Hypersonics STEM Curriculum

Wind Tunnel Energy

Grade	Time	Subject Area	Key Concepts
4	70-90 min	Physical Science Engineering Design	Energy

Lesson Overview

In this lesson, students use a wind tunnel to observe the transfer of energy from electrical to kinetic and from object to object. Students will test how varying the amount of energy (speed of fan) changes the energy transfer and motion of the five different objects.

Prior to the lesson, students should have learned about the different types of energies (kinetic, potential, electrical, sonic, light, thermal, and chemical). Throughout the lesson, there are questions for students to answer that are intended to bring out their prior conceptions of and experiences with energy. These questions are useful in that they help instructors gauge their instruction to better address any misaligned conceptions students may have.

This lesson follows a 5E lesson format. The different E's can be done together or as separate lessons. Depending on the set up of the class and available materials, each group could build their own wind tunnel (directions are included in the Wind Tunnel Testing handout) or a set of wind tunnels could be set up as stations around the classroom for groups to use as they are ready to test their objects. It may take longer to do the lesson if groups are sharing wind tunnels.

NGSS & CCSS Standards

4-PS3-1 Use evidence to construct an explanation relating the speed of an object to the energy of that object.

4-PS3-2 Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

4-PS3-3 Ask questions and predict outcomes about the changes in energy that occur when objects collide.

Learning Objectives

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

- Explain how energy is transferred in a wind tunnel.
- Predict how a variety of objects will be affected by different levels of energy provided by flow.
- Observe how energy is transferred from air to an object through a collision.

- Give evidence of how the motion and speed of an object change with the energy transfer.

Essential/Overarching Question

How is energy conserved and transferred in a wind tunnel?

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.

Energy – the ability to do work. The ability to apply a force and causing an object to move.

Kinetic Energy – energy of motion.

Potential Energy – stored energy. Energy held by an object due to a change in position, shape, or electrical configuration.

Chemical Energy – stored energy in chemical bonds such as atoms and molecules. The energy is released during a chemical reaction.

Electrical Energy – form of energy resulting from the movement of electric charge.

Light Energy – electromagnetic radiation visible to the eye. A form of kinetic energy caused by photons moving with wavelike properties.

Sonic Energy – sound energy. Energy related to the vibrations of materials. Sound energy is transferred by pressure waves moving through a medium (material).

Thermal Energy – heat energy. Energy possessed by an object due to the movement of the particles within the object. As temperatures rise, particles move more, increasing thermal energy.

Law of Conservation of Energy – energy is neither created or destroyed, it is simply transferred from one object or type of energy to another.

Wind Tunnel – a large tube with air moving inside. Wind tunnels are used to investigate air flow around an object placed in the passage.

Science Concepts Overview

The law of conservation of energy states that energy cannot be created or destroyed, it can be transferred from one form of energy to another. The total energy of a system is constant. When energy is "lost", it is transferred out of the system as heat energy.

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.

Flow can transfer energy to other objects. For example, wind (flow) transfers its energy (kinetic) to the blade of a wind turbine when they collide, causing the blade to move (kinetic energy). And that kinetic energy is then transferred to electric energy.

Materials List

- ☐ Cardboard (enough to make one wind tunnel per group)
- ☐ Clear plastic (overheads, sheet protectors, acrylic sheet, etc. – one per wind tunnel)
- ☐ Small fan with different speed settings (one per wind tunnel)
- ☐ Scissors

- ☐ Box Cutter (for teacher use)
- ☐ Tape (duct tape is best)
- ☐ Goggles or other eye protection (one per student)
- ☐ An assortment of small, light objects to place in the wind tunnel – different shapes, weights, some aerodynamic, some boxy, etc.
- ☐ Rulers (one per group)
- ☐ Energy Type Scavenger Hunt handout (one per student – there are two handouts per page)
- ☐ Wind Tunnel Energy handout (one per student)

Lesson Preparation

Prior to the lesson, the instructor should gather materials for the wind tunnel build, find objects for testing in the wind tunnels, as well as make copies of the Energy Type Scavenger Hunt and Wind Tunnel Energy handouts.

As different fans will provide different amounts of flow, it is suggested that the instructor tests the objects with the fans ahead of time to make sure the fans are strong enough to create a flow that has a noticeable interaction with the objects.

If the instructor does not plan to have each group of students make their own wind tunnel, they should have the wind tunnel stations built and set up ahead of time.

Safety

Due to the nature of this lesson, it is recommended that the class take the following safety precautions:

- Participants should wear eye protection.
- Participants should be reminded to not place objects, including fingers, in the fans.
- Wind tunnels should be placed so the fans blow away from other groups in case of flying objects.
- Participants should be reminded to be mindful of where they walk in the classroom, so they do not walk in the path of a wind tunnel in case of flying objects.
- Instructors should cut the observation window for students.

Procedure

Engage (10 minutes)

1. To start the lesson, review with students the different types of energy.
2. Students will go on an energy type scavenger hunt to find examples of different types of energy. As students find an example, they should record it in their Energy Type Scavenger Hunt handout. This activity can be done inside or outside. Be sure to define the scavenger hunt boundaries for the students.
3. As a class, review the different examples of energy that the students found.

Explore (10 minutes)

4. As class or as individuals, read the first ✈ paragraph on the Wind Tunnel Energy handout.
5. Have students label the picture of the wind tunnel with as many types of energy as they see as a think pair share. Give students a couple minutes to think and record their ideas.
6. Have students pair up and compare how they labeled the wind tunnel energy types.
7. Have groups share out with the class. As the class shares out, document their ideas on a board.
8. Have students individually answer the following question on the Wind Tunnel Energy handout:
    - You labeled multiple types of energy in the picture. Where does the energy come from?
9. Have students share their ideas of where the energy comes from. Allow students to share their prior conceptions of conservation of energy before moving forward in the lesson.

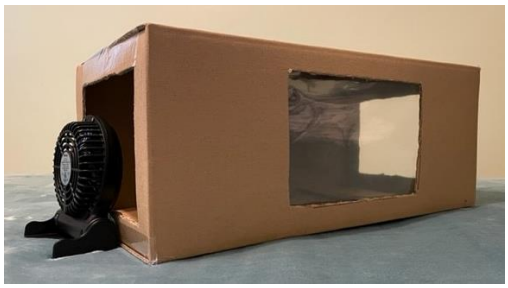
Explain (10 minutes)

10. As a class or as individuals, read the second ✈ paragraph on the Wind Tunnel Energy handout.
11. Loop back to the prior question and ask students how that paragraph changes their prior response.
12. Ask students to now answer the following prompt:
    - In the space below, describe how energy is transferred from one type to another throughout the wind tunnel. You can use sentences or draw a diagram.
13. Have students work in a group to compare their answers. Ask students to report out to the class what each of their models have in common.
14. Work as a class to build a class model of how energy is transferred in a wind tunnel. If needed, remind students that when the wind collides with an object, energy is transferred just like when two solid objects collide.

Elaborate (30 minutes)

15. As a class or as individuals, read the third ✈ paragraph on the Wind Tunnel Energy handout.
16. Students should answer the question at the end of the paragraph:
    - How does the flow affect you in those examples?
17. For the wind tunnel experiment, groups of 2-4 are ideal.
18. Either students can build their own wind tunnels, or the instructor can have premade wind tunnels set up around the classroom. If students are building their own wind tunnel, instructions are provided in the Wind Tunnel Energy handout:
    - Gather your materials: cardboard box, clear plastic, tape, fan.

- Take a medium sized cardboard box and open/cut the box so that it is open at opposite ends. You may want to make sure any flaps are taped down.
- On one side of the box, draw an observation window. The window should be slightly smaller than the clear plastic you will use as your window.
- Ask an adult to cut out the window for you.



- Tape the clear plastic on the inside of your box. Trim the clear plastic if it is too large to fit in your box. Make sure all sides of the plastic are completely taped down.
- Place the fan at one open end of the wind tunnel so that it is blowing in the box. Make sure to set up your wind tunnel so that it blows away from other groups.

19. After building the wind tunnel, students should record their initial ideas of energy transfer by the flow by answering the following question on the Wind Tunnel Energy handout:
    - The fan in the wind tunnel has three different speeds. What do you think happens to the total amount of energy and the energy transfer as you turn the speed up on the fan? What makes you say that?
20. Students should start their data collection by gathering their 5 objects and testing each object in the wind tunnel:
    - Record your prediction of how the object will be affected by the flow.
    - Place the object in the wind tunnel.
    - Turn the fan on the low speed and record your observations.
    - Turn the fan up to the medium speed and record your observations.
    - Turn the fan up to the high speed and record your observations.
21. Following the data collection, students should complete the data analysis questions:
    - Where did the objects get the energy to move?
    - How did the energy transfer change as the fan speed got bigger?
    - Which object had the biggest change in motion due to the flow?
    - What other objects would be interesting to test in your wind tunnel?

Evaluate (10-30 minutes)

22. Ask students to work with their group to report their findings. This could be done in a variety of ways: verbal debrief, presentation slide, memo, email, etc. Give students the following prompt:
    - As scientists, it is important to share, compare, and review our results with other scientists. You are to work with your group to create a (insert reporting style) that highlights your key takeaways and big ideas from your data

collection. This should be a clear, concise (insert reporting style), so it should be no longer than (insert size limit).

STEM Career Connections

- Aerospace engineering
- Military aircraft design
- Car racing industry
- Architect

Extensions

As a further *explain* or *elaboration*, students could be asked to pick another situation where energy is transferred/conserved and explain the process that their situation goes through.

Students could complete an *evaluation* where they are asked to explain how wind turbines use conservation of energy differently than wind tunnels (opposite order).

References & Resources

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Energy Type Scavenger Hunt

Search the area for an example of each of the different types of energy. Record your energy sources in the table below.

Light	Sonic (Sound)	Thermal (Heat)	Kinetic (Motion)
Potential (Stored)	**Chemical**	**Electrical**	**Other**

Name: _____ Date: _____

Energy Type Scavenger Hunt

Search the area for an example of each of the different types of energy. Record your energy sources in the table below.

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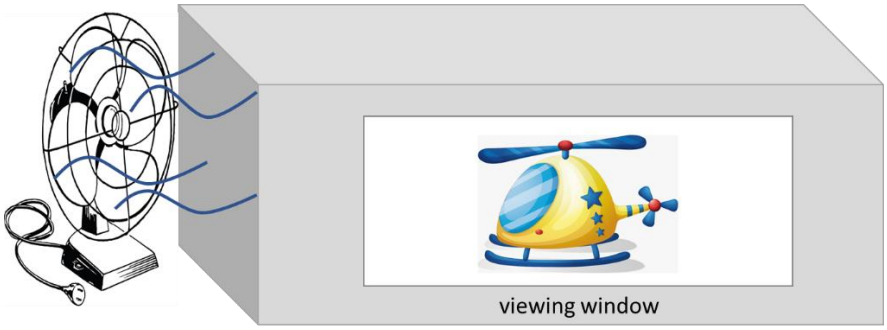
Name: _____ Date: _____

Wind Tunnel Energy

✈ Below is a diagram of a homemade **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).



Use the list below to label the different types of energy that you observe in the picture of the toy helicopter inside of the wind tunnel. You can use the same energy type multiple times. You do not have to use all of the energy types.

Light	Sonic	Thermal	Kinetic	Potential	Chemical	Electrical

You labeled multiple types of energy in the picture. Where does the energy come from?

✈The wind tunnel is a great example of energy being transferred from one type of energy to another or from one object to another. The **law of conservation of energy** states that energy cannot be created or destroyed. Energy can be transferred from one object to another. Or energy can be transferred from one energy type to another. For example, when a ball rolls down the hill, the ball converts potential energy to kinetic energy. When a plant undergoes photosynthesis, it converts light energy into chemical energy. And when one ball collides with another ball, some of the kinetic energy from the first ball is transferred to the second ball.

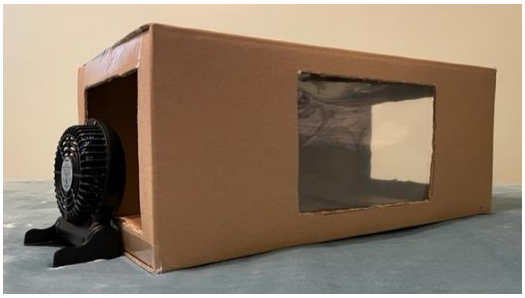
In the space below, describe how energy is transferred from one type to another throughout the wind tunnel. You can use sentences or draw a diagram.

✈ Scientists study how energy is transferred from air flow. Understanding how flow effects objects is important. This is especially important when objects speed up to approach the **speed of sound** and then move at **supersonic** (faster than the speed of sound) and **hypersonic** (five times the speed of sound) speeds. For example, think about how a large wind gust affects you differently than a small breeze. Or, how the flow feels when you are riding a bicycle or skateboard at a slow versus a fast speed. *How does the flow affect you in those examples?*

We are going to work as scientists studying how energy transferred from air flow effects different objects.

To build your wind tunnel:

- ☐ Gather your materials: cardboard box, clear plastic, tape, fan.
- ☐ Take a medium sized cardboard box and open/cut the box so that it is open at opposite ends. You may want to make sure any flaps are taped down.
- ☐ On one side of the box, draw an observation window. The window should be slightly smaller than the clear plastic you will use as your window.
- ☐ Ask an adult to cut out the window for you.
- ☐ Tape the clear plastic on the inside of your box. Trim the clear plastic if it is too large to fit in your box. Make sure all sides of the plastic are completely taped down.
- ☐ Place the fan at one open end of the wind tunnel so that it is blowing in the box. Make sure to set up your wind tunnel so that it blows away from other groups.



The fan in the wind tunnel has three different speeds*. What do you think happens to the total amount of energy and the energy transfer as you turn the speed up on the fan? What makes you say that?*

Pick five different objects to study. Make sure to pick objects that have different sizes and shapes. For each object:

- ☐ Record your prediction of how the object will be affected by the flow.
- ☐ Place the object in the wind tunnel. If your object is small, you may want to put it on a platform to make sure it is in the flow.
- ☐ Place a ruler beside your object and tape it down so you can measure how far it moves.
- ☐ Turn the fan on the low speed and record your observations and measurements.
- ☐ Turn the fan up to the medium speed and record your observations and measurements.
- ☐ Turn the fan up to the high speed and record your observations and measurements.

Data Collection

Object	Prediction	Observations		
		Low Speed	Medium Speed	High Speed

Data Analysis

Where did the objects get the energy to move?

How did the energy transfer change as the fan speed got bigger? What data supports your claim?

Which object had the biggest change in motion due to the flow? What data supports your claim?

What other objects would be interesting to test in your wind tunnel? What makes you say that?