# Hypersonics STEM Curriculum

## Sound vs Light

| Grade | Time | Subject Area | Key Concepts |
|---|---|---|---|
| 6-8 | 35 min | Physical Science | Waves<br>Speed/velocity |

### Lesson Overview

In this lesson, students will use online resources through a WebQuest to learn the similarities and differences between sound waves and light waves.

### NGSS Standards

MS-PS4-2 Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

### Learning Objectives

By the end of this lesson, students will be able to:

- Explain the similarities and differences between sound waves and light waves.
- Compare the relative speeds of sound and light to other items.
- Share ideas of how the speeds of sound and light effect hypersonic travel.

### Essential/Overarching Question

How are sound waves and lights waves similar and different?

### Key Vocabulary

**Speed** – the rate at which an object is moving. Speed is calculated by dividing the distance travelled by the time it took to travel that distance.

**Speed of Sound** – the rate at which sound moves through a medium. The speed of sound depends on both the density and the temperature of the medium. The speed of sound through air at 20° C (68° F) at sea level is 343 m/s (767 mph).

**Mach** – the ratio of the speed of an object to the speed of sound or how many times the speed of sound an object is moving. It is often followed by a number indicating the ratio; for example: Mach 1 is the speed of sound, Mach 2 is twice the speed of sound, Mach 5 is five times the speed of sound.

**Sonic** – speeds equal to the speed of sound (Mach 1).

**Subsonic** – speeds smaller than the speed of sound (less than Mach 1).

**Transonic** – speeds near (Mach 0.8-1.2) the speed of sound where drag is highest (e.g. sound barrier).

**Supersonic** – speeds greater than the speed of sound (Mach 1 and greater).

**Hypersonic** – speeds greater than five times the speed of sound (Mach 5 and greater).

**Fluid** – a substance with no fixed shape; a liquid, gas, or plasma. A substance that flows when an external force is applied to it.

**Flow** – the motion of a fluid (liquid, gas, or plasma) when it experiences unbalanced forces.

**Wave** – the propagation of a disturbance from one location to another that carries energy in an organized manner.

**Oscillate** – to move or swing back and forth in a regular speed.

**Wavelength** – the distance between identical points (crest to crest, trough to trough) of two consecutive waves.

**Frequency** – the number of occurrences of a repeating event per unit time.

**Pitch** – a property of sound that is determined by the frequency of the vibration of the sound wave. The highness or lowness of a tone.

**Color** – the spectrum of electromagnetic wavelengths that are visible to the human eye. The visible spectrum is roughly from 400 nm to 700 nm.

**Amplitude** – the maximum displacement by a point on a vibrating body or wave measured from its equilibrium position

**Mechanical Wave** – an oscillation of matter that transfers energy through a medium.

**Transverse Wave** – a wave vibrating perpendicular to the direction it is moving.

**Longitudinal Wave** – a wave vibration parallel to the direction it is moving.

**Pressure Wave** – a wave that carries a change in pressure through a material. The waves have peaks and troughs of high and low pressure.

**Electromagnetic Wave** – waves that are created as a result of vibrations between an electric field and a magnetic field, These include radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays.

**Sound Wave** – a longitudinal pressure wave that travels through a medium. The pressure waves are created by vibrating objects.

**Speed of Light** – the maximum speed at which electromagnetic radiation (which includes visible light) can travel, when it propagates through a vacuum, $c = 3 \times 10^8$ m/s. This number is slower when EM travels through materials.

**Medium** – a material that moves energy from one location to another.

**Vacuum** – a space devoid of matter.

## Science Concepts Overview

A wave is a disturbance that transfers energy from one point to another. An oscillating object causes waves. A wave can travel in two different ways. A transverse wave is a wave where the direction of the disturbance is perpendicular to the direction the wave is traveling. A longitudinal wave is a wave where the direction of the disturbance is parallel to the direction the wave is traveling. Regardless of the type of wave, there are three key measurements to describe a wave: amplitude, wavelength and frequency. Amplitude is the maximum displacement of the oscillation from its equilibrium position. A wavelength measures the distance between identical points on the wave – typically crest to crest or trough to trough. And, the frequency measures the number of oscillations per unit time.

Light is one specific type of wave, an electromagnetic wave. Light is created when vibrating electrons release energy. This vibration creates synchronized electric and magnetic fields. When we say light, we typically refer to the visible light spectrum. However, visible light is just a small fraction of the different types of electromagnetic waves, which also includes radio waves, microwaves, infrared radiation, ultraviolet radiation, x-rays, and gamma rays. All waves in the electromagnetic spectrum are made the same way; the only difference between them is the frequency/wavelength/energy of the waves. Regardless of the type of electromagnetic wave, they all move at the speed of light, $C = 3 \times 10^8$ m/s when traveling through a vacuum.

Sound is a different type of wave, a longitudinal pressure wave. Sound waves need a medium (a solid, liquid, or gas) to travel through. The speed at which sound travels depends on the density of the medium; traveling faster through more dense mediums and slower through less dense mediums. For example, the speed of sound through air at 20° C (68° F) at sea level is 343 m/s (767 mph). We tend to classify sound by its frequency or pitch. A sound with a low frequency is called a low pitch and a sound with a high frequency is called a high pitch.

The speed of sound is an important point of reference for hypersonics. Since there is such a large possible range of speeds that objects travel, it can be hard to compare those speeds. In many cases, we compare the speed of an object to the speed of sound. When we compare the speed of an object to the speed of sound, we do so with a ratio called the Mach number. The Mach number is calculated by dividing the speed of an object by the speed of sound. And the Mach number can be a whole number (Mach 3) or a decimal (Mach 0.6). Additionally, we categorize speeds by the size of their Mach number. Speeds less than Mach 1 are subsonic. Speeds greater than Mach 1 are supersonic. And speeds greater than Mach 5 are hypersonic.

## Materials List

- ☐ Devices with access to the internet (one per student)
- ☐ Sound vs Light handout (one per student)

## Lesson Preparation

Prior to the lesson, the instructor should make copies of the Sound vs Light handout, and ensure that the devices that the students will be using to do the WebQuest are charged and connected to the internet.

If possible, the instructor should provide students with either an electronic copy of the Light vs Sound handout and/or links to the websites through whatever learning platform is used at their school. This will help students more easily and quickly get to the correct resources.

## Safety

There are no additional safety concerns beyond normal classroom procedures for this lesson.

## Procedure

***Engage (5 minutes)***

1. Watch the following video with your students. The video shows an assortment of flyovers at sporting events https://www.youtube.com/watch?v=xgLmMuQ2V4U
2. Pose the following questions to your students:
    - In the videos, do you see the aircraft or hear the aircraft first?
    - Why do you think this happens?
    - What is another example of an object or phenomenon that you see and hear at noticeably different times?

***Explore/Explain/Elaborate/Evaluate (30 minutes)***

3. The Sound vs Light handout will take students through the 5E process. Students will explore different online resources and then explain and elaborate on their understanding of the concepts presented by answering questions. The handout can be collected and used as an assessment.
4. Ideally, students would work individually on this lesson. If there is not a one-to-one student to electronic device ratio, students can work in groups.

## STEM Career Connections

- Aerospace engineering
- Military pilots
- Physicists
- Acoustician
- Optical scientist

## Extensions

As an additional *engage* and *explore*, students could be provided with slinkies and jump ropes to visualize the different types of waves.

Students could further *elaborate* on their understanding of sound waves by reading this article on what would happen if sound waves traveled at the speed of light (https://www.livescience.com/what-if-speed-of-sound-sped-up) and explaining how that would change the answer to the Sound vs Light handout.

To further *explore* light and sound, students can watch the following videos and learn how their bodies receive and interpret data from light (https://www.youtube.com/watch?app=desktop&v=O0PawPSdk28) and sound (https://www.youtube.com/watch?v=LkGOGzpbrCk) waves.

## References & Resources

Animations Xplaned. (2020, December 8). *Visualizing the speed of light and speed of sound* [Video]. YouTube. https://www.youtube.com/watch?v=yGZwLFPLB0o

Dom Productions. (2020, May 31). *Top 10 stadium flyovers, black hawks, F-22, B2 stealth bomber* [Video]. YouTube. https://www.youtube.com/watch?v=xgLmMuQ2V4U

Kurzgesagt – In a Nutshell. (2015, October 15). *What is light?* [Video]. YouTube. https://www.youtube.com/watch?v=IXxZRZxafEQ

MED-EL. (2013, August 16). *Understanding sound waves | MED-EL* [Video]. YouTube. https://www.youtube.com/watch?v=XLfQpv2ZRPU

Rootle. (2017, November 16). *What is a Wave in Science?* [Video]. YouTube. https://www.youtube.com/watch?v=N7MQt703HDw

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Talented Tuber. (2017, April 11). *Difference between subsonic, supersonic and hypersonic speed* [Video]. YouTube. https://www.youtube.com/watch?v=LBJ3tXCjzN0

TED-Ed. (2013, September 19). *Light waves, visible and invisible - Lucianne Walkowicz* [Video]. YouTube. https://www.youtube.com/watch?app=desktop&v=O0PawPSdk28

TED-Ed. (2018, June 19). [Video]. *The science of hearing - Douglas L. Oliver*. YouTube. https://www.youtube.com/watch?v=LkGOGzpbrCk

TED-Ed. (2015, February 10). *The sonic boom problem - Katerina Kaouri* [Video]. YouTube. https://www.youtube.com/watch?v=JO4_VHM69oI

Towell, G. (2019, December 5). *Sound & light (physics): How are they different?*. Sciencing. https://sciencing.com/waves/

Whitcomb, I. (2022, March 29). What if the speed of sound were as fast as the speed of light?. LiveScience. https://www.livescience.com/what-if-speed-of-sound-sped-up

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# Sound vs Light

✈ **Objective:** Upon the completion of this activity, you should be able to explain the similarities and differences between sound waves and light waves. You should be able to explain how the speeds of sound and light compare to the speeds of hypersonic aircrafts.

✈ **Instructions:** Use the links provided below to explore different internet resources on light and sound. Use the information provided in the different resources to answer the questions that follow.

Rootle. (2017, November 16). *What is a Wave in Science?* [Video]. YouTube. https://www.youtube.com/watch?v=N7MQt703HDw

Animations Xplaned. (2020, December 8). *Visualizing the speed of light and speed of sound* [Video]. YouTube. https://www.youtube.com/watch?v=yGZwLFPLB0o

Kurzgesagt – In a Nutshell. (2015, October 15). *What is light?* [Video]. YouTube. https://www.youtube.com/watch?v=IXxZRZxafEQ

MED-EL. (2013, August 16). *Understanding sound waves | MED-EL* [Video]. YouTube. https://www.youtube.com/watch?v=XLfQpv2ZRPU

Sparks, R. (2023, January 30). *Light waves vs. sound waves: How are they different?*. Optics Mag. https://opticsmag.com/light-waves-vs-sound-waves/

Towell, G. (2019, December 5). *Sound & light (physics): How are they different?*. Sciencing. https://sciencing.com/waves/

1. Fill in the table below about characteristics of sound and light waves.

| | **Sound** | **Light** |
|---|---|---|
| Sketch an example of a wave. | | |
| How is it created? | | |
| What type of wave is it? | | |
| Does it require a medium to travel? | | |

| | Sound | Light |
|---|---|---|
| Can it travel in space? | | |
| How/why does the speed vary with different mediums? | | |
| Does it travel faster through solids, liquids, or gasses? | | |
| What is the typical speed in air? | | |
| What sense do we use to observe the wave? | | |
| What do different frequencies represent? | | |

2. How are sound and light waves similar?

3. How are sound and light waves different?

4. When lightning strikes, will you see it or hear it first? Why?

5. How fast are they? Calculate how long it would take for the following to go 100 meters:
    a. A person walking 2 m/s

    b. An airplane flying 268 m/s

    c. A sound wave 343 m/s

    d. A hypersonic (5 times the speed of sound) aircraft 1715 m/s

    e. A light wave $3 \times 10^8$ m/s

6. How do the times to go 100 meters compare for the items above?

7. Hypersonic aircrafts fly faster than sound, but slower than light. How do you think that effects their flight?

8. How do you think that effects how we observe their flight?

9. How would the light and sound waves generated from a hypersonic flight change if the aircraft was in space?