

# Energy

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# Energy

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## Give it a Ride!

**Passport Question:** \_\_\_\_\_ energy is stored energy. \_\_\_\_\_ energy is energy in motion.

**Passport Answer:** **Potential** energy is stored energy. **Kinetic** energy is energy in motion.

**Learning Target:** Students learn that kinetic energy is the energy of motion and potential energy is stored energy. The energy of an object can change to and from kinetic and potential.

### **Materials:**

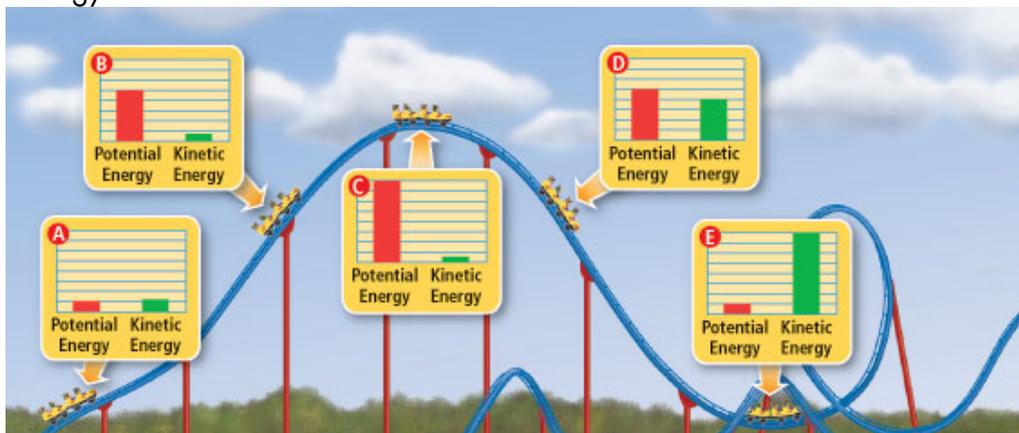
- Roller coaster tracks
- Medium sized marbles,
- Target boxes
- iPad with energy diagram

### **Background:**

Energy. What are we talking about? We can't really see energy, touch it, or smell it, but we see evidence of energy every day. In physics, **energy** is the capacity to do work and **work** is done whenever an object is moved. Energy can be described as "whenever something happens, there is a property of the system that does not change in amount and we call that property energy." Don't get hung up on the energy definition. The key points are this:

- Energy always remains constant in amount
- Energy cannot be created nor destroyed
- Energy is a property of objects and not an object itself

Energy also comes in many forms. One form of energy is motion, called **kinetic energy**. Another form is stored energy, or **potential energy**. Potential energy is the energy that a body has because of its position, composition, or state. For example, potential energy is contained by a raised ball (by virtue of its position), a stick of dynamite (by virtue of its composition), and a compressed spring (by virtue of its state). Kinetic energy is the energy a body has because of its motion or activity. When a raised ball is dropped, its potential energy changes into kinetic energy as it falls; as it bounces up from the ground, some of its kinetic energy changes back into potential energy.



## Energy

### **Procedure:**

- Ask the students what they know about kinetic and potential energy and introduce the terms of potential and kinetic.
- Have students place images in either the "Examples of Kinetic Energy" or "Examples of Potential Energy" piles.
- Have students compete in a roller coaster challenge with the challenge of trying to get the marble in all three boxes.
- Tell students that by adjusting the height of the track, the marble will have a different amount of potential energy.
- Ask students what happens to the potential energy as the marble starts moving. Where is the most kinetic energy? The most potential energy.
- After the roller coaster demonstration, show students the iPad demo that shows a real-time conversion of potential and kinetic energy on a roller coaster to see if they were right.

### **Discussion**

#### How did you change the potential energy of the marble?

Students elevate the track depending on which target they are trying to aim for. When the marble is just about to be released, it is at its maximum potential energy. Too high of a track, the marble will eventually convert this large amount of potential energy to kinetic energy. By lowering the track, the student reduces the amount of potential energy and will cause the marble's speed to decrease.

#### What do kinetic and potential energy have to do with a roller coaster?

When the train or marble is at the top of the hill it has potential energy. When it goes down the hill the potential energy becomes kinetic energy and the train or marble picks up speed.

## **Keep Your Eye on the Ball!**

**Passport Question:** True or False: Energy cannot be created nor destroyed, only converted into different forms

**Passport Answer:** True

### **Materials:**

- Soda can pendulum
- Tennis ball with a string

**Learning Target:** Students will understand that energy is conserved in a system and can only be converted into different forms

### **Background:**

The law of conservation of energy states that energy cannot be created or destroyed. It can change to different forms but it is always the same amount of energy in a system. Energy transformations occur in a system when energy changes into different forms. Energy transformations can occur within an object, or between objects. Think about the engine in a car. The chemical energy of the fuel is transformed into the thermal and mechanical energy of the motor and tires.

Tsunamis represent another type of energy transfer. Waves you see at the beach are usually created when wind transfers energy to the ocean's surface. However, with tsunamis, the potential energy in tectonic plates or an underwater landslide can be transformed into the kinetic energy of moving tsunami waves. In this activity, we'll explore transfer of potential and kinetic energy in a pendulum.

### **Procedure & Discussion:**

#### Station 1: Soda Can Pendulum

- Have a student put the Soda-Can pendulum in motion by pulling back one of the cans and releasing it.
- Ask students is the total energy of the system (the two cans) increasing? What about the potential (stored) and kinetic (movement) energy of each can? As one can slows down, the other can speeds up. The total energy in the system remains the same

#### What's happening in the Soda Can pendulum? Is the total energy of the two cans the same?

The total energy of both cans stay the same. The energies of each can changes forms from potential to kinetic and vice versa. As the energy of one can changes from kinetic to potential (i.e. the can slows down), the energy of the other can changes from potential to kinetic (i.e. the can speeds up).

#### Station 2: Tennis Ball Pendulum

- Place volunteer/student against a wall, tell them not to move and to keep their head back on the wall
- Hold the tennis ball an inch or so away from their nose

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- Ask students if they think the ball is going to hit them? Why or why not? (It won't, as long as you don't move your head).
- Let go of the ball, DO NOT THROW/PUSH; just simply let it leave your hand

### Why doesn't the ball hit you?

As long as you do not move your head, the ball will not hit you, even if we used something really heavy like a bowling ball! Why not? As the ball moves away from you, it is picking up speed. It is converting potential energy, from its height, into kinetic energy, the energy of motion. Once it passes the lowest point, the opposite begins to happen. It is now moving against gravity, and some of its kinetic energy is converted into potential energy. Once all of the kinetic energy has been converted, it stops and starts to move downwards again.

In a perfect system, this would keep happening over and over, with no energy lost. Realistically, energy is lost from the system by friction and eventually the ball will stop swinging.

## Energy

### **Some Like It Hot**

**Passport Question:** Name the 3 methods of heat transfer and an example of each.

**Passport Answer:**

1. Conduction – examples include heating a metal pot on a gas stove
2. Convection – examples include heating a room with a fire place and the hot air rises and cold air sinks; warmer water at the surface of a lake or swimming pool, wind currents, hot air balloon, lower floors of a building being cooler than the top floor
3. Radiation – examples include sun warming the Earth, a light bulb, a camp fire, warm rocks or sand radiating heat

**Learning Target:** Students understand that heat is energy transferred between objects and that heat can be transferred in three ways: conduction, convection, and radiation.

**Materials:**

Conduction station

- Temperature gun
- Various materials – Styrofoam, plastic, metal and wood

Convection Station

- Hot water
- Erlenmeyer flask w/ red dye
- Blue ice cubes
- Heat plate w/ convective fluid

Radiation Station

- Radiometer
- Lamps
- Metal w/ stripes
- 

**Background:**

Heat is the transfer of thermal energy (when we say thermal energy, we're talking about kinetic energy or the movement of molecules). Heat is transferred from an object at higher temperature to another at a lower temperature and occurs in three ways (*see passport answer for examples*):

**Conduction** is heat transfer between objects that are in physical contact.

**Convection** is heat transfer between an object and its environment due to fluid motion.

**Radiation** is the transfer of heat as waves of (electromagnetic) energy that can travel through space.

Video link on Heat transfer: <https://www.youtube.com/watch?v=wDfeQTbmj94>

Video link on Crooke's Radiometer: <https://www.youtube.com/watch?v=llxqNcipTWA>

**Procedure & Discussion:**

Tell students they will investigate heat transfer or movement at three different stations. This heat comes from a source. It will be their challenge to discover the source of the heat and observe how it gets to the material.

Station 1: Conduction

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- Tell the students to put their hands to their cheeks and describe the temperature of their hands. Have them rub their palms together very quickly for about a minute, and then touch their cheeks again. What is the temperature now?
- Tell students to feel the different objects. Which objects feel warmer or colder to touch?
- Use the temp gun to show that all the objects are the same temperatures
- Tell students that some materials are just really good at conducting heat. What material is the best conductor of heat?

### What caused the heat in their hands? How does the heat get to their cheeks?

- In Station 1, rubbing your hands together causes friction and energy is released in the form of heat. When you touch your cheeks the heat is conducted directly from your hands to your cheeks. When you touch a piece of metal it feels cold. That's because metal is a good conductor of heat—that is it is good at transferring heat from your hand to it. Styrofoam is a poor conductor of heat and it doesn't feel as cold as the metal because there is less heat transfer occurring between your hand and the piece of Styrofoam.

### Station 2: Convection

- Show the students the convection tub and ask what they think will happen when you add a blue ice cube to the side. It should fall and sink. Why does this happen?
- Show students the convective fluid on the hot plate. These are what we call convective currents. Where will the liquid that is heated on the bottom go? Why does the liquid on the top sink?

### What's going on?

- In Station 2, the warm and cold water creates convection currents. Cold water sinks and warmer water is pushed upwards, creating a convection current. We can see the rise and fall when the ice cube or colored hot water is added.

### Station 3: Radiation

- Tell the students to use the flashlight and see what happens to the radiometer. They can hold the cellophane between the flashlight and the radiometer (it helps to hold the flashlight close to the radiometer). Encourage them to try it with white light from the flashlight too. Which color causes the vane to spin fastest? What is the heat source?

### What's going on?

We used a device called a radiometer, which has four vanes that revolve on a needle point within a glass globe from which most of the air has been removed. The opposing sides of each vane within the radiometer are alternately dark and light in color. As light (radiation) hits the vanes, the lighter side reflects the light while the dark side absorbs it. As the dark side absorbs the radiant energy, a difference in temperature develops between the vanes. The freely moving air molecules bounce off the dark side with a great deal of energy. As the air molecules "kick" away from the dark side of the vane, momentum transfer causes the vanes to spin away from the side from which they kicked (that is away from the dark side of the vane). Stronger light means that more energy will be absorbed on the dark side, and the air molecules will "kick off" faster and with greater force. Therefore, as the light gets brighter, the vane begins to spin faster

## **Color Combinations**

**Passport Question:** When you combine red, green, and blue light, what color light do you get?

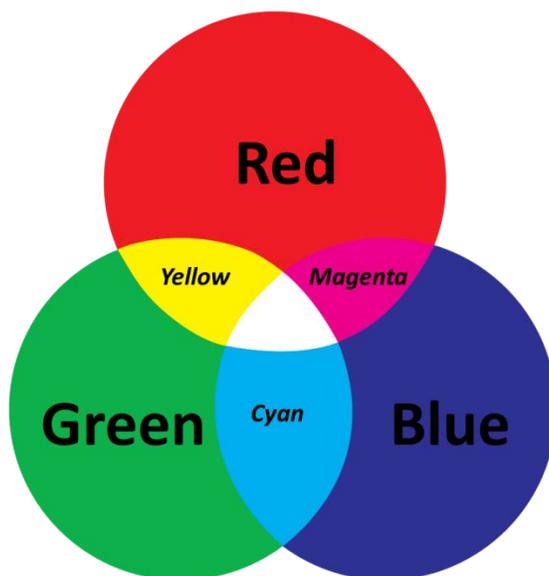
**Passport Answer:** White light

**Learning Target:** Students explore the different color combinations of the 3 primary colors— red, green, and blue and together, the three primary colors of light makes white light.

### **Background:**

We all know the colors of the rainbow- red, orange, yellow, green, blue, indigo and violet (ROY G. BIV). But where do colors like pink and brown come from? We can create many more colors with different combinations of **primary colors**.

What about secondary colors? **Secondary colors** are colors that can be produced by a mixture of equal parts of two primaries. A mixture of green and blue light, for example, makes cyan; cyan is therefore a secondary color. The colors we see in the rainbow are the primary and secondary colors. The primary colors of light are red, green and blue. When the three primary colors are combined, they produce white light. In this activity, students experiment with flashlights of the primary colors to create new colors.



**Materials:** • Flashlights with colored gels,

• White particle board

### **Procedure**

- Have at least 2 students for this activity
- Turn on the flashlights to the brightest setting (two clicks on the flashlight)
- Give each student a flashlight and have them shine the light on the white particle board
- Have students combine colors and observe the colors they see

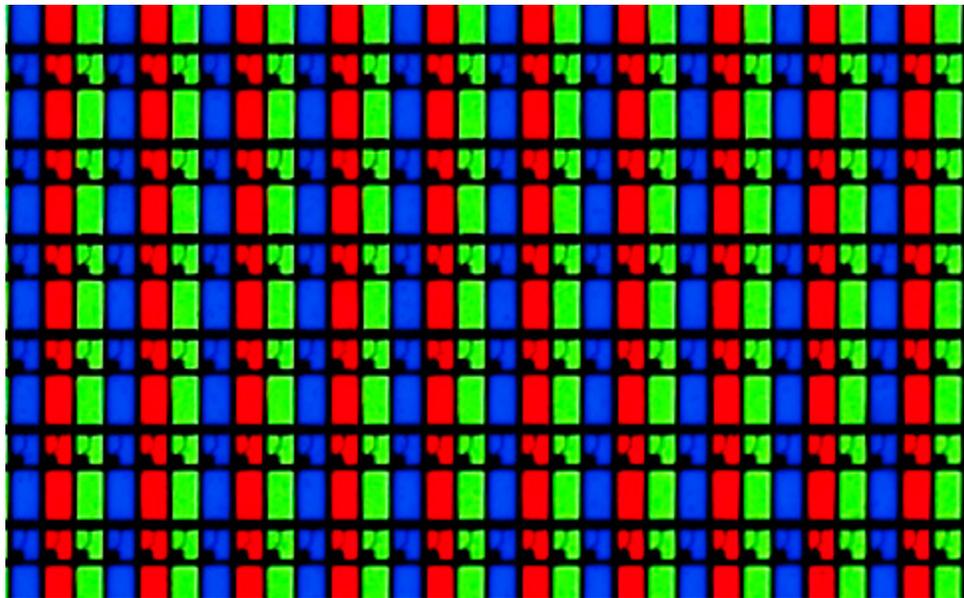
## Energy

- Ask students “What happens to the intensity of the color when you add two flashlights?”
- Have them use the flashlights to mix different colors and record them on the sheet. What happens when you have all three colors together?
- Encourage students to work together and create different colors. “How many colors can you make?”

### **Discussion:**

#### Why are red, green, and blue colors important?

These primary colors (Red, Green, & Blue) can be combined even more to form the variety of colors in your crayon box. This is how computer monitors and televisions work—using only red, blue and green they make hundreds of different colors that we see on our screens. They do this with pixels—small colored dots that our brains assemble into images. Below are is an example of LCD pixels.

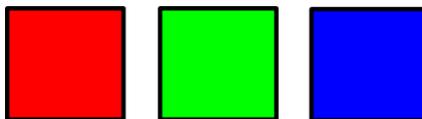


Human eyes evolved to recognize red, blue and green as the primary colors of light. Our powers of color vision derive from cells in our eyes called cones, three types in all, each triggered by different wavelengths of light. Light is actually an incredible mixture of an infinite number of different colors, but your eyes approximate it to reddish, bluish and greenish.

## Colored Shadows

**Passport Question:** Color-in the 3 primary colors of light.

**Passport Answer:**



**Learning Target:** Students learn shadows result from blocking light and can have colors.

### **Materials:**

- 3 colored bulbs
- Surge protector
- White board

### **Background:**

There are three **primary colors** of light: red, green, and blue light. When you combine all three, you get white light.

So how do you get colored **shadows**? Shadows occur because an object blocks a path of light and does not allow the light to pass through the object. Now if you have two bulbs spaced apart, each a different primary color of light, you'll get two shadows of an object. Each shadow is caused by one color being blocked by the object. The shadow is then "colored" in or filled in with light from the other bulb, hence colored shadows. If a third light bulb is added, then two primary colors fill-in the shadow. Two primary colors make a **secondary color** and now you get shadows of cyan, magenta, or yellow.



Video link: <https://www.youtube.com/watch?v=7WTldc67-7Y>

### **Procedure**

- Ask students what makes a shadow and have they ever seen a colored shadow.
- Turn on one color and show students a shadow
- Explain that shadows are created by an object blocking light. Ask students how many shadows do they see (1)
- Now turn on a second bulb. Now how many shadows do they see (2)
- Explain that each bulb is sending out light and that the object is blocking the light at a specific angle and creating a shadow. The shadow is being filled in with the other color of light not being blocked at that angle
- Now turn on all three bulbs and make shadows using hands, pencils, and other narrow objects each
- Ask students what color shadows do they see

## Energy

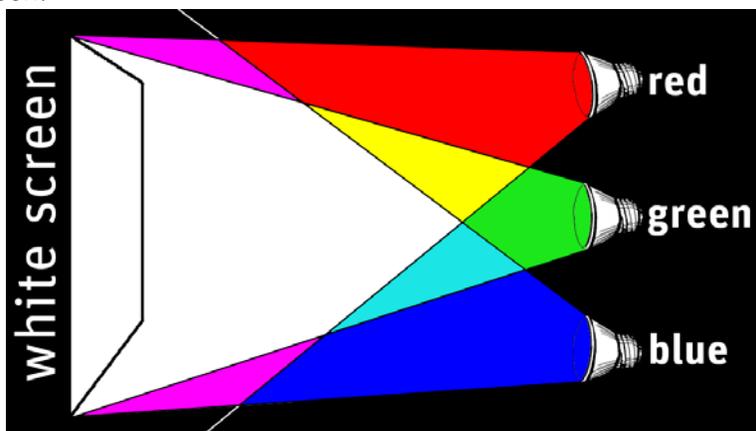
### Discussion:

#### What's happening?

With these three lights, you can make shadows of seven different colors: blue, red, green, black, cyan (blue-green), magenta (a mixture of blue and red), and yellow (a mixture of red and green).

If you turn off the red light, leaving only the blue and green lights on, the lights mix and the screen appears to be cyan, a combination of blue and green. When you hold the object in front of this cyan screen, you will see two shadows: one blue and one green. In one place the object blocks the light coming from the green bulb and therefore leaves a blue shadow; in another place it blocks the light from the blue bulb to make a green shadow. When you move the object close to the screen you will get a very dark (black) shadow, where the object blocks both lights.

When you turn off the green light, leaving the red and blue lights on, the screen will appear to be magenta, a mixture of red and blue. The shadows will be red and blue. When you turn off the blue light, leaving the red and green lights on, the screen will appear to be yellow. The shadows will be red and green.



#### Optional: biology tie-in

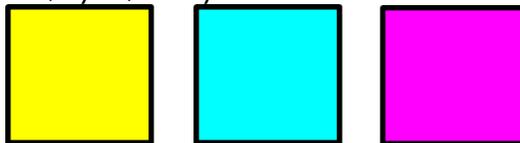
The retina of the human eye has three receptors for colored light. One type of receptor is most sensitive to red light, one to green light, and one to blue light. With these three color receptors, we are able to perceive more than a million different shades of color.

It may seem strange that a red light and a green light mix to make yellow light on a white screen. A mixture of red and green light stimulates the red and green receptors on the retina of your eye. Those same receptors are also stimulated by yellow light—that is, by light from the yellow portion of the rainbow. When the red and green receptors in your eye are stimulated by a mixture of red and green light or by yellow light alone, you will see the color yellow.

## **The Three Little Pigments**

**Passport Question:** Color-in the 3 secondary colors of light.

**Passport Answer:** Magenta, cyan, and yellow



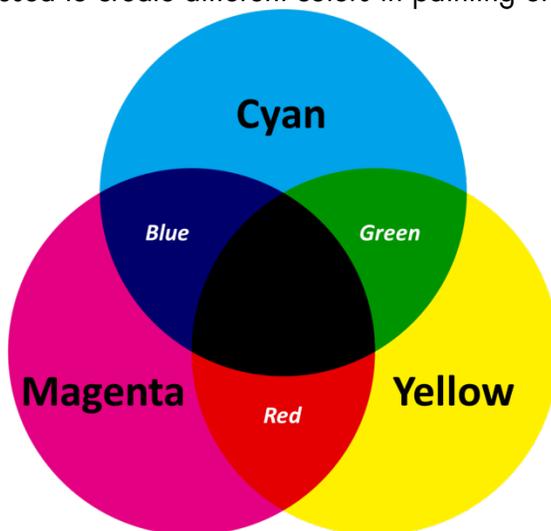
**Learning Target:** Students learn that secondary colors are pigments and can be used to create a variety of colors.

**Materials:**

- Lamp
- Transparencies in yellow, magenta, cyan, black, and full-colored.

**Background:**

If you combine red, green, and blue light, you get white light. These are the primary colors of light. However, if we mix red, blue, and green paint, we don't get white. Why? Well that's where secondary colors come into play. **Secondary colors** are colors that can be produced by a mixture of equal parts of two primary colors. The secondary colors of light are also known as the primary colors of **pigments** or dye (not red, yellow, and blue, as many people are taught) and are used to create different colors in painting or printing.



More information: <https://www.youtube.com/watch?v=r8ejTUNwgTo>

**Procedure**

- Tell students that cyan, magenta, and yellow (CMY) are secondary colors, produced from the three primary colors of light—red, blue, and green.
- Have students overlay CMY transparencies one at a time and ask them what colors do they notice

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- Using the color circle diagram, ask students to make a prediction of what color will be generated
- Lastly, have students overlay the black transparency and compare to the full color transparency. What do you notice?
- Some arrangements of the transparencies are better. Encourage students to play around and find the arrangement that gets closest to recreating the full-colored transparency.

### **Discussion:**

Why do we get an image and why can't you use red, green, and blue instead?

It is easier to recreate an image using secondary colors. So much so that printers only use cyan, magenta, and yellow. Why? On a piece of paper, red, green, or blue inks each absorb the other two primaries. For example, if you print something in red, only red light is reflected back to your eyes. But cyan, magenta, and yellow inks each absorb only one primary color and can be combined to form many colors more efficiently. If you print something in cyan, both blue and green light is reflected back.

What happens when you combine two secondary colors?

When you combine secondary colors, a primary color appears. Why that specific primary color? Well, it is because the secondary colors block or "subtract" the other primary colors and only allow one primary color to pass. This principle is known as color subtraction and occurs when white light hits a secondary color or pigment; some of that white light is subtracted.

For example, if a cyan sheet is held up to the light, all colors of white light pass through the clear or uncoated areas. However, in the portions of the sheet where the cyan pigment is more intensely coated, virtually all red light will be blocked. If the magenta sheet is held up to the light, the green light will be blocked. The yellow sheet blocks the blue light.

If two layers are aligned, the primary colors of light may appear. For example, if a solidly colored portion of cyan acetate is held against a solidly colored portion of yellow acetate, only green light is seen. This is because cyan subtracts red light and yellow subtracts blue light, allowing only green light to pass through (look at the color wheel to predict combinations). Cyan, magenta and yellow combine to create different colors and intensities of light.

When all CMYK (K stands for black and used to add detail) acetates are overlaid, depending on where you look on the acetates, various colors and various intensities are subtracted from the white light. This allows you to make an infinite number of colors from different combinations of CMYK.

## Great Wall of Color

**Passport Question:** Did you see colors reflected in the bubble film?

**Passport Answer:** Yes

**Learning Target:** Students learn that bubble films have different colors and that's because some light is reflected back at a greater intensity.

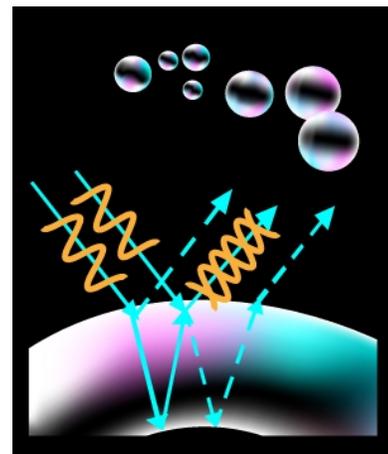
### **Materials:**

- Bubble solution
- Bubble painting,
- Black PVC pipes
- Petri dish

### **Background:**

Light waves come in many frequencies—frequency being the number of waves that pass a point in space during any time interval. There are many types of light we cannot see, including microwaves, ultraviolet and X-rays. The light that we can see is called the **visible spectrum**, or white light. And while sunlight looks white or yellow, it's actually made of many different colors of light, each with their own frequency. You have probably seen this spectrum in a rainbow: red, orange, yellow, green, blue, indigo and violet.

The colors of a soap bubble come from white light, which contains all the colors of the rainbow. When white light reflects from a bubble film, some of the colors get brighter, and others disappear. This phenomena is known as interference.



Video link: <https://www.youtube.com/watch?v=vQW94GVN524>

### **Procedure:**

- Make sure the strings and any other surfaces that will come into contact with the soap film on are wet with the soap solution
- Slowly lift up the painting and have students notice the colors
- Gently shake the frame back and forth and notice the pattern of waves on the film.
- Have students poke the painting and pop the soap bubble
- Stand a few feet away and blow gently onto the soap film. Notice that it stretches out into a bulge when you blow and returns to its original flat shape when you stop.
- Have students wet their fingers with some bubble solution and now poke the new painting
- Now try coating a small piece of PVC pipe entirely in bubble solution. Have students push one end through the film and pop the bubble inside (if one forms) to make a "hole" in the soap film?
- Have students dip the black PVC pipe into the petri dish to view the film up close

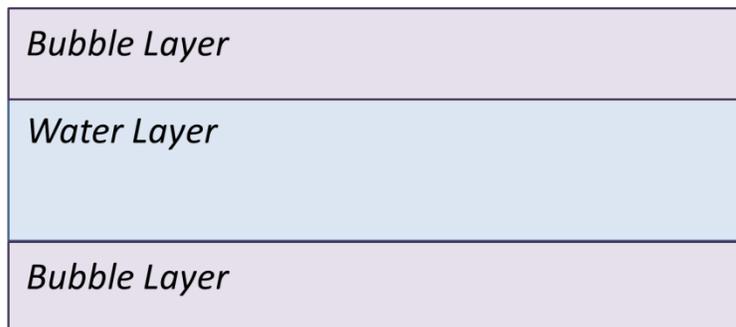
## Energy

### Discussion

#### Why do you see these colors?

These colors are different light waves—red is red light waves and green is green light waves.

Light waves, like water waves, can interfere with each other. A bubble film is a sort of sandwich: a layer of soap molecules, a filling of water molecules, and then another layer of soap molecules.



When light waves reflecting from one layer of soap molecules meet up with light waves reflecting from the second layer of soap molecules, the two sets of waves interfere. Some waves add together, making certain frequencies or colors of light brighter. Other waves cancel each other, removing a frequency or color from the mixture. The colors that you see are what's left after the light waves interfere. They're called interference colors.

The interference colors depend on how far the light waves have to travel before they meet up again—and that depends on the distance between the layers or the thickness of the soap film. Each color corresponds to a certain thickness of the soap film. By causing the liquid bubble film to flow and change in thickness, a puff of wind makes the bubble colors swirl and change.

#### What's happening to the soap film on the PVC pipe?

The film thins out over time, and you see a remarkable change from colors to lines to a clear film. As the film thins, more colors cancel out. The very thinnest film—one that's only a few millionths of an inch thick—looks black because all the reflecting wavelengths of light cancel. When the soap film looks black, it's just about to pop.

## The Sky is Purple?

**Passport Question:** What gives the sky its color?

**Passport Answer:** Light scattering + white light (sunlight)

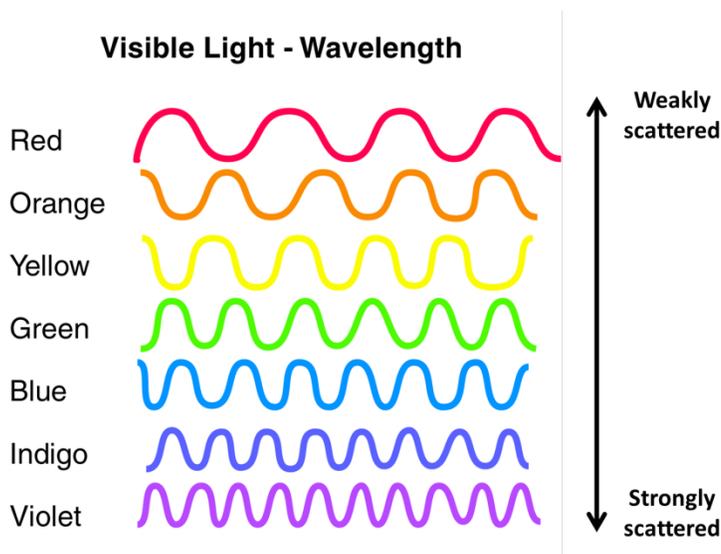
**Learning Target:** Students understand that sunlight consists of different colors and that the sky is blue because blue light strongly scatters off atmospheric molecules compared to other colors.

**Materials:** Container with milky-clear water, hot glue sticks, 2 sunset eggs, flashlight

### Background:

Wait, the sky isn't purple—it's blue! So why are we asking about purple? The short answer is scattering. In this activity we'll find out what this is and how it affects the color of the sky.

As light passes through the atmosphere, atoms actually absorb and reemit the light. This doesn't change the *intensity* of light, but it does change the *direction*. And this change in direction—we call **scattering**— is ten times stronger for violet light than for red.



This particular type of scattering is called **selective scattering** or **Rayleigh scattering**. Blue light has a short wavelength and a high frequency, so it is strongly scattered.

When you look up at the sky, the light you see has been scattered and redirected toward your eyes. Because you are seeing only scattered light, the sky appears blue. But violet light has an even shorter wavelength and a higher frequency than blue light, so by all accounts the sky light should be violet! It appears there is more to the story! If we judge by the most prominent color, the sky *is* violet. But the sky *appears* blue due to the limitations of our eyes. Our sensitivity to light decreases as we reach the shortest wavelengths of the visible spectrum. The violet is there, but our eyes can only weakly detect it. *What we see is blue—present in large quantities and easily detected by our eyes.*

Informational link: <https://www.youtube.com/watch?v=ro2MmmdARrs> (1<sup>st</sup> question)

Video link on Electromagnetic Spectrum: <http://www.pbs.org/video/2219781967/>

### Procedure:

- Have students place a white light at one end of the sunset egg and look at the light that comes out of the side of the egg.

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- Introduce the term scattered light. What color is the scattered light?
- Next, look at the light that goes through the egg. This is the transmitted light (all of the light that isn't scattered). What color is the transmitted light?
- Have students light on the other end of the egg and on the egg's side. What do you notice now?
- Light the container with milk. Is the color different from the side of the container than the end? Use a white board to see difference of transmitted light with and without tank.
- Explain that many materials can scatter light. Light the end of a hot glue stick and tell students that molecules in the atmosphere do the same thing that hot glue stick does: scatter light.

### **Discussion:**

#### What color is the scattered light?

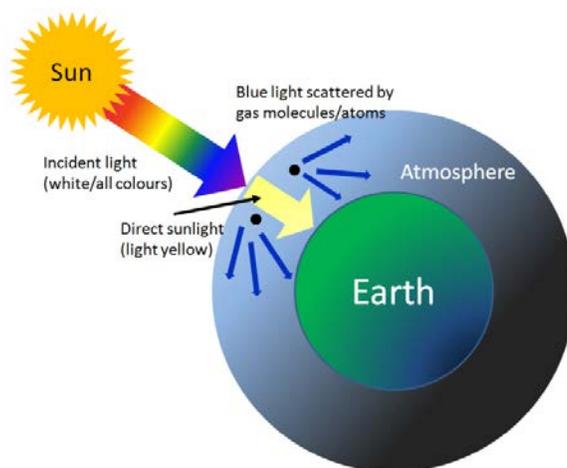
The scattering from the crystals in the egg is selective scattering just like in the atmosphere. Blue light is scattered out of the egg and can be seen from the side.

#### What color is the transmitted light?

The longer wavelengths, red and orange, can pass through the egg without being scattered. Thus, the transmitted light from the sunset egg and milky container appear golden yellow.

#### What color is the sky when the sun sets?

At sunrise and sunset we see the sun at an angle, and the light has to pass through 12 times more of the atmosphere to get to our eyes. All of the shorter wavelengths scatter away and we are left with the beautiful reds and oranges of the sunrise and sunset.



## Super Spectroscopes

**Passport Question:** A spectroscope is a tool used for observing a spectrum of \_\_\_\_\_

**Passport Answer:** Visible light

**Learning Target:** Students observe four emission spectra through spectroscopes and understand elements emit different wavelengths of light

### **Materials:**

- Spectroscope power supply
- Spectroscopes (x2)
- Gas tubes (x4)
- Tape
- Scissors
- Toilet paper rolls
- Paper circles with slits
- Diffraction material

### **Background:**

When elements are heated and in a gaseous state, they give off energy in the form of light. Each element gives off a limited number of wavelengths of light. This group of wavelengths is called the **emission spectrum** of an element and is unique to an element. It's akin to a fingerprint for an element.

A **spectroscope** is a device that can be used to look at emission spectra. Spectroscopes use a process called **diffraction**. Diffraction is the spreading out of waves, such as light waves, as they pass around an obstacle or go through an opening. As light passes through the opening of a spectroscope, the waves spread in such a way that they produce a spectrum. The opening is called a **diffraction grating**, which is a small sheet of glass marked with thousands of parallel lines.

### **Hydrogen:**



### **Helium:**



### **Procedure**

*Caution! Do NOT remove spectrum tubes from the power supply while it is plugged in. High voltage runs between the sockets and is a risk of electrocution. The spectrum tubes are fragile and must be handled with care. The spectrum tubes should not be turned on for more than 30 seconds at a time.*

- First, have the students observe each of the light sources with the naked eye.
- Ask students what they observe

## Energy

- Now look at the light sources through the spectroscopes provided. Tell them to write down the colors they see. Do they fade or blend into each other?
- The students can make their own spectroscope to take home.
- Tell them to observe different light sources, including lights at night. Be sure not to look directly into the Sun!

### **Discussion:**

Does each light source produce the same group of colors or spectrum?

Yes! The emissions spectrum of an element is always the same.

Why are the groups of color for each light source different?

Simple spectroscopes, like the one described here, are easy to make and offer users a quick look at the color components of visible light. Different light sources may look the same to the naked eye but will appear differently in the spectroscope. The colors are arranged in the same order but some may be missing and their intensity will vary. The appearance of the spectrum displayed is distinctive and can tell the observer what the light source is.

Why are spectroscopes important?

One of the important applications of spectroscopes is their use for identifying chemical elements. Each element radiates light in specific wavelength combinations that are as distinctive as fingerprints. Knowing the "spectral signatures" of each element enables astronomers to identify the elements present in distant stars by analyzing their spectra. They also allow astronomers to analyze starlight by providing a measure of the relative amounts of red and blue light a star gives out. Knowing this, astronomers can determine the star's temperature. They also can deduce its chemical composition, estimate its size, and even measure its motion away from or toward Earth.

### **Spectroscope Prep**

1. Cut out the circles and the squares and slots inside them.

#### **Instructions for Building a Spectroscope**

1. Cut a small square (about 2 cm) of diffraction grating. Tape the diffraction grating to the square hole in the circle.
2. Tape the circle with the grating inward to one end of the tube.
3. Place the circle with the slot against the other end of the tube. While holding it in place, observe a light source such as a fluorescent tube. Be sure to look through the grating end of the spectroscope. The spectrum will appear off to the side of the slot. Rotate the circle with the slot until the spectrum is as wide as possible.
4. Tape the circle to the end of the tube in this position. The spectroscope is complete!

## **Refraction Action**

**Passport Question:** The bending of light is called \_\_\_\_\_

## Energy

**Passport Answer:** Refraction

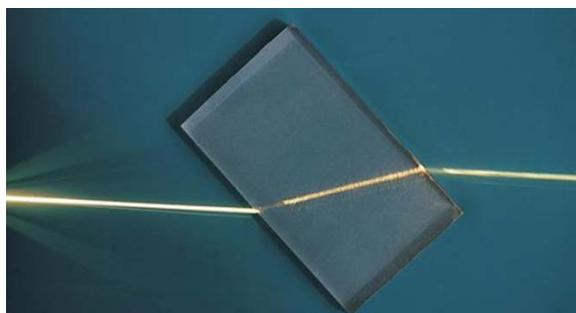
**Learning Target:** Students learn that refraction occurs when lights hits a different medium and changes direction or bends.

**Materials:**

- Index cards w/sharpies
- Pint glasses & jars
- Pulley stand with beakers

**Background:**

A **medium** is a substance or material that carries a wave. For example, the medium for an ocean wave is water, the medium for a stadium wave are the fans in the stadium, the medium for sound is air, etc.



When a light wave travels from one medium to another, the light wave can actually bend. We call this bending of light **refraction**. Refraction makes it possible for us to have lenses, magnifying glasses, prisms and rainbows. Even our eyes depend upon this bending of light. Without refraction, we wouldn't be able to focus light onto our retina. Every material has an **index of**

**refraction** that is linked to the speed of light in the material. The higher the index of refraction is, the slower the light travels in that material.

Video link: <https://www.youtube.com/watch?v=OdcHCRF00jM>

**Procedure & Discussion**

- Introduce the term medium and show students a picture of an the ocean wave. Ask them what medium the wave is traveling in (water!)
- Tell students that light can pass through different mediums and that when light travels from one medium to another, light can bend or refract and can alter what we see.

Station 1: Optical illusions

- Have students use the different glasses and jars of water to see how images get altered. Challenge them to rotate the images instead of the jars and glasses
- Have students put an index card with an arrow behind a glass with water. Tell students to close one eye and slowly move the card back until they see the arrow reverse.
- Have students write their names down and try to see their names reversed.

How does bending of light reverse the arrow?

## Energy

Light traveled from the air, through the glass, through the water, through the back of the glass, and then back through the air, before hitting the arrow. Anytime that light passes from one medium into another, it refracts or bends

Just because light bends when it travels through different materials, doesn't explain why the arrow reverses itself. To explain this, you can also think about the glass of water as if it is a magnifying glass. When light goes through a magnifying glass the light bends toward the center. Where the light all comes together is called the focal point, but beyond the focal point the image appears to reverse because the light rays that were bent pass each other and the light that was on the right side is now on the left and the left on the right, which makes the arrow appear to be reversed.

### Station 2: Disappearing beaker station

- Ask students can they spot the smaller beaker in the larger beaker
- Using the pulley system, raise the smaller beaker until students can see it. Students can lower the beaker, just be careful not to lower it too fast!
- Ask them if they can see the smaller beaker in the prism now.
- Show students the magnifying glass out of the beaker and how it magnify images
- Carefully lower the magnifying glass into the beaker and observe. Ask students if they see a magnified image.

### Why does one beaker disappear and not the other?

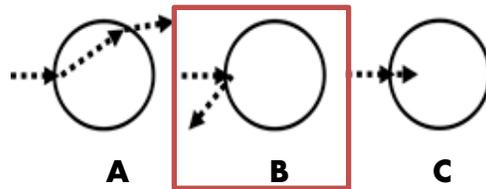
You see a glass object because it both reflects and refracts light. When light traveling through air encounters a glass surface at an angle, some of the light reflects. The rest of the light keeps going (transmitted), but it bends or refracts as it moves from the air to the glass.

While transparent, each large beaker contains a different liquid, water or glycerin. Light travels slower in glycerin and in fact, light travels at about the same speed between glycerin and beaker glass. This means less reflection will occur at the boundary and the less refraction will occur for the transmitted light. Put it another way, the speed of light does not change as it enters the beaker surrounded by glycerin. No reflection and no refraction will take place, and the beaker will be invisible. The difference in speed between water and the beaker is large enough that the beaker is visible.

## Laser Light Show

**Passport Question:** Which image represents reflection? (Circle one)

**Passport Answer:**



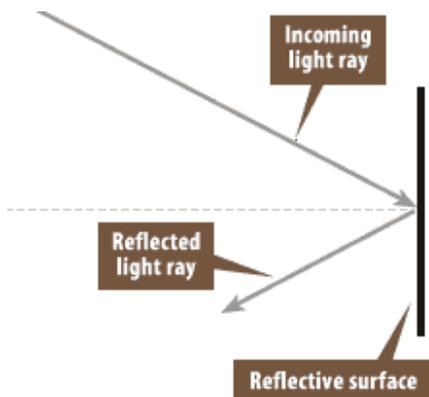
**Learning Target:** Students will learn about reflection, refraction, and absorption of light using lasers, mirrors, and Jell-O. Students will also understand the basics of fiber optics and total internal reflection.

### Materials

- Green laser
- Red Laser
- Container filled w/ water
- Petri dishes w/ JellO

### Background:

Light waves come in many frequencies—frequency being the number of waves that pass a point in space during any time interval. When a light wave of a specific frequency strikes an object, a number of things can happen. The light wave can be absorbed where light is converted into heat. It can be transmitted, where the light wave can pass through an object without being absorbed. Light can also be reflected and refracted.



**Reflection** is the bending back of light waves from a surface. Reflection of light makes it possible to see objects and an object's color results from the way visible light interacts with an object's surface. **Refraction** occurs when light hits a different medium, such as going from air to water, and changes its direction.

Under certain conditions, waves are completely reflected from a boundary between two transparent materials. This phenomenon is called **total internal reflection** and is used in fiber optics.

### Procedure

Warning: Students are okay to use the red laser with discretion. Tell students to be very careful with lasers and not to point them in anyone's eyes. They should not use the green laser!

- Outside of the "light and dark room," turn on a laser and point it at the wall. What do you see? Can you actually see the light traveling from the laser to the wall, or do you just see the light at the wall?

## Energy

- Show students the three Jell-O samples and ask them predict what will happen when you shine the laser into them.
- Have students test out all three samples and students make observations
- Try pointing the laser at angle to cause the light to refract in the Jell-O. Use a white foam board to track the path of the light. You can remove the Jell-O dish to see where the light would shine unobstructed. Compare the paths. Are they different?
- Enter the “light and dark room” and shine the laser at a mirror. Observe the effect. Try to reflect the laser beam off of as many mirrors as possible.
- To demonstrate fiber optics, place tape over the hole in the bottle and fill the bottle with water. With one hand, hold the bottle over the bucket or the edge of the sink. With your other hand, hold the flashlight on the side of the bottle across from the hole. Remove the blue tape. Have students observe what happens. How does the light enter the bottle and what does it do as it comes out of the hole? What happens if you catch the water in another container like a bowl as it drains?

### **Discussion:**

#### What’s happening between the three Jell-O samples?

The red Jell-O doesn't absorb red light, so you can see the red beam transmitted. The blue Jell-O absorbs red light (but not blue or green light), so the red beam isn't visible. Remember, the light is being absorbed is just light energy being converted into heat.

If you angle the laser, the light rays both reflect and refract. Why? Well, light is traveling from air to the Jell-O medium and this change in medium causes light to slow down. The change in speed causes the direction of the beam to refract, or bend. When going from a high-speed material such as air to a lower-speed material such as gelatin, the beam will bend into, or towards, the gelatin.

#### Why is the laser reflecting in the water stream and not transmitting through?

The light inside the stream of water behaves as it would inside an optical fiber. The light beam bounces around inside the stream, reflecting back and forth off the inner “walls” of the water. It’s as if the inside of the water is coated with mirrors and the laser is bouncing off of the mirrors inside the stream of water. This is total internal reflection!

#### Optional: How do optical fibers transmit light?

Suppose you want to shine a flashlight beam down a long, straight hallway. Just point the beam straight down the hallway – light travels in straight lines, so it is no problem. What if the hallway has a bend in it? You could place a mirror at the bend to reflect the light beam around the corner. What if the hallway is very winding with multiple bends? You might line the walls with mirrors and angle the beam so that it bounces from side-to-side all along the hallway. This is exactly what happens in an optical fiber: a succession of zigzag reflections until it exits from the other end of the fiber

## It's a Mirror-cle!

**Passport Question:** Why does it look like you are flying?

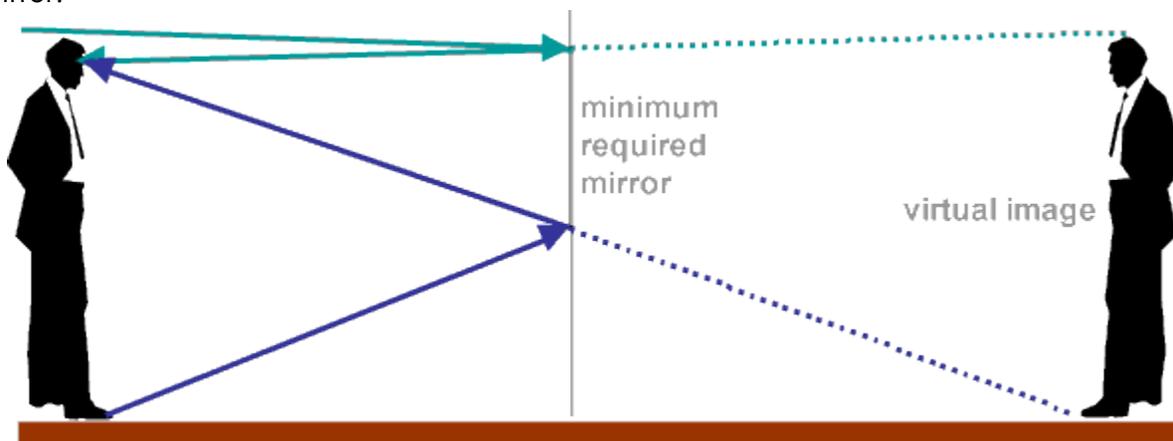
**Passport Answer:** The foot off the ground is reflected and looks like a second foot.

**Learning goal:** Students will understand that mirrors reflect light and that images are not on a mirror but are formed behind a mirror

### Materials:

- Lab stands
- Tape point
- Large mirror
- Composite face stand
- Infinite mirror setup

**Background:** Most people have noticed that images in a mirror do not look exactly the same as the object. One property of reflected images that accounts for this particular illusion is the **position** of the image. *The image is not on the mirror but is actually formed behind the mirror.* It is as far behind the mirror as the object is in front, as shown in the image below. Thus, the reflected image of the lifted leg appears at about the same position behind the mirror as the demonstrator's "second" leg. So our brain tries to tell us that the image is the leg behind the mirror.



Optical illusions occur when what we see does not match what is actually happening. The brain can be tricked into seeing something that isn't really there, or that isn't what it appears. This activity uses the properties of mirrors and reflection to create the illusion that a person can fly and that our face is actually a mixture of two faces!

### Procedure & Discussion

#### Station 1: Flying Mirror

- Mount the mirror vertically. Instruct the student to stand with one foot in front of the mirror and one in back. Mark a spot on the floor for them to stand on.

## Energy

- Tell them to balance on the foot that is behind the mirror and lift the one that is in front of it.
- To the observers, both legs appear to leave the ground!

### Is the student really flying? Why do we think he or she is?

If you stand with the edge of a large mirror bisecting your body, you will appear whole to a person who's observing from the front. To the observer, the mirror image of the visible half of your body looks exactly like the real half that is obscured behind the mirror.

You look whole because the human body is symmetrical. The observer's brain is tricked into believing that an image of your right side is really your left side.

### Biology tie-in

Your eyes and brain work together to make a picture of the world. This eye-brain system assumes that the light has traveled in straight lines to reach your eyes. In order for the light to travel in a straight line to your eyes, your head would have to be behind the mirror and thus virtual images are formed behind a mirror.

### Station 2: Composite Face

- Have two students sit across from each other, about 12 inches from the mirror strips
- One student moves their head up or down until he or she can see his or her eyes in the other side of the same mirror strip that you are looking into
- Instruct a student to move until their eyes are looking through the space directly below the mirror strip they were looking in previously.
- Have the other person move his or her head the same way. How does this composite face compare with the previous one

### Station 3: Infinity mirror

- Have students in the eye hole and ask what they see

## Currently Working

**Passport Question:** A solution with ions is able to conduct electricity.

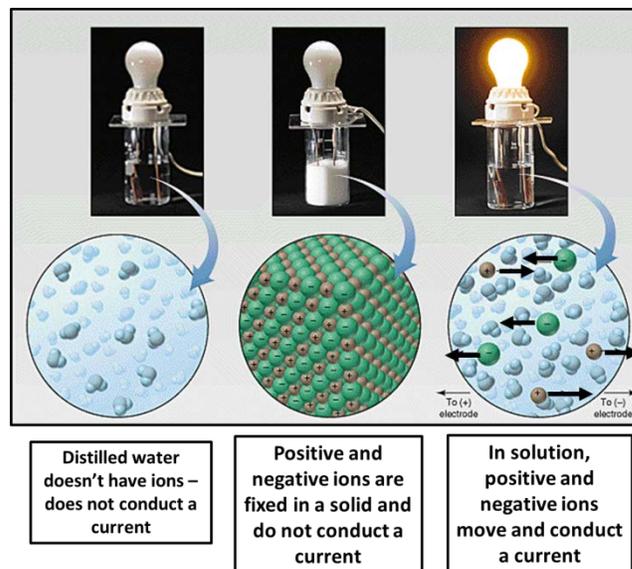
**Passport Answer:** True

**Learning Target:** Students will learn that solutions with charged particles can conduct electricity

**Materials:** Conductivity meter(s) with LED bulb attached, different solutions in 10mL beakers (Lake Tahoe water, tap, saltwater, water with baking soda, sugar water)

### Background:

An electric current is a flow of electrical charge. Conductors are materials that permit electrons or other charged particles to flow freely—it's this movement that produces electricity. The most common conductors of electricity are metals and solutions. A **solution** is a mixture in which two substances are mixed uniformly—an example is salt water. When an acid, a base, or a salt is dissolved in water, the molecules break into electrically charged particles called **ions**. A solution can conduct electricity if it contains ions. In this experiment students will determine which solutions are able to conduct electricity using a homemade conductivity meter.



### Procedure:

- Ask the students if they have ever been in a thunderstorm at the beach or the pool. Could they stay in the water? Why or why not? Tell them that this experiment has to do with conducting electricity in solutions. The students will be testing which solutions conduct electricity and light up the bulb.
- Demonstrate the light by touching the ends of the “leads” together briefly. The bulb should light up.

Note: LED bulbs may stay lit for a couple seconds afterwards and Xmas lights may blow out if they the leads are in contact for too long!

- There are beakers labeled “Tap,” “Salt,” “Lake Tahoe,” “Baking Soda,” and “Sugar.” Each one of the cups should have 10mL of the type of water named.
- Ask students to predict which solutions will light up the bulb.

Discussion-

Which solutions caused the bulb to light up? Why did those work?

The solutions with ions (or charged particles) were the ones to light up.

## Energy

What is happening and what is needed to carry an electric current?

When the two leads are connected by a solution, the current is carried only if there are charged particles or ions in the solution to carry it. Solutions like the salt water have ions and so are able to conduct electricity. If the two terminals touch the piece of metal, the current is carried entirely by electrons that can move through the wire and metal.

Why don't some solutions light up?

Because pure water has few ions, it is a poor conductor. Uncharged molecules that dissolve in water, like sugar, do not conduct electricity. If there are ions, positive ions will move in one direction, negative ions will move in the opposite direction, and the electric current can move and light up the bulb.

So do think it would be dangerous to swim in the ocean during a storm? Why or why not?

The salt water of the ocean and the chlorine water in the pool are both solutions with ions, so it is dangerous to swim during a thunderstorm—you might be on the receiving end of the electric current!

Other than the bulb lighting up, did you notice any other reactions such as bubbles in the water?

Yes! If you see bubbles forming, this is caused by electrons separating from the salt molecules.

## **Electricity: It's Magnet-ificent**

**Passport Question:** In this activity you observed (Circle One)

**Passport Answer:**

- a) Electricity causing chemical reactions
- b) Copper wire rotating on a battery and magnet
- c) An electromagnet picking up a paper clip
- d) All of the above**

**Learning Target:** Students will learn that charged particles like electrons can create magnetic fields when in motion

### **Materials:**

#### Electrolysis of H<sub>2</sub>O

- Batteries w/ long screws
- Petri dish w/ indicator dye
- Magnet
- Epsom salt
- Spoon

#### Electromagnets

- Nail with copper wire
- D battery
- Magnet
- Paper clips

#### Rotating Wires

- Copper wire designs
- D batteries
- Molybdenum magnets
- Plastic Blue motors

**Background:** Batteries have both a high and low potential end and thus a potential difference – we call this voltage. When you connect both ends with a wire or a material that allows charges to flow, the battery pumps electrons from the low potential to the high potential. This is analogous to a roller coaster, where a motor-driven chain serves to move the roller coaster car from a low spot (low gravitational potential) to a high spot (high gravitational potential). The battery is like the motor-driven chain and the electrons are like the roller coaster cars. Once the electrons flow, you have electricity!

As charged particles move, they also generate a magnetic field around them. If you really want to understand why, watch the first video below. When moving charges are placed in a permanent magnetic field as in a magnet, the charges feel a force called Lorentz force. The concept that moving charges generates magnetic fields has numerous applications and is evident in our everyday lives (motors, musical equipment, MRI machines, etc.)

Video link: [https://www.youtube.com/watch?v=xER1\\_SYqI44](https://www.youtube.com/watch?v=xER1_SYqI44)

Video link: <https://www.youtube.com/watch?v=9FCYGbOWk4w>

### **Procedure and Discussion:**

#### Station 1: Electrolysis of water

- Fill the petri dish with the indicator solution
- Add a teaspoon of Epsom salt to the petri dish and stir until the salt dissolves
- Tell students that they're going to split water! With electricity and show model of water molecule and its associated parts
- Ask students to put battery with long leads into solution and observe what's happening

## Energy

- Tell students they'll revisit the reaction during the other activities
- When you revisit, ask students what changes they noticed. Did you see bubbles forming at the screw tips? Did one screw emit more bubbles than the other?
- Look and see which battery terminal is associated with which volume of bubbles, and which terminal is associated with which indicator color.

### What did you notice?

The different areas of color should begin to swirl in opposite directions. This is because a moving electric charge such as an ion also has a magnetic field. The field from the permanent magnet underneath the dish starts to push on the mini-magnet ions and influences how they move.

At the positive electrode, two oxygen atoms get pulled from two  $\text{OH}^-$  ions and combine to make oxygen gas,  $\text{O}_2$ . This leaves an abundance of free  $\text{H}^+$  ions, which makes it more acidic at the positive terminal—so your indicator should show an increase of acid at the positive terminal. Likewise, when hydrogen ions combine to make hydrogen gas ( $\text{H}_2$ ) at the negative

### Station 2: Rotating wires

- Have students examine the three demo motors. What differences do you see?
- Have students place copper loop on blue motor with magnet and battery. Give it a little push and observe the wire rotate
- Have students balance wire figures on the battery-magnet and see if they start rotating. Ask students what they did to get the wire rotating

### Rotating wires: What differences do you see? How did you get your wire rotating?

The world's smallest motors only work when there is a battery, magnet, and a wire. The wires, battery, and magnet rotated when the copper wire was near or touching the magnet. As electrons move from the battery to the wire, they experience a force. The force is perpendicular to the wire, causing the wire to rotate.

### Station 3: Electromagnet

- Show students the nail with copper wire around the nail
- Have students try to pick up paper clips with the nail. Would you say that the nail is a magnet?
- Connect the copper wire to the battery and ends and see if students can pick up the paperclips. What is the battery supplying that wasn't there before?

### Electromagnet: What is the battery supplying that wasn't there before?

When the wire is connected to the battery, the battery is supplying electrons in motion. When electrons move, they form mini-magnets with induce a magnetic field. The nail serves as a magnetic core, which strengthen the magnetic field. Ask students if we were to remove the nail, would we still have a magnetic field? (Yes, electrons are still in motion!)

## **Human Battery**

**Passport Question:** Which pair of metals produced the most current?

**Passport Answer:** Copper + Aluminum

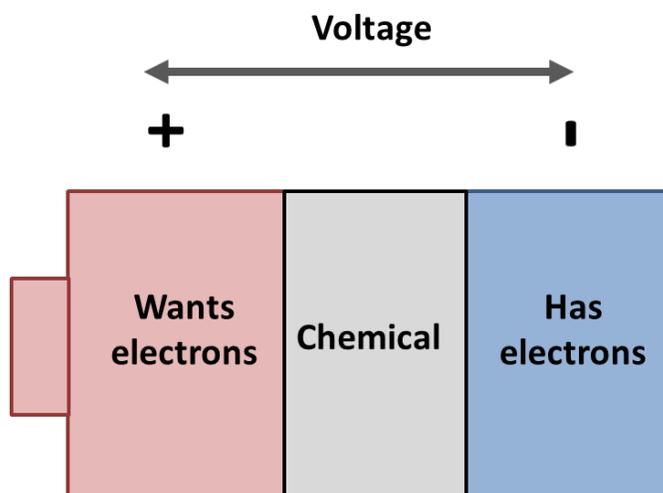
## Energy

**Learning Target:** Students will understand the basics of a battery and that electrons are sent from one side of the battery to another through a series of chemical reactions

### Background:

A battery has three basic parts: a positive end, negative end, and a chemical in between them.

The negative end has more electrons (negatively charged particles) and this creates a charge difference, or **voltage**, between the two ends. The electrons want to “get away” from each other but can’t travel through the chemical that’s between the ends. The chemical is known as the **electrolyte** and does not allow electrons to flow through.



When we connect a wire to both ends, this allows the electrons to flow from the negative end, where lots of electrons are, to the positive end, and thus create a **current**. This flow of electrons is what makes an electrical current.

But won't we run out of electrons on the negative end? That's where the electrolyte comes in. The electrolyte reacts with both ends to supply more electrons and maintain the voltage across the ends. Over time, the electrolyte becomes depleted and can't supply anymore electrons.

### Materials:

- Four metal plates
- Salt spray
- Multimeter
- Current Leader Board

### Procedure

- Ask the students what they know about batteries. Tell them that today they will be a battery!

## Energy

- Show them the setup and explain that the multimeter measures electrical currents in amperes. *Make sure the setting is on DCA 2000 $\mu$ .*
- Instruct them to place their left hand on the copper or brass and the right hand on the aluminum or zinc panel. What happens to the meter?
- Tell them to try different combinations of metals to see which produces the most current. What happens if you use just your fingertips instead of your whole palm?
- Try it with a partner. Hold each other's hands and each place one hand on a different metal. What happens to the current reading?
- Try getting your hands sweaty or spray some saltwater solution on them. What happens to current now?
- Have students write their currents on "Current Leader Board" and what metals produced that current

### **Discussion**

The thin film of sweat on your hands acts like an electrolyte solution and reacts with the metal plates.

For example, when you touch the copper plate, the copper gives up negatively charged electrons and acquires a positive charge. When you touch the aluminum plate, it takes electrons and becomes negatively charged.

This difference in charge between the two plates creates a flow of electrical charge, or electrical current. Because electrons can move freely through metals, the excess electrons on the aluminum plate flow through the meter on their way to the copper plate. In addition, negative electrons move through your body from the hand touching the copper to the hand touching the aluminum. As long as the reactions continue, the charges will continue to flow and the meter will show a small current.

Your body resists the flow of current. Most of this resistance is in your skin. By wetting your skin you can decrease your resistance and increase the current through the meter. Since two people holding hands have more resistance than one person, the flow of current should be less.

## **Sizzling Static Electricity**

**Passport Question:** Uncharged objects become charged by gaining or losing\_\_\_\_\_.

**Passport Answer:** electrons

# Energy

**Learning Target:** Students will understand the basics of static electricity

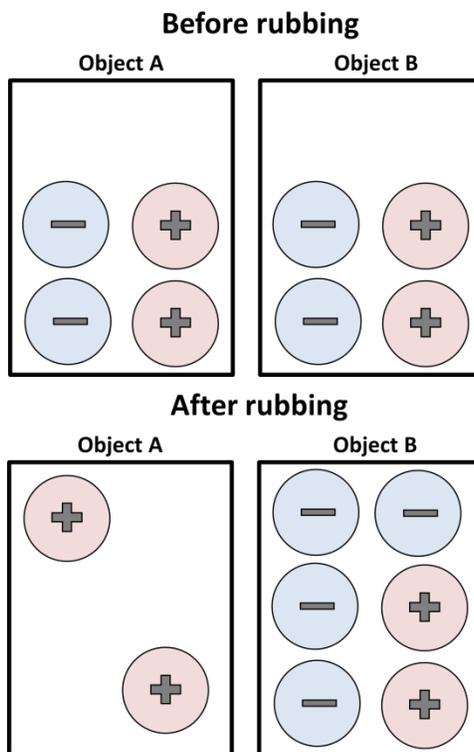
**Materials:**

- Van de Graff generator
- Pie pans w/ Styrofoam
- Magic wand
- Balloons
- Tinsel
- Stopwatch

**Background:**

Scientists use the terms conductors, insulators, and semi-conductors. The labels are used to describe how easily energy is transferred through the object by a moving charge. The spaces between the atoms, as well as the type of atoms, determines whether an object a good conductor or a good insulator (poor conductor).

When two poor conducting materials come into contact with each other, one material may "capture" some of the electrons from the other material. If the two materials are now separated from each other, a **charge imbalance** will occur. The material that captured the electron is now negatively charged and the material that lost an electron is now positively charged. This charge imbalance is where "static electricity" comes from. The term "static" in this case is deceptive, because it implies "no motion," when in reality it is very common and necessary for charge imbalances to flow. Static electricity exists until the two groups of opposite charges can find a path between each other to balance the system out.



**Procedure and Discussion:**

Station 1: Explore Van de Graff generator

- Crank the Van de Graff generator by hand to produce static electricity but be sure not to touch the large metal ball.
- While cranking the generator place the big wand within proximity of the large ball at the top of the generator and notice the arc current between the 2 balls.
- Now that generator is discharged, have a student place one hand on the generator, keeping the other hand free. Crank the generator for 1-3 minutes and rub the balloon against their hair to speed up the process. Ask the students what they feel and see if their hair starts rising
- Have students light up a compact fluorescent bulb. Students can put the metal end directly on the sphere while cranking

What's happening with the Van de Graff generator?

## Energy

The Van de Graaff generator is an electrostatic generator which uses a moving belt to accumulate very high electrostatically stable voltages. Look at how the rubber belt rubs against the wheel at the bottom of the generator – as the rubber and wheel come in contact with each other they produce electrons (negatively charged particles) that are captured by the ball; this is also known as static electricity. The small wand is capturing protons (positively charged particles.)

### Why does your hair stand on end when you touch the Van de Graaff generator?

Because the generator is charging you with electrons and each of the strands of your hair have the same net charge – like charges repel each other, so each of your hair strands want to move away from each other.

### Station 2: Flying Tinsel

- Have students hold the pie-pan by the Styrofoam cup and make sure they aren't touching any of the pie pan
- Crank the Van de Graaff generator by hand and have students place the pie-pan on the main ball. *Students can also use the magic wand too.*
- Now with their charged pie-pan, drop a piece of tinsel and challenge students not to lose the tinsel.
- Using the other tinsel, place on the magic wand and have students power the wand

### Why is the tinsel flying?

It's because the electrostatic repulsion from the pie pan (pie pan and tinsel have similar charges) pushes the tinsel up and holds it in the air even though gravity is pulling it down.

### Station 3: Balloon challenge

- Next, blow up two balloons and tie them. Ask students what will happen if you hold them against the wall (they fall).
- Rub the balloon back and forth against your hair for about 20 seconds. After the allotted time, stick the balloon to the wall. Time whose balloon sticks to the wall the longest.

### Why does the balloon stick to the wall?

Rubbing the balloon generates static electricity the same way as the Van de Graaff generator. Friction can separate positive and negative charges. As negative charges build up on the balloon, they attract the positive charges on the wall. The balloon will stay against the wall until all the static electricity is dispersed.

## **Good Vibrations**

**Passport Question:** What creates sound?

**Passport Answer:** Sound is created by a vibrating object

**Learning Target:** Students understand that sound is created by a vibrating object

## Energy

### Materials:

- Tuning forks
- Ping pong balls
- Water container
- Speakers
- Wine glasses
- Voice Visualizer
- Rags
- Rubbing alcohol
- Oobleck
- Garbage bags

### Background:

Where does sound come from? The short answer is **vibrations**. Sound is created when something vibrates. Vocal cords vibrate to create voices, guitar strings vibrate to create music, doors vibrate when someone knocks on them – it all comes down to vibrations. The vibrations are energy and energy can be transferred from one object to another. Almost anything that vibrates can produce sound. When something vibrates it pushes the particles around it, and those particles in turn push the air particles around them, carrying the pulse of the vibration in all directions from the source. The particles themselves don't move very far, but the transfer of energy can be very fast – about 760 miles/hour in air, depending on the temperature and humidity. So in all the above cases, the energy from the vibrations transfers into the air and the air, in turn vibrates until it reaches your ear. Your eardrum then vibrates, causing other structures in your ear to vibrate. All of this, in turn, stimulates nerves that send impulses to your brain which translates it all into how we understand sound. In this activity students will use different materials to “see” sound waves caused by vibrations.

### Procedure and Discussion:

- Ask students if they have ever seen sound. Tell that today we're going to!
- Tell students that you can feel the sound of your voice by putting a hand on your body while you talk. Where can you feel the most vibrations?

#### Station 1: Tuning Forks

- Have students strike the tuning forks with the rubber mallet (only use rubber side) and bring the forks up to their ears
- Have students place tuning forks in water
- Using scratch paper, have students draw what they see
- Have student strike the tuning fork and this time gently touch the Ping-Pong ball with it.

#### Where can you feel the most vibrations?

When we talk, the sound comes from our voice box which is in the throat. You can feel it best if you place your finger lightly on the middle of your throat.

#### What did you feel when you touched the tuning fork after you hit it?

You felt the tuning fork vibrate and placing next to your ear you were able to hear sound

#### What happens when you touch the Ping-Pong ball with the tuning fork?

## Energy

We saw that sound can move things. The energy in the tuning fork is transferred to the Ping-Pong ball. The amount of energy transferred determines how far the Ping-Pong ball moves—if you strike the tuning fork harder, the ball will move farther.

### Station 2: Voice Visualizer:

- Explain the object and what it does (balloon with mirror attached and a laser pointed to the mirror and you can “see” your voice)
- Have students speak into the voice visualizer making different sounds
- Ask them what part of the object is vibrating
- Use a rag with some rubbing alcohol to disinfect mouth region

### Station 3: Glass Harp

- Demonstrate that glasses with water can make sound by gently wetting your finger and rubbing the rim of the glass
- Ask students to try and tell them to lightly touch and see if they can generate sound
- Depending on the frequency of your rubbing, you may also generate waves in the water

### Why do you think the glass harp makes noise?

By rubbing your fingers on the glass, the sides begin to vibrate and they push air back and forth, creating sound vibrations.

### Station 4: Jumping salt and oobleck

- Open up tone generator on iPad
- Make sure the speaker plays the tone—the speaker should already be set up.
- Place salt on plastic plate and ask students what they think will happen when the music is turned on
- Place a garbage bag on a speaker and put oobleck on top of the garbage bag
- Ask students what they think will happen when the music is turned on

### Why does the salt and oobleck bounce?

Both materials receive sound energy from the speaker and begin to vibrate or jump.

What happens when the speaker plays different tones? A tone is a sound that repeats at a certain frequency and as each tone creates a specific type of vibration. You’re seeing these types of vibrations as the salt and oobleck “jump”

## Musical Coat Hangers

**Passport Question:** Which is the best medium for sound waves to travel?

**Passport Question:** Solid

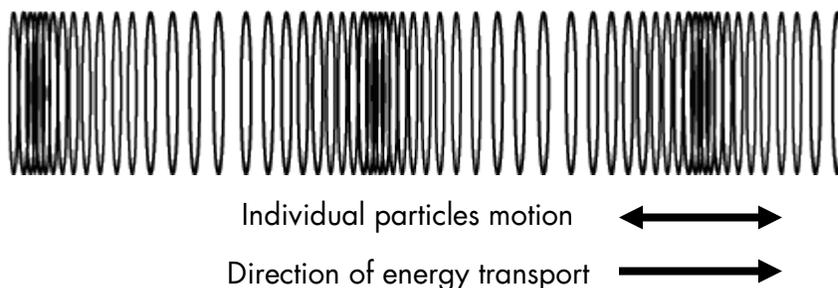
**Learning Target:** Students understand that sound travels in waves and that the speed of sound depends on the medium sounds waves travel in.

### **Materials:**

- Slinky machine
- Jar with ice
- Hangers with strings
- Metal object
- Water container

### **Background:**

Just like light, sound travels in **waves** and a vibrating object creates the waves. A sound wave is described as a **longitudinal wave**, which means the motion of the individual particles of the medium is in a direction that is parallel to the direction of energy transport



A **medium** is a substance or material that carries the wave. The wave medium is not the wave and it doesn't make the wave; it merely carries or transports the wave from its source to other locations.

In the case of a slinky wave, the medium through that the wave travels is the slinky coils. In the case of a water wave in the ocean, the medium through which the wave travels is the ocean water. In the case of a sound wave moving from the church choir to the pews, the medium through which the sound wave travels is the air in the room. And in the case of the stadium wave, the medium through which the stadium wave travels is the fans that are in the stadium.

In this activity, we're going to explore what medium is the best for sound to travel in.

Video Link on longitudinal wave: <https://www.youtube.com/watch?v=j1Q5TFMqsFo>

## Energy

### Procedure:

- Have students create longitudinal waves with the slinky and observe the wave and the Einstein head attached to the slinky. What way is energy being transported? Do the paper strips move parallel or perpendicular to this direction?
- Ask them to find the areas of compression and rarefaction. Show them a picture of a sound wave. See if they can point out areas of compression and areas where it's not compressed
- Have students wrap their fingers around the strings and bump into objects. What do you hear?
- Have students put their fingers in their ears (string still wrapped around)
- Have students bend over so the coat hanger can swing freely and bump it against a wall or chair.
- Try it again, but this time with your forefingers in your ears.
- Experiment by bumping the coat hanger against different objects. What do you hear?

### Discussion:

How does the wave travel along the slinky? What is this kind of wave called?

The energy is being transported from end of the slinky to the other and the paper strips are moving (displaced) in a direction parallel to the wave. This is a longitudinal wave.

What do you hear the first time you bump the coat hanger against something?

What do you hear when you have your fingers in your ear? Is it a different sound?

What objects produce the loudest sounds when bumped?

Why is the sound louder when you have your fingers in your ear?

When we hear a sound, it normally travels through air to reach our ears. But sound can also travel through solids and liquids. Solid objects carry sound waves most effectively, then liquids and then gases.

In the first part of the experiment, the coat hanger hits a metal object and starts vibrating. The vibrations make sound waves that travel through the air to reach the ears and the sound is very quiet. In the second part, the sound waves travel through the string (a solid material) to reach our ears. Rather than traveling through the air, the vibrations can travel through your hands and through your ear directly to the fluid inside your cochlea in your inner ear. Instead of traveling from solid to air and back to solid, the vibrations move from one solid (the string) to another (your bones), and then into the fluid of your cochlea. As a result, the sound you hear is much louder and richer. The hanger makes the same sound in both situations, but in one you provide a path that lets more of the sound reach your ears.

Why the difference between materials?

In some materials, the molecules are tightly packed together; in other materials, the molecules are more loosely arranged. How close the molecules are to one another can affect how easily they can bump into each other to start a vibration moving along.

## Resonance in Motion

**Passport Question:** To make Ball #4 vibrate, you had to shake:

**Passport Question:**

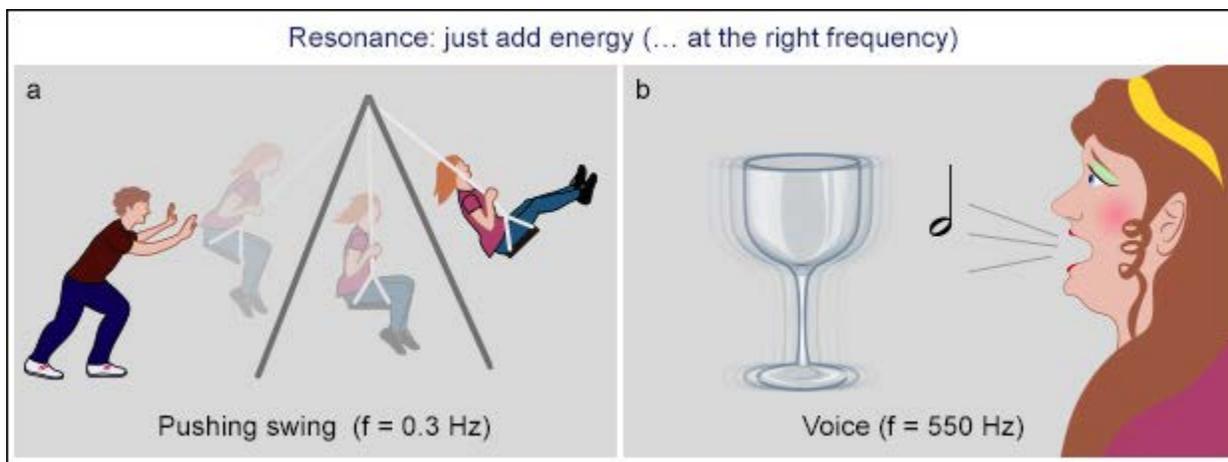
**Learning Target:** Students will understand that a very small force, when applied repeatedly at just the right time, can induce a very large vibration.

### Materials:

- Resonator (wooden dowels with balls)
- Resonance rings
- Pendulum
- Ping pong ball with string
- Resonance boxes

### Background:

A very small force, when applied repeatedly at just the right time, can induce a very large motion. This phenomenon is known as resonance. The example of a swing (that you might sit on at the park) is one of the best ways to describe resonance. With a swing, small pushes applied over time build up a large amplitude of motion. This happens because each push is synchronized to the natural motion of the swing. A forward push is always given when the swing is as far back as it can go. The swing is like a pendulum, which has a **natural frequency** or a frequency that an object likes to vibrate. By applying small pushes at a frequency matched to the natural frequency, we are able to create a large motion. The interaction of the repeating pushes and the natural motion of the swing is what creates resonance. The effect of resonance is that the swing's motion gets large even though the pushes are small. Resonance is not a single thing; it is an interaction between a driving force, the frequency of the driving force, and the natural frequency of an object.



Video Link on resonance: <https://www.youtube.com/watch?v=hcXbyS2Cf2o>

Video link on resonance at the Exploratorium: <http://www.exploratorium.edu/snacks/resonator>

### Procedure:

- Have the student start the pendulum by moving the heavy soda can (one with liquid)

## Energy

- Ask the student what empty cans seem to move more on the pendulum. What is the similarity between the empty can that is moving more and liquid-filled can?
- Have students gently shake the resonator and slowly increase their rate of shaking
- Ask students if all of the balls move when they shake the resonator
- Shake the resonance rings both side to side and up and down. Ask the student if they can make two rings shake at the same time.
- Have the student place the resonant boxes with the open sides facing each other and strike the one not touching the ping pong ball. What do they notice and what do they think happened?
- Have the student strike the box again and then clamp down on the tuning fork to make the box stop vibrating. Now have the student go over to the next box. Ask if they hear anything from the other box.

### **Discussion:**

#### Barton's Pendulum: What part of the pendulum has more motion?

When the student sets the pendulum in motion, all the objects begin to move with the same frequency but with different amplitudes (how high they swing). However, the object that has the same length string as the driver pendulum has the greatest amplitude as it has the same natural frequency as the driving force. Students should see that the string length is about the same for the driving object and the object that has the greatest amplitude.

#### Resonator and Resonance Rings: What's happening?

The frequencies at which each ring or ball vibrates most easily—its resonant frequencies—are determined by several factors, including the ball's mass and wooden dowel stiffness and length. Stiffer objects have higher resonant frequencies, whereas more massive ones have lower resonant frequencies. Ball 4 on the resonator has the thicker dowel and will only vibrate when you shake the resonator at a high frequency.

#### Resonance Boxes: What did you notice about the ping-pong ball?

When you strike one tuning fork, it vibrates at a certain frequency. These vibrations will cause the other tuning fork to vibrate weakly. The other tuning fork will then transfer some of its energy to the ping pong ball and cause it to bounce. When you clamp down on the first tuning fork, you can faintly hear the sound of the second tuning fork if you put your ear next to it.

