

## Activity 1.4 Pressure, Temperature and Wind

### 1.4.1 The Interaction of Temperature and Pressure

### 1.4.2 Highs, Lows, Winds and Jet Streams

#### Teacher Background

According to Charles' Law, at a constant pressure the volume of gas increases as the temperature increases. Likewise the volume of gas decreases as the temperature decreases. There is a point where the molecules of the gas are so tightly packed that the gas either condenses into a liquid or freezes into a solid.

If warm air rises why does the air get cooler the higher you go in elevation? Most of the Sun's rays are absorbed by the surface of Earth, both land and ocean. (See Activities 1.1 and 1.2.) Through conduction, the air immediately above the surface is then warmed. Through convection, the warm air, which is less dense, rises. As it rises it expands still more because the pressure is less. As it continues to expand the molecules spread farther and farther apart, thus colliding less with other molecules. Since temperature is, in reality, the measurement of heat energy (defined as the motion of molecules) less energy means lower temperatures. The air then starts to sink, the pressure increases and the molecules come back together, increasing the temperature.

On cloudless, dry nights the air near the surface of the ground becomes colder than the air above it. This is called a "temperature inversion" and is simulated in the second step of this hands-on Activity when students place the small beaker with cold water into the large beaker with warm water. Since cold air is denser than warm air, the cold air mass is trapped below the warmer air, causing pollution to be locked in beneath the inversion. If this trapped air reaches the dew point, dew, fog or frost forms.

**SAFETY NOTE TO TEACHERS:** Goggles should be worn with this experiment as per local guidelines. Jars and small vials may be substituted for the beakers, but there is a danger of glass breakage when Pyrex type containers are not used.

#### Objectives

Students will observe convection.

Students will simulate what happens in a "temperature inversion."

Students will observe that as the temperature of a gas increases the volume increases and as the temperature of a gas decreases the volume decreases.

#### Vocabulary

anticyclone

Charles' Law

cyclone

inversion

molecules

pressure

temperature

thermal equilibrium

Materials (for each team of students)

two 50 ml beakers

two 250 ml beakers

thermometer

red food coloring

240 ml of cold water

220 ml of hot water

tongs

goggles

WEATHERlogs (for each student)

LFSTORM Standards Correlation sheet (for teacher reference)

Engage

Ask students to explain how the molecules in a gas are packed together (loosely.) How is that different from in a solid (rigid and fixed), or in a liquid (tighter than a gas, looser than a solid)? How can you speed up the motion of the molecules? (Add heat) What causes something to float? (It has less density than the liquid.) Why does something sink? (It's denser than the surrounding liquid.) Discuss the fact that temperature is actually the measurement of thermal energy and that the temperature of any object will eventually reach thermal equilibrium (see Glossary) if it is left long enough.

Explain/Explore

Procedure

Note: since this is a relatively sensitive experiment, we suggest you walk students through it, rather than allowing them to implement it themselves, using a Worksheet (as in all Section 2 Activities.)

Have each team of students heat 220 ml of water to approximately 60 degrees Celsius (140 degrees Fahrenheit) and use cold water that is approximately 25 degrees Celsius (75 degrees Fahrenheit). You can use water that is at different temperatures than these, but to get the best results the difference *between* the two temperatures should be approximately 35 degrees Celsius or 65 degrees Fahrenheit.

“Pour approximately 200 ml of *cold* water into the large beaker. Place two or three drops of red food coloring into the small beaker. Pour approximately 20 ml of the warm water into the small beaker. Using tongs, carefully lower the small beaker into the large beaker. Observe. Draw what you observed in your WEATHERlogs.”

“Pour approximately 200 ml of *warm* water into the large beaker. Place two or three drops of red food coloring into the small beaker. Pour approximately 40 ml of cold water into the small beaker. Using tongs carefully lower the small beaker into the large beaker. Observe. Draw what you observed.”

#### TEACHER TIP:

To get the best results the small container should only be partially filled. The water level of the larger container must be just above the top of the smaller container when it is placed inside the large container.

When the small beaker with hot water is lowered into the large beaker with cold water, students should see the hot water rise to the surface and sit on top of the cold water. It will remain suspended for several minutes, and then as thermal equilibrium is reached the entire beaker should appear light red in color.

When the small beaker with cold water is lowered into the large beaker with hot water there should be very little mixing. Students need to lower the beaker as straight down as possible. Even if a little of the cold colored water is spilled, they will still see that most of the cold water remains in the little beaker until the temperature begins to change. In this situation, since cold water sinks, the red dye will be spread throughout the beaker much faster than in the other situation.

#### Expand/Adapt/Connect

Materials (Teacher demonstration only)

flask

balloon

bowl or pan with ice water and bowl or pan with warm water

goggles

WEATHERlogs (for each student)

LFSTORM Standards Correlation sheet (for teacher reference)

**SAFETY NOTE TO TEACHERS:** Goggles should be worn. Soda bottles may be substituted for the flasks, but remember there is the danger of glass breakage if you do not use Pyrex type containers.

#### Procedure

Hold up the flask and discuss if anything is in the flask. (Air) Place the neck of the balloon over the mouth of the flask, trapping air inside the flask. Place the balloon covered flask into the warm water. Hold the flask upright while you are doing this. It should only take a minute to get the desired results. (Balloon will inflate.) Then place the flask into the ice water. Hold the flask upright and you should immediately see a change in the balloon. (Balloon will deflate.) Explain your results.

Discuss that in the first experiment the warm air expanded and rose. When warm air rises it cools. Cold air holds less moisture than warm air which causes the water vapor to condense and form clouds. (See Activity 2.1, "Making Clouds.")

Explain that the second experiment is what happens in a temperature inversion. In this situation fog or clouds close to the ground form when the cool air reaches its dew point.

### Activity 1.4.2 Highs, Lows, Winds and Jet Streams

PTK wishes to thank Glen Freimuth, Professor of Earth Science, Richland Community College, Decatur, IL, and “Project DataStreme” team leader, who worked with a member of the LFSTORM Instructional Materials development team to create and review this Activity. The “hand-twist” procedure is used by “DataStreme,” a Teacher Enhancement project of the American Meteorological Society. P2K thanks AMS and its Education Director, Ira W. Geer, for permission to adapt and use this procedure and the DataStreme High and Low pressure worksheets.

### Teacher Background

It’s often said that we live under an “ocean of air.” We usually can’t see it or smell it because pure air is odorless and invisible. We take air for granted. In the words of the old Chinese saying, “a fish is the last to know that it lives in water.” But air is real, has weight (see Activity 3.1, “Making a Barometer”) and behaves according to the laws of fluid dynamics, albeit a very thin liquid.

When air is in motion, however, none of us take it for granted. We feel a gentle breeze, and relax. And we take precautions when the strong winds of hurricanes or tornadoes threaten. Our world is washed by air in motion all the time, even in the absence of violent weather. For just as an ocean has currents, so does the air in our atmosphere. We call these currents of moving air “wind.” From the joy of flying a kite to the fear of an approaching storm, our lives are constantly affected by wind. We welcome a cool breeze in the summer but dread the biting cold wind of the winter. It unfurls our flags, erodes the natural landscape grain by grain of rock and sand, and drives huge weather systems across the country. What is the cause of the wind?

Like an ocean of water exerting great pressure at its depths, the atmosphere presses upon everything within its boundaries. Air has mass, and due to the gravitational pull of the Earth, it has weight. In fact, the weight of a column of air at sea level is equivalent to 1.0 kg per square centimeter (14.7 lbs per square inch). That’s as heavy as a small bowling ball resting on your thumb!

Just as a submarine experiences less pressure from the surrounding water as it nears the surface, so air pressure decreases with an increase in elevation or altitude. With less air above, there is less mass being pulled down by gravity, resulting in lower air pressure. Air flows from regions of high pressure to regions of low pressure. These differing regions are the result of the uneven heating of the Earth’s surface and variations in water vapor present. (See Activity 1.1.) Imagine filling a bath tub with water and attempting to push the water with your hands to one end. The water quickly flows back to its original level, resisting the momentary variation in weight from one end of the tub to the other.

Like water, air always flows toward regions of lower pressure and we experience this flow of air as wind. Its speed and direction are influenced by Earth's rotation and the surface over which it flows. In the northern hemisphere, air flows into a low pressure center in a counter-clockwise manner. This is caused by the Coriolis Effect (see sidebar) and friction, and the resulting low pressure flow of air is called a "cyclone." Air flows into the low pressure center and is carried aloft. In contrast, denser, heavier air sinks in a high pressure center and flows outward in a clockwise manner. This is called an "anticyclone." The greater the difference in neighboring pressure centers, the stronger the flow of air between them. Smaller scale examples of air flow can be caused by the uneven heating of land and water along a coastline resulting in land breezes and sea breezes. Local winds can also be triggered by variations in the heating of different surfaces such as urban concrete and rural vegetation. (See Activity 1.2 for illustrations of both these last 2 points.)

#### The Coriolis Force

"An apparent force observed on any free-moving object in a rotating system. On the Earth, this deflective force results from the Earth's rotation and causes moving particles, including the wind, to deflect to the right in the Northern Hemisphere and to the left in the Southern Hemisphere." (from "Meteorology Today", C. Donald Ahrens, see Resources.)

For more on the Coriolis Effect see:

[http://zebu.uoregon.edu/~js/glossary/coriolis\\_effect.html](http://zebu.uoregon.edu/~js/glossary/coriolis_effect.html)

Explanation and diagrams.

[http://ww2010.atmos.uiuc.edu/\(Gh\)/guides/mtr/fw/crls.rxml](http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/fw/crls.rxml)

Background information, including a movie showing how it works using a playground merry-go-round.

#### Objectives

Students will apply the "hand-twist" model to determine wind direction around high and low air pressure centers.

Students will predict changes in surface wind direction caused by movements of high and low air pressure systems.

#### Materials and Preparation (for each student)

pencil

Worksheets 1.4.2.1 & 1.4.2.2

WEATHERlogs

LFSTORM Standards Correlation sheet (for teacher reference)

## Engage

Ask your students to explain why the wind blows. (Differences in air pressure.) From which direction does a north wind blow? (Winds are always named for the direction from which they blow: a north wind is blowing *from* the north *towards* the south.) What causes the wind to blow from different directions? (Proximity to high and low pressure centers, variations in local surface heating.) What effect does a south wind have on local temperature? (For the Northern hemisphere, a south wind generally brings warmer temperatures from the Tropics.) A north wind? (Generally brings cooler temperatures—unless you live in the southern hemisphere: weather and climate are good reminders that the northern and southern hemispheres experience nature’s forces differently, and that we should constantly remind students that the Coriolis forces, and the rotation of winds around high and low pressure areas, vary depending on which side of the equator you may live.) What direction does air flow in a tornado or hurricane in the northern hemisphere? (Counter-clockwise.)

## Procedure

1. Distribute Worksheet 1.4.2.1, “High”, to each student.
2. Direct the student to draw a small circle around the large “H” appearing on the map.
3. “Place the map on a desk top or table surface. Bring the thumb and fingertips of your left hand close together and place them on the circle.
4. Slowly rotate your hand (not the map) in a clockwise manner and gradually spread out your thumb and fingers as you lower your palm to the surface. Practice this motion until you can achieve a full twist comfortably.
5. Place your thumb and fingertips back in the starting position in the circle. Mark and label the positions of your thumb and fingertips 1, 2, 3, 4 and 5 respectively.
6. Slowly rotate your hand clockwise while gradually spreading your thumb and fingers and lowering your palm. Stop, mark and label the new positions 1, 2, 3, 4 and 5 respectively. (If you labeled your thumb 1, continue using 1 for your thumb’s new positions, etc.)
7. Follow the same procedure in quarter steps until your palm rests on the surface.
8. Connect the numbers for each finger and thumb, successively, resulting in five smooth curved lines. (Connect all the 1’s together, all the 2’s together, etc.) Draw arrows on the lines showing the directions your thumb and fingers moved.
9. The spiral you have drawn represents airflow *out* of a high pressure system.”
10. Distribute Worksheet 1.4.2.2, “Low”, to each student.
11. Direct the student to draw a small circle around the large “L” appearing on the map.
12. “Place the map on a desk top or table surface. Place your hand flat on the map, fingers spread, with your palm on the circle.
13. Slowly rotate your hand (not the map) in a counter-clockwise manner and gradually draw your thumb and fingers together until they touch as you raise your palm. Practice this motion until you can achieve a full twist comfortably.
14. Place your hand flat on the map, fingertips spread, in the starting position with your palm on the circle. Mark and label the positions of your thumb and fingertips 1, 2, 3, 4 and 5 respectively.
15. Slowly rotate your hand counter-clockwise while gradually drawing your thumb and fingers together and raising your palm. Stop, mark and label the new positions 1,2,3,4 and 5 respectively.
16. Follow the same procedure in quarter steps until your thumb and fingers touch together and your palm is at its highest point.

17. Connect the numbers for each finger and thumb, successively, resulting in five smooth curved lines. (Connect all the 1's together, all the 2's together, etc.) Draw arrows on the lines showing the directions your thumb and fingers moved.
18. The spiral you have drawn represents airflow into a low pressure system.
19. Describe the flow of surface wind around a high pressure system. (Clockwise and spiraling outward.)
20. Describe the flow of surface wind around a low pressure system. (Counter-clockwise and spiraling inward.)
21. The motion of your palm represents the vertical direction of air in high and low pressure centers. What is the vertical motion of air in a high? (Downward.) What is the vertical motion of air in a low? (Upward.)
22. Examine the Activity 1.4.1 Sheets. From which direction is the wind blowing in the city west of the High? (South) From which direction is the wind blowing in the city west of the Low? (North)
23. As the high and low pressure centers move eastward across the U.S., how will wind directions change for the surrounding cities?"

#### Expand/Adapt/Connect

Examine current U.S. weather maps showing low and high pressure centers. Determine the wind directions for cities surrounding these high and low pressure centers and predict changes in wind direction as the systems move eastward across the U.S. Compare your predictions to forecasts for the various cities.

#### Suggested URLs

[http://www.comet.ucar.edu/dstreme/images/sfc\\_pres.gif](http://www.comet.ucar.edu/dstreme/images/sfc_pres.gif)

Current atmospheric pressure maps, from the AMS "DataStreme" Project

[http://ww2010.atmos.uiuc.edu/\(Gh\)/guides/crcim/act/prs.rxml](http://ww2010.atmos.uiuc.edu/(Gh)/guides/crcim/act/prs.rxml)

Introduces the characteristics of low and high pressure systems.

<http://www.usatoday.com/weather/wdenalt.htm>

Background information on the density of air, and a link to calculate the density of air at different temperatures.