***Properties of Air***

*Adapted from http://www.agiweb.org/education/energy/wind/index.html*

We are all familiar with the feeling of wind blowing. The air around us is constantly in motion, and though invisible, contains a stream of moving particles that flows and mixes above the Earth's surface. Scientists and engineers face great challenges in harnessing the wind for power. The \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ is the lowest portion of the Earth's atmosphere. It starts at the Earth's surface and goes up to a height of 7 to 20 kilometers. The air that makes up this layer is a mixture of atoms and molecules of different gases. About 99 percent of dry air is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (approximately 78%) and \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (approximately 21%). Carbon dioxide and argon make up most of the other one percent. Air often contains water vapor as well. The amount of water in the air varies from close to zero percent up to five percent over time, and from one place to another.

Because air on the smallest scale simply consists of individual \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ , the building blocks of matter, it has mass. The density of air is the amount of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ in a given volume of air. This means that if there are more molecules of air gases in a specific, constant volume of air, the density is greater than it would be if there were fewer molecules of the same gases in the same volume. The gravitational attraction between the Earth and the gases of the atmosphere pulls particles of gas toward the center of the Earth. As a result, the weight of the gases at the top of the atmosphere presses down on the gases below (lower in the atmosphere, closer to the Earth’s surface), causing the air particles to compress and squeeze closer together, which increases the density of the air. For this reason, the density of air \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ as you get closer to sea level.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ is the weight of a column of air pushing down on a surface area. Air pressure at any point depends on the weight of the air above. Sea-level air has the weight of the whole atmosphere pressing on it. Therefore, air pressure is greatest at sea level. Air near the top of the atmosphere has less weight pressing on it, and therefore has lower air pressure. This means that, much like the density of air, air pressure \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ with increasing altitude.

A change in altitude is not the only thing that produces changes in air pressure and air density. Temperature (or heat energy) affects air pressure and density as well. What, specifically and scientifically, is a thermometer measuring when it determines the temperature of a substance? Write your answer, using complete sentences, in the space below.

***Temperature is a measure of***

When air is heated, the molecules and atoms that make up the air gain kinetic energy, which simply means that they move with greater \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_. As the molecules in the heated air move faster, they bump into each other more frequently and with more “oomph”-- because they are colliding more frequently and vigorously, the air particles start to become spaced farther apart. As a result of the air becoming more spaced apart, the volume of the air increases. Since the mass of the air stays the same, but the air now takes up more volume, the density of the air \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_. When air is cooled, the opposite happens. As the air is cooled, the molecules that make up the air lose kinetic energy, meaning that they move slower and slower. As the speed of the particles decreases, they collide more gently than they did at high temperature, and these gentle collisions don’t push the particles very far apart after they crash into each other. As a result, the density of the air \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ as the air cools. There are fewer molecules exerting pressure in a given volume of warm air than there are in an equal volume of cool air. Since warm air (air with fewer molecules in a given volume) has less mass than the same volume of cooler air, it exerts less air pressure than cool air. This means that, in general, **air pressure decreases as temperature increases.**

To explore how the properties of air change with temperature, let’s take a large plastic bag and fill it with warm air using a hair dryer. Once the bag is full of warm air, it is sealed shut so that it is almost bursting at the seams.

***What are two things that you think will happen to the bag of air if we place it outside on this cold winter day?***

Let’s place the bag out the window and observe what happens to it over 10-15 minutes. Record your observations below.

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Has the number of air molecules in the bag changed at all since we placed the bag outside? \_\_\_\_\_\_\_\_\_\_

Has the volume of the air in the bag changed at all since we placed it outside? \_\_\_\_\_\_\_\_

How have these changes affected the density of the air?

How has the motion of the air molecules in the bag changed since we placed it outside?

Predict what will happen to the bag of air once we bring it back into the warm classroom. Specifically discuss what happens to the mass of the air, the number of air molecules in the bag, the temperature of the air, the kinetic energy of the air particles, the volume of the air, and the density of the air.

what happens to—

the mass of the air?

the number of air molecules in the bag?

the temperature of the air?

the kinetic energy of the air particles?

the volume of the air in the bag?

the density of the air?

What is the word that we commonly use to describe air movement? \_\_\_\_\_\_\_\_\_\_

Now, let’s think about how changes in air temperature and density affect the ways that air moves. Thinking about ocean currents, explain how air density differences might cause air to move. Be specific.

How would differences in air temperature cause air to move? Be specific: when warm air and cold air meet each other, where would wind blow to, and where would it blow from?

***Air Pressure, Air Temperature, and Wind***

Because air is a fluid, it can move easily from place to place across the Earth’s surface, and from one height above the Earth’s surface to a different (higher or lower) height. Although there are several forces and other natural factors that can affect the direction in which air moves (such as the rotation of the Earth), differences in air pressure between separate regions of the atmosphere are what sets the air in motion. **Wind is the movement of air from an area of higher pressure to an area of lower pressure**. Most differences in air pressure are caused by the unequal heating of the atmosphere—regions of the Earth that receive more direct sunlight during the daytime than other regions add more heat to the air above it than regions that receive less sunlight. We’re having winter in Maine right now because the days are short (the sun isn’t out for a long time) and the sun is low (far south) in the sky. The air around us is cold because there isn’t much sunlight to warm it up.

When air over an area of the Earth's surface is heated, *it expands and becomes less dense*. As the air becomes less dense, *its air pressure decreases*. If a nearby surface is not heated as much, the air above it will be cooler and denser, and this cooler, denser air exerts greater pressure than the warm air, *so it flows underneath the warmer, less dense air, forcing it to rise*. In this way, **equilibrium** is achieved as high-pressure areas of the atmosphere relieve their pressure by moving into low-pressure areas, producing wind!

What does the word **equilibrium** mean in the above sentence?

*“If I could make wind in a bottle….”*

Is it possible to use these properties of air to create wind in a laboratory? Surprisingly, the answer is yes—we *can* use differences in air temperature and air density to create wind!

Examine the apparatus pictured below. This is a diagram of the “connected tubes” device that we played with back in the Ocean unit. For this activity, we will place ice water in the bottom of one of the tubes, and hot water in the bottom of the other tube.

Ice water

Hot water

What will happen to the temperature of the air above the ice water?

What will happen to the temperature of the air above the warm water?

What will happen to the density of the air above the cold water? Above the warm water?

How will the air pressure exerted by the air over the ice water change?

How will the air pressure exerted by the air over the warm water change?

Based on what you know about air temperature, air density, and air pressure, do you believe that wind will be created in the tube device? Explain, and then make a diagram below to show how you think that the air in the tube will move.

Watch as smoke is added to the tube device. The smoke will move along with the air as the air moves through the tubes, showing where wind is blowing. Is the smoke moving in the way that you predicted?

**Local winds** are winds that blow over short distances. They are caused by the unequal heating of the Earth's surface within a small area. A good example of how local winds form occurs on land that is next to a large body of water. It takes more energy to warm up a body of water than it does to warm up an equal area of land. This means that as the Sun heats Earth's surface during the day, the land warms up (gains heat) faster than the water. The air over the land becomes warmer than the air over the water. The warm air expands and rises, creating a low-pressure area. The relatively heavier, cooler air blows landward from the water and moves underneath the warm air, creating wind. At night, the process is reversed and winds flow towards the water because the air cools more rapidly over land than over the water.

**Monsoons** are large scale seasonal wind patterns that blow over large regions. The most prominent examples occur in Africa and southern Asia. They are caused by large and consistent differences in air pressure between land and water that occur with the seasons. For example, in the summer in South and Southeast Asia, the land gradually gets warmer than the ocean. A large flow of air blows steadily inland from the ocean all summer, even at night. In the winter, the land cools and becomes colder than the ocean. The air blows steadily from the land to the ocean.

**Global winds** are winds that blow steadily in specific and consistent directions over thousands of kilometers. Much like local winds and monsoons, global winds are created by unequal heating of the Earth's surface. Near the equator, energy from the Sun strikes the Earth almost directly from overhead. The direct rays from the Sun heat the Earth's surface intensely. Warm air rises in this region, creating a continuous belt of low pressure. In contrast, the polar regions experience the same amount of energy form the Sun, but spread out over a larger area. This is because the sun's rays strike the Earth at a low angle and the heat is dispersed. As a result, temperatures near the poles are much lower than they are near the equator. The air is cold and dense, which causes it to sink, creating a region of high pressure.

If the Earth did not rotate, global winds would blow in a straight line from the poles (area of high pressure) toward the equator (area of low pressure). However, the Earth rotates from west to east underneath the moving winds, making it seem as if the winds curve. As a result, in the Northern Hemisphere, global winds blowing toward the north gradually turn toward the northeast. Global winds blowing toward the south gradually turn toward the southwest. In the Southern Hemisphere, a south wind becomes a southwest wind and a north wind becomes a northwest wind.