# Science Expo 2024

# **Physical Science**

# Activity Descriptions

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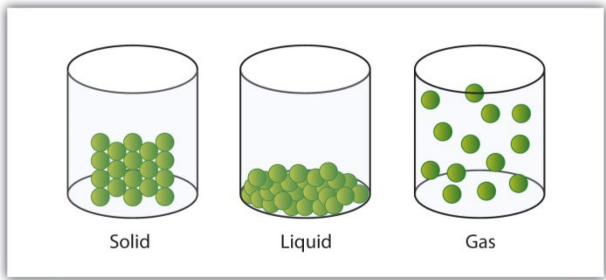
# Properties of Matter Activities

## Matter on the Move

**Passport Question:** What are the three states of matter?
**Passport Answer:** Solid, liquid, gas




**Learning Target:** Students will be able to identify what the three phases of matter look like based on how close the molecules are to one another and how much they are able to move.

**Materials**:

- 3 plastic plates
- Approximately 100 marbles (depending on the size of the plates)
- 3 baskets
- 2 pieces cut to the same size as baskets
- 270 Ping pong balls
- Blow dryer
- Marker (color one ball in each basket)
- Extension cord
- Laminated solid, liquid, gas labels and pictures

**Background**:

It is hard to imagine that matter is made of molecules since it is impossible to see the individual molecules. In this activity, we will show how molecules behave when they are in solid, liquid, and gaseous states.

**Procedure:**

1. Ask students what the three states of matter are. If they do not know use water as an example (when it freezes it turns into ice, the solid state, and when it gets really hot it evaporates into steam, the gas state).
2. After tell them how in science we use models by taking something really big or small and make it a size we can relate to. The marbles represent molecules or atoms, things that you can only see under a microscope. Based on this information, have the students examine the relative space between the marbles on the three plates and determine which state of matter

each plate is.

3. Next, place the blow dryer underneath the ping pong balls so they shift around in the available space. Have the students follow the colored ball, so they can follow the motion of a single "molecule"
4. Have the students match the model to each correct state of matter.
5. A blow dryer provides the heat to simulate the heating and cooling of gas, liquid and solid: the faster the balls move, the hotter the substance. Learners observe how the balls move at a slower rate a lower "temperatures"
6. How do the ping pong balls move differently? Explain that this represents how atoms move in matter when it is in each of the three phases. Have the students match the pictures of solid, liquid and gas to the corresponding pictures.

**Discussion:** *How do the marbles move differently?* *How do the ping pong balls move differently*? Also have them identify each phase by using the models.

Explain that this represents how molecules move in matter when it is in each of the three states.

*What about molecules and this model are different than in real life?*

A model is a representation, generally miniature, to show the construction or appearance of something. Models are used to explain and predict the behavior of real objects or systems. Molecules are tiny, so you can't actually see them moving with the naked eye, this is just a representation, not the real thing.

*What did you notice about the movement of the different phases, did one move more or faster than the other states?*

Gas takes up the whole space and moves around freely, liquid moves around a little but still maintains the shape of its container and solid holds its shape and does not move at all.

If you have more time: Adding heat to a gas increases the internal energy. The molecules of the gas move faster and strike the walls of their container more often, yielding an increase in pressure (force per area). This increased pressure simulated by the faster motion of the balls, which strike the sides of the basket harder and more often. Cooling the gas (lowering the speed or moving the blower farther away from the basket) lowers the internal energy, slowing the motion of the molecules and thus lowering the pressure. If you blow air on one side of the bottom of the basket and not the other, the balls will eventually "condense out." That is, they will form a pile on the side away from the blower, where it is "cooler.

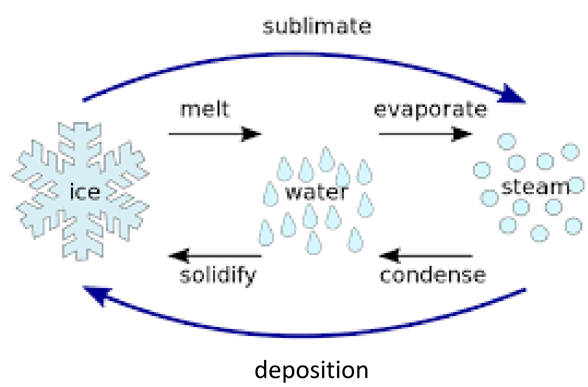
# Phase Change Poppers

**Passport Question:** What is the phase change when a solid changes directly into a gas?
**Passport Answer:** Sublimation

**Learning Target:** Students will understand the phase changes that occur between solids, liquids, and gases, special emphasis on sublimation. They also learn that air compressed in the tube expands during this process.

**Materials:**

- Safety Goggles
- Tall "Airborne" container
- Dry Ice
- Mortar and Pestle
- Screwdriver
- Cooler
- Metal Spoon
- Two plastic bags
- Ice
- Protective gloves
- Laminated word "sublimation"




**Background:**

Dry Ice is the solid form of carbon dioxide, a normal part of our earth's atmosphere. Carbon dioxide is the gas that we exhale during breathing and the gas that plants use in photosynthesis. It is also the same gas commonly added to water to make soda water. Dry Ice is particularly useful for freezing, and keeping things frozen because of its very cold temperature: –109.3°F or -78.5°C. Dry Ice is widely used because it is simple to freeze and easy to handle using insulated gloves. Handling it without insulated gloves can cause frostbite. Dry Ice changes directly from a solid to a gas in normal atmospheric conditions through a process called sublimation. This is why it gets the name "dry ice." The opposite process, which changes carbon dioxide from a gas to a solid, is called deposition.

**Procedure:**

1. Put a small amount of crushed dry ice in one plastic baggy. Place water ice in a second plastic baggy. Have students observe both bags and discuss observations.
2. Have everyone wear safety goggles.
3. Crush a small amount of dry ice with the mortar and pestle (you can leave some in there so you don't have to go in the cooler each time).
4. Using a spoon take a small amount of dry ice from the mortar

and pestle and put it in the "Airborne" container.

5. Making sure that the top of the container is pointed directly at the ceiling, place the lid on the container. Hold the container with one hand. "Fire in the hole…" **Make sure it is not pointed at anyone!**

**Discussion:** *What happened?*

When the solid $CO_2$ sublimates and turned into gas the molecules moved further away from each other, took up more space, and this expansion caused the lid to pop off the container.

*What are the three states of matter?*

SOLID—LIQUID—GAS

*How does matter achieve various states and how does this relate to the process of phase changes?*

Matter changes as a result of heating and cooling. This vocabulary explains the various phase changes.
Freezing: Liquid to Solid (Cooling)
Melting: Solid to Liquid (Heating)
Evaporation: Liquid to Gas (Heating)
Condensation: Gas to Liquid (Cooling)
Sublimation: Solid to Gas (Heating)
Deposition: Gas to Solid (Cooling)

*Can you explain why the lid launched off of the container?*

When dry ice sublimates, it expands. The mass stays the same, but the volume increases.

# Invisible Mass

**Passport Question:** Air has mass.
**Passport Answer:** True or False (Circle one)

**Learning Target:** Students will comprehend that all matter has mass, even gases, just because you cannot see it does not mean that it is not there.

**Materials:**
- One empty 2-liter bottle
- One Fizzkeeper pump cap
- One digital scale

**Background:**

Air is usually invisible, so most of us don't give it much thought at all. In fact, when students are asked about the mass or weight of air, many are perplexed. Air seems like it doesn't have mass, but it does. Ask students, "Can you feel the air around you? Do you think it weighs anything?" We can measure the mass of air by weighing it before and after pumping air molecules into a bottle.

**Procedure:**
1. Attach a Fizzkeeper cap to a 2–liter bottle. Don't pump any extra air into the bottle. Have students feel the bottle, checking for weight and pressure.
2. Weigh the bottle on a triple beam balance and record your findings.
3. Ask students to predict what will change if you pump extra air molecules into the bottle and then measure its mass.
4. Have students use the Fizzkeeper to pump more air molecules into the bottle. They can keep a count of the number of pumps if they like. If you have an accurate balance, students can measure the mass of the bottle as a function of the number of pumps. There is a clear trend, but at some point, the mass will stop increasing as the pump caps can't pump any more air into the bottle. It can take between 45 to 60 pumps to see a change in mass.
5. When the bottle is pumped as full as it can be, have the students pass the bottle around checking again for weight and pressure. What do they notice?
6. Weigh the bottle on the digital scale and compare and discuss your two findings. If there are more molecules in the bottle, there's more pressure and more mass!

**Discussion:** *Why did the mass increase when we pumped air into the bottle?*

Air has mass, because of this air is exerting pressure on our bodies all the time. In this experiment students pumped more air into the bottle creating more mass and pressure. Notice that the bottle is much more firm now. Due to the increased mass, the bottle now resists the pressure from students squeezing it.

# It's a Gas

**Passport Question:** When citric acid and baking soda react, what bubbles out of the solution?
**Passport Answer:** Carbon Dioxide

**Learning Target:** Students will understand that chemicals can break down and form new chemicals when a chemical reaction takes place. This new chemical may end up in a different state of matter during the process.

**Materials:**

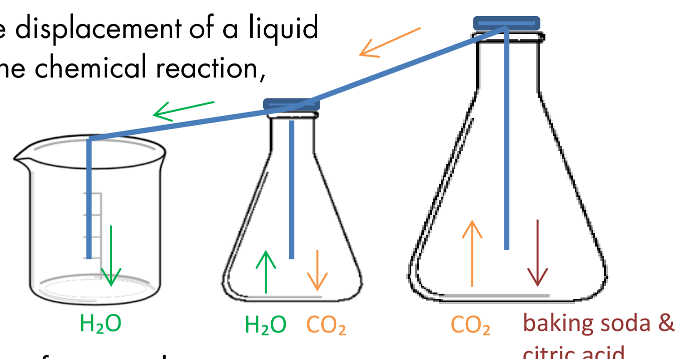
- Three beakers
- One small Erlenmeyer flask
- One large Erlenmeyer flask
- 250 mL of water
- Blue Food coloring
- Teaspoon of baking soda
- Teaspoon of citric acid
- Tube/stopper setup
- Safety goggles
- Water pitcher
- Dump bucket
- Laminated word "Carbon dioxide"

**Background:**

This activity demonstrates a chemical reaction. Reactants (the original substances that react to each other) are changed during the process, so the end result (the product) is a substance that is chemically different from the two reactants. This differs from a physical change because the products of a chemical reaction cannot be easily converted back to the two reactants.

In this reaction, citric acid, baking soda (sodium bicarbonate) and water react to form carbon dioxide. Because the citric acid is unstable, it immediately breaks down into carbon dioxide and water. The fizzing that you see is the carbon dioxide gas bubbling out of the solution.

The second aspect of this experiment is the displacement of a liquid by a gas. When carbon dioxide is produced in the chemical reaction, it exerts pressure on the large flask. Some of that gas flows through the tube into the small flask, which displaces the water. As a result, some water moves through the second tube into the beaker.




**Procedure:**

1. Put on a pair and have students also wear safety goggles.

2. Add 200 ml blue water to the small flask.
3. Assemble the flasks, beaker, and tubing. Put the end of the loose tube in the beaker.
4. Add one teaspoon baking soda to the large flask. Add 50 ml of water. Swirl to mix the contents.
5. Add one teaspoon citric acid to the large flask and quickly replace the stopper. Hold the stoppers on both flasks. <u>Be sure to hold tube that flows into the empty beaker as it can move around due to the pressure of the water.</u>
6. Notice the bubbling gas produced in the large flask. Where is the gas going?
7. Try adding more citric acid. Does the reaction continue?
8. Rinse large flask.

**Discussion:** *<u>Why did the water moved from the flask to the beaker?</u>*

The chemical reaction of baking soda ($C_6H_8O_7$) and citric acid ($C_6H_8O_7$) and water ($H_2O$) produces the gas carbon dioxide ($CO_2$). The gas moves through the tubing into the flask with the water and displaces the water. Explain that gas takes up space and can exert pressure, even if it is not visible. For example, gas pressure inflates a balloon or escapes as fizz when you open a soda. Explain that what they saw was a chemical reaction and a phase change from liquid to gas.

# Slime Time

**Passport Question:** What type of fluid acts like both a liquid and a solid?
**Passport Answer:** A non-Newtonian fluid/Oobleck

**Learning Targets:** Students will learn that a non-Newtonian fluid has physical properties that act like a solid sometimes and a liquid at others.

**Materials:**

- Sheet
- Measuring cups
- 1 cup cornstarch
- Large bowl or pan
- Green Food coloring
- ½ cup water

**Background:**

Oobleck slime is a suspension (a liquid containing small solid particles that easily separate out of the mixture) of cornstarch and water. Under certain conditions, this substance has the properties of both a liquid and a solid. It is called a non-Newtonian liquid because sometimes it doesn't behave like a liquid should, according to Isaac Newton's laws. When struck, most liquids splatter and splash. However, when a non-Newtonian liquid is struck by a force, the physical structure of the material changes, increasing the thickness of the solution, making it behave more like a solid.

**Procedure/Discussion:** Try different experiments with the oobleck in the pan.
Put a small plastic toy on the surface. *Does it sink?* Yes.

*How does the substance react when you press on it quickly?* It sinks slowly and acts like a solid by resisting the student's hand. *Slowly?* It sinks faster, it acts like a liquid and there is no resistance on the student's hand.

*What happens when you slap your hand or punch your fist into the substance?* It acts more like a solid, it resists the student's hand.

*When does it act like a solid or a liquid?* It acts more like a liquid when there is no pressure and more like a solid when pressure is added.

*Can you roll a small amount of it into a ball?* Yes. What happens if you set the ball in your hand? It loses its shape and drips like a liquid.

*What happens if you put just a tiny amount between your fingers and then rub your fingers* *together?* It holds its shape and can be moved around like a solid.

# Magic Hat

**Passport Question:** What is the definition of density?
**Passport Answer:** How tightly packed a material is and how much space it takes up or Mass/Volume.

**Background:** The density of a material is its mass per unit volume. Mathematically, density (ρ) is defined as mass (m) divided by volume (V): $\rho=m/V$. Another way to conceptualize this is by thinking of how packed together the molecules of a material are.

In general, density can be increased or decreased by changing either the pressure or the temperature. Increasing the pressure always increases the density of a material. Increasing the temperature generally decreases the density, but there are notable exceptions to this generalization. For example, the density of water increases between its melting point at 0 °C and 4 °C; similar behavior is observed in silicon at low temperatures. Pressure has a much stronger effect on the density of gasses than on the density of solids or liquids.

**Learning Target:** Students will learn that objects with the lowest densities will rise to the top of a mixture while objects with greater densities will sink to the bottom.

**Materials:**

- Two ping-pong balls
- Two metal balls (same size as ping-pong balls)
- Bag of pinto beans
- Magic Hat

**Procedure:**

1. Pour the beans into the hat.
2. Bury the ping-pong balls under the beans and lay the metal balls on top. Make sure students don't see this for more of a wow factor!
3. Ask students, "What do you think will happen if we shake the hat?"
4. Gently shake the hat. The metal balls will sink to the bottom and the ping-pong balls will rise to the top.

**Discussion:** *Have students make observations and try to explain what happened.* Then take out one of each item and pass around to the students.

*What do you notice about these three items?*

Introduce the concept of density. An object's density is its mass divided by its volume. Another way to think of this is how packed together the molecules in an object are. Of the three objects we experimented with, the metal ball has the highest density, the ping- pong ball has the lowest density, and the pinto bean is somewhere in between. As a result, the metal balls sank to the bottom of the bowl and the ping-pong balls “floated up” or “rose up to the top”.

*Can the students think of three other objects that we could do the same experiment with?*

Students could use rice, golf balls, and styrofoam balls. Answers will vary.

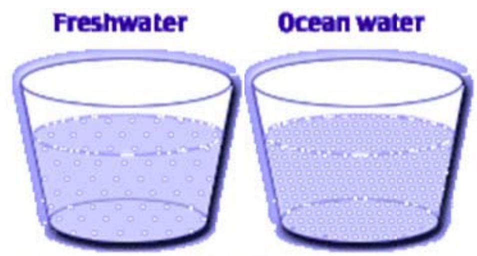
# Floating Golf Ball

**Passport Question:** Which is more dense, freshwater or saltwater?
**Passport Answer:** Freshwater or Saltwater (Circle one)

**Learning Target:** Students will learn that even water can have different densities. Saltwater is more dense because it has more molecules in it taking up space.

**Materials:**

- 16 oz plastic cups (5)
- Salt (5 lbs)
- Plastic spoons (2)
- Water
- Water pitcher
- Golf balls (10)
- Dump bucket
- Beaker (3)



Freshwater is made up of water molecules with a little bit of salt in it. Ocean water is made up of water molecules with a lot of salt. When put in the same container, denser materials fall to the bottom and less dense materials sit on top.

**Procedure:**

1. Pass out one plastic cup and one spoon for each group of students.
2. Fill the cups 1/2 full with water
3. Have the students make a hypothesis: Will the ball sink or float when it is placed in the water?
4. Test the hypothesis by placing the golf ball in the water. It will sink to the bottom of the cup.
5. Talk to the students about changing the density of water using salt. By adding salt, we will increase the density of the solution. Will this make a difference?
6. Have students experiment to see how much salt is needed to make the ball float. **Make sure to mix the solution so that the salt can dissolve in the water! It takes about four spoonfuls of salt to make the ball float in half a cup of water.**
7. You may have to occasionally stir saltwater demonstration beakers to keep the salt in suspension.

**Discussion:** *Why doesn't the ball float in fresh water?*

Initially, the golf ball is denser than the water, so it sinks to the bottom.

*Why the ball floats in the salt water?*

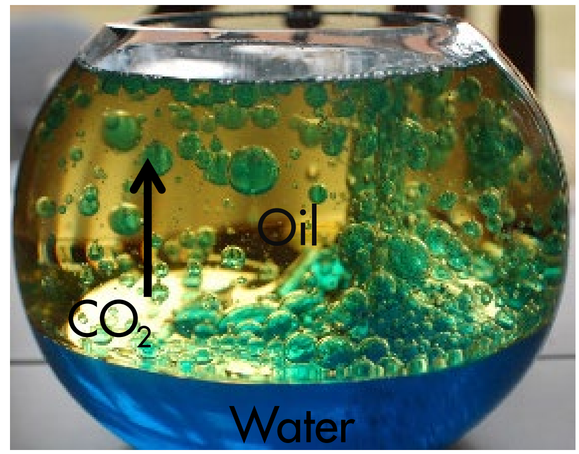
On a molecular level, the salt is filling the microscopic spaces that exist between water molecules; this process packs the atoms that make up the solution together, which increases the density of the solution to the point that it is greater than the density of the golf ball. This is similar to what you experience when swimming in salt water. Ask the students if they've ever tried swimming in the ocean. Unlike when swimming in a pool, they can float almost effortlessly due to the density of the water.

Properties of Matter

# Gassy Lava Lamp

**Passport Question:** What is a chemical reaction?
**Passport Answer:** A process that rearranges molecular structure of a substance.

**Learning Target:** Students will learn that liquids have different densities. They will learn that oil is less dense so it sits on top of water. They will also learn that a gas is even less dense so it will bubble out of the mixture.




**Materials:**

- 4 clear plastic bottles
- 4 bottles of dark food coloring
- 2 bottles of vegetable oil
- ½ tablet of Alka-Seltzer per bottle per experiment
- Room temperature water
- Flashlight

**Procedure:**

1. Bottles prepped beforehand filled with ½ colored water and ½ oil
2. Have the students shake a bottle as hard as they can and ask if they think it will settle back to oil on top and water on the bottom (It takes around 30 seconds to settle)
3. Then break an antacid table in half and drop it in and watch what happens, ask the kids if they can tell which are gas droplets and which are water droplets?
4. Put the flight light underneath or behind it for greater affect

**Discussion:** *Do oil and water have different densities? How can you tell?*

The density of a liquid determines whether it will float above or sink below another liquid. A less dense liquid will float on top of a more dense liquid. Some liquids will mix together easily, and others will stay separated. Oil is less dense than water so it floats on top of the other liquid. Even if you shake it thoroughly it will settle back out to their different layers of density.

*What happens when you add the antacid to the bottle? Why do you think this happens?*
A chemical reaction is taking place. $CO_2$ is formed, rises and releases out of the mixture because it is a gas and is the least dense substance in the mixture.

*Would the same thing occur if the antacid was put into only oil?*
No, the chemical composition of oil is different so $CO_2$ would not be formed.

*What happens if the lid is screwed on after the tablet has been added?*
The $CO_2$ remains trapped in the bottle creating more pressure. Once bottle is opened the pressure is released. The sound is the same as when you open a new bottle of soda, in both cases carbon dioxide is being released into the air.

# Stacking Colors

**Passport Question:** Liquids that are more dense will have a higher _____
**Passport Answer:** Viscosity

**Learning Target:** Guests will learn that the fluids that are more dense will sink while fluids that are less dense will rise.

**Materials:**

- Small test tubes
- Test tube rack
- Pipettes
- Dawn dish soap
- Water
- Rubbing Alcohol
- Lamp oil
- Light Karo Syrup
- Vegetable oil
- Honey

**Procedure:**

1. Tell guests that they will be trying to stack the liquids on top of each other in their test tubes.
2. Explain that they should be stacked from highest density on the bottom to the lowest density on the top.
3. Explain that liquids of different densities won't mix as long as the liquid with the lower density is sitting on top of the liquid with the higher density. Show how liquids with higher densities are more viscous (move more slowly) compared to lower density liquids.
4. Give each guest a pipette and test tube. They will try to stack the liquids in order from highest density to lowest density.
5. After they have all the liquids in their test tube, observe their results.

**Discussion:**

How did the guests determine which liquids were most dense?

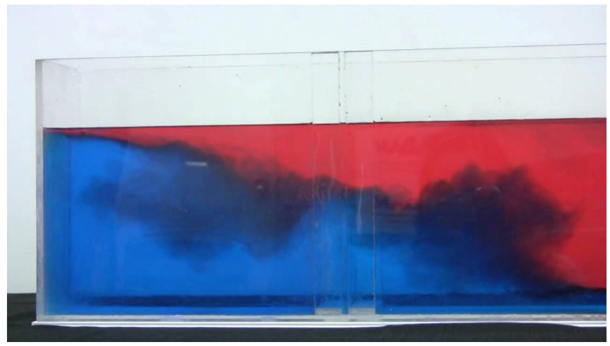
*Liquids that are more dense will have a higher viscosity or "thickness" than liquids that are less dense.*

*Can the guest think of any other liquids that are very dense? Liquids that are less dense?*

# Hot and Cold Density

**Passport Question:** How can you change the density of water?
**Passport Answer:** You can change the density of water by changing its temperature.

**Learning Target:** Students will comprehend that you can alter the density of water by changing its temperature. Cold water has a higher density so it sinks while warmer water is less dense so it floats above the colder, denser water.



**Materials:**

- Hot water dyed yellow (jet boil or hot pump)
- Cold water dyed blue
- Ice
- Cooler
- Water pitcher
- Seiche Model (clear plastic model with divider)
- Light
- Pipette
- Dump bucket
- Extension cord
- Rags

**Procedure:**

1. Place the hot water on one side and the cold water on the other. **Try to keep the levels equal as you add the water.**
2. Remove the breaker from between the two liquids and allow them to flow together
3. Have to students go to eye level with the water so they can see the stratification.

**Have the hot water be as hot as possible and keep adding ice to the cold water. The greater the difference in temperature the less the colors will blend.

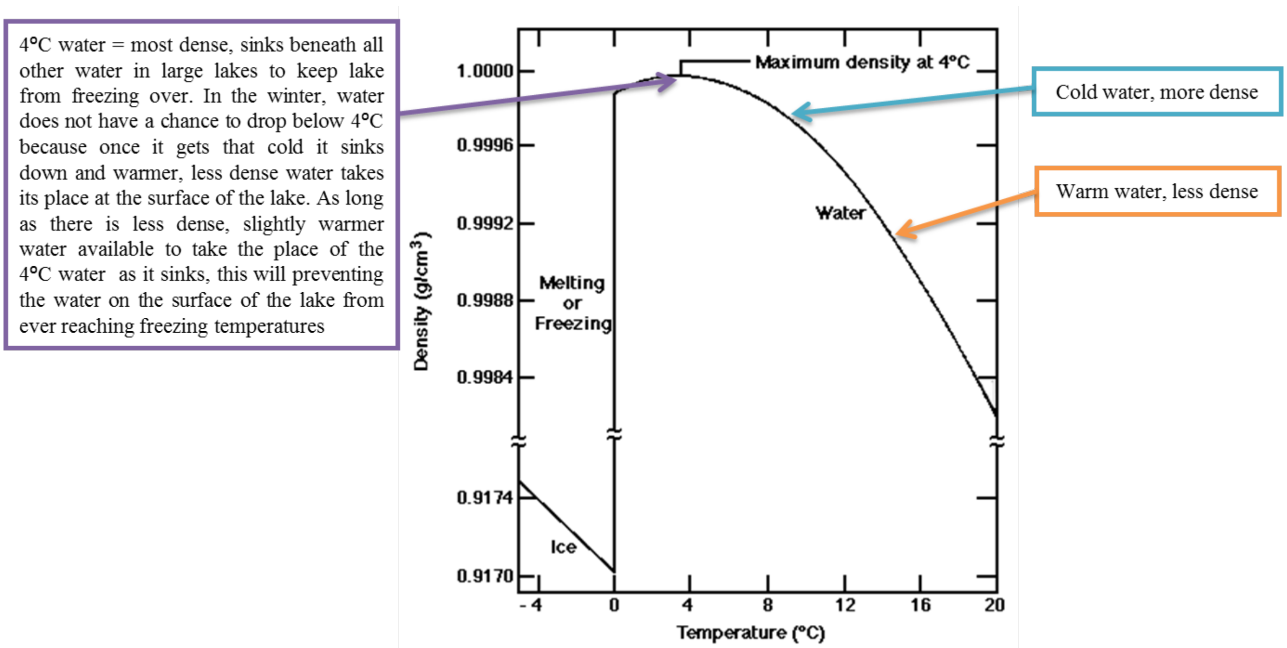
**Discussion:** *What they think would happen if you placed the cold blue water on top of the hot yellow water?* Try adding a pipette of cold, blue water and observe what happens. The cold, blue water will sink to the bottom where the water is the same density.

*What does your experiment show the students about the relative densities of hot and cold water? Based on your observations, would you expect equal volumes of hot and cold water to weigh the same? Which temperature of water would you expect to weigh the most?*

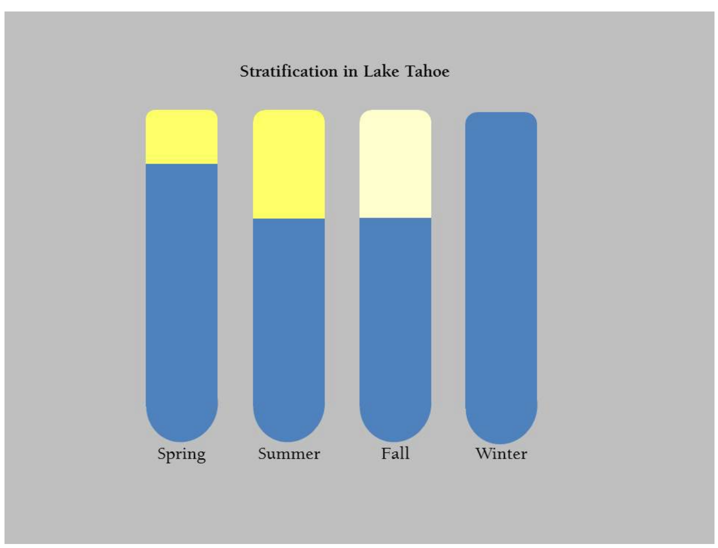
Cold water is has a higher density than warm water. The molecules of the cold water are more compact causing it to weigh more and sink below the warmer water. Water is most dense at 4°C or 39°F, therefore water that is warmer than this temperature will float on top.

Relate hot water and cold water to lake mixing. Ask students about swimming in summer, do they feel the warm layer on top and the cold on the bottom?

When the water on the top of the lake is warmer than the water at depth, the lake does not mix very much. This is often the case in warmer months because the sunlight warms the top layers of water, but does not reach the depths of the lake. When the air is very cold in winter and cools the surface of the lake, the cold water sinks to the depths and causes the lake to mix.




Density of water (and ice) as a function of temperature. Note maximum density of water at 4%C. (Data from Pauling 1953 and Hutchinson 1957: 204.)



# Changing the Density of an Object

**Passport Question:** Can two objects have the same volume but different densities? Why?
**Passport Answer:** Yes, because they have different mass

**Learning Target:** Students will understand that you can change the density of an object by increasing the mass a little and volume a lot.

**Materials:**

- regular coke cans
- diet coke cans
- water
- small water-resistant item that sinks
- large plastic container
- bubble wrap
- tape
- cloth/ rag

**Procedure:**

1. Holding the cans sideways, place a can of regular cola and a can of diet cola in the water. Observe. What do they notice? Why does one can sink and one can float?
2. Remove cans and use a paper towel to dry off the outside of the regular coke can
3. Cut a piece of bubble wrap so that it is as wide as the height of the can. The length of the bubble wrap should be just enough to go around the can once.
4. Wrap the can in bubble wrap and use tape to attach it securely.
5. Place the modified can in the water. Can you make the can float? Or what can you do to make the floating can sink?

**Discussion:** *Tell students that the cans are made of the same material and have the same volume and are filled with the same amount of soda. Why do you think one can sinks and the other floats? Since the volumes are the same, what must be different about the sodas?*

The mass of the regular soda is greater than the mass of the diet soda. The regular soda has 30-40 grams of sugar dissolved in it. The diet soda is sweetened with an artificial sweetener that takes many fewer grams to achieve a similar level of sweetness.

*How can they make the can of regular coke float without opening the can?*
Students may propose shaking the can, since this doesn't change the mass, they can try this. Students may suggest putting something on the can to increase its volume. Ask students if they can think of something that would add volume to the can but not add much weight. Students should realize that mass is increased slightly, while volume is increased much more. When the density of this larger combined object is less than the density of water, it floats.

*Ask students to use the terms mass, volume and density to explain why adding the bubble wrap helped the can float.* Be sure students understand that it is the combined mass and volume of the can and the bubble wrap that makes the can and bubble wrap object less dense than water so that it floats.

Tell students that life jackets work in a similar way. Ask students why a life jacket helps a person float. Explain that a person wearing a life jacket floats because of the combination of the body and the life jacket is less dense than water.

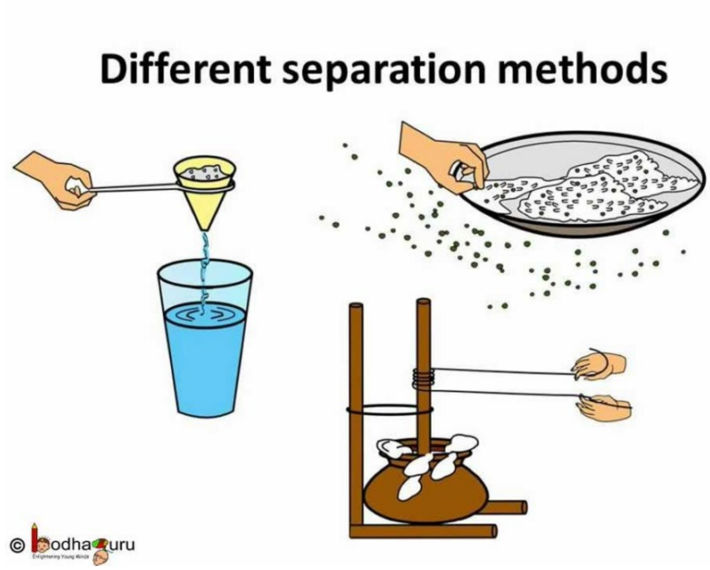
# Separation Anxiety

**Passport Question:** Are mixtures separated by chemical or by physical means?
**Passport Answer:** Chemical or Physical (Circle one)

**Learning Target:** Students will understand that mixtures can be separated physically. The density or magnetic properties of an object can be used to help separate them from a mixture.

**Materials:**

- Two cups sand
- One cup of small plastic beads
- One cup iron filings
- One cup poppy seeds
- Four magnets
- One plastic tablespoon
- One plastic cup
- Water and water pitcher
- One small strainer
- One stirring rod
- One small plastic bucket for waste
- Four petri dishes




**Background:**

Chemists often separate substances by their different properties or characteristics. Plastic beads, water, poppy seeds, iron fillings and sand have different densities. Substances with a lower density than water, such as plastic beads will float on water. Objects, such as sand, with a greater density than water will sink. Many substances, like salt, dissolve in water, while others, like plastic beads, sand, and iron fillings, do not. If you heat salt-water or leave it in the sun, the water evaporates, leaving solid salt behind. Some objects, like iron fillings, can be pulled out of mixtures using their magnetic properties.

There are probably many ways to separate out the 4 components of the mixture in this activity. One straightforward way is to pick out the beads and use a magnet to pull out the iron filings. Then you can add water to the remaining mixture, which will dissolve the salt. Mix the solution and decant it through a filter. The poppy seeds are less dense than the sand and will tend to get caught in the filter rather than staying at the bottom with the sand. Both of these can now be collected and dried off. Evaporating the salt water by boiling or waiting a few days will recover the salt. The basic properties of size, magnetism, density, and solubility are common features used to recover pure substances from the mixtures that natures supplies

A similar method to the one used in this experiment is used at many recycling facilities to separate materials. Previously it was necessary to separate all recycled materials at home before pickup, but now many can be mixed together and separated at the recycling center. Magnets can be used to separate many metals; water can separate materials with a higher density from those of a lower density.

**Procedure:**

1. Put a scoop of mixture in front of each student (into a petri dish)
2. Tell the students there are four components in the mixture and they need to separate them using the tools in front of them
3. First have them use the magnet to remove the iron fillings
4. Then place the mesh over the plastic cup and slowly pour the mixture over it. The beads will stay in the mesh.
5. Next pour a little water into the cup. The poppy seeds will float and the sand will sink. Explain how you can scoop the poppy seeds out with a spoon and boil the water off to get the sand. Dump the wet mixture into the waste container. Water can be boiled off it at the end to reuse it.

**Discussion:** *What properties helped you separate sand, beads, poppy seeds, and iron fillings?*

Explain that all of these objects are part of a mixture because they are not chemically joined together – they can be separated by physical means. The different materials density played a role in separating the objects. The poppy seeds are less dense so they float, while the sand sinks. Magnetism allowed them to remove the iron fillings using a magnet.

*Chemists spend much of their time separating mixtures and solutions. Can the students think of real life examples?*

Separating oil from water after an oil spill, removing environmental contaminants, etc.

# Exothermic vs. Endothermic

**Passport Question:** _______________ reactions release energy in the form of heat. (For example, Calcium chloride mixed with water feels warm and can be used to melt ice.) _______________ reactions absorb energy in the form of heat. (For example, Urea mixed with water feels cold.)
**Passport Answer:** Exothermic, Endothermic

**Materials:**
- Two 250-ml Erlenmeyer flasks
- Two 1-tsp measuring spoons
- Two small plastic funnels
- Two 250-ml beakers
- One 25-ml graduated cylinder
- Calcium chloride pellets
- Urea
- Two colors of masking tape. Instant heating packs, as an example
- Safety goggles
- Water and water pitcher

**Background:**

In this activity, students will learn that some reactions release energy in the form of heat and others absorb energy, making their surroundings colder. There are practical uses for these kinds of chemical reactions. Calcium chloride, for instance, produces heat when it reacts with water. This is why it is used in deicers; it melts snow or ice.

Exothermic reactions produce heat because energy is produced when chemical bonds are broken and formed. Endothermic reactions absorb heat while breaking and forming new bonds, which is why they cause their surroundings to feel colder.

**Setup:**
1. Label 250-ml squirt bottle "Water"
2. Using one color of tape, label a flask, a funnel, a teaspoon, and a beaker "Calcium Chloride."
3. Using the other color of tape, label a flask, a funnel, a teaspoon, and a beaker "Urea."

**Procedure:**
1. Always wear safety goggles.
2. Use the graduated cylinder to pour 15 ml of $H_2O$ into each flask.
3. Use the funnel to add 1 teaspoon urea to the flask marked "urea", and 1 teaspoon calcium chloride to the flask marked "calcium chloride." (Be sure to keep measuring spoons and chemicals separate!)
4. Swirl both flasks 5-10 times.

5. Touch the bottoms of the flasks to feel temperature changes.
    a. Which reaction is warm, or exothermic? (Calcium chloride)
    b. Which reaction is cold, or endothermic? (Urea)
6. When finished, empty both flasks and rinse with water.

**Discussion:**

*Which of these chemicals do you think is sprayed onto airplane wings to melt?*
Calcium chloride.

*Which of these chemicals works like the chemical used in first aid instant cold packs?*
Urea.

*Do the students understand the difference between exothermic and endothermic?*
Answers will vary.

# Forces and Motion Activities

## Van de Graaff generator

The Van de Graaff generator is a classroom classic with a surprising heritage in cutting-edge particle physics. As well as making your hair stand on end, these machines were used to accelerate particles through millions of volts.

Apparatus

1 × Van de Graaff generator
1 × electrically-insulating stool
Some confetti, or aluminium foil, or foil cake trays

The demonstration

This demonstration involves high voltages, and so it should never be done by anyone with a pacemaker or other internal electrical device, or who thinks they might be pregnant.

The first part of this demo requires a volunteer from the audience. It works best on someone with long, light-coloured hair free from ties and styling products: light hair is often thinner, which means it will stand up more easily, and is also easier to see. Don't pick on an individual (they might be pregnant, or just shy!), but if you could encourage someone fitting that description that gives you the best chance of success.

Give your volunteer a round of applause and find out their name. Check that they aren't wearing any metal jewelry etc, and ask that they remove it if so. Put it safely to one side.

Get the volunteer to stand on an electrically-insulating stool. Place one hand on top of the generator dome, and get them to hold out their other hand flat. In this, place some confetti, pieces of aluminium foil, or cake tins. If you have a suitable light, dim the main lights and illuminate their head from behind to emphasise the forthcoming hairdo.

Check they're feeling OK, turn on the generator, and stand back. The only thing they need to do is not to take their hand from the dome and, should they do so, not try to replace it (or they'll get a shock!).

The objects in their hand will leap out and, by the time that's finished, their hair should be standing up pretty nicely. Get them to shake their head around a bit to encourage this.

Get the volunteer to take their hand off the dome, and jump down with both feet, and give them a round of applause!

How it works

The rubber belt inside the Van de Graaff generator runs between two rollers made of different materials, causing electrons to transfer from one roller to the rubber, and from the rubber onto the other roller, by the triboelectric effect. Brushes at the top and bottom provide a source and sink for these charges, and the top brush is electrically connected to the Van de Graaff's dome and so the charge will spread out across the dome.

This accumulated charge would like to distribute itself over as large a volume as possible, and so it will also spread out across anything you connect to the metal dome, including your volunteer. The reason it's important to stand them on something electrically-insulating is that the charge would like even more to spread out over the whole Earth, and connecting them to that will both massively reduce the effect, and also cause an electric shock as the current flows from the Van de Graaff to earth through its unfortunate human intermediary.

When insulated, the build-up of charge on the volunteer causes forces light objects to spread out as far as possible too, causing the confetti or foil to leap from their hand and then causing the individual hairs on their head to stand up. When they jump off the stool, the charge immediately flows to earth and their hair will immediately return to normal.

To work out the voltage of the Van de Graaff generator, and thus the voltage on our volunteer, we can use the length of the sparks in combination with the breakdown voltage of air—the voltage required to cause air to dissociate into ions and become conductive. This voltage is about 30,000 V/cm for dry air (hot, humid or lower-pressure air will tend to spark more easily). Sparks from the Van de Graaff are typically a few centimetres long, giving a voltage between 50,000 and 150,000 V.

Their propensity to generate sparks is the fundamental limitation of Van de Graaff accelerators, or indeed any accelerator design based on a large, static voltage. Those used for research managed to get up to over 20 MV by clever use of insulating materials, right down to careful choice of the gas in which the generator sits to minimise the chance of sparks. A Van de Graaff can thus be used to accelerate particles up to reasonably high energies: moving an electron through 1 V gains it an energy of 1 eV, so energies of over 20 MeV are achievable by this method (and more if accelerating nuclei with greater than a single electron charge).

# Hoverboard

Passport Question: What is Newton's 1st law of motion?

Passport Answer: A body at rest stays at rest, and a body in motion stays in motion unless other forces act on it.

Learning Target: Students will learn Newton's three laws of motion.

Background Information:

Newton's three laws:

1. Law of inertia: "Objects at rest want to stay at rest, objects in motion want to stay in motion"
2. The relationship between an object's mass (m), its acceleration (a), and the applied force (F) is: F = ma. Acceleration and force are vectors; in this law the direction of the force vector is the same as the direction of the acceleration vector.
3. For every action there is an equal and opposite reaction.

Materials:

- Hovercraft
- Ball

Procedure:

1. 1st law- Pull the person on the hovercraft, explain how a frictionless environment will cause this theory to hold true. "Objects at rest want to stay at rest, objects in motion want to stay in motion"
2. 2nd law- Make the person on the hovercraft, heavier or lighter by giving them the medicine ball and show more force is needed to get them moving or the same force will move them slower if more mass is added. "To increase acceleration do you want more mass or less mass? Less mass."
3. 3rd Law- Demo this by throwing a ball back and forth. The person on the hovercraft will be pushed backwards when they throw the ball.

Discussion:

The hover craft mimics a frictionless environment so Newton's theories can hold true. In an environment with friction the variable of friction must be added.

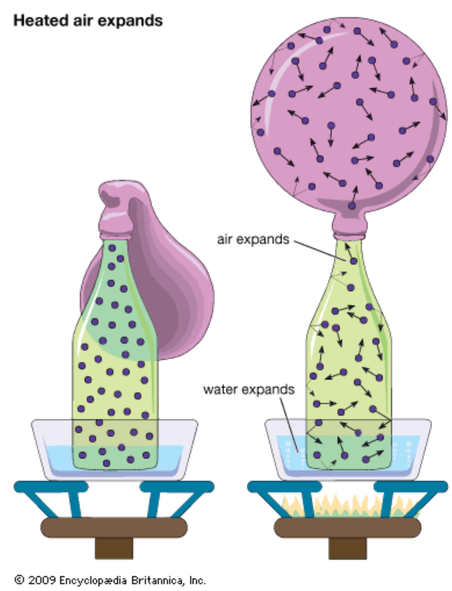
# Automatic Balloon Inflator

**Passport Question:** Which takes up more space?
**Passport Answer:** Hot air or Cold air? (Circle one)

**Learning Target:** Students will learn that air expands when heated, and contracts when cooled.

**Background information:**
We can't see air, yet it is all around us. Air takes up space and can expand and contract with changes in temperature.

The pressure exerted by a gas is directly related to the temperature. The higher the temperature the more pressure exerted. This is because higher temperatures "excite" the molecules and allow them to move around more, and push on their surroundings. The faster they move around, the more energy they have to do work. This energy is kinetic energy, the energy of motion. When air molecules are cooled down, they have less kinetic energy; therefore they move around less, do less work, and exert less pressure on their surroundings.



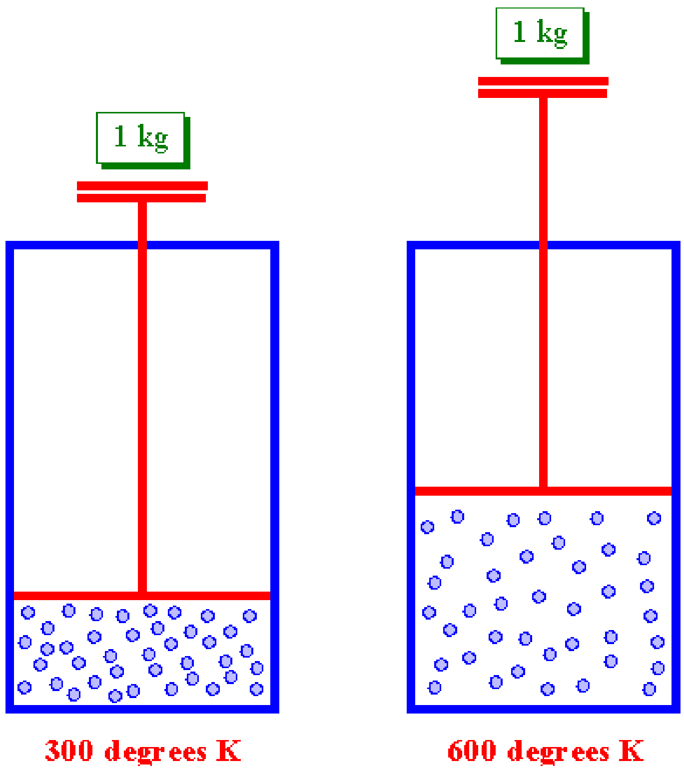

**Materials:**
- (1) Empty plastic bottle
- Balloon
- Hot water
- Ice water
- (2) clear containers

**Procedure:**
1. Place balloon over the neck of the bottle.
2. Ask students what they think will happen if you put the bottle in the hot or cold water?
3. Place the bottle into the hot water. The balloon will start to inflate. Ask the students what they think is happening?
4. Remove the bottle from the hot water and place it directly into the ice water. The balloon begins to deflate. Ask the students what they think is happening?

**Discussion:** *What happened to the balloon when it was in cold water? Hot water? Why do you think this happened?*

The air molecules in the bottle heat up or "excite" when placed into the hot water. When they warm up, they move around more and move out of the bottle and into the balloon, thus filling the balloon.

When we take the bottle out of the hot water, the air molecules cool down and move less and return to the bottle, thus shrinking the balloon.



# Mystery Candle

**Passport Question:** Is the pressure higher or lower inside the flask?
**Passport Answer:** Higher Lower (Circle one)

**Learning Target:** Students will understand that air exerts more or less pressure on a system depending on the temperature of the gas.

**Materials:**
- Baking pan
- Water
- Food coloring
- Candle (tea light)
- Lighter
- Erlenmeyer Flask

**Background Information:** We can't see air, yet it is all around us. Air takes up space and can expand and contract with changes in temperature. The pressure exerted by a gas is directly related to the temperature. <u>The higher the temperature the more pressure exerted</u>. This is because higher temperatures "excite" the molecules and allow them to move around more, pushing on their surroundings. The faster they move around, the more energy they have to do work. This energy is <u>kinetic energy</u>, the energy of motion. When air molecules are cooled down, they have less kinetic energy; therefore they move around less, do less work, and exert less pressure on their surroundings.

A high pressure area is a location where high force is being exerted over a certain area. <u>Air or water prefers to move from a high pressure area to a low pressure area where less force will be exerted on it.</u>

**Procedure:**

1. Fill the pan with about an inch of water. Add 2-3 drops of food coloring to the water. (this makes the movement of water easier to see)
2. Place the candle in the middle of the water.
3. Light the candle.
4. Have a student cover the candle with the Erlenmeyer flask.
5. Have the students make verbal observations about what is happening to the water around the flask, the candle flame and the movement of the water.

**Discussion:** *What happened inside the flask? What happened outside the flask?*
The candle flame heats the air in the vase. This hot air expands and exerts more pressure on the vase until it pushes out of the vase – which is why we see bubbles.
Because so many air molecules escaped, we have less air molecules inside the flask (lower pressure) compared to outside the flask (higher pressure).

Remember that air in a high pressure area prefers to be in a low pressure area; (similar to you being in a crowded room versus an empty room!) therefore it pushes down onto the water trying to get into the flask. Because the water is in the way, the water gets pushed into the flask.

*A common misconception regarding this experiment is that the consumption of the oxygen inside of the bottle is also a factor in the water rising. While there is a possibility that there would be a small rise in the water from the flame burning up oxygen, it is extremely minor compared to the expansion and contraction of the gases within the bottle. Simply put, the water would rise at a steady rate if the oxygen being consumed were the main contributing factor, rather than experiencing the rapid rise when the flame is extinguished.

# Magic Card

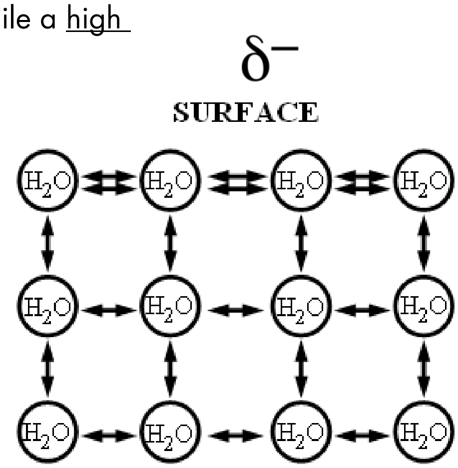
**Passport Question:** What bond is breaking when the water spills out?
**Passport Answer:** Adhesion **OR** Surface tension

**Learning Target:** Students will learn that the atmosphere exerts pressure on objects. Cohesion and adhesion are two types of strong bonds that form between water molecules and other surfaces.

**Materials:**

- Water
- Medium sized mason jar
- (2) Jar bands with mesh of different grades
- Note card

**Background information:**
Atmospheric pressure is defined as the force per unit area exerted against a surface by the weight of the air above that surface. The atmosphere weighs down on you with a force of 14.7 pounds per square inch, or about a ton per square foot. We're largely unaware of this tremendous pressure because it's been with us since we were born.
A low pressure area is defined as an area with few air molecules, while a high pressure area is an area with many air molecules.



Surface tension—molecules at the surface form stronger bonds

Water is a polar molecule, meaning that one end has a partial negative charge and the other end has a partial positive charge.

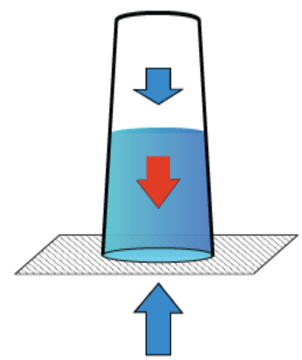
In a water molecule the Oxygen atom steals electrons from the hydrogen atoms creating a dipole, a molecule that has a positive end and a negative end. Think about each water molecule like it is a tiny magnet, where like charges repel each other and unlike charges attract, you'll see that there is a small attractive or cohesive force between each water molecule.

At the surface, there are fewer water molecules to cling to since there is air above, not more water. These surface molecules experience a net inward force due to the molecules below pulling down, but no molecules above pulling up to balance it out.
This force is responsible for surface tension, where the molecules contract and resist being stretched or broken.

These positive and negative ends on a water molecule are also attracted to other materials, this is called adhesion.

**Procedure:**

1. Fill the lidless jar to the top. Place the card over the top of the jar.
2. Quickly turn the jar upside down, holding onto the card.
3. Carefully remove your hand from the card. The card should stay adhered to the jar.
4. Still holding it upside down, slowly slide the card off of the cup. The water will spill out.
5. Repeat steps 1-4 with the smaller grade mesh lid screwed on.
6. Remove the card. The water does not spill out!
7. While still holding it upside down, have the students gently tap the mesh. Then tilt it slowly to empty the water.
8. Fill the jar, screw on the mesh lid. Ask the students what they think will happen when you flip it WITHOUT the card?
9. Quickly flip the jar. Some water spills out but eventually stops.
10. Repeat steps 1-4 with the larger grade mesh lid screwed on.



**Discussion:** *How does the card stay on the cup?*
The atmospheric pressure pushes up on the card, keeping it from falling. Imagine the air molecules all around us randomly colliding with the note card, continuously pushing it against the glass.
*Isn't the weight of the water enough to overcome that atmospheric pressure keeping the index card up?*
No, it's not. This is due to the air pocket left at the bottom (now top) of the glass. In this space, there are not very many air molecules (low pressure area). With so few air molecules present, they do not push down very much on the water. This prevents the water's weight from pushing the card down. Because there are more air molecules pushing up on the card (high pressure area), it exerts more upward force than the water exerts downward.

*Why doesn't the card slide off the cup? (Like a wet cup slides on a counter top?)*
Water's strong surface tension bonds helps form a seal around the glass rim. The water molecules are also attracted to the card, and adhere (or stick) to it. This keeps the card from sliding!

*Why doesn't the water spill out of the cup when the card is removed a the smaller mesh lid?*

The water molecules form adhesive bonds to the metal of the mesh, again forming a strong seal due to surface tension. By tapping on the mesh, you break the surface tension bonds and can feel some water spill out. But those bonds reform very quickly!

*What happens when you tip it without the notecard?*
The force of the atmospheric pressure in the glass plus the weight of the water molecules overcome the atmospheric pressure pushing up against them and the mesh, and some water spills out. It reaches a point, however, where the surface tension bonds form and are strong enough to overcome the force of the atmospheric pressure and weight of the water and stop leaking water.

*Why doesn't the water stay in the cup with the larger grade mesh lid?*
The wire squares are too far apart to allow the water to form cohesive and adhesive bonds.

# Gravity Keeps You Down

**Passport Question:** ___________causes falling objects to slow down.
**Passport Answer:** Air resistance.

**Learning Target:** Students will learn that air resistance causes objects to fall at different rates depending on their size and shape.

**Materials:**

- Cardboard box
- Feather

**Background Information:** All objects (regardless of their mass) experience the same acceleration when in a state of free fall. When the only force is gravity, the acceleration is the same for all objects. On Earth, this acceleration value is 9.8 m/s$^2$. This is such an important value in physics that it is given a special name - the acceleration of gravity - and a special symbol: **g**. So, according to this an elephant and a feather will fall at the same rate and hit the ground at the same time. But we know this isn't the case. Why not?

Air resistance, also called drag, refers to forces that oppose the relative motion of an object through a fluid, liquid, or gas. These forces act in a direction opposite to the oncoming flow velocity.


When an object is falling, air resistance acts to push it back up. Air resistance is the opposite of gravity for an object falling down. It pushes up while gravity pulls down. This is only true for objects falling straight down. If the object is falling left or right, then air resistance will be in the opposite direction.

Forces and Motion

Terminal velocity is when the upward force of air resistance equals the downward force of gravity, the object no longer accelerates. The heavier the object is, the greater its terminal velocity is. For example, an elephant (heavy) would need to fall longer to reach its terminal velocity whereas a feather (light) reaches its terminal velocity rather quickly.

**Procedure:**

1. Do a demo with the feather and the box, drop them separately. *Note that it takes the feather longer to reach the ground than the box. Ask them why they think this is? (air resistance)
2. Ask the students if they can figure out a way to drop the feather and the box at the same rate?
3. Place the feather on top of the box and drop it.

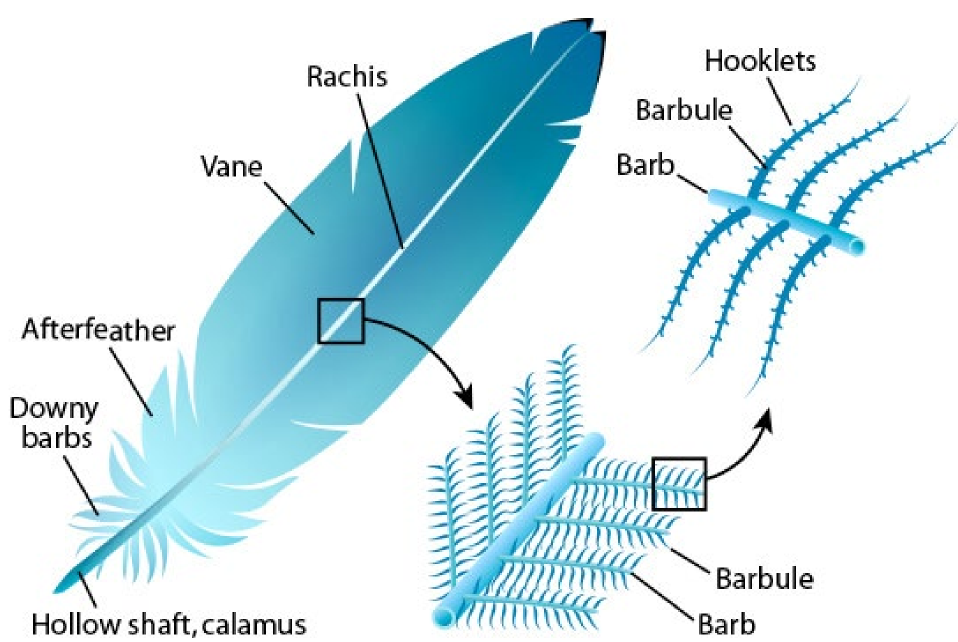
**Discussion:** *Why does the feather fall slower than the box when dropped separately?*

Air resistance is what makes objects fall at different rates. The more surface area and drag an object has, the slower it will fall. The feather is smaller than the box, but it has higher surface area. This is because a feather contains many barbs (like branches) and those barbs contain barbules (more branches) and each barbule contains hooklets (MORE branches) [see diagram below and on table]! Each barb and barbule increases the total surface area and slows the feather down.

When we place the feather on top of the box, the air pushes up on the box then is diverted out and around the box, but it is never able to reach the feather. So the feather and the box fall at the same rate!

Think about a sky diver with and without a parachute—how fast they fall is drastically different!

This experiment will help the students learn that without air resistance all objects will fall at the same rate. In physics we often talk about a "vacuum". This is a space with no matter, no air that can resist movement. These vacuums do not exist in nature, and perfect vacuums are impossible to produce, but partial vacuums get close.



# Strike a Balance

**Passport Question:** What physics concept keeps objects balanced?
**Passport Answer:** The center of gravity of an object.

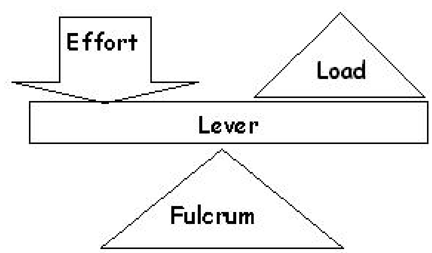
**Learning Target:** Students will learn that the center of gravity keeps objects from falling over.

**Materials:**
- (2) Balancing birds
- Balancing Person
- Tall item for the balancing figurine to stand on
- Wooden fulcrum
- Wooden lever
- Water bottle (optional)
- (3) Bean bags

**Background Information:** In physics, the center of gravity of an object is the average location of its weight. In a uniform gravitational field, it coincides with the object's center of mass.

Gravity causes objects to pull toward each other. In the world around us, we can best explain gravity by letting things drop to the floor or ground. Gravity pulls objects and people toward the earth. That is why things fall to the ground, and also why people and objects don't just float around in the air. The center of gravity is the factor that keeps people and objects balanced. It is the average place of the entire weight of a person or a thing. The center of gravity in an object is not always the central-most point. For example, in people, our center of gravity is slightly higher than our waist, because we hold more weight in our top half of our body than our bottom half.

A Fulcrum is the point on which a lever turns in moving an object. A simple example of a fulcrum is a seesaw.



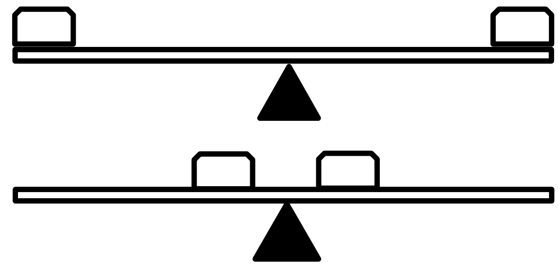

**Procedure A:**
1. Have the students investigate the balancing bird.
2. Have the students investigate the balancing person.

**Discussion:** *Can you balance the bird on your fingertip by its wing? Where is the center of mass in the bird? If you push the person what happens? Why does the person not fall over?*

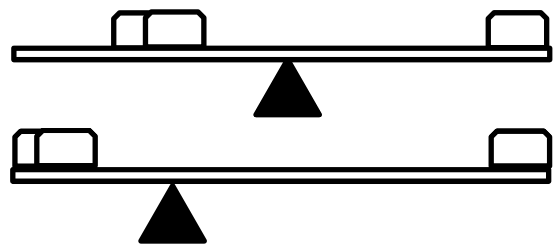
The bird's center of mass is its beak; the weight in its wings equals the weight in its body/tail allowing it to balance by the center point.
The center of gravity in the person is low due to the majority of the weight being below his feet. This allows the person to "rock" back and forth, without toppling over.

**Procedure B:**
1. Show the students the fulcrum and explain what a fulcrum is.
2. Tell them you have 3 challenges for them.

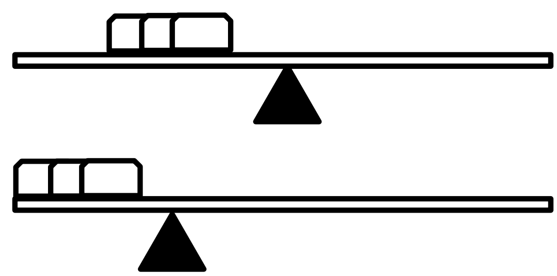
**Challenge 1:** balance the lever on the fulcrum with 1 bean bag on each side.
Tip: The bean bags must be placed equal distance from the fulcrum.



**Challenge 2:** balance the lever on the fulcrum with 2 bean bags on one side and 1 on the other.



**Challenge 3:** balance the lever on the fulcrum with 3 bean bags on one side and none on the other.



**Discussion:** *What did you need to do to balance the lever in each challenge?*

In the first challenge the fulcrum is centered. If the bags placed on each side are equal distance from the center, the lever stays balanced.

In the second challenge, there are two possibilities. One is with the fulcrum centered again. But this time we need to move the 2 bean bags closer to the fulcrum to keep the lever balanced. The other option is to place the bean bags on the ends of the lever, and move the fulcrum closer to the side with 2 bean bags.

In the third challenge, there are again two possibilities. The fulcrum and the bean bags must be closer together. This could be with the fulcrum in the center, or off-center.

# Spanning the Distance

**Passport Question:** A lever that is supported on only one end is called a________?

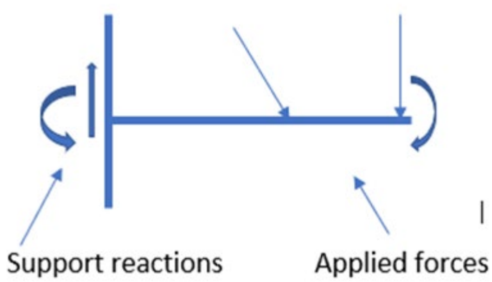
**Passport Answer:** Cantilever

**Learning Target:** Students will learn the effects of balanced and unbalanced forces on an object.

**Materials:**

- Paint paddles (three bins full with 50 or so in each)
- Washers
- Measuring tape

**Background information:** A cantilever is a lever where the point where it is supported is at one end instead of the middle like a seesaw. Cantilevers are used to support heavy things rather than lift or move them. They are built in a way that they can withstand the force of gravity and the weight of objects on top of it, despite only being supported on one end. The structures of cantilevers are in balance to support heavy weights. Cantilevers are everywhere: balconies, light posts, etc. You can make your arm like a cantilever. If you extend your arm forward or sideways it is still attached to your body but the other end where your hand is at its ready to hold things. What's the heaviest thing you can hold without bending your elbow?




**Procedure A:**

1. Let the students explore how to build a cantilever using the paint paddles
2. Using the principles of a cantilever they are only allowed to build off the edge of the table.

3. Measure from the point where the cantilever is no longer touching the table to the end of the cantilever

**Discussion:** How far were you able to build the cantilever out to?

Was there any method that made it easier to build out farther, than another? The students should notice that if they build a stronger base on the table by layering the paint paddles, they can build out farther.

**Procedure B:**

1. Now we want to introduce weight onto the cantilever and allow students to explore balancing all those forces.
2. Count out 30 washers.
3. Give the students the challenge: How long can a cantilever span with 30 washers and 15 paint paddles.

**Discussion:** *Were you able to complete the challenge?*

How easy or hard was it to stick to only 15 paint paddles but balance the weight of the washers on top of the cantilever? Engineers run into this problem when building cantilevers. They must understand the forces acting on the bridges like gravity and be able to build them to support the weight of many cars. Additionally, they also have to build it with a certain amount of materials to stay within their budget.

Whose cantilever was the longest?

| Student Name | Distance |
|---|---|
| | |
| | |
| | |
| | |
| | |

# Magnet Magic

**Passport Question:** Magnetic fields cause magnetic _________________and _______________
**Passport Answer:** Attraction and Repulsion

**Learning Target:** Students will understand that magnets create a magnetic field which can attract or repel other magnetic objects.

**Materials:**

- Coins, paperclips, wood, soda can tab, etc
- Iron filings in plastic case
- Magnet bars, disks, etc. with polarity marked
- Magnetic fun set with experiments (instructions in box)
- (1) set of buzzing hematite torpedo magnets
- (1) bag of Mag Man magnets

**Background information:**

Magnetism- A property of certain materials that causes them to attract iron or steel.

Ferromagnetic- The property of being strongly attracted to either pole of a magnet. Ferromagnetic materials, such as iron, contain unpaired electrons, each with a small magnetic field of its own, that align readily with each other in response to an external magnetic field.

Magnet- objects that produce magnetic fields and attract metals like iron, nickel and cobalt. A magnetic field has lines of force that exit the magnet from its north pole and enter its south pole.

Permanent magnets - create their own magnetic field all the time.

Temporary magnets- produce magnetic fields while in the presence of a magnetic field and for a short while after exiting the field.

If the same pole ends of two magnets are placed near each other, they will repel, whereas if two opposite poles are placed near each other they will attract.

**Procedure:**

1. Have students investigate which materials are magnetic by using a ceramic magnet and seeing which objects it attracts or repels.
2. Have students investigate how magnets interact (repel, attract) using the polarity marked magnets and the magnets on the wooden dowels.
3. Have students investigate magnets with the iron filings.

**Discussion: Discussion:** *<u>How do you know if something is 'magnetic'?</u>*

It 'sticks' to the magnet. These are called ferromagnetic materials; they become temporary magnets and can have other magnets or ferromagnetic materials stick to them.

*<u>Why do magnets sometimes push away from each other and sometimes pull towards each other?</u>*

Magnets have a North and South Pole, A magnetic field has lines of force that exit the magnet from its north pole and enter its south pole. Same pole ends will repel, and opposite pole ends will attract.

# Magnet Mania

**Passport Question:** True or False: All metals are magnetic.
**Passport Answer:** False.
**Learning Target:** Students will understand that not all materials are magnetic, magnets have magnetic fields, and students will investigate the strength of a magnetic force.

**Materials:**

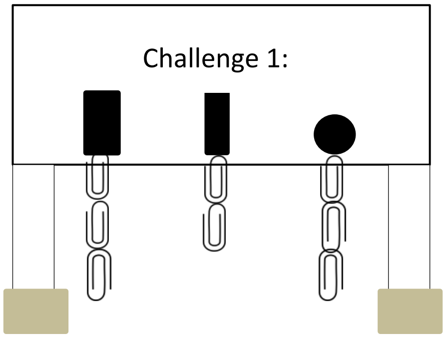
- 'Test Magnetic Strength' Board & wooden bases
- Different size/strength magnets (2 of each)
- Paperclips
- Washers
- (2) Plastic boxes with track
- (2) Large metal marbles
- (2) strong disk magnets
- (2) PVC pipes

**Background information:**

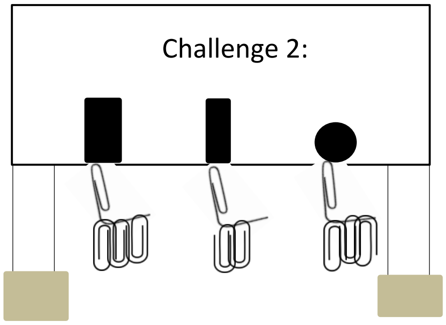
- Magnetism- A property of certain materials that causes them to attract iron or steel.
- Ferromagnetic- The property of being strongly attracted to either pole of a magnet. Ferromagnetic materials, such as iron, contain unpaired electrons, each with a small magnetic field of its own, that align readily with each other in response to an external magnetic field.
- Magnet- objects that produce **magnetic fields** and attract metals like iron, nickel and cobalt. A magnetic field has **lines of force** that exit the magnet from its north pole and enter its south pole.
- **Permanent** magnets - create their own magnetic field all the time.
- **Temporary** magnets- produce magnetic fields while in the presence of a magnetic field and for a short while after exiting the field.
- If the same pole ends of two magnets are placed near each other, they will repel, whereas if two opposite poles are placed near each other they will attract.
- Neodymium magnets (the silver disk magnets) are rare-earth magnets that are the strongest permanent magnets you can buy! **NOTE:** these magnets are incredibly attracted to each other and they WILL pinch fingers! Keep them separated, and out of the children's hands.

**Procedure:**

1. Place the foam core into the wooden base. Attach different magnets near the bottom of the board by placing a magnet on the front and back of the board.
2. Tell the students you have 3 challenges for them to test the strength of magnets. (Have students make hypotheses before each challenge)
3. Challenge 1: Who can form the longest paperclip chain?




4. Have each student choose a magnet and try to attach as many paperclips as they can. You can also magnetize the paperclips by rubbing it onto a magnet first.
5. Challenge 2: How many paperclips can you hang from one magnet? (You could use washers instead, but be consistent for all magnets in order to compare them.)
6. Bend one paperclip into a hook, and attach it to the magnet. Hang paperclips on this hook until the hooked paperclip falls.
7. Challenge 3: Who can finish the track fastest?
8. 2 students will guide a large metal marble through the track in the plastic boxes using the magnet underneath to move it. Have the students place the PVC pipe piece around the magnet to use to move the magnet around (the magnet should NOT be removed from the board). The student that finishes first wins.




**Discussion:** *<u>Were your hypotheses correct? Which magnet was strongest?</u>*

In challenge 1, we are testing how strong the magnetic force is in the magnet. Paperclips are not magnetic on their own, but the magnet can temporarily magnetize the paperclips by passing its magnetic force onto them. You can even remove the magnet and your chain will stay intact!

In challenge 2, we are testing how much weight a magnet's magnetic field can hold. The more paperclips (or washers), the stronger it is.

In challenge 3, we are testing how strong the magnetic force is when separated by a solid. Electromagnetic fields have the ability to go through solid objects such as plastic. But the thicker the object is, the more difficult it is to retain that magnetic attraction. Another difficulty in this challenge is the weight of the metal marble. It is heavy enough to break the magnetic field attraction if it is going fast enough.

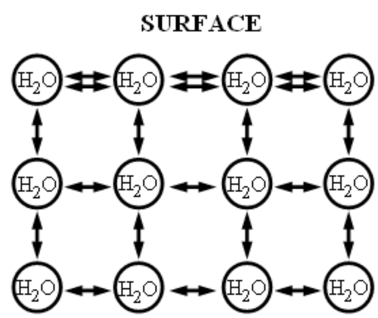
# $H_2$Olympics

**Passport Question:**
Cohesion is the attraction between water molecules and other water molecules.
Adhesion is the attraction between water molecules and other materials.
Surface Tension is the strong bonds formed between water at the surface.
Capillary Action is the movement of water molecules within materials.

**Learning Target:** Students will learn basic properties of water including cohesion, adhesion surface tension and capillary action.

**Materials:**
- Pennies
- Pipette
- (1) square tin baking dish
- Water
- Forks
- Paper clips
- 2 different paper towel brands, cut into strips
- Wide mouth, tall Mason Jars
- Ruler

**Background information:**



Surface tension—molecules at the surface form stronger bonds

In a water molecule the Oxygen atom steals electrons from the hydrogen atoms creating a dipole, in this case a molecule that has a positive end and a negative end. If you think about each water molecule like it is a tiny magnet, where like charges repel each other and unlike charges attract, you'll see that there is a small attractive or cohesive force between each water molecule.

At the surface, there are fewer water molecules to cling to since there is air above, not more water. These surface molecules experience a net inward force due to the molecules below pulling down, but no molecules above pulling up to balance it out.
This force is responsible for surface tension, where the molecules contract and resist being stretched or broken.

These positive and negative ends on a water molecule are also attracted to other materials, this is called adhesion.

Capillary action is movement of water within the spaces of a porous material due to the forces of adhesion, cohesion and surface tension.

**Procedure A: PENNY DROPS**

1. Students use a pipette, to carefully place as many drops on the penny as possible, before it spills.

**Discussion:** *What happens to the water drops as you add them?*
They form one large, dome-shaped water drop. This shape is due to surface tension. The strong, cohesive bonds of surface tension can break and form easily, which is why we see one drop getting bigger and not many separate water drops.

**Procedure B: FLOATING PAPERCLIPS**

1. Use a fork to suspend paper clips on top of water.
2. See how many you can suspend! Use a magnet to remove the paperclips from the water.

**Discussion:** *Why do the paperclips sometimes sink and other times float?*
They're not actually floating! Cohesion can be seen through water's surface tension. Surface tension acts a 'skin' and can be strong enough to hold small objects such as paper clips and even insects. Adhesion can be seen where the water and the metal of the paper clip are touching.

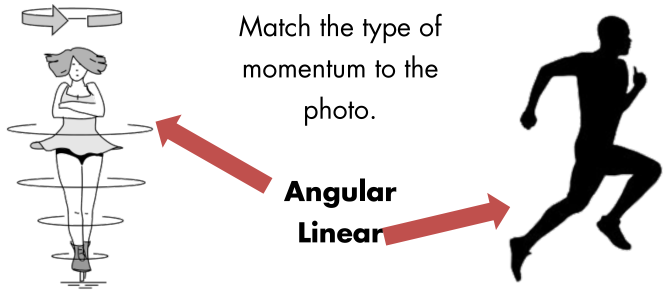
**Procedure C: SOAK IT UP**

1. Make a hypothesis of which paper towel will absorb more.
2. Fill the mason jars with about an inch of water dyed with food coloring.
3. Have the students dunk the paper towels into the water and count to 30.
4. Measure the height absorbed for each towel.

**Discussion:** *How does the water 'climb' the paper towels?*
Capillary action! This movement occurs when water molecules attract the molecules of other things (like a paper towel, or your shirt) and to each other. But the molecules can only travel so far before the force of gravity stops them from continuing.

# <u>Show Me the Momentum!</u>

**Passport Question:**

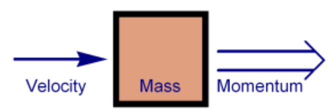



**Learning Target:** Students will learn what linear momentum is and how it can be transferred between two objects (i.e. two balls colliding).

**Materials**:

- Ramp
- 1 canister filled with cotton balls
- 1 canister filled with rice
- Timer (could be on your phone)
- Newton's Cradle
- (3) tennis balls
- Ball race track and blocks at the end
- (3) happy/unhappy ball sets
- Fastest track with three metal balls

### Background Information:




<u>Linear Momentum (ρ)</u> depends on an objects mass (m) and velocity (v). The more linear momentum an object has, the more difficult it is to stop that object. $\boldsymbol{\rho} = \mathbf{m} \times \mathbf{v}$

<u>Force</u>, a push or pull that gives an object linear momentum.

If the Force acting on an object is removed, the momentum on the object is <u>conserved</u> and remains constant. The momentum can still be changed by changing the mass or the velocity of the object.

Linear Velocity (v) is the distance traveled (x) over time (t). $\mathbf{v = x / t}$

**Procedure A: Cotton balls vs. Rice**

1. Have the students to pick up the canisters and observe the differences between them.
2. Ask them which canister they think will hit the bottom *harder* (not faster)? The one that hits harder will be harder to stop.
3. Ask them which canister will have more momentum. The canister that hits harder will have more momentum.

4. Have one student place the canister filled with cotton balls at the top of the ramp, and hold it in place with the insert. Have another student place their hand on the outside of the finish line.
5. Remove the insert to let the canister roll down.
6. Repeat procedure with the canister filled with rice. Which one hits the bottom hardest?

**Discussion:** *Which canister hit the bottom harder?*
The canister full of rice hit harder, because it is heavier. Therefore, it had a higher linear momentum.

**Procedure B: Race Track**

1. Ask the students which ball they think will reach the end first (considering the balls are the same size and mass). Do they have different or the same momentum?
2. Start all three balls at the top of the track and let them go at the same time by using the block to push them.

Discussion: *Which ball won the race?*
The tracks that had ramps allowed the balls to convert its potential energy (at the top of the slope) into kinetic energy at the bottom of the slope which meant they had a higher velocity throughout the track.

Specifically, the ramp with the largest height gave the ball the greatest velocity and was able to move the fastest. The second fastest was the other track with a ramp just not as large of a height. Whereas the marble that was going straight stayed at a constant speed and could not change its velocity.

Procedure C: Bouncing Balls

1. Examine the happy/unhappy balls. Do you feel a difference? (the happy ball is elastic and made of neoprene and the unhappy ball is inelastic and made up of polynorborene)
2. Next, drop the happy/unhappy balls at the same time from the same height, what happens?

Discussion: Elastic and inelastic collisions. One ball is very resilient, or bouncy, and will rebound to its initial height or position when striking a surface. The other ball hardly bounces at all as it absorbs all of the energy from a collision. What happens afterward can be described mathematically using equations to compare conservation of momentum in the two cases.

1. Place the tennis ball on top of the water balloon and drop them. What happens?

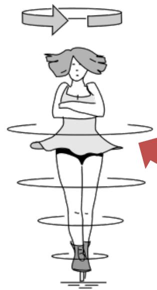
Discussion: When they are dropped together, most of the ballons momentum is not lost, but is transferred to the tennis ball. The tennis ball now has greater momentum and thus increases speed which allows it to travel higher. Remember the equation for linear momentum, **ρ** = m x v, we aren't changing the mass of the balls, but we are changing the momentum, which affects the velocity.

1. Using the Newton's Cradle, hold one ball up in the air, but do not drop it. Ask the students what they think will happen when you let it go?

Discussion: In the Newton's Cradle, we see momentum being transferred through multiple balls. When one ball is lifted and dropped it collides with the second ball. The next three balls seem to stay still, while the fifth ball, on the opposite end, is set into motion. The momentum of the first ball (from being lifted and dropped) is transferred to through the center balls and into the fifth ball where we see it get thrown up. That ball comes back down, and sends the momentum back through the line, and this process is repeated!

# Momentum Machine

**Passport Question:**



Match the type of momentum to the photo.

**Angular**

**Linear**

**Learning Target:** Students will learn what angular momentum is and that it depends on how fast an object is rotating and how its mass is distributed.

**Materials**:

- Hand weights (2-3lbs)
- Lazy Susan

**Background Information:**

Angular Momentum (L) depends on an objects mass (m), velocity (v; perpendicular to radius), and distance from its center of rotation (r). The greater the angular momentum of an object is, the more difficult it is to stop that object from rotating. $\mathbf{L} = \mathbf{m} \times \mathbf{v} \times \mathbf{r}$

Torque (τ) is a measure of how much force acting on an object causes that object to rotate about an axis.

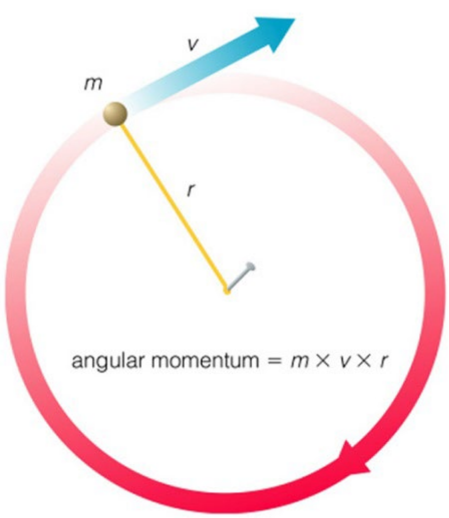
Every rotating object has an Angular Velocity (ω) and a Linear Velocity (v).

Angular velocity is the ratio of the angle travelled (θ) over time (t). $\boldsymbol{\omega} = \frac{\boldsymbol{\theta}}{\boldsymbol{t}}$

Linear Velocity (v) is the distance traveled (x) over time (t). $\mathbf{v} = \frac{\boldsymbol{x}}{\boldsymbol{t}}$

Angular Velocity (ω) and Linear Velocity (v) are related in this formula. $\mathbf{v} = \mathbf{r}\boldsymbol{\omega}$

By combining and rearranging the equations (below) for Angular Momentum and Angular Velocity, we can see that **r** and **ω** are inversely related. Therefore, if the object is moved further from the axis, or **r is increased**, then the angular velocity **(ω) decreases.** And vice versa.




$$\boxed{\begin{gathered} \boldsymbol{L} = \boldsymbol{m} \times \boldsymbol{r\omega} \times \boldsymbol{r} \\ \boldsymbol{L} = \boldsymbol{m} \times \boldsymbol{\omega} \times \boldsymbol{r}^2 \\ \boldsymbol{r}^2 = \frac{\boldsymbol{L}}{\boldsymbol{m} \times \boldsymbol{\omega}} \end{gathered}}$$

If the Torque (τ) acting on an object is removed, the momentum on the object is conserved and remains constant. The momentum can still be changed by changing the distance from the axis.

**Procedure**:

1. Have a student sit cross legged on the lazy susan.
2. Give the student the hand weights to hold in each hand. Have them hold their arms out.
3. Give them one small push so that the student begins to spin slowly.
4. On command, have the student bring the two weights to his or her chest. The student's rotation rate will dramatically increase. Tell the student to extend the weights again, and the rotation rate will decrease.
5. Ask students their observations, focus in on how fast they are rotating when do move their arms inwards and outwards.

**Discussion:** *What happens when the student brings their arms in?*
They spin faster.

We set the student in motion using Torque, or a push, giving the student and the lazy susan angular momentum. By not pushing the chair continuously, we removed the Torque, yet the angular momentum was conserved, or stays the same. At least until the student brings their arms in.

Because angular momentum is conserved, if one factor of the equation is changed, another must change in the opposite direction in order to keep things balanced.

Angular momentum depends on mass, velocity, and distance from the axis. *Did we change the mass?* No. *Did we change the velocity after the first push?* (To change it would require more pushes or to stop the chair) No. *Did we change the distance of the mass from the axis?* Yes! By pulling their arms in, they reduced the distance of the weights from the axis (the student's body) which increases their angular momentum which in turn, increases angular velocity.
Check for understanding by asking, what would happen if we changed mass or velocity?

Mass is further away from axis of rotation
➔ Lower angular speed

Mass is closer to axis of rotation
➔ Greater angular speed

# Energy Activities

## 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.

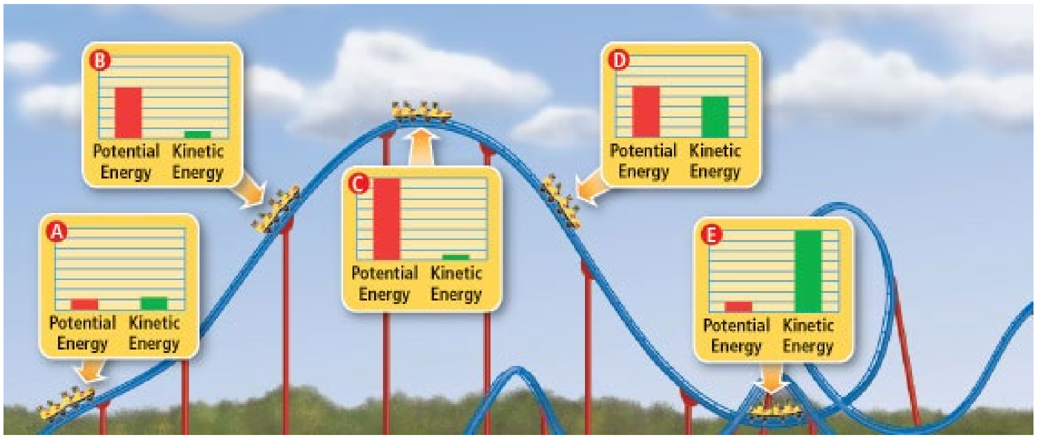
**Learning Target**: Students learn that kinetic energy is the energy of motion and potential energy is stored energy. The energy of an object can change to and from kinetic and potential.

**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.




**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 the 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.

# 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:**
- Temperature gun
- Various materials – Styrofoam, plastic, metal and wood
- Hot water Erlenmeyer flask w/ red dye
- Blue ice cubes
- Heat plate w/ convective fluid
- Radiometer
- Lamps

**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*
- 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

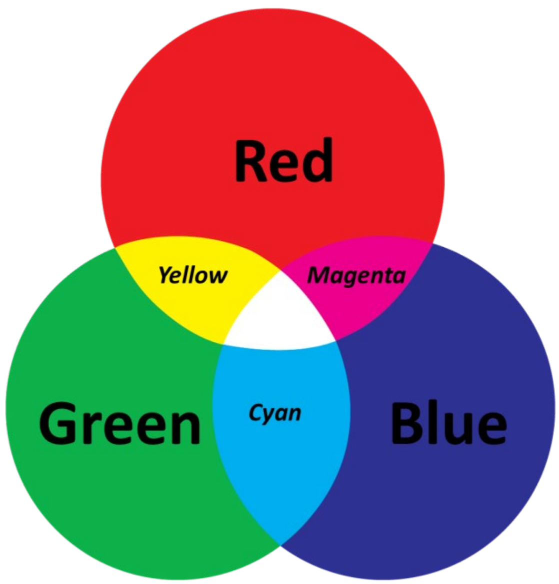
**Passport Question:** When you combine red, green, and blue light, what color light do you get?

**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.

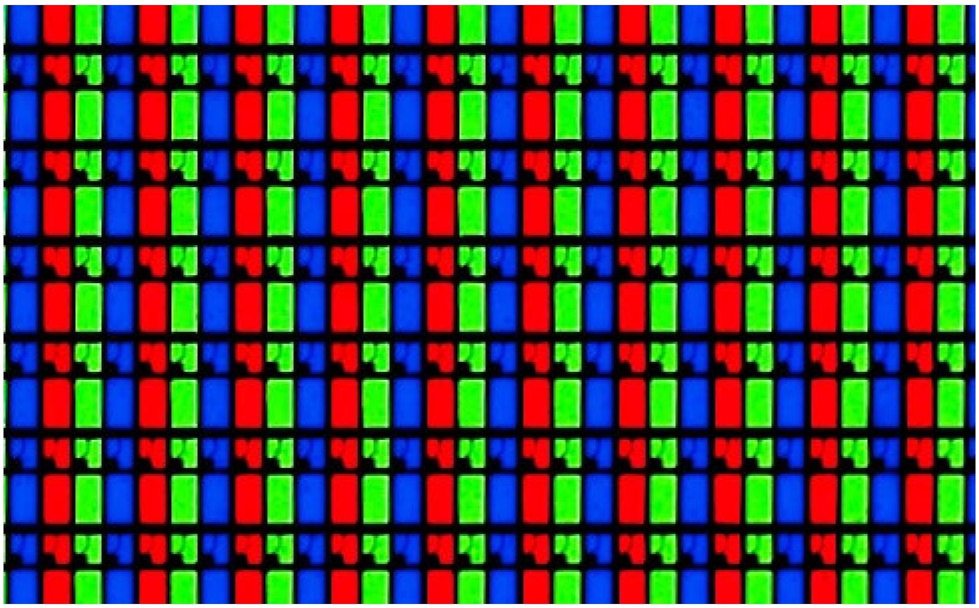



**Materials**: • Flashlights with colored gels, • White particle board

**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
- 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?*
Theses 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:** What secondary colors are produced by the following primary light combinations?
**Passport Answer:** Red + blue = magenta, blue + green = cyan, green + red = yellow

**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](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

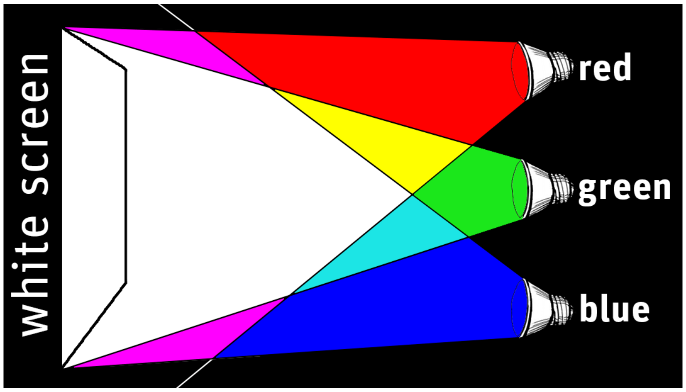
**Discussion:**

<u>*What's happening?*</u>

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.

# 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" (PVC pulley frame)
- Black short PVC pipes

**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**:

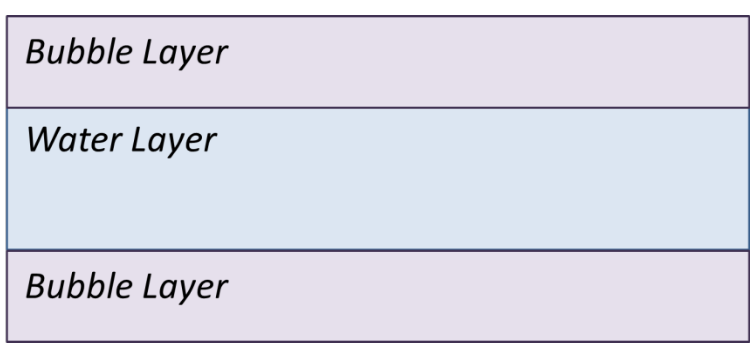
- Make sure the strings and any other surfaces that will come into contact with the soap film on are wet with the soap solution
- Slowly lift up the painting and have students notice the colors
- Gently shake the frame back and forth and notice the pattern of waves on the film.
- Have students poke the 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

**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.

# 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)

### 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 a small sheet of glass marked with thousands of parallel lines.


**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
- 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?
- 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!

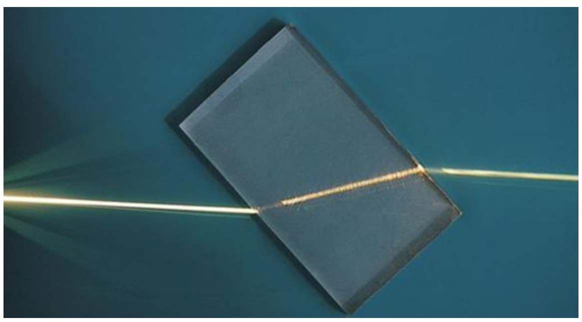
# Refraction Action

**Passport Question:** The bending of light is called ____________
**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
- Glycerin

**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 if 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?*

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.

# It's a Mirror-cle!

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

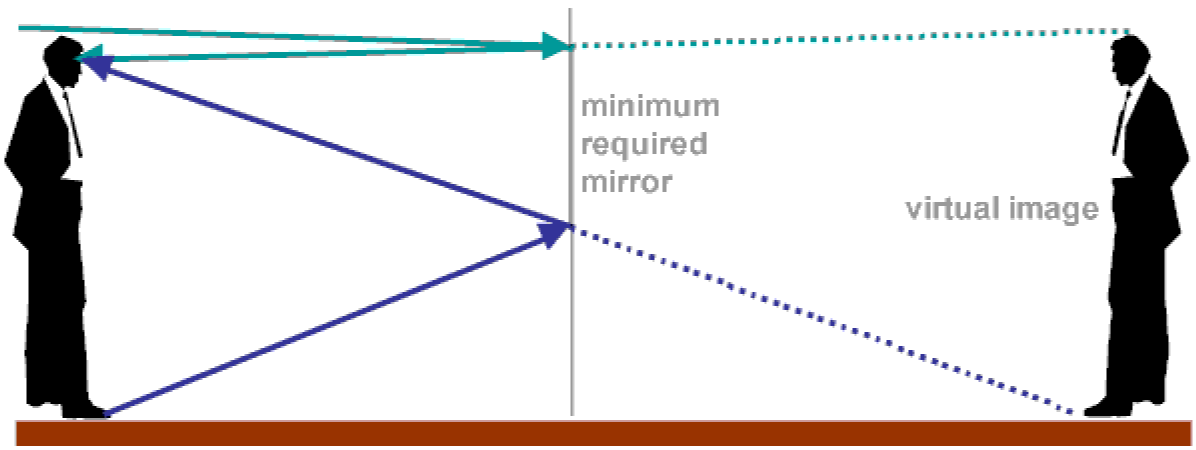
**Passport Answer:** The foot off the ground is reflected and looks like a second foot.

**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.
- 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 mover 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 them what they see

# Seeing Sound

**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

**Materials**:

- Tuning forks
- Ping pong balls
- Water container
- Speakers
- Wine glasses
- Salt
- 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?*
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: 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 3: Chladni Plate*

- Sprinkle salt/sand on the metal plate
- Apply a generous amount of rosin to the bow
- Place one finger lightly on the edge of the plate, creating a node
- Run the bow along the side of the plate to produce a high frequency sound
- Observe patterns in the salt/sand and ask the students what is happening

*Why does the salt create patterns?*

When the Chladni Plate achieves a resonance condition, 'standing waves' are created. This is similar to the effect in a vibrating string – except this is in two dimensions. The sand concentrates in areas where the plate was not vibrating. The places where the sand did not collect show how far sound waves moved the sand. The places where the sand did collect represent nodes between waves. A node is the point of zero amplitude, meaning the particles at those points were not moved by waves.

## Musical Coat Hangers

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

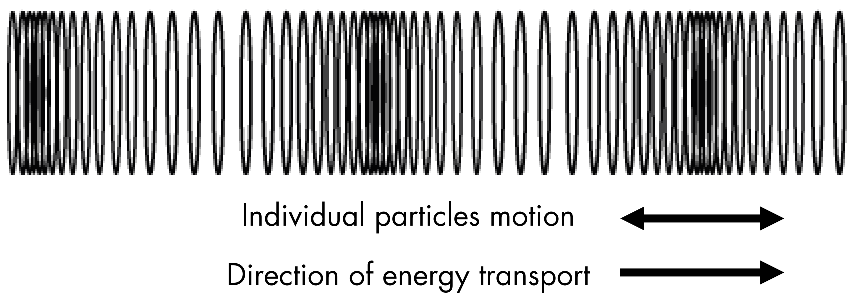
**Learning Target:** Students understand that sound travels in waves and that the speed of sound depends on the medium sounds waves travel in.

**Materials:**

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

**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

**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.