Hypersonics STEM Curriculum

A Super Sonic WebQuest

Grade	Time	Subject Area	Key Concepts
6-8	90 min	Physical Science	Speed/velocity Waves Kinetic Energy

Lesson Overview

In this lesson, students will do a WebQuest to learn the difference between subsonic, supersonic, and hypersonic speeds as well as how supersonic speeds can create sonic booms. Each of the four sections of the WebQuest provide a combination of videos and websites for students to use as resources to answer the questions.

NGSS Standards

MS-PS3-1 Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.

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

MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Learning Objectives

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

- Explain the difference between subsonic, supersonic, and hypersonic.
- Explain what causes a sonic boom.
- Use the law of conservation of energy to explain how a whip can move at supersonic speeds.
- Explain how the creation of a sonic boom effects our abilities to travel at hypersonic speeds.

Essential/Overarching Question

How do you create a sonic boom?

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).

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

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

Shock Wave – an area of an abrupt change in pressure from a wave front caused by an explosion or an object moving faster than the speed of sound.

Sonic Boom – a loud sound associated with when a shock wave, created by an object traveling faster than the speed of sound, passes over an acoustic sensor (like our ears).

Doppler Effect – a change in frequency of waves (sound or light) due to the source and/or observer moving relative to one another. The frequency of the wave increases as the source and observer move towards one another and decreases as they move away.

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.

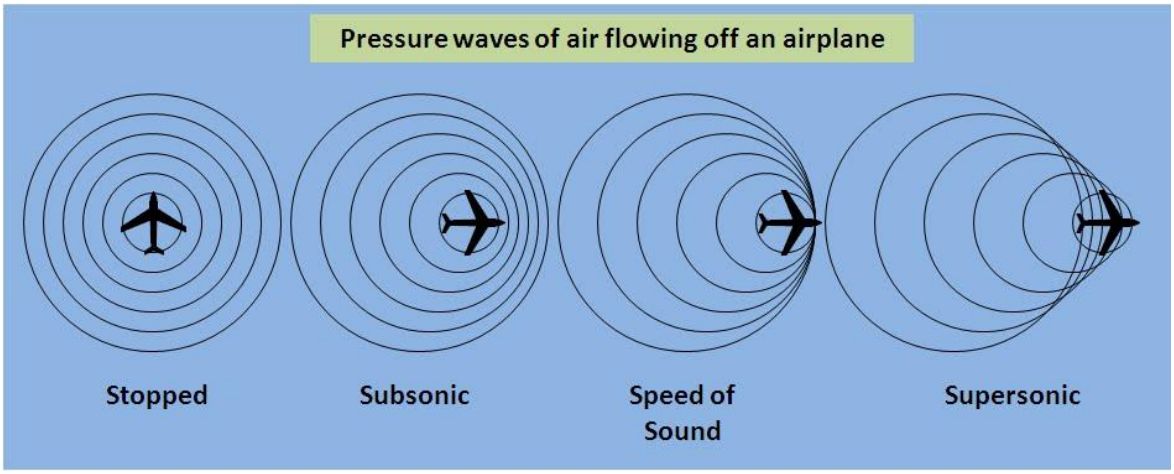
Science Concepts Overview

When an object makes a sound, it releases sound (pressure) waves at a steady frequency that move away from the object in a spherical pattern as shown in the stopped picture below.

When that object begins to move, it continues to make the make sound waves at that same frequency. Because the object is moving as it is making sound waves, the sound wave fronts are closer to one another in the front of the object and further apart behind the object as shown in the subsonic picture below. As the object speeds up, the bunching in the front and the spreading in the back increases.

When the object reaches the speed of sound, the object is now moving as fast as it is releasing sound waves. This creates a buildup of sounds waves in the front of the object as shown in the speed of sound picture below.

As the object moves faster than the speed of sound, the object is moving faster than it is creating sound waves, which results in a cone of pressure waves as shown in the supersonic picture below. As the object passes an observer, there is an abrupt increase (at the front of the object) and then decrease (at the end of the object) of pressure due to the buildup of pressure in the cone, which causes a sonic boom.



https://www.physicscentral.com/buzz/blog/index.cfm?postid=103798762154496933

Materials List

- ☐ A towel (may work better if the towel is damp)
- ☐ Devices with access to the internet (one per student)
- ☐ A Super Sonic WebQuest handout (one per student)

Lesson Preparation

Prior to the lesson, the instructor should find a towel, make copies of the A Super Sonic WebQuest 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 A Super Sonic WebQuest 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. Start the lesson by collecting student's prior knowledge and experiences with sonic booms asking students:
    - Have you ever created a snapping or cracking noise with a towel?
    - What do you do to get the towel to make the cracking noise?
    - What do you think causes the towel to make the noise?
2. Do a towel snapping demonstration for the students. You should attempt to make a snapping noise with the towel multiple times with some attempts causing a snap while others do not. This sometimes works better with a damp towel. Ask students:
    - What do you notice about the towel as it is snapped?
    - What do you think causes the towel to make the noise?
3. Remind students that it is not appropriate to snap towels at one another and that the act of snapping someone with a towel can cause serious injury.

Explore/Explain/Elaborate/Evaluate (85 minutes)

4. The A Super Sonic WebQuest handout will take students through the 5E process. In each of the four sections, students will explore different online resources and then explain and elaborate on their understanding of the concepts presented by the resources by answering questions. The handout can be collected and used as an assessment.
5. 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
- Aircraft design
- Marine biologists

Extensions

As an extended *elaboration*, students could further research and create a presentation for the class on one of the other science concepts mentioned in the different resources such as: doppler effect, conservation of energy, shock wave, pressure wave, etc.

References & Resources

Air Force. (n.d.). *Sonic Boom*. https://www.af.mil/About-Us/Fact-Sheets/Display/Article/104540/sonic-boom/

American Physical Society. (2011, January 21). Flight of the Concorde. *Physics Central*. https://www.physicscentral.com/buzz/blog/index.cfm?postid=103798762154496933

Banke, J. (2018, April 3). *Sonic Boom Heads for a Thump*. NASA. https://www.nasa.gov/topics/aeronautics/features/sonic_boom_thump.html

BBC Studios. (2009, January 16). *Pistol shrimp sonic weapon - Weird nature - BBC wildlife* [Video]. YouTube. https://www.youtube.com/watch?v=XC6I8iPiHT8

Discovery. (2015, January 16). *Science behind wet towel snaps | MythBusters* [Video]. YouTube. https://www.youtube.com/watch?v=SGGi7AqEvrY

Gibbs, Y. (2017, August 15). *NASA Armstrong Fact Sheet: Sonic Booms*. NASA. https://www.nasa.gov/centers/armstrong/news/FactSheets/FS-016-DFRC.html

NASA. (n.d.). *Mach Number*. NASA. https://www.grc.nasa.gov/WWW/k-12/airplane/mach.html

NASA Video. (2021, August 20). *X-59: Sonic booms explained* [Video]. YouTube. https://www.youtube.com/watch?v=laM0Nv8nkw4

Nat Geo WILD. (2019, May 29). *Mantis shrimp packs a punch | Predator in paradise* [Video]. YouTube. https://www.youtube.com/watch?v=E0Li1k5hGBE

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

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

The Royal Institute. (2018). *Why is cracking a whip so loud?* [Video]. YouTube. https://www.youtube.com/watch?v=DGH3GMiHNls

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Dr. Lori M. Stiglitz
JHTO Workforce Development Lead

Dr. Stephanie Stehle
JHTO Curriculum Specialist

Name: _____ Date: _____

A Super Sonic WebQuest

Objective: Upon the completion of this activity, you should be able to explain the difference between subsonic, supersonic, and hypersonic. You should be able to explain what causes a sonic boom and how this phenomenon effects our ability to travel at hypersonic speeds.

Instructions: For each section, use the links to explore different internet resources. Use the information provided in the different resources to answer the questions that follow. You are welcome to reuse resources for other sections and search out other resources as needed.

Section 1: What does supersonic and hypersonic mean?

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

NASA. (n.d.). *Mach Number*. NASA. https://www.grc.nasa.gov/WWW/k-12/airplane/mach.html

1. What is the difference between subsonic, supersonic, and hypersonic? How can you use Mach numbers to explain this difference?

2. Different resources use different units when expressing the speed of sound. Look up the speed of sound in: mph (miles per hour), km/h (kilometers per hour), and m/s (meters per second).

3. Calculate the Mach number for the following objects and categorize them as subsonic, supersonic, or hypersonic. (Assume the speed of sound is 343 m/s.)
    a. galloping horse (12 m/s)
    b. a bullet train (90 m/s)
    c. Bell X-1 aircraft (364 m/s)
    d. spacecraft launching (7823 m/s)

4. What is the fastest vehicle you have traveled in? Look up an estimate of that vehicle's speed (in m/s), calculate the Mach number, and categorize the speed as you did above.

✈ Section 2: What is a sonic boom?

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

Air Force. (n.d.). *Sonic Boom*. https://www.af.mil/About-Us/Fact-Sheets/Display/Article/104540/sonic-boom/

American Physical Society. (2011, January 21). Flight of the Concorde. *Physics Central*. https://www.physicscentral.com/buzz/blog/index.cfm?postid=103798762154496933

1. What causes a sonic boom?

2. Draw a picture that shows the difference between the sound waves created by an aircraft stopped, flying at subsonic speeds, and flying at supersonic speeds.

3. There are many factors that play into whether someone will hear a sonic boom or not. Name at least two factors and how they affect the range of who will hear a sonic boom.

✈ Section 3: Where else do supersonic speeds and shock waves occur?

BBC Studios. (2009, January 16). *Pistol shrimp sonic weapon - Weird nature - BBC wildlife* [Video]. YouTube. https://www.youtube.com/watch?v=XC6I8iPiHT8

Nat Geo WILD. (2019, May 29). *Mantis shrimp packs a punch | Predator in paradise* [Video]. YouTube. https://www.youtube.com/watch?v=E0Li1k5hGBE

The Royal Institute. (2018). *Why is cracking a whip so loud?* [Video]. YouTube. https://www.youtube.com/watch?v=DGH3GMiHNls

Discovery. (2015, January 16). *Science behind wet towel snaps | MythBusters* [Video]. YouTube. https://www.youtube.com/watch?v=SGGi7AqEvrY

1. How do animals use shockwaves and speed to their advantage?

2. In your own words, explain the science behind how and why a whip cracks.

3. At the beginning of class, a towel was "snapped." Why did the towel make that noise?

4. The video from section 2 explained that scientists believe a dinosaur, the diplodocus, may have been able to crack its tail faster than the speed of sound. Based on what you learned in this section, how do you think that was possible?

✈ Section 4: Can we safely travel at hypersonic speeds?

NASA Video. (2021, August 20). *X-59: Sonic booms explained* [Video]. YouTube. https://www.youtube.com/watch?v=laM0Nv8nkw4

Banke, J. (2018, April 3). *Sonic Boom Heads for a Thump*. NASA. https://www.nasa.gov/topics/aeronautics/features/sonic_boom_thump.html

Gibbs, Y. (2017, August 15). *NASA Armstrong Fact Sheet: Sonic Booms*. NASA. https://www.nasa.gov/centers/armstrong/news/FactSheets/FS-016-DFRC.html

1. Do you think that we can we safely travel at supersonic and hypersonic speeds? Why or why not?

2. What would be the benefits of being able to travel at supersonic speeds?

3. There are many factors that affect the intensity of a sonic boom. If you were designing an aircraft to travel at supersonic speeds, what would be three factors that you would focus on to decrease the sonic boom intensity?