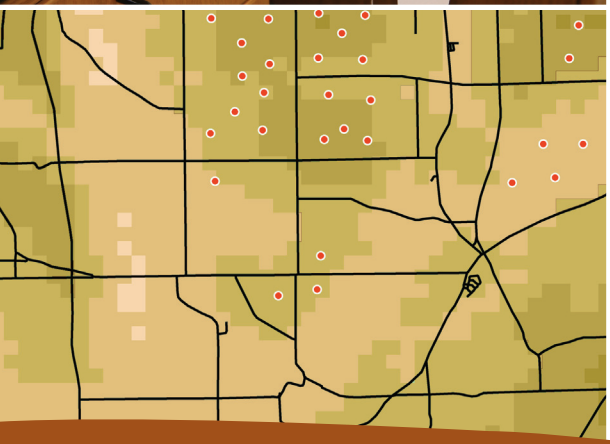
WindWise Education

Transforming the Energy of Wind into Powerful Minds



A Curriculum for Grades 6-12

www.WindWiseEducation.org

WindWise Education was developed with funding from the New York State Energy Research & Development Authority.

WHAT CAUSES WIND?

LESSON 3

KEY CONCEPT

Students will learn about the forces that cause wind and the ways in which these forces are measured.

TIME REQUIRED

1 – 2 class periods

GRADES

6 – 8

SUBJECTS

Physical Science
Social Studies
Earth Science

windwise education
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BACKGROUND

The movement of air, also called wind, is driven by 2 primary forces: changes in air temperature/pressure and the rotation of the Earth. The forces that cause wind can be measured and quantified and are the basic elements of a daily weather forecast. Students learn how these forces work and how they are measured with barometers, thermometers, and anemometers.

OBJECTIVES

At the end of the lesson, students will

- Understand the relationship between temperature and pressure in the context of the gases in the atmosphere
- Know what forces cause wind
- Be able to explain how land surfaces affect wind

METHOD

Through observing a series of demonstrations and participating in hands-on activities, students learn about the relationship between temperature and pressure. On the molecular level, students describe what causes changes in pressure. Students then relate these concepts to topography and larger weather patterns.

MATERIALS

Air Pressure/Air Temperature Demonstration

- ❑ Bottle with opening just smaller than an egg (iced coffee bottles work well)
- ❑ Hard-boiled egg, peeled, or a small water filled balloon
- ❑ Matches or lighter

Air Can Exert a Force

- ❑ 1-2 balloons per student

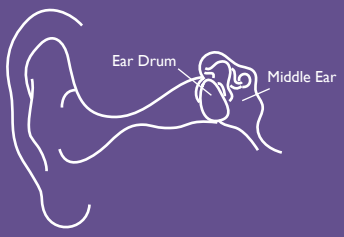
Build a Barometer (1 set for each barometer)

- ❑ A straight-sided glass jar with screw top lid. Drill two ¼ inch holes in lid.
- ❑ A narrow plastic 6” ruler
- ❑ Clear tape
- ❑ 9” of clear plastic tubing (¼ inch internal diameter)
- ❑ Water
- ❑ Red food coloring
- ❑ Small clamp

Air Pressure (1 set for a demonstration or for each pair of students)

- ❑ Plastic syringes (5 to 10 ml size)
- ❑ Clear plastic tubing or straw (¼ inch diameter)

EAR POPPING



Ears "pop" when there is an imbalance between the pressure inside and outside the ear. An airplane tries to maintain an air pressure in the cabin that is similar to that of the air on the ground. When the air pressure in the cabin changes, however, an internal blockage such as mucus can prevent equalization of pressure on each side of the ear drum. As a result, the ear drum is pushed in or out creating a "popping" sensation.

GETTING READY

- Read the reading passage to become familiar with the relationship between temperature and pressure and how these forces cause wind.
- Try all demonstrations ahead of time to ensure they are working correctly.
- Make copies of the worksheets for each student.
- Assign the reading passage for homework if desired.

ACTIVITY

Step 1: Beginning Questions for Students

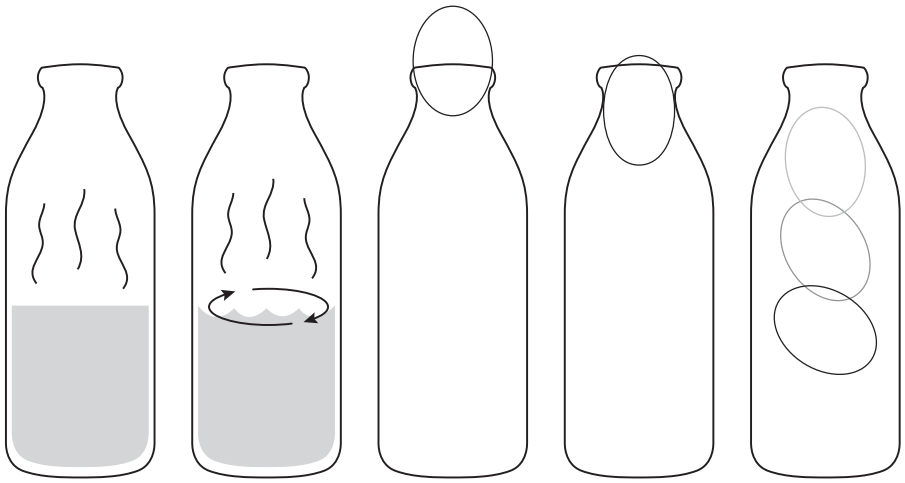
- What do you think causes wind?
- Why is it windy sometimes and calm at other times?
- Have you noticed wind is more likely to blow during the day and be calm during the night?
- Have you ever had your ears pop? Why do you think this happens?
- How do you measure changes in air pressure?
- Why does air pressure change?
- Why does a hot air balloon rise and then drift with the wind?

End the discussion by explaining the relationship among air temperature, air pressure, and wind speed. Use the diagrams in this lesson and the reading passage.

Have students complete the worksheets during the following demonstrations.

Step 2: Air Pressure/Air Temperature Demonstration

Add hot water into the glass bottle and leave for a few seconds to thoroughly warm up the glass, then discard the hot water. Immediately place the narrow end of a peeled hard-boiled egg over the mouth of the bottle so that it seals the opening. Observe what happens and discuss this with the students.



Hints for Discussion: As the air is heated it begins to "expand." This happens because air molecules become energized and move around faster causing them to bump into each other more often. This causes the molecules to move apart and the air to expand. This expansion causes some air to escape from the bottle, which may make the egg wobble when it is first put on top of the bottle. As the air inside the bottle cools, it contracts. The egg creates a seal over the top of the bottle. There is less air in the bottle (because the air escaped when warm), causing unequal pressure to occur between the air in the bottle and the air outside the bottle. The greater air pressure on the outside pushes the egg into the bottle, thereby removing the seal and equalizing air pressure inside and outside the bottle.

This demonstrates two important points

- Warm air expands
- High pressure pushes towards low pressure

Step 3: Air Can Exert a Force (student hands-on activity)
Hand out balloons to all students. Have students place the balloon on a desk, lay a book on top of it, and then try to blow the balloon up.

Challenge: what is the heaviest book you can move this way?

Step 4: Build a Barometer (demonstration or hands-on activity)
Now that students understand that air exerts a force caused by differences in pressure, have them build a simple barometer to show how pressure is measured. Show students a real barometer or download an image off the Internet (see Additional Resources).

Tape the tube to the ruler and then tape the ruler to the inside of the glass container.

Position the ruler and tube so that the bottom of the tube is clear of the bottom of the container, the top of the tube is above the top of the container, and the top of the ruler is inside the container. Cut the top off the ruler if necessary (see Figure 1).

Half-fill the container with water and add some food coloring to make observation easier.

Suck some water up the tube, seal the top with your finger, and quickly seal the top with clay (or a clamp) so that the column in the tube is clearly higher than the level in the container.

If air pressure rises, the level in the tube will go up. If it falls, the level will fall. The change can be measured against the ruler in millimeters.

Explain that millibars (mb) are the units used to measure pressure in a mercury barometer. A standard barometer is a thin tube at least 30 inches long. At sea

level, mercury will be forced up this tube 29.92 inches, which is equivalent to 1013.25 mb. Higher pressure will force the mercury higher in the tube. Lower pressure will see the mercury drop. To give an example, a strong hurricane may have pressure as low as 27 inches of mercury (914.36 mb) and a high pressure system that brings calm, clear weather may have pressure higher than 31 inches (1049.82 mb).

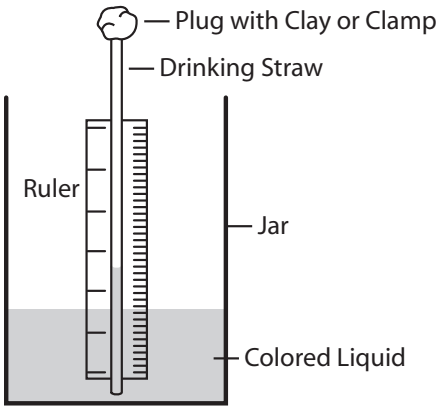


Figure 1: A Simple Barometer

Have students observe the barometer each class period during the next week or two to see what changes there are.

Step 5: Air Pressure (demonstration or hands-on activity)
Hand out syringes, tubing, and binder clips (1 set per 2 students).

Connect tubing to the syringe and force air in and out by alternately pulling and pushing on the syringe plunger.

When the plunger is pulled out, it causes lower pressure inside the syringe. Air moves from high (outside) to low (inside) pressure and enters the syringe. When the plunger is depressed, the pressure inside the syringe rises and air flows out (from high to low pressure again).

Clamp the tube (you will need to fold the tubing back on itself to create a functional seal) and then try to pull air into the syringe. What happens? Why?

Air cannot enter the syringe and thus the plunger cannot be pulled out. If the seal is not perfect, some air will flow into the syringe.

Unclamp the tube, pull out the syringe plunger halfway, and then reclamp the tube (fold the tube again). Now depress the plunger. What happens? Why?

The plunger cannot be depressed unless there is somewhere for the air to go. As you try to depress the plunger, you increase the air pressure inside the syringe and the high pressure exerts a force against you that prevents you from pushing in the plunger. If the clamp seal is not perfect, air will escape, but there will still be resistance.

Step 6: Air Pressure Changes and Air Movement Demonstration
Optional: this step can be difficult to get to work.

Add the lid to the top of the barometer jar. It should have 2 ¼ inch holes drilled in it—one for the straw attached to the ruler and one more. The holes

should be just big enough for the straw and plastic tubing to fit tightly.

Pull the plunger of a syringe half way out. Connect it to a piece of plastic tubing at least 18 inches long. Insert the other end of the tubing through the hole in the lid of the barometer.

Add a daub of Vaseline around each tube where it passes through the lid to create a tight seal (It is very difficult to create a perfect seal).

Pull very gently on the syringe and watch what happens to the level of the liquid in the tube.

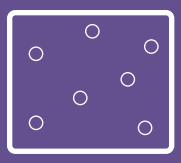
Push very gently on the syringe plunger. Observe the level of the liquid in the tube. What happens? Why?

If you have good seals, you should see the column in the tube fall when you pull on the plunger (lower pressure) and rise when you push on it (higher pressure). The barometer is sensitive to pressure change, as previously explained. The amount of pressure increase or decrease can be measured against the scale on the ruler in the homemade barometer.

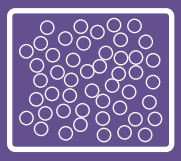
Step 7: Volume, Molecules, Equilibrium, and Pressure
Spend a few minutes using the diagrams on the worksheet to explain what causes changes in pressure at the molecular level.

- Emphasize that air moves from regions of high pressure to regions of low pressure.
- When a syringe is at rest, air pressure inside and outside is the same.
- When the syringe is pulled, the volume inside the syringe increases, so pressure decreases because there is more space between molecules. More air molecules move in from the region of high pressure outside the syringe to try to cause equilibrium.
- When the syringe is pushed, the opposite happens. The volume inside the syringe decreases, creating less space between molecules so that pressure rises and air molecules move out of the syringe to cause equilibrium.

Step 8: Temperature and Pressure
Refocus on the air pressure/air temperature demonstration for a minute. An increase in temperature adds energy to gas molecules in the air, which causes them to move about faster. This action creates more collisions, which cause molecules of gases in the air to move farther apart (expansion). In the confines of a bottle, the only way out is up through the mouth of the bottle. When air warms in the atmosphere, the same thing happens. Molecules move farther apart, creating less dense air that rises, which in turn creates an area of low pressure. Air from higher pressure areas will tend to move towards areas of lower pressure in order to replace the rising air, which creates wind. Areas with more intense heating will more actively rise, which will create stronger winds.



Heated air



Cooler air

Step 9: Relationship among Temperature, Pressure, and Wind
Have students study worksheet diagrams 1 and 2 and complete the questions.

Step 10: Wrap Up
If there is time, hold a summary discussion with the students.

EXTENSION

Use the simple barometer that you made to measure pressure in the classroom and on different floors of the school. For every 10 meters (about 33 feet) of change in altitude, there is a 1 mb change in pressure. If you can get high enough, you may be able to measure this difference. If the school does not have a second or third floor, you may want to get permission to access the roof. Make sure you can take all readings at around the same time to eliminate variable conditions.

Air Temperature, Volume and Density
A good visual example of how air molecules behave when heated and cooled is to partially blow up a balloon and tie it shut. Measure the circumference of the balloon and then put it in a microwave for 30-60 seconds. Measure the circumference again as soon as the balloon is removed from the microwave. The circumference (and volume) will increase because the air molecules were heated up, causing them to move farther apart. As the air molecules move farther apart, they cause the volume of the balloon to increase. The balloon still contains the same number of air molecules, but have the same number of molecules, but they have different volumes and, therefore, different densities. The molecules in the cooled balloon are more dense than the molecules in the heated balloon.

VOCABULARY

Anemometer – Instrument used to measure wind speed.

Barometer – Instrument used to measure atmospheric pressure.

Millibars – A unit used to measure air pressure. 1 Millibar = 1/1000th of a bar. 1 Bar is roughly equal to atmospheric pressure at sea level.

Pressure (in the atmosphere) – The force created by weight of air pushing down.

Thermometer – Instrument used to measure temperature.

Topography – The study and mapping of the shape of surface features of the earth such as mountains, valleys, rivers and lakes

RELATED ACTIVITIES

- Lesson 4: Where Is It Windy?

ADDITIONAL RESOURCES

ABOUT.COM—http://inventors.about.com—Search for "barometer" on this site.

BRASSBINNACLE.COM—www.brassbinnacle.com—Search for "barometer" and then click on the code number for an illustration.

NATIONAL WEATHER SERVICE—www.nws.noaa.gov—Type in your zipcode to see your current and recent barometric pressure.

UNIVERSITY OF WY—http://weather.uwyo.edu/upperair/uamap.html—Get maps of current barometric pressure and wind.

NY STATE STANDARDS

Intermediate Level Science–Standard 4: The Physical Setting
Key Idea 2:
Many of the phenomena that we observe on Earth involve interactions among components of air, water, and land.

Performance Indicator 2.2
Describe volcano and earthquake patterns, the rock cycle and weather and climate changes.

Major Understandings:
2.2i Weather describes the conditions of the atmosphere at a given location for a short period of time.

2.2j Climate is the characteristic weather that prevails from season to season and year to year.

2.2k The uneven heating of Earth's surface is the cause of weather.

2.2l Air masses form when air remains nearly stationary over a large section of Earth's surface and takes on the conditions of temperature and humidity from that location.

Weather conditions at a location are determined primarily by temperature, humidity, and pressure of air masses over that location.

2.2m Most local weather condition changes are caused by movement of air masses.

2.2n The movement of air masses is determined by prevailing winds and upper air currents.

The Physical Setting–Earth Science: Standard 4 (High School)
Key Idea 2:
Many of the phenomena that we observe on Earth involve interactions among components of air, water, and land.

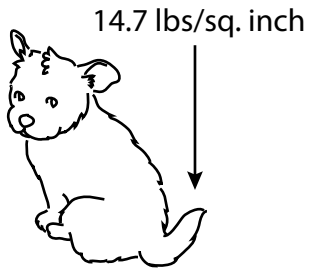
Performance Indicator 2.1:
Use the concepts of density and heat energy to explain observations of weather patterns, seasonal changes, and movements of the Earth's plates.

Major Understandings:
2.1e Weather variables are interrelated.

For example:
temperature and humidity affect air pressure and probability of precipitation
air pressure gradient controls wind velocity

READING PASSAGE

The common definition of wind is that it is air that flows from high pressure to low pressure.



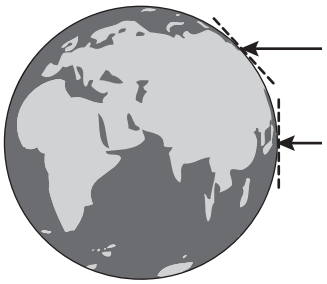
A column of air, one square inch in cross section, measured from sea level to the top of the atmosphere would weigh approximately 14.7 pounds. If you think about how many square inches your body has that is a lot of weight! Why don't we feel it?

What causes differences in pressure? The nearer air is to the ground, the more pressure it is under because air above pushes down on air below. Air is made of gas molecules, which have weight, and it is this weight that causes pressure. A 1 square inch column of atmospheric air pushing down creates approximately 14.7 lbs of pressure at sea level. At higher altitudes, the pressure is less simply due to the fact that there are fewer air molecules above.

Pressure in different places and at different times of the day varies because of the way energy from the sun is distributed. As the sun's rays hit the earth, land, water, and vegetation absorb the energy, some of which is given off as heat, which then heats the surrounding air. When air molecules heat up, they speed up and move farther apart when they collide with each other more often. This causes them to increase the amount of space (more volume) they take up. When air molecules cool down, they come closer together, taking up less space (less volume). As the volume of the air molecules increases, the density decreases. Conversely, as the volume of the air molecules decreases, the density increases. The density of the air causes it to move. More dense, cooled air will fall, and less dense, heated air will rise. As air rises and falls in different places, it creates differences in pressure. Air moves from areas of higher pressure to areas of lower pressure and creates what we call wind.

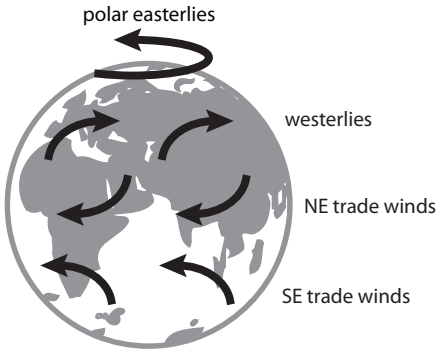
The Earth's spherical shape, topography, vegetation, and water bodies all ensure that not every part of the Earth will receive energy in the same manner and amount. There will be differences in air pressure due to different temperatures, causing variation in the amount of air rising and falling and therefore variation in wind velocity and direction. For example, sea water heats more slowly than land, creating a major difference in pressure between land masses and oceans. Friction with the ground surface is also a factor; especially where mountain ranges create barriers to wind.

Differences in pressure represent half the explanation of what causes wind. The second part is related to the Earth's rotation. As the world turns from west to east, the atmosphere turns too and in the same general direction. It is for this reason that the prevailing winds in most places blow from a westerly direction generally toward the east. Different levels of air in the atmosphere experience different effects from the Earth's rotation. Air high up in the atmosphere is not as affected as air below, setting up a situation where air can flow in opposite directions at different altitudes (you may have seen clouds moving in different directions at different heights).



The sun hits the Earth at different angles in different places. This creates uneven heating.

Latitude affects how much solar radiation is received each day and returned to space each night. Tropical latitudes receive direct warming from the sun, whereas "high latitudes" (toward either pole) receive solar energy at an oblique angle due to the curvature of the Earth. Tropical latitudes therefore warm more easily than high latitudes and so there is a fairly constant rising of air away from the tropics (low pressure), which causes air from surrounding areas to move toward the tropics. Sailors call this constant air flow the "trade winds," which are very reliable.



Trade winds

Land, water, topography, and the types of vegetation affect how much sunlight is absorbed and reflected. Snow cover plays a major role by reflecting most solar radiation it receives back into space. This creates cool air over the extreme northern and southern latitudes as well as over extensive mountain ranges. Cool air is denser than warm air and sinks to the surface, creating large areas of high pressure. This sets up many of the winter storms experienced in northern states such as New York when cold arctic air spreads south due to this high pressure.

A related concept to wind formation and rotation is the Coriolis effect. Large masses of moving air, such as those described above, are pulled into circular rotation due to the Earth's rotation. Instead of air moving in direct lines from high pressure areas to low pressure areas, it is bent into curves. In the northern hemisphere, this causes air to flow clockwise around high pressure areas (anti-cyclones) and counter-clockwise around low pressure areas (cyclones). Severe storms are cyclones with very low pressure. These flows are reversed in the southern hemisphere.

Coriolis effect

Since differential temperature is the major factor that affects pressure, it is common for large areas of warm air (originating from closer to the equator) to come into close proximity with large areas of cooler air (usually originating closer to the poles). Warm and cold air masses do not readily mix, and where they meet the cold air will push under the warm air, forming a "front." A front can create windy and rainy weather, sometimes with thunderstorms and tornadoes.

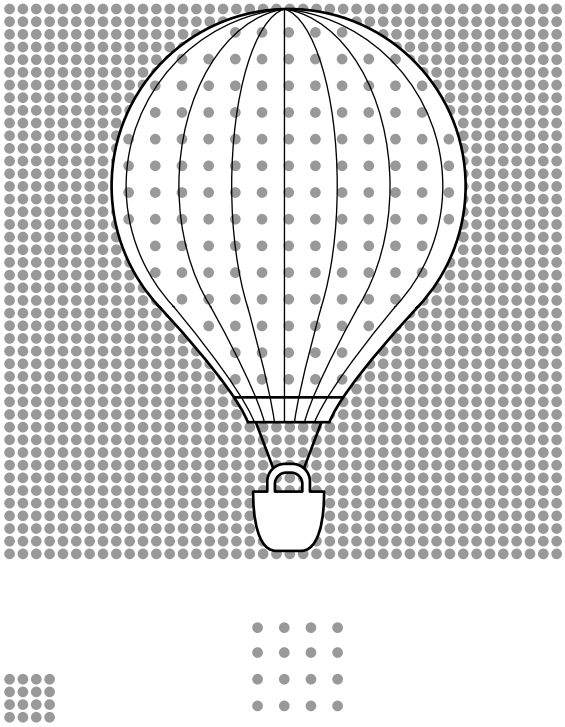
This reading passage was adapted from material found on two websites

- http://ezinearticles.com/?Exploring-What-Causes-Wind&id=1956623
- http://www.weatherdudes.com/facts_display.php?fact_id=35

HOW DOES A HOT AIR BALLOON WORK?

A hot air balloon has gas heaters to heat the air inside it. As the air is heated, the air molecules gain kinetic energy (from the heat) and begin to move faster. This increases how often they collide with each other, which causes them to move farther apart. As they move farther apart, the overall density of the air in the balloon becomes less than the density of the air outside the balloon. The balloon begins to rise because the less dense hot air lifts the balloon and "floats" on top of the more dense, cooler air around it.

To bring the balloon down, some of the hot air is let out in openings at the top and cooler air is brought in through the bottom (the heat is turned off). This increases the density of the balloon and causes it to lower.



Heating air causes it to expand and become less dense.

CAREER PROFILE: BILL QUINLAN, METEOROLOGIST

I joined the WCJB TV20 Weather Team in Gainesville, Florida, in 1996. I present the weather at 5:30, 6:00, and 11:00 pm weeknights and oversee the WCJB TV20 weather staff and severe weather coverage for the station. I love weather and am happy that I have a career that allows me to study the weather every day. I love to explain complex weather phenomena to television audiences.

To become a meteorologist, you need to study weather in college. To present weather forecasts on television, it also helps to study mass media. My qualifications include a bachelor's degree in meteorology from the University of Massachusetts and also a Certificate in Broadcast Meteorology from Mississippi State University.

I have been awarded Seals of Approval by both the National Weather Association and the American Meteorological Society. I also present lectures to numerous organizations, including civic groups, schools, and retirement communities in North Florida, where I live with my wife and son.

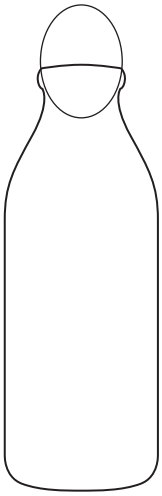
Name_____ Date_____ Class_____

WHAT CAUSES WIND

Relationship between temperature and pressure

1. What happened to the egg on top of the bottle you were observing?

2. Why did this happen? Label pressure areas on the drawing.



Air can exert a force

1. Could you blow the balloon up when it was under a book?

2. How can air cause a book to rise? Draw an image and label.

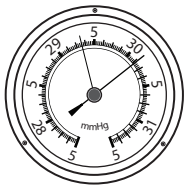
Millibar conversion

At sea level, air pressure causes a mercury barometer to rise to a height of 29.92 inches, which is equivalent to 1013.25 millibars.

1. Given the above information, calculate the air pressure in millibars.

   a. 28.2 inches of mercury = _____ mb. This represents ____ pressure.

   b. 30 inches of mercury = _____ mb. This represents ____ pressure.



2. How many inches of mercury would the barometer stand at if the pressure was 1030 mb?

Air moves due to pressure changes

1. When you clamped the tube, why could you not pull the syringe plunger out? (Explain in terms of differences in air pressure within and outside the syringe.) Draw and label an image.

2. When you clamped the tube, why could you not push the syringe plunger in? (Explain in terms of differences in air pressure within and outside the syringe.) Draw and label an image.

Air pressure changes and air movement demonstration

Explain what is happening to the barometer, in terms of differences in air pressure, as air is pushed in and pulled out of the container by the syringe. Draw and label an image.

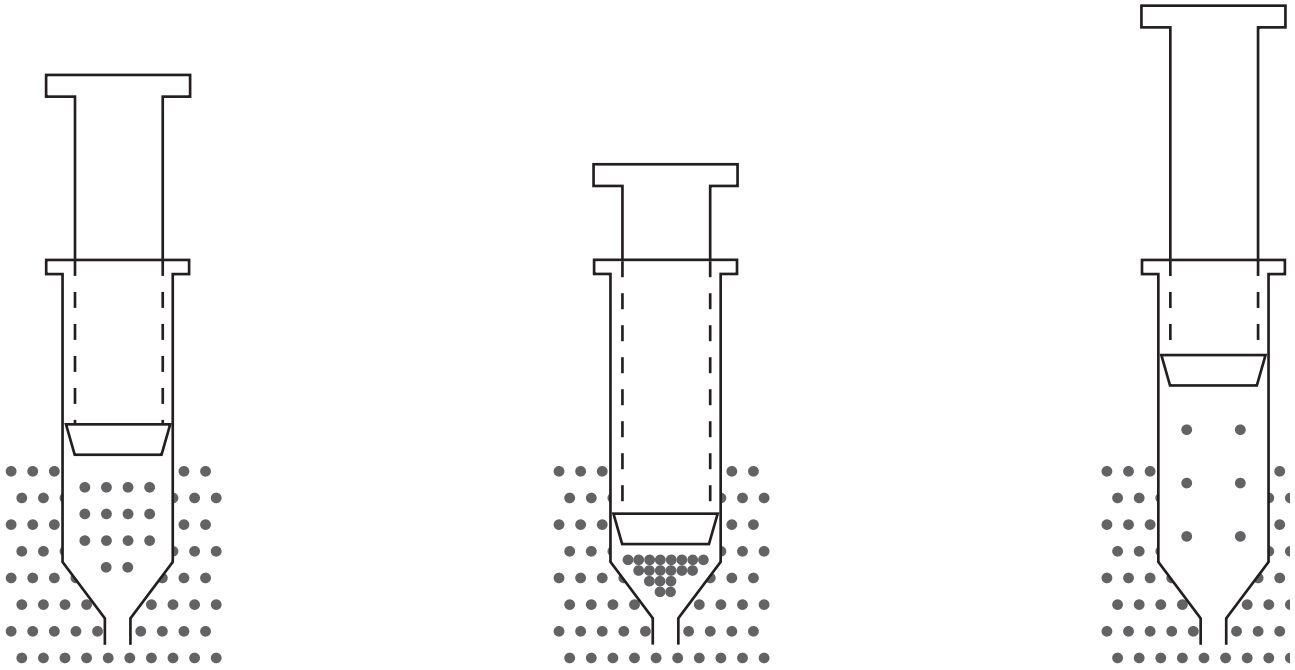
Name_____ Date_____ Class_____

Volume, molecules, equilibrium, and pressure

1. Add arrows at the bottom of the syringes to show the direction of air flow and fill in the blanks about what has happened to the air pressure inside the syringe.

A **B** **C**

No Air Movement _____pressure _____pressure



Pressure at equilibrium (Higher or lower?) (Higher or lower?)

2. Land and water heat and cool at different rates. Land heats and cools much faster than water. In coastal areas and areas near large lakes, this phenomenon causes the direction of winds to change at different times of the day and night. Based on what you now know about the relationship between temperature and pressure and how this creates conditions for wind, *circle the correct word in the sentences below and then draw arrows on the diagrams to show which ways the wind will blow.* If you live in a coastal area or near a large lake, you can regularly feel this daily change in wind direction.

a. On sunny days, the sun heats the land in the morning more quickly than it heats the nearby ocean. Because of this, the air over the land will **rise / fall** and the pressure over the land will **increase / decrease**. Because of this, the wind will blow **toward / away from** the ocean and **toward / away from** the land.

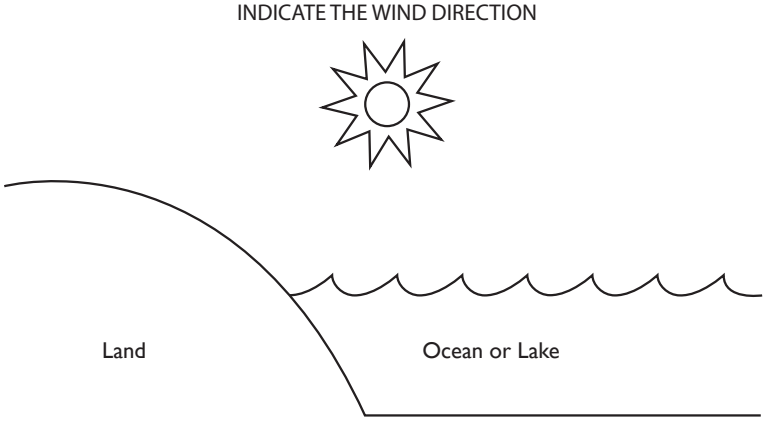


Diagram 1: 11am on a sunny day

Draw in arrows on Diagram 1 below to show where air is rising and falling and in which direction the wind will flow.

b. In the evening, when the sun goes down, the land will cool down, which cools the air above it. Because of this, the air over the land will **rise / fall** and the pressure over the land will **increase / decrease**. Because of this, the wind will blow **toward / away from** the ocean and **toward / away from** the land.

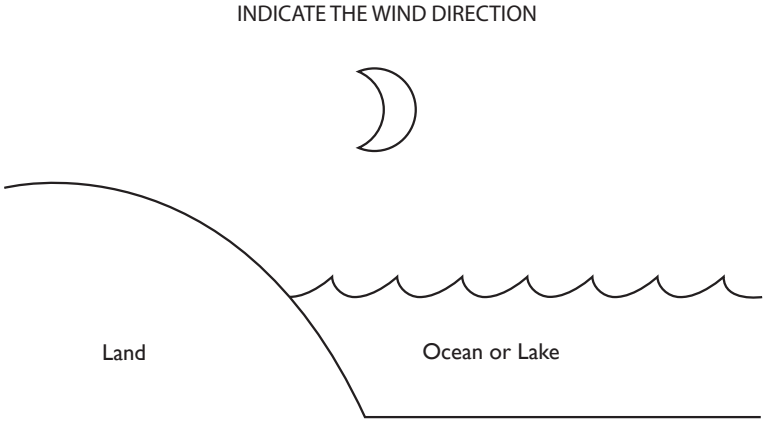
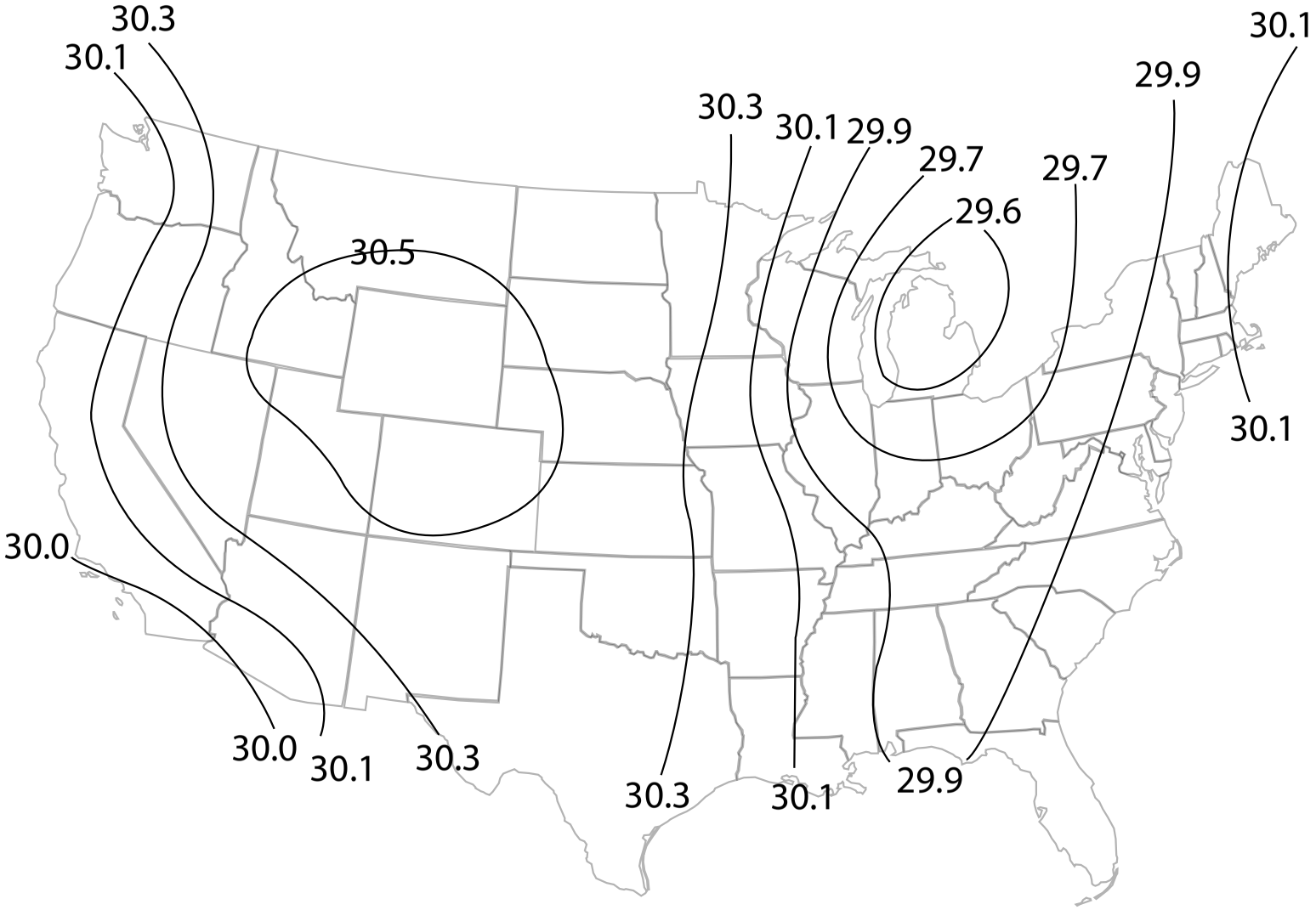


Diagram 2. 11pm on a clear moonlit night

Draw in arrows on Diagram 2 below to show where air is rising and falling and in which direction the wind will flow.

Label the map with High and Low Pressure. Where is air rising? Falling?

Optional: go online to find air pressure maps. What is the barometric pressure at your school?



WHAT CAUSES WIND

Relationship between temperature and pressure

1. What happened to the egg on top of the bottle you were observing?
   Student observation

2. Why did this happen? Label pressure areas on the drawing.
   Heat inside the bottle warmed the air, causing it to expand (molecules farther apart) and rise, which created lower pressure inside the bottle. The egg then blocked the entrance, causing a barrier to form between the higher pressure outside the bottle and the lower pressure inside. As the air inside the bottle cooled, the air contracted (molecules now closer together) and the higher pressure air from outside pushed its way into the bottle by pushing the egg through the opening.

   Label the diagram with "Lower Pressure" on the inside of the bottle and "Higher Pressure" on the outside above the egg.

Air can exert a force

1. Could you blow the balloon up when it was under a book?
   Student observation

2. How can air cause a book to rise? Draw an image and label.
   Explanation: As a balloon is blown up it inflates due to higher pressure forming inside than outside. This higher pressure exerts a force that can lift objects, such as books.

Millibar conversion

At sea level, air pressure causes a mercury barometer to rise to a height of 29.92 inches, which is equivalent to 1013.25 millibars.

1. Given the above information, calculate the air pressure in millibars.
   a. *28.2 inches of mercury = 955 mb. This represents Low pressure.*
   b. *30 inches of mercury = 1,016 mb. This represents High pressure.*

2. How many inches of mercury would the barometer stand at if the pressure was 1030 mb?
   30.41 inches

Air moves due to pressure changes

1. When you clamped the tube, why could you not pull the syringe plunger out? (Explain in terms of differences in air pressure within and outside the syringe.) Draw and label an image.
   With the tube clamped, there is no way for air pressure to equalize inside and outside of the syringe. Pulling the plunger out causes lowered air pressure within the syringe, which creates a need for air to enter from the outside, where the pressure is now higher. Since air cannot move due to the clamp, there is resistance to changing the internal volume so that the pressure remains the same.

2. When you clamped the tube, why could you not push the syringe plunger in? (Explain in terms of differences in air pressure within and outside the syringe.) Draw and label an image.
   Same answer as number 1 above except the pressure differential is reversed.

Air pressure changes can be measured and cause air movement

Explain what is happening to the barometer, in terms of differences in air pressure, as air is pushed in and pulled out of the container by the syringe. Draw and label an image.

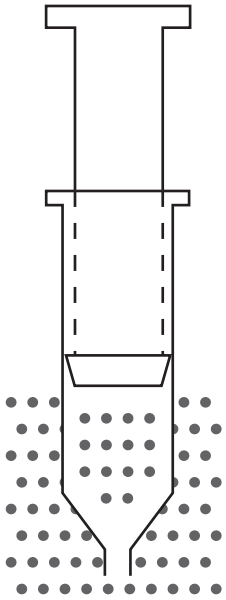
When the syringe plunger is pushed in, it forces air into the barometer, which raises the pressure and causes the colored water to rise up the tube.

The reverse is true when the syringe plunger is pulled out.

Volume, molecules, equilibrium, and pressure

1. Add arrows at the bottom of the syringes to show the direction of air flow and fill in the blanks about what has happened to the air pressure inside the syringe.

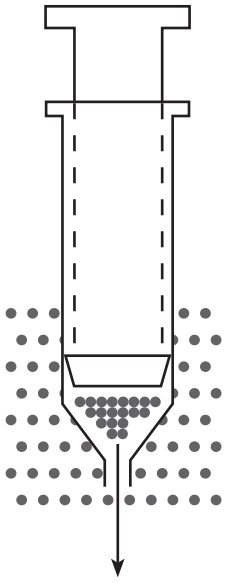
A



No Air Movement

Pressure at equilibrium

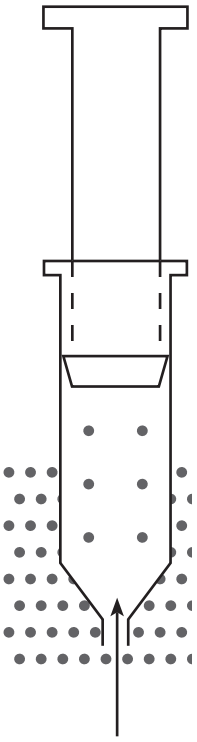
B



_____pressure

(Higher or lower?)

C



_____pressure

(Higher or lower?)

2. a. On sunny days, the sun heats the land in the morning more quickly than it heats the nearby ocean. Because of this, the air over the land will **rise / fall** and the pressure over the land will **increase / decrease**. Because of this, the wind will blow **toward / away** from the ocean and **toward / away** from the land.

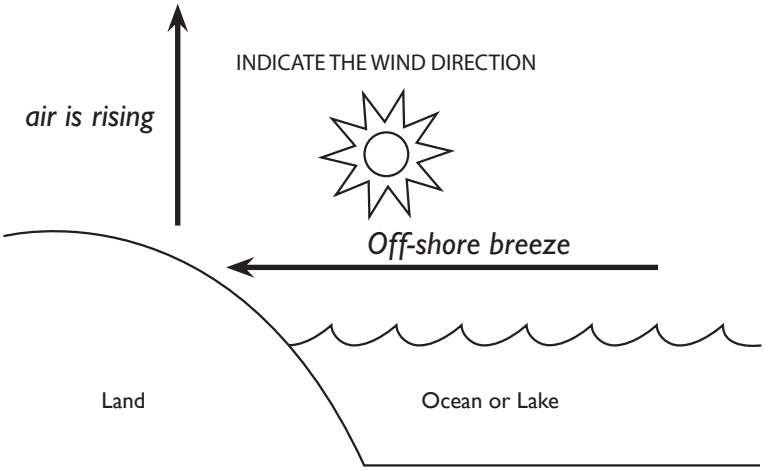


Diagram 1: 11am on a sunny day

Draw in arrows on Diagram 1 below to show where air is rising and falling and in which direction the wind will flow.

b. In the evening, when the sun goes down, the land will cool down, which cools the air above it. Because of this, the air over the land will **rise / fall** and the pressure over the land will **increase / decrease**. Because of this, the wind will blow **toward / away** from the ocean and **toward / away** from the land.

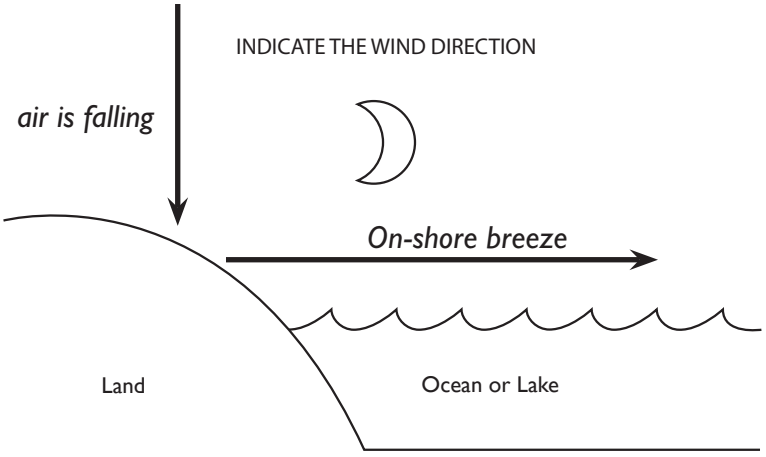


Diagram 2. 11pm on a clear moonlit night

Draw in arrows on Diagram 2 below to show where air is rising and falling and in which direction the wind will flow.

US Map with Isobars

High pressure is over the western states centered over Wyoming with a pressure of 30.5 inches of mercury. Air is falling in this area.

Low pressure is over the Midwest centered over Michigan with a pressure of 29.6 inches of mercury. Air is rising in this area.