Hypersonics STEM Curriculum

Can it Go Hypersonic?

Grade	Time	Subject Area	Key Concepts
5	50 min	Physical Science	Forces

Lesson Overview

In this lesson, students will watch videos of an assortment of "everyday objects" that are placed inside a Mach 6 wind tunnel. Students will make observations of the motion of the objects and draw conclusions of how the forces on the objects as well as the shape of the object effect their motion.

NGSS Standards

5-PS2-1 Support an argument that the gravitational force exerted by Earth on objects is directed down.

Learning Objectives

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

- Make observations of everyday objects in a Mach 6 wind tunnel.
- Explain the meaning of hypersonic.
- Explain what a shock wave is.
- Explain how different forces effect an object while in a wind tunnel.
- Evaluate everyday objects on their ability to fly at hypersonic speeds.

Essential/Overarching Question

Can everyday objects move at hypersonic speeds?

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.

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).

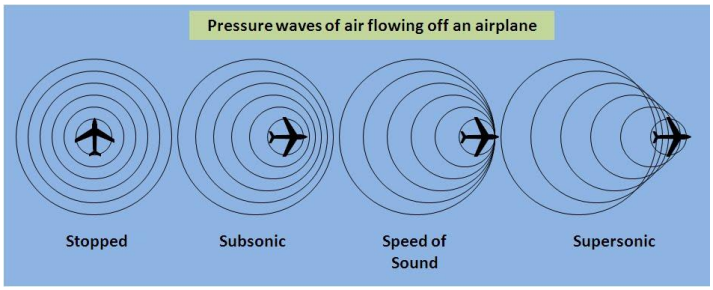
Science Concepts Overview

When an object moves, at any speed, it moves through a fluid. A fluid can be any liquid or gas. In most cases, the object is moving through the air. As the object moves through the fluid, the fluid moves around the object. (This is also the case when the object is stationary, and the fluid is moving.) The motion of the fluid is called the flow. As speeds increase, the flow becomes more of a factor in the movement of the object. For example, we typically do not notice the air moving around us as we walk, but we do when we are riding a bicycle or a skateboard. As objects move into supersonic (faster than the speed of sound) and hypersonic speeds (faster than five times the speed of sound), understanding the flow becomes more important and largely factors into the design of the objects.

Wind tunnel testing is used to investigate how objects interact with flow. It can be used to simulate objects moving through a fluid, such as an aircraft moving though air, or a fluid moving around an object, such as wind moving around a building. Wind tunnel testing can be done on a smaller scale model, as we are doing, or with full size objects if the wind tunnel is large enough.

In addition to flow, pressure waves become an issue when objects move faster than the speed of sound. When an object is at rest, 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

- ☐ Devices with access to the internet (one per student)
- ☐ Can it Go Hypersonic? handout (one per student)

Lesson Preparation

Prior to the lesson, the instructor should make copies of the Can it Go Hypersonic? handout and ensure that the devices that the students will be using to do the activity are charged and connected to the internet.

If possible, the instructor should provide students with either an electronic copy of the Can it Go Hypersonic? 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 (10 minutes)

1. Start the lesson by collecting students' prior knowledge on hypersonics by asking the following questions:
    - What does it mean for an object to be going at hypersonic speeds?
    - What objects typically move at hypersonic speeds?
    - What would happen if everyday objects were to move at hypersonic speeds?
2. Individually, or as a group, have students read the introduction and exploration sections of the Can it Go Hypersonic? handout.
3. Students should label the diagram with arrows showing the direction of the force caused by the wind and the gravitational force on the object in the wind tunnel.

Explore (20 minutes)

4. Ideally, students should work individually on this lesson. If there is not a one-to-one student to electronic device ratio, students can work in groups.
5. Students will watch a series of videos from the Everyday Objects at Not-So-Everyday Speeds (EONSES) YouTube series. They will need to watch EONSES Part 1, EONSES Part 2, and then pick four other videos of their choice. Each video shows a different "everyday object" inside of a wind tunnel at Mach 6. https://www.youtube.com/@hypersoniceverydayobjects/featured
6. For each video, students will need to fill in the data table with a description of the object in the wind tunnel, a sketch of the object, and observations of how the object interacts with the flow in the wind tunnel.

Explain (10 minutes)

7. Students will share their understanding of the science concepts by answering analysis questions 1-6 on the Can it Go Hypersonic? handout:
    - Different videos used different ways to explain how fast hypersonic is. Which explanation was your favorite? How did it explain hypersonic?
    - The objects were flying at Mach 6. What does Mach 6 mean?
    - What is a shock wave? Where do shock waves form?
    - How does the gravitational force effect the motion of the objects in the wind tunnel?
    - How does the force of the wind effect the motion of the objects in the wind tunnel?
    - Which force do you think had a greater effect on the motion of the objects? What data supports your claim?

Elaborate (5 minutes)

8. Students will evaluate the different objects on how they performed in the wind tunnel by answering analysis questions 7-9 on the Can it Go Hypersonic? handout:
    - Which of the objects that you observed performed the best at hypersonic speeds? What data supports your claim?

- What are the characteristics of the objects that performed well at hypersonic speeds? What data supports your claim?
- What are the characteristics of the objects that performed poorly at hypersonic speeds? What data supports your claim?

Evaluate (5 minutes)

9. Students will be asked to share what they learned in the lesson in analysis question 10 on the Can it Go Hypersonic? handout:
    - What is one thing that you learned in this lesson that you are excited to share with others?
10. Have students share out their "thing they learned" with the class.

STEM Career Connections

- Aerospace engineering
- Military pilots
- Aircraft design
- Wind tunnel technicians

Extensions

As a further *elaborate*, students could write an email to Everyday Objects at Not-So-Everyday Speeds (EONSES) (hypersoniceverydayobjects@gmail.com) proposing a new object to test in their wind tunnel. Students should use data from their observations as evidence to support their suggestion of why their object should be used in the next experiment. This could be done individually, as a group, or as a class.

References & Resources

Education.com. (n.d.) *Science project: Wind tunnel* experiment. https://www.education.com/science-fair/article/physics_experiments-wind-tunnel/

Everyday Objects at Not-So-Everyday Speeds (n.d.). *Home* [YouTube channel]. YouTube. https://www.youtube.com/@hypersoniceverydayobjects/featured

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SciShow. (2019, July 8). *A surprisingly simple secret to supersonic flight* [Video]. YouTube. https://www.youtube.com/watch?v=kGefMLHJBKA

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Can it Go Hypersonic?

✈ Introduction

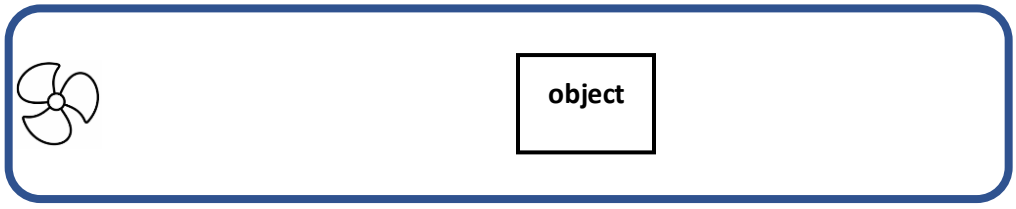
Objects travel at a variety of speeds and often, those speeds are compared to the speed of sound as a reference. The ***speed of sound***, or the speed that a sound travels from its source to its observer, can vary, but is typically 343 m/s at room temperature. ***Subsonic*** refers to objects traveling slower than the speed of sound. ***Transonic*** refers to objects traveling just below and just above the speed of sound. ***Supersonic*** refers to speeds greater than the speed of sound. And ***hypersonic*** refers to objects traveling at more than five times the speed of sound. Hypersonics is currently a key area of research.

An important tool to explore how objects are effected by supersonic and hypersonic speeds is a ***wind tunnel***. A wind tunnel is a large tube that provides moving air. The movement of air is called the ***flow***. Objects can be placed inside the wind tunnel to test how objects interact with the flow. This can simulate objects moving through air (for example, testing how steadily an airplane will fly at high speeds). Or this can simulate air moving around an object (for example, testing how a building will hold up to hurricane level winds).

Not all objects are designed to move at hypersonic speeds. While space shuttles and sounding rockets are designed to be able to travel at hypersonic speeds, cars and trains are not. You are going to watch a series of videos that explores how everyday objects would behave at hypersonic speeds.

✈ Exploration

You are going to watch a series of videos showing everyday objects in a hypersonic wind tunnel. The diagram below shows a wind tunnel with an object in it. The ***flow*** (motion of a fluid) moves from left to right.



- In the diagram above, draw and label an arrow that shows the direction of the force of the wind on the object.

- In the diagram above, draw and label an arrow that shows the direction of the gravitational force on the object.

Everyday Objects at Not-So-Everyday Speeds (n.d.). *Home* [YouTube channel]. YouTube. https://www.youtube.com/@hypersoniceverydayobjects/featured

- Watch EONSES Part 1, EONSES Part 2, and four other videos of your choice.
- For each video, describe the object in the wind tunnel, make a sketch of the object, and make observations of how the object interacts with the flow in the wind tunnel.

Object Description	**Object Sketch**	**Observations**
Diamondback Terrapin		
Rubber ducky		

✈ Analysis

1. Different videos used different ways to explain how fast hypersonic is. Which explanation was your favorite? How did it explain hypersonic?

2. The objects were flying at Mach 6. What does Mach 6 mean?

3. What is a shock wave? Where do shock waves form?

4. How does the gravitational force effect the motion of the objects in the wind tunnel?

5. How does the force of the wind effect the motion of the objects in the wind tunnel?

6. Which force do you think had a greater effect on the motion of the objects? What data supports your claim?

7. Which of the objects that you observed performed the best at hypersonic speeds? What data supports your claim?

8. What are the characteristics of the objects that performed well at hypersonic speeds? What data supports your claim?

9. What are the characteristics of the objects that performed poorly at hypersonic speeds? What data supports your claim?

10. What is one thing that you learned in this lesson that you are excited to share with others? What data supports your claim?