and that vibrating air in our ear is how we hear. When a speaker is playing music, you can sometimes see it vibrating and the reason it does that is because it is creating sound waves.

The doppler effect is when an object emitting sound is moving towards you, passes you, and then moves away from you. A very common example is an ambulance.

When an ambulance with its siren on approaches you, the sound waves have more energy from the speed of the ambulance. The higher the energy of a wave the higher pitch it will be. The same is true for lower energy waves and lower pitch. This is why when the ambulance is coming towards you it sounds high-pitched, and when it is moving away from you it has a lower pitch.

What is cool about the doppler effect as it applies to all waves. Light is also a wave, and so when light is moving towards an observer it has more energy than light moving away. On a small scale, with a flashlight for example, the effect is not noticeable. However, in astronomy this is a very common and heavily used effect. Astronomers can figure out how far away an object is and how fast it is moving away or towards us by using the doppler effect. This is called redshift and blueshift. Redshift means the object is moving away from us since red light has lower energy than blue light and blue light means the object is moving towards us. Everything in the universe is redshifted, except for a few galaxies in our local area, such as the Andromeda Galaxy.

A final, and important note, is that the doppler effect is relative. This means that the effect is only observed from our perspective, and that the people driving the ambulance don't experience the effect.

Additional Resources:

- Speakers vibrating from sound - https://www.youtube.com/watch?v=QJ4IzzXH8P0&ab_channel=ClassicsCast

References:

1. <https://courses.gobbler.com/courses/the-fundamental-principles-of-sound/lessons/what-is-sound/topic/longitudinal-wave/>
2. <https://www.physicsclassroom.com/class/waves/Lesson-3/The-Doppler-Effect>