Under Pressure & Blue Skies
Weather and Air Pressure Connections

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This workshop and its activities and PowerPoint are freely available at our Website along with additional Earth system science educational resources.

Spark.ucar.edu/events/under-pressure
Students observe that air takes up space and that the absence of air can result in crushing behavior. **NOTE:** This activity requires adult assistance and supervision.

**What you'll need:** Per adult demonstrator:
- One 12-ounce soda can
- Water
- One bowl of ice water approximately 6” deep or greater
- One pair of tongs
- One hot plate or electric burner

**Directions:**
1. Have observers stand or sit approximately five feet from the demonstration.
2. Fill an empty 12-ounce soda can with approximately one or two tablespoons of water.
3. Place the soda can directly on a hot plate or electric burner, and wait for the water inside the can to begin to boil and evaporate.
4. Next, have an adult quickly but safely lift the soda can off the burner with a sturdy pair of tongs. (Be sure to wear safety glasses.) Immediately immerse the soda can upside down into a large bowl of ice water.
5. What happens to the soda can? Why?

**Ask yourself the following questions:**
1. What happens to the air inside the soda can when it is heated?
2. What happens to the water inside the can during the activity?
3. How does the contents inside the can change during the activity?
4. Why did the can implode? What happens to water vapor when it is cooled? What took the place of the water vapor in the can after it condensed back into a liquid?
5. How much force was exert to crush the can? Force from what?

**Science background:**
Although air is invisible, it still takes up space and has weight. In this experiment, when the air in the soda can is heated, the air inside the can will rise and some will escape. When the water in the can is heated, it begins to evaporate becoming water vapor, a gas. It fills much of the newly created space left by the escaping air. When the can is placed in the tub of ice water, the water vapor instantly condenses back into liquid water.

What takes the place of the water vapor and steam? Nothing! For a brief second, the can is filled with only a little water and air, and a lot of empty space! 14.7 pounds of air pressure per square inch on average at sea level (1 kg per square cm) is pressing on the outside of the can, but very little air is pushing back from the inside. Consequently, the can is crushed in seconds by the greater air pressure pushing on it from the outside. That's NOT your usual pop!

**Learn more online!**
- **Stuff in the Sky** [http://eo.ucar.edu/kids/sky/index.htm](http://eo.ucar.edu/kids/sky/index.htm)
- **Web Weather** [http://eo.ucar.edu/webweather/](http://eo.ucar.edu/webweather/)
- **UCAR Science Education** [http://spark.ucar.edu/teachers](http://spark.ucar.edu/teachers)
**Plunger Pull**

Students observe that air exerts pressure, something easy to see using air of very low pressure or a vacuum.

**What you’ll need:**
- One set of suction cups or plungers, standard size. Wood handles are best to remove.

**Directions:**
1. Put the plungers together, with concave sides facing one another.
2. Notice that they touch but do not stick together.
3. Put the plungers firmly together, with concave sides facing one another again, put this time push to remove the air that is held and shared between the two half spheres. Notice what happens.
4. Hold the plungers by their outside ends and try to pull them apart. Do not twist or peel them, just pull. Are you able to pull them apart?

**Ask yourself the following questions:**
1. Is suction a force or does air exert a force and cause suction?
2. How much weight do you think you are trying to pull apart if air weighs 14.7 pounds per column inch on average at sea level?

**Science Background:**
Although air is invisible, it still takes up space and has weight. In fact, it may surprise you to know that air weighs 14.7 pounds per column inch at sea level, or put another way, over 2,100 pounds per column cubic foot! Wow! The reason we don’t feel its weight is because air, like all fluids, doesn’t just push down. Instead, it pushes in all directions. Water has weight too, but you aren’t crushed when you swim to the bottom of a deep pool because water, like air, also pushes in all directions. But just try to lift all that water you’re swimming under. It weighs over 62 pounds per cubic foot!

In 1654, Otto von Guerick performed a demonstration similar to the activity you just performed with the plungers. He used two metal hemispheres, which were 22 inches in diameter and placed them together in the shape of a single sphere. He had invented the world’s first vacuum pump shortly before 1654, which pumped air out of his sphere instead of into it. When created a vacuum, the two hemispheres held together tightly. No human could pull Otto’s sphere apart, so in front of Emperor Ferdinand III of Germany and others, he attached two eight-horse teams to each end of his sphere. Despite a great effort, the horses could not pull his sphere apart. After all, they were trying to pull apart nearly 3 tons!

When air is inside the sphere, it exerts the same amount of force as the air on the outside of the sphere. When you remove the air inside of the sphere, however, the air on the outside presses the two halves of the sphere together. If you peel the plungers apart slightly and let air back inside of it, its two sides will no longer stick together as the force on the inside and outside will once again be the same.

**Learn more online!**
- WebWeather [http://www.eo.ucar.edu/webweather/](http://www.eo.ucar.edu/webweather/)
- Kid’s Crossing [http://eo.ucar.edu/kids/sky/index.htm](http://eo.ucar.edu/kids/sky/index.htm)
- UCAR Science Education [http://spark.ucar.edu/teachers](http://spark.ucar.edu/teachers)
Students observe that air takes up space. It's only when air in the bottle escapes, that more air is easily added.

What you'll need:
Per student:
• 1-liter plastic bottle
• Another 1-liter plastic bottle with a 1” diameter hole plugged with a stopper
• 2 balloons per person
• 1 cup water per student

Directions:
1. Push a balloon inside a plastic bottle and stretch the balloon opening over the bottle's top.
2. Attempt to blow up the balloon inside the bottle. What happens?
3. Next, place a new balloon into the plastic bottle with a 1” diameter hole in its side that has been plugged with a stopper. Stretch the balloon opening over the lip of the bottle like before.
4. With the stopper plugging the hole, can you blow up the balloon?
5. Unplug the stopper in the plastic bottle and attempt to blow up the balloon yet again. What happens? Why?
6. With the balloon inflated inside the bottle, plug the bottle's hole with the stopper. What happens to the air inside the balloon this time?
7. Fill the inflated balloon with water while it is inside the bottle. Step outside or place the bottle over something that can catch liquid. Now unplug the stopper and watch the waterworks.

Ask yourself the following questions:
1. What happens to the balloon inside the bottle when you try to inflate it with the hole plugged and unplugged? What makes the difference?
2. After the balloon is inflated and the hole in the bottle plugged, what prevents the air from escaping from inside the balloon?
3. When water is placed in the inflated balloon inside the bottle, what causes it to gush out when the bottle's unplugged?

Science background:
Although air is invisible, it still takes up space and has weight. This is evident when the balloon is placed inside the bottle and you try to inflate it. It's nearly impossible to add any amount of air! When the bottle with the hole is used, however, inflating the balloon is nearly effortless. The air inside the bottle is able to escape, freeing up space for the balloon to now inflate. If you then plug the hole on the outside of the bottle, the balloon will remain inflated. How does this happen? What keeps this air in place? This is a consequence of the air pressure being lowered inside the bottle when its hole is plugged. The high pressure air inside the balloon is pulled toward the low pressure area inside the bottle. When you add water inside the balloon then unplug the bottle, watch out! Unplugging the bottle will release low pressure's hold on the higher pressure air inside the balloon and allow outside air to enter the bottle once again. Not only will the balloon collapse, the water inside of it will be propelled by the force of the air.
Students brainstorm various ways a balloon placed on a bottle's opening can be inflated. The catch is, the balloon cannot be touched.

What you'll need:
• one clear glass bottle, 1 liter or more in size
• a large round-shaped balloon to place on the bottle opening
• hot water heated in a large kettle, pan, or coffee urn
• "Magic" wand (optional)

Preparation to Directions:
1. Begin the activity by telling students that you need their help solving a problem you've been presented with. Show them the large glass bottle with a balloon on it. Tell them that someone gave you a challenge: to blow up the balloon without touching it in any way.
2. Ask the students if this can be done and if they have any ideas as to how? Solicit and encourage their input by telling them you are willing to try just about anything to succeed in answering this challenge correctly.
3. Equate student responses with particular fields of science. For example, if they say "mix baking soda and vinegar," then tell them that there's no way at this point to get that into the bottle but that they are thinking like a chemist, which is a smart way to think! If someone suggests putting a hole in the bottle with glass cutters, tell them they might be a future engineer as that is the type of solution that they might come up with.... Should some suggest placing the bottle in a heat source, tell them that they are thinking like a meteorologist or physicist, someone who studies how air moves.
4. If a student fails to come up with the suggestion to heat the bottle, tell the students that you have been wondering about hot air balloons. What causes a hot air balloon to rise? Tell them that you would like to see if the methods used to get a hot air balloon to rise will work with your balloon on the bottle.

Directions:
1. Place the bottle into the hot water source so that all students can observe any results. Wait briefly until the balloon begins to inflate. It is likely that many students will be surprised.
2. Ask the students if you added anything to the bottle or if there was something in the bottle all along?
3. Ask the students if the same thing that happened to the balloon happens to them when they take a hot bath? Why do they think this experiment doesn't work on them like it does on a balloon? Accept all answers and tell them that that can be an extension lesson.
4. Explain to the students that air can be a bit of a mystery to many people because it is invisible. What seems like magic, can actually be explained using knowledge about science and how a fluid like air and water behave when heated.
5. Use the applets on Spark's Web Weather for Kids website (http://eo.ucar.edu/webweather/basic.html) under Weather Ingredients -- Temperature, Volume to illustrate how molecules of air behave differently when they are heated or cooled, and how the temperature of the air relates to its volume. If web access is not available or in addition to the web activity, try the kinesthetic activity that follows.

For Teachers:

Student Learning Objectives
Students will:
• learn that air’s volume changes with temperature
• learn that air can both expand and contract depending on if its temperature increases or decreases

Class time
• 30-45 minutes

Grades
• K - 4th grade

National Science Standards
• A: Science as Inquiry
• D: Earth Science

Spark, UCAR Science Education
Kinetic Engagement
1. Tell the students that you know a way that they can actually see air. Using your magic wand, you can turn everyone’s fingers into the particles of air comprised mostly of nitrogen, oxygen and few other trace gases. On the count of three, tell them to clap their hands and the magic will occur.

2. Most of the students’ hands will remain together following the clap. Exclaim that their air is cold air: hardly moving and more closely compact than warmer air in the room. Tell the students that if cold air could talk, it would say, “I don’t need much room,” and encourage the class to repeat the refrain.

3. With your own fingers and hands, show the students how warm, warmer and hot air behaves. Start moving your fingers and hands quicker and quicker, and use more space as your fingers move rapidly. Tell your class that if warm and hot air could talk, it would say, “I need more room!” Ask the students to demonstrate the motion of warm air, hot air, and cold air and to exclaim what that temperature of air would say if it could talk. How does temperature impact the motion of air?

4. Turn the students’ “air” back into fingers. To have students explore properties of air further using the Spark activity, Bubbles on Bottles.

Reflection and Assessment
Ask the students the following questions:
1. What caused the balloon to grow in size?
2. What will happen to the balloon once it and the bottle are removed from the hot water? How long do you think it will take? Why?

Avoiding Misconceptions
It is possible that many or a few students will tell you that the balloon blows up because hot air rises, however, the balloon inflates primarily as a result of its greater volume as it is heated. To illustrate these to students, turn the balloon and bottle upside down while it is inflated. The balloon will remain inflated. Hot air will only rise in the presence of cooler air next to it. On a hot day, for example, the air can be very still.

Background Information
Volume refers to the amount of space occupied by a substance or object, such as air. When air is heated, its volume increases as particles move faster and faster. When air is cooled, its motion slows and its volume decreases resulting in an increase in its density (the mass per unit volume of an object). The formula that scientists and others use to determine the volume of a substance is: \( \text{Volume} = \text{Mass} \times \text{Density} \)

Related Web Pages for Students
- http://eo.ucar.edu/webweather/
- http://eo.ucar.edu/kids/sky/index.htm
- http://www.ucar.edu/learn
- http://spark.ucar.edu

Bubbles on Bottles
Created by Teresa Eastburn, Spark, UCAR Science Education
www.spark.ucar.edu
Students observe that a change in the temperature of air can impact the size of a bubble placed on a bottle that is cooled and/or heated.

What you’ll need:
For each pair of students:
- 2 clear plastic 1 liter bottles
- plastic shoe box or similar
- small plastic containers
- hot water in an open top kettle
- ice water
- dishwashing soap - diluted

Directions: (this can be altered to a format that best fits the activity when necessary)
Intro to directions followed by steps in both instructions and the activity:
1. File a clear plastic shoebox with 3” - 5” of ice water for each group of two to four students (have hot water on standby to fill a shoebox container in the same way for each group).
2. Add approximately 1/4” of diluted dishwashing soap to a small container for each group.
3. Demonstrate dipping the narrow open end of the bottle (mouth) into the soap container to form a film over it, then have students practice this. If the film pops, simply ask students to repeat the procedure.
4. Next place the bottom of the bottle into the cold water. Have students record what happens.
5. Carefully provide a shoebox with 3” - 5” of hot water in it to each group, making sure to review common safety precautions.
6. Have students experiment and record what happens when the bottom of a bottle with soap film over its mouth is placed in the hot water.
7. Encourage students to place their bottle in both the hot and cold water without breaking the bubble to see it rise and fall due to the temperature change.

Reflection and Assessment
Ask the students the following questions:
1. Is the same amount of air in the bottle if the bubble does not pop?
2. Is the volume of air increasing or decreasing in the bottle when it is warmed? What happens when the air is cooled?
3. What could you do to make the bubble grow larger or smaller? Do you know?

Background Information
Convection is the transfer of heat by the movement or flow of a substance from one position to another. Temperature is a measure of the average speed or kinetic energy of molecules. These are both demonstrated in this activity, as changes in the temperature of air inside the bottle makes the air's volume grow or shrink. The warm bath causes the air inside the bottle to warm and expand, thus increasing the volume that the air needs. The air pushes the bubble up above the bottle's mouth. The cold bath creates a slower and consequently more densely packed air mass that sinks into the bottle, pulling the bubble inside the bottle's neck. As the temperature in the bottle fluctuates between cold and warm, the bubble serves as a tracer of invisible air – showing students how the mass of air in the bottle remains the same, but the space it takes up (its volume) changes as a result of its temperature.
Students extent their learning about air to the larger atmosphere and weather, and to other fluids such as water.

Materials
- red and blue food coloring
- ice water
- clear, narrow container or fish tank (see suppliers below)
- 1 red and 1 blue wrist band for each student

Preparation for Demonstration
1. Fill the clear plastic tank halfway with water at room temperature.
2. Place funnels of the same size at each end of the tank.
3. Place 1-cup of warm water in a measuring cup with a spout and handle for easy pouring. Add a few drops of red food coloring at the appropriate time (see below).
4. Prepare 1-cup water with crushed ice. Add a few drops of blue food coloring at the appropriate time (see below).

Directions
1. Ask students if they can see the air in the room. Tell them that air is a fluid, just like water, but water can be seen. Consequently, we are going to use water as a model for air in the atmosphere. The water in the tank is representing air in the sky. The hot and cold water we are going to add to this model represent a cold air mass and a warm air mass.
2. Select two student volunteers, one to be "Hot" and one to be "Cool." Give "Hot" the cup of warm water and "Cool" the cup of ice water. If the tank you are using has a method to divide the tank evenly in two, do so by placing the divider in place.
3. Ask the class to predict the color that the water will become once the red and blue water (hot and cold air mass) are added. On the count of three, have "Hot" and "Cool" add their air mass to the atmosphere and then sit down to observe with the class. Make sure the tank can be seen by all students and have them articulate and record what they observe.
4. Once the two colors reach the middle of the tank, introduce the concept of a weather front to the students. Give each student one blue wrist band to represent the cold air mass to wear on their left hand, and one red wrist band to wear on their right wrist. Tell them that a weather front is where two different masses of air come together. Have students put their cold (red) and warm (blue) fists together, and show them that this represents a weather front, just as the red and blue ‘air’ in the tank.
5. Next slowly lift the divide between the two different colored ‘air’ masses. The dense red cold ‘air’ mass will extend below the blue warm ‘air’. This is what happens in the larger atmosphere to bring about a change in the weather. And it all starts with heat from the Sun putting air in motion. We call this process convection.

For Teachers

Student Learning Objectives
- Students learn that water behaves much like air, and when hot & cold substances mix, heat will transfer from one position to another
- Students learn that convection is what causes our atmosphere to mix and create weather

Grade
- appropriate for upper elementary to higher grade-level students

Time
- 20 minutes

National Science Standards
- A: Science as Inquiry
- B: Physical Science
- D: Earth Science

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**Background Information**

Convection is the transfer of heat by the movement or flow of a substance from one position to another. It is how heat is transferred in a fluid, which includes air and water. Temperature, on the other hand, is a measure of the average speed of molecules. Higher temperatures increase their motion while lower temperatures reduce their speed. This is apparent when you add food coloring to hot water or cold water. The food coloring will readily mix in the hot water, but you will need to stir the cold water to mix color into it.

Density is the mass of something in a given space, a property that can describe a gas, liquid, or solid. Since all atoms and molecules weigh something (have mass), the more of them there are in a given space, the greater their density will be. The cool water in this demonstration is more dense than the warm water, which is why it sinks to the bottom of the tank. The warm water’s molecules are moving faster and requiring a greater volume of space. Consequently, the warm water is less dense because there are fewer molecules in a given space and rises above the cold water.

Molecules in Earth’s atmosphere constantly bounce off each other and everything else around them. The force exerted by these air molecules is called air pressure. The mixing of air due to the rising and setting of the sun, which changes the heat being added to the atmosphere, creates the daily convection currents that mix our air from top to bottom creating one of the components in our daily weather patterns.

**Learn More Online!**

- Spark, UCAR Science Education, http://spark.ucar.edu
- NCAR’s Web Weather for Kids, http://eo.ucar.edu/webweather/

For more advanced weather content visit:

For information on where to purchase a density flow tank:
- Density flow tanks are available for purchase online through Educational Innovations, Inc.
Here's an experiment that demonstrates why there are clouds in the sky. It involves air, invisible water vapor, particles we call condensation nuclei, and air pressure. The cloud comes later.

What you’ll need:
• A 1-liter clear plastic bottle
• A rubber stopper with a small hole in it
• A tire pump to attach to the rubber stopper
• Water or rubbing alcohol
• An adult assistant

Directions:
1. Put on your safety glasses and have your assistant do the same.
2. Add approximately a half-teaspoon of rubbing alcohol to the inside of the bottle so that it coats the sides. (You can do this experiment with ¼ cup of water, too.)
3. Plug the rubber stopper into the bottle and pump 10 times, making sure to have your assistant hold the stopper so it doesn’t pop off the bottle.
4. Pump 10 times. Notice how clear the air is in the bottle after you do this.
5. Now, have your assistant pull the rubber stopper off the bottle. Notice what the air looks like now. A cloud has formed.
6. Put the plug back onto the bottle with the cloud still in it, and pump about 5 times. What happens to the cloud? It disappears! Why?

Ask yourself the following questions:
1. What is required for water vapor to condense so that visible droplets or water crystals appear in a cloud (condensation nuclei, cooling temperature and low pressure)?
2. What are the skies like where you are, clear or cloudy? How did that happen?

Science Background:
This experiment is as much about air pressure as it is about clouds! When you pump a lot of air into the bottle, you create HIGH PRESSURE. The air crowds together and warms, and there’s NO CLOUDS. Skies are clear!

When you remove the stopper, you LOWER THE PRESSURE by letting much of the pumped-in air out. The air expands and cools. Any vapor in the air cools, too, causing it to condense on particles and form small droplets that make a visible cloud. What was once INVISIBLE becomes VISIBLE! It’s not magic, but it’s definitely magical!

In this experiment, we used rubbing alcohol because it evaporates faster than water. As a result, we get a very visible cloud quickly, but we could use water, too, just like the real world does. When air pressure is high, there is more air above you so it is heavier, denser, and sinking. The skies are clear because the air is sinking and not rising upward. Sorry! There are no clouds on high-pressure days, but there is a lot of sunshine!

Learn more online!
• WebWeather http://www.eo.ucar.edu/webweather/
• Kid’s Crossing http://eo.ucar.edu/kids/sky/index.htm
• UCAR Science Education http://spark.ucar.edu/teachers
Students observe that air under high pressure will move toward a low-pressure area and that certain objects in the air’s path may move in the same direction.

What you’ll need:
• 1 clean, clear 12 ounce plastic beverage bottle with cap off
• One small round paper wad

Directions:
1. Hold the bottle approximately a hand’s distance from your mouth with the bottle flat on its side and the opening pointing directly at your mouth.
2. Place the small round paper wad on the edge of the inside lip of the bottle opening.
3. Stand as still as possible and blow into the bottle. (Do not move your head or the bottle during this process.)
4. Observe what happens to the paper wad.
   Note: Your objective is NOT to get the paper into the bottle, but to observe what happens naturally in the process of this investigation to the paper.

Ask yourself the following questions:
1. Why doesn’t the paper go into the bottle?
2. If I blow softly, will the paper go in then, and if not, why not?
3. Where is the air pressure highest? Where is it lowest?
4. What would happen to the paper if there was a hole placed in the closed end of the bottle?

Science background:
Although air is invisible, it still takes up space and has weight. Under normal atmospheric conditions, there is a lot of “empty” space between air molecules. Under high pressure conditions, the air is more dense, and when low pressure conditions exist, the air is less dense. When air moves at great speeds, this also makes the air less dense and results in lower air pressure. A good analogy are cars on a freeway. The faster the cars go, the more space that exists between them. But when their speeds slow, they crowd together.

When you blow into a bottle, air is compressed into a finite space and the air pressure in the bottle increases. Think about a balloon. When you blow it up, you trap air inside of it as well. If you let go of the balloon before tying it, the air rapidly exists. This is because air moves from areas of high pressure toward areas of low pressure. The greater the difference in the pressure, the faster the air will move. The air blown into a bottle is a lot like air blown into a balloon. If it’s not trapped, it will rush out of the bottle toward lower pressure. Consequently, the paper is pushed out of the bottle instead of into it.

In the larger atmosphere, air moves toward low pressure but it’s motion is influenced also by the spin of the Earth. This is called the Coriolis Effect and causes air to move counterclockwise around low pressure in the Northern Hemisphere and clockwise in the Southern Hemisphere.

Learn more online!
• UCAR Science Education http://spark.ucar.edu/teachers
Students observe how a single breath of air can fill a large trash bag due to the Bernoulli Effect.

What you’ll need:
• Two 10-gallon or larger plastic trash bags

Directions:
1. Have students guess how many breaths it takes to blow up a large plastic trash bag. Determine the amount by having a student blow into the bag using the traditional method of blowing into a small opening at the bag’s opened end. Based on the sample, have the students approximate how many more breaths would be needed to fill the bag entirely.
2. Ask the students if they think it might be possible for someone to blow the bag up using just one breath.
3. Have students demonstrate that it is indeed possible by having each of them hold the trash bag open approximately 1 to 3-foot distance from his/her mouth.
4. Using only one breath, ask the students to blow as hard as they can to fill it up, then quickly squeeze the bag’s end closed with their hands.
5. You can also have two groups race to fill a bag, one using the traditional approach, and one blowing into a large opening of the bag from approximately a two- to three-foot distance. This approach can provide humor if the group using the traditional method is unaware of the other team’s tactic.

Ask yourself the following questions:
1. How can a single breath of air fill the bag?
2. Will it work with a smaller or larger bag? (Use the Windbag™ to find out.) Will it work with a small and/or slow breath of air also?

Science background:
In the early 1700s, a Swiss mathematician and scientist by the name of Daniel Bernoulli discovered that the faster air travels, the lower the pressure it exerts.

In our example, the stream of moving air creates an area of lower pressure, which attracts high pressure air adjacent to the stream of air from your lungs. As a result, it is not just a single breath of air that fills the trash bag, but rather air from the surrounding area also.

Our atmosphere is always trying to maintain steady air pressure. As a consequence, an area of high pressure will move toward an area of low air pressure in an attempt to restore balance. Pressure will never be steady around the Earth, however, no matter how hard the atmosphere tries to balance itself. This is due to the Sun’s uneven heating of the Earth’s surface, which creates ever changing areas of high pressure and low pressure.

Learn more online!
• Stuff in the Sky http://eo.ucar.edu/kids/sky/index.htm
• Web Weather http://eo.ucar.edu/webweather/
• UCAR Science Education http://spark.ucar.edu/teachers
Students observe the Bernoulli Principle in action: as the velocity of a fluid increases, the pressure exerted by that fluid decreases.

**What you'll need:**
For each pair of students:
• Paper or clear plastic tubes of various lengths with a 3” opening at each end. Mailing tubes work well.
• 1 or more ping pong balls
• Hair dryer

**Directions:**
1. Turn the hair dryer on and point it and the stream of air upward at a 90 degree angle to the ground.
2. Place the ping pong ball in the stream of air and let go of it.
3. Place the tube like a hat on top of the ping pong ball floating in the air stream. Do not let go of the tube.
4. Repeat the activity using tubes of various lengths. Tubes of various widths can also be explored.

**Ask yourself the following questions:**
1. Why does the ping pong ball float in the stream of air produced from the hair dryer?
2. Why does the ping pong ball travel up and out of the tube?
3. Why does the height reached by the ping pong ball vary depending on the length of the tube?
4. Why does the ping pong ball travel farther with greater air speed?
5. What happens to the ping pong ball if you cover the top of the tube when it is placed on top of the air stream? Why?

**Science background:**
This activity is based on Bernoulli’s Principle, named after the Swiss mathematician and scientist Daniel Bernoulli (1700-1782) more than 250 years ago. It states that as a fluid’s velocity increases, the pressure exerted by that fluid decreases.

In this example, the ping pong ball initially floats in the air stream because air accelerates as it is forced into a narrow tube, and the air pressure drops as a consequence. It stays suspended in the air stream because the speed of moving air is increased over its curved surface. This results in a corresponding decrease in air pressure around the ball’s surface and produces lift. The high pressure air immediately outside the air stream hugs the low pressure system and snuggles the ball, keeping it in place.

The wind tunnels or tubes cause the air stream to accelerate as it is funneled into a smaller area. This increase in velocity lowers the air pressure in the tube. High pressure air moves toward low pressure, so this lower pressure air literally sucks the ball up into the tube.

A good rhyme when it comes to air: High pressure to low, high pressure to low, that is where the air tries to go!
Weather Map Know-How

Students will learn about various kinds of weather maps and how they are used.

Materials
For each group of 3-5 students:
• One specific type of weather map from a reputable online weather site (e.g., temperature, wind, precipitation, radar, satellite, fronts, jetstream, surface weather maps)
• Computers and internet access

Directions
1. Print out a variety of weather maps covering a particular country or region for a specific day and hour such as a visible satellite map, an infrared satellite map, a weather frontal map, temperature contour map, radar/precipitation map, wind-speed map, etc. (use the weather Web sites above as a resource). Give one map to each small group of students.
2. Using the internet as a resource, ask each group to identify what their specific map shows, how the information is gathered, and why it is important and/or useful to weather forecasters and meteorologists (see Summary of Maps provided). Students should also think about the history of weather observations and technology.
3. After the students have researched their particular weather map, have each group of students teach the class about the value of their particular map in terms of forecasting weather; the technology that makes it possible; how long society has used such maps; and how we might have gained and/or conveyed this information in the past, if it was possible at all.

Inquiry questions:
1. Why is it helpful to use different types of weather maps?
2. Do you think some are more important than others? Why?
3. Do you know of any other types of maps often used during weather forecasts (e.g., UV index, heat index, pollen counts)? What is their importance?
4. What is the history of some of these maps? How long have they been in use? What technology is needed to make them possible?
5. How do you think your map was compiled? Are computers necessary?
6. Can you think of another map pertaining to weather that could be helpful?
7. Do we know everything we need to know in order to make accurate weather predictions? What advancements or information might still be sought to improve our forecasting capabilities?
8. If you wanted to be a weather forecaster, what skills and knowledge might be helpful to you? Where might you work?

Background Information
Modern forecasting involves collecting information about the current state of the atmosphere; analyzing this information, usually with a computer, to extend the observations to locations where no observations are available (for example, in remote ocean areas); and then using weather models that move the current state of the atmosphere ahead in time – via mathematical formulas that capture our understanding of the physics and fluid dynamics that govern the atmosphere – to make a forecast. In the past, the human forecaster used to be responsible for generating the entire weather forecast from the observations. Today, we not only have computers and models that have greatly advanced our forecasting capabilities, but we also have numerous advancements in observations tools –-- weather balloons, satellites, doppler radar, wind profilers, automated weather stations, and more –-- that have revolutionized what we are able to observe and learn about Earth’s weather. Today’s forecasts usually extend to no more than 14 days, with reliability diminishing with time. Today’s forecasts rely upon observations and models, combined with expert human judgment and decision making.

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The weather is constantly being measured all over the world. This data goes into weather maps that you can find on the Internet. Analyzing maps with the current weather conditions is an essential part of the entire forecast process. Basically, if we do not know what is currently occurring, it is nearly impossible to predict what will happen in the future. Below is a summary of various weather maps and what we can learn from them.

**Air Mass/Front Maps:** These maps illustrate where fronts and high and low pressure systems are located. Solid black contour lines, called isobars, are drawn on such maps, which connect areas of similar pressure. The closer the isobars are to each other, the stronger the pressure gradient and the stronger the wind. Blue fronts are cold fronts, red fronts are warm fronts, alternating red and blue fronts are stationary fronts, and purple fronts are occluded fronts. These maps are particularly helpful since specific weather conditions result from high and low pressure systems.

**Dew Point Maps:** The dew point temperature is the temperature the air would have to be to become saturated, or in other words to reach a relative humidity of 100%. Dew points provide insight into the amount of moisture in the air. The higher the dew point temperature, the higher the moisture content is for air at a given temperature. When the dew point temperature and air temperature are equal, the air is said to be saturated. Dew point temperature is NEVER GREATER than the air temperature. Therefore, if the air cools, moisture must be removed from the air, and this is accomplished through condensation. This process results in the formation of tiny water droplets that can lead to the development of fog, frost, clouds, or even precipitation. Relative humidity can be inferred from dew point values. When the air and dew point temperatures are very close, this indicates that the air has a high relative humidity. The opposite is true when there is a large difference between air and dew point temperatures, which indicates low relative humidity.

**Radar Maps:** The most effective tool to detect precipitation is radar. Radar, which stands for Radio Detection And Ranging, has been utilized to detect precipitation, and especially thunderstorms, since the 1940s. Radar enhancements have enabled forecasters to examine storms with more precision. Doppler radar is what is most commonly used today. It can detect motions toward or away from the radar, as well as the location of precipitation areas. This ability to detect motion has greatly improved the meteorologist's ability to peer inside thunderstorms and determine if there is rotation in the cloud, often a precursor to the development of tornadoes.

**Precipitation Maps:** These maps are developed using doppler radar and show the reflectivity of particles in the atmosphere such as rain, snow or hail. The color of the precipitation corresponds to the rate at which it is falling. Precipitation maps are a type of radar map that are usually viewed at local or regional scales, although large scale precipitation maps are also available.

**Satellite Map:** Satellite images of Earth have been with us nearly 50 years now -- since the launch of the world's first successful weather satellite, TIROS 1, in 1960. After much advancement through the years, satellite images now provide us with cloud and weather observations from high in the upper atmosphere. They also allow us to obtain measurements of radiation from both the Earth and atmosphere. There are many different types of satellite weather maps, for example, visible, infrared, and water vapor.

- **Visible Satellite Map:** Visible satellite images provide information about cloud cover from photographs of the Earth. Areas of white indicate clouds while shades of gray indicate largely clear skies. However, it is difficult to distinguish among low, middle, and high level clouds in a visible satellite image because they capture the amount of light reflected or scattered by clouds, which can be similar at different levels in the atmosphere.

- **Infrared Satellite Map:** Infrared satellite images measure temperature of clouds. In these photographs, warmer objects appear darker than colder objects, which appear brighter. Since high level clouds are colder than low level clouds, they appear brighter. Color enhancements use colors ranging from purple to red to make certain features stand out that would otherwise be a shade of gray.

- **Satellite Water Vapor Maps:** In satellite images showing water vapor, dark colors indicate drier air, and brighter shades of white signify areas with greater moisture. This information on both moist and dry air helps forecasters identify swirling wind patterns in the mid-troposphere and jet stream.
Relative Humidity Map: This color-filled contour map shows the current relative humidity. Relative humidity is the ratio of water vapor contained in the air to the maximum amount of water vapor that can be contained in the air at the current temperature. The map's key shows the corresponding relative humidity for each color.

Surface Map: Weather plots are shown on surface maps and represent weather information for a given place in time. These plots help meteorologists convey a lot of information about the weather in a given locale without using a lot of words. When all stations are plotted on a map, a "picture" of where the high and low pressure areas are located, as well as the location of fronts, can be obtained. At right is a typical example of one of many weather plots you might find on a surface map and the information it conveys.

Temperature Map: This surface meteorological chart shows the temperature pattern over the area in the map. Surface temperature reported at each station in the U.S. are contoured every five degrees Fahrenheit. (Celsius is used in many other countries.) Areas of warm and hot temperatures are depicted by orange and red colors, and cold temperatures (below freezing) are shaded blue and purple. Areas of sharp temperature gradients (several contours close to each other) tend to be associated with the position of surface fronts. Fronts separate air masses of different temperature and moisture (and therefore density) characteristics. The key below the image shows the corresponding temperature value for each color.

Upper Air Winds/Jet Stream Map: The upper air/jet stream weather maps show current wind speeds and directions for the atmosphere at certain altitudes – usually 8,000 -10,000 meters above ground for the jet stream and at various other altitudes (specified in millibars that correspond to the air's pressure at a particular height). Sometimes these maps also include a color-filled contour map with the wind vector arrows displayed to show the wind direction. The key shows the corresponding wind speed for each color. Wind maps can be created for Earth's surface as well as for the jetstream and/or upper atmosphere. Upper atmosphere wind maps are vital to accurate general weather forecasts and severe storm predictions. These maps also provide information that is especially important to the airline industry.

Time on Weather Maps
Since local time varies around the world, meteorologists everywhere need a common point in time if their observations are to be meaningful to others in different time zones. Universal Time Coordinate (UTC) is what all forecasters use, which is also referred to as Zulu time (Z). You will notice all weather maps, radar, and satellite images have their time expressed in UTC. Doing so allows the many different elements that create our weather (e.g. the high and low pressure systems, fronts and precipitation areas) to be viewed together at the same point in time. UTC uses a 24-hour system of time notation. “1:00 a.m.” in UTC is expressed as 0100, pronounced “zero one hundred.” Fifteen minutes after 0100 is expressed as 0115. Try to convert your local time to UTC. Learn more and check your answer at www.timeanddate.com/worldclock/.
Students learn techniques to determine locations of high and low pressure systems by analyzing US pressure maps and drawing corresponding isobars.

What you’ll need:
• colored pencils
• unplotted pressure maps

Directions:
1. As a class, review and discuss various isobar maps, then attempt to create your own individually or with a partner.
2. Choose one millibar reading between 992 mb and 1036 mb to begin (992, 996, 1000, 1004, 1008, and so on at 4 mb intervals).
3. Use a particular colored pencil to place a dot on the map where that millibar reading is found.
4. Use a different colored pencil for each millibar interval and continue to place dots on the map that correspond to that specific interval.
5. After you have found all your corresponding numbers, you can begin to connect the dots of the same color on the map. Interpolate locations where the isobar should be drawn when the readings do not directly correspond to the pressure in millibars being connected.

Ask yourself the following questions:
1. Have any of my isobars crossed?
2. Where are areas of low pressure and high pressure on the map. Place a red “L” and a blue “H” in these areas.
3. Since air moves clockwise around high pressure and counter-clockwise around low pressure in the Northern Hemisphere, which way are winds blowing in various places on your map? Place arrows to represent wind direction around your map’s highs and lows.
4. Where do you think the area of greatest winds might be located on your map if the strongest winds are found in areas with closely drawn isobars representing changes in pressure over short distances?

Science Background:
Isobars are lines drawn on a weather map connecting points of equal pressure. Drawing them is a bit like connecting the dots. Although that sounds easy, drawing isobar contour lines is a skill that takes practice. Isobars are usually drawn at 4 millibar intervals: 992 mb, 996 mb, 1000 mb, 1004 mb, 1008 mb, 1012 mb, 1016 mb and so on. When there is no other corresponding millibar measurement of equal value to connect to, one should find pairs of adjacent stations with readings close to the millibar measurements being drawn. For example, if you’re connecting isobar contour lines for 1024 mb, you would draw your isobar line of 1024 mb between two numbers that straddle and are close to 1024 mb, perhaps 1021 mb and 1028 mb. An isobar continues to be drawn until it reaches the end of the plotted data or closes off a loop as it encircles data. It is important to note that an isobar line never crosses over another. Also, pressures lower than the isobar value are always on one side of the isobar and higher pressures are consistently on the other side. Lastly, neighboring isobars will tend to take similar paths.