Ultra Long Duration Balloon

Balloon properties and flight

GRADE LEVELS

Grades 5 – 8

OBJECTIVES

While completing the following activities, students will:

- Describe the relationship between pressure and volume.
- Describe the relationship between pressure and temperature.
- Investigate buoyancy characteristics and balloons.
- Determine the relationship between balloon measurements.
- Track the ULDB's flight.

KEY WORDS

buoyant force
Celsius
circumference
density
diameter
Fahrenheit
gravity
helium
mercury thermometer
metric system
parachute
payload
polyethylene
spherical
volume

BACKGROUND INFORMATION

Balloons have been used for decades to conduct scientific studies. While the basics of ballooning have not changed, balloon size has increased and their dependability has improved greatly. The Wallops Flight Facility manages the NASA Balloon Program, which offers capabilities and benefits for scientific research that cannot be duplicated by other methods.

NASA balloons are constructed of thin, .002 centimeters (.0008 inches), **polyethylen**e material (special plastic), about the same thickness as ordinary sandwich wrap. The balloon system includes a balloon, a **parachute** and the **payload** that holds instruments to conduct an experiment.

Helium is used in these scientific balloons that can carry a payload weighing as much as 8,000 pounds (3,600 kilograms)about the weight of three small cars. They can fly to an altitude of 26 miles (42 kilometers), with flights lasting an average of 12 to 24 hours. Some special purpose long duration balloon flights have lasted more than two weeks.

There are three types of balloon missions:

Conventional Balloons
- science funded by NASA
- flight duration of 1 to 2 days
- zero pressure balloons
- mission cost $50k - $300k

Long Duration Balloons
- science funded NASA
- flight duration of 5 to 20 days
- zero pressure balloons
- primarily launched in Polar Regions during summer (constant daylight)
- mission cost $750k - $1750k

Ultra-Long Duration Balloons (ULDB)
- science funded by NASA
- flight duration of 60 to 100 days
- super pressure balloons
- initially to be launched in the Southern Hemisphere
- mission cost $1500k - $2600k

The ULDB is made of advanced materials and uses a new pumpkin-shaped balloon design to achieve flights of up to 100 days. The ULDB is completely sealed and pressurized in order to maintain constant altitude night and day. The payload consists of a solar power system, radio receivers and transmitters, computers, batteries and other systems required for the science experiment.

The ULDB has important advantages to the science community:
- They can be launched from locations worldwide to support scientific needs.
- They can be readied for flight in as little as six months.
- They offer a low cost method of conducting science investigations.
- They provide a stable platform for longer flight duration.
- The payload can be recovered and re-used.

The experiments conducted from a scientific balloon provide information on the atmosphere, the universe, the Sun and the near-Earth and space environment.

Scientific balloons offer direct research measurements in the atmosphere and near Earth environment for multi-disciplinary experiments — space sciences, applications, and technology. They offer the capability of obtaining scientific measurements at specific altitudes at specific times as well as multiple locations at a particular time. They also offer a platform for flight testing materials, instrumentation and experiments to be used for future space missions.

When launched the balloon is partially filled with helium and launched with the payload section suspended beneath it. As the balloon rises, the helium expands, filling the balloon until it reaches float altitude in two to three hours.

After the science measurements are complete, flight controllers send a radio command that separates the payload from the balloon. The payload floats back to the ground on a parachute where it can be retrieved and flown again. Payload separation creates a large tear in the balloon material, which releases the remaining helium. The balloon also falls to the ground and is retrieved and discarded. The balloon and payload land approximately 45 minutes after separation.

ACTIVITY ONE

How does volume affect the pressure of a balloon?

TEACHER PREPARATION

Pressure is the amount of force pushing against a specific amount of area. Increasing the pressure means more force is pushing against the same area. When we stand on the ground, we are exerting pressure against the ground below our feet (and there's an equal force pushing up against our feet). If we carry extra weights, we would increase the pressure under our feet because we are pushing harder against the same area. However, if we increased the size of our shoes and spread the same force over a larger area, the pressure decreases. That's why we can step across deep snow when we wear wide snowshoes.

When an object is surrounded by a gas or liquid, it experiences pressure from all directions. A diver in the ocean can feel the water pushing inward. If the diver drops deeper into the water, the pressure increases, because the pressure depends on the total amount of water above the diver.

Pressure and Volume

The pressure of a gas or liquid can be increased by decreasing its **volume**. When the volume of an ideal gas is decreased to half its original size (and the temperature is kept constant) the pressure of the gas doubles. The container walls and anything inside the container experience twice the force. The pressure increases because the same number of molecules are taking up half the volume and are colliding twice as often. We can also increase the pressure by increasing the amount of gas in a constant volume.

The scientific balloons launched by NASA are only partially filled with Helium when they are released. As they rise through the layers of the atmosphere, the air pressure decreases. With a finite amount of Helium in the balloon and the pressure decreasing, what happens to the balloon's shape and/or size?

MATERIALS

- Large syringe
- Tube
- Pressure gauge
- Vacuum pump
- Erlenmeyer filtering flask
- Small balloon
- Rubber stopper

QUESTIONS

- What is the relationship between pressure and volume of a liquid or air?

PROCEDURE

Step 1
Fill the syringe half full with air. Connect the syringe to the pressure gauge using the tube. Push on the syringe and observe the pressure reading on the gauge. Pull on the syringe and observe the pressure reading on the gauge.

Step 2
Blow just a small amount of air in the balloon. Push the balloon into the filtering flask and seal with the rubber stopper. Using the vacuum pump, remove the air from the flask.

CONCLUSION

- Discuss what happened to the pressure reading as the volume changed.
- Discuss what happened to the balloon with the outside pressure was reduced.
- Answer the questions posed in the beginning of the activity.

ACTIVITY TWO

How does temperature affect the pressure of a balloon?

TEACHER PREPARATION

Most of the time in the United States when we talk about temperature, we usually refer to the temperature scale known as the **Fahrenheit** scale. Zero Fahrenheit was the coldest temperature that the German-born scientist Gabriel Daniel Fahrenheit could create with a mixture of ice and ordinary salt. He invented the **mercury thermometer** and introduced it and his scale in 1714 in Holland, where he lived most of his life. In the scientific world, there is another scale that is more commonly used. This is known as the **Celsius** scale. Anders Celsius, a Swedish astronomer, introduced his scale in 1742. For it, he used the freezing point of water as zero and the boiling point as 100. For a long time, the Celsius scale was called "centigrade." The Greek prefix "centi" means one-hundredth and each degree Celsius is one-hundredth of the way between the temperatures of freezing and boiling for water. The Celsius temperature scale is part of the "**metric system**" of measurement (SI) and is used throughout the world.

All the scientific data that is received from the instruments on the balloon sent up by NASA is in degrees Celsius. Your class wants to know how to convert that to Fahrenheit. What is the relationship between the Fahrenheit and Celsius scales?

Heat

Temperature is a quantitative description of the average energy of motion of molecules in a material. Higher temperatures mean the molecules are moving, vibrating, and rotating with more energy. In the United States, temperature is measured in degrees Fahrenheit (F). In other countries, which use the metric system, temperature is measured in degrees Celsius (C).

0°C Freezing point of water
25°C Acceptable room temperature
37°C Normal body temperature
100°C Boiling point of water
100°C Average temperature inside a hot air balloon

Heat and Temperature

The terms heat and temperature are sometimes used synonymously, but they do not mean the same thing. When two objects with different temperatures are in contact, there is an exchange of energy from the hotter object to the colder object. Heat is the amount of energy that transfers from the hotter object to the colder object.

Pressure and Temperature

Pressure of an ideal gas is directly proportional to temperature, increasing at the same rate as temperature increases. Doubling the temperature doubles the pressure. Molecules travel faster at higher temperatures, so they collide with other objects more frequently.

In 1662, a scientist by the name of Robert Boyle first establish the relationship between pressure and volume of gases. Since that time it has since been known as Boyle's Law. In this activity students will determine the relationship between pressure and the volume of air confined in a syringe. When the volume of the syringe is changed by moving the piston, a change in the pressure exerted by the confined gas results and visa versa

Celsius and Fahrenheit

MATERIALS

- Fahrenheit thermometer
- Celsius thermometer
- Ice water
- Room temperature water
- Boiling water
- Three beakers or cups

QUESTIONS

- What is the relationship between the Celsius and Fahrenheit scales?

PROCEDURE

Step 1
Place the two thermometers in the beaker of ice water. After waiting one minute, record the temperature readings from each thermometer.
Step 2
Place the two thermometers in the beaker of room temperature water. After waiting one, minute, record the temperature readings from each thermometer.
Step 3
Place the two thermometers in the beaker of boiling water. Record the temperature readings from each thermometer.

Water Type	Fahrenheit Temperature	Celsius Temperature
ice		
room temp.		
boiling		

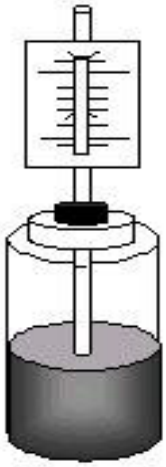
CONCLUSION

- Describe the pattern between the Fahrenheit scale and the Celsius scale.
- Answer the questions posed in the beginning of the activity.

MAKING AN AIR THERMOMETER

MATERIALS

- Glass bottle, 1-pint size
- Rubber stopper with 1 hole
- Glass tubing to fit h 24" long
- Water or alcohol
- Dye or colored ink
- Sealing wax or para
- Scotch or masking t
- Cardboard strip, 10"
- Ordinary thermomet



PROCEDURE

Step 1
Place the glass tubing, sealed at one end, through the stopper. Fill the tube full of water colored with the dye.
Step2
Quickly invert the tube, placing the lower end in a bottle about one-fourth full of the colored water. Press the stopper firmly in the bottle. Adjust the liquid in the tube by loosening the stopper or pressing it further into the bottle until the liquid is about half way along the exposed portion of the tube above the stopper.

Step 3
Use the wax to seal the tube in the stopper and the stopper in the bottle. Tape the cardboard to the tube above the stopper.
Step 4
Note the temperature on an accurate thermometer. Record this temperature on the cardboard, which will act as a temperature scale. Place the thermometers in a different temperature situation and leave them for a few minutes to allow the thermometers to register the new temperature. Note the new reading and mark on the scale.
Step 5
Carefully measure the distance between the two readings on the scale, and mark other degrees of temperature on it, as all other changes will be in the same proportion.

Incredible Shrinking Balloon

The following should be done as a demonstration.

MATERIALS

- Two balloons
- Cooler of ice
- Cooler of boiling water

QUESTIONS

- What is the relationship between pressure and temperature?

PROCEDURE

Step 1
Blow up the two balloons to the same size. Place one balloon in the cooler of ice and one in the cooler of boiling water.
Step 2
After 15 - 20 minutes remove the balloons. Observe the sizes of the balloons.

CONCLUSION

- Describe what happened to the two balloons.
- Discuss what effect the temperature has on the pressure of the air inside the balloon.
- Discuss what you think happens to most scientific balloons during the day and at night.
- Answer the question posed in the beginning of the activity.

EXTENDED ACTIVITY

Race to the top of the World

Using three helium filled balloons, test different aspects of balloon flight at different temperatures. Leave one balloon at room temperature, heat one balloon with a hair dryer and place one balloon in a freezer. Have the students investigate which balloon will rise faster. The students can also determine which balloon can carry more payload using string and small weights, paper clips or clay.

ACTIVITY THREE
Why do balloons float?

Buoyancy

TEACHER PREPARATION

In addition to the downward force of gravity, an object inside a fluid experiences a force directed straight up, opposite to the direction of **gravity**. This force is due to the difference in pressure above and below the object. The pressure is different because there is more mass above the bottom than above the top of the object. Therefore, the fluid pushes up from the bottom more than it pushes down from the top. This net force is called a **buoyant force**.

A ship floats on top of the water because the buoyant force is stronger than the force of gravity. The strength of the buoyant force is equal to the weight of water, which would fill the volume of water displaced by the object. If a 1 cubic meter (m^3) cube is submerged in water, the buoyant force equals the weight of 1 m^3 of water, or 1000 kg. If the cube weighs less than 1000 kg, it floats in water.

Archimedes' Principle
Archimedes, the Greek mathematician, discovered the principle of buoyant forces while sitting in his bathtub. He discovered that the upward buoyant force on a submerged body was equal to the mass of the displaced liquid. The displaced volume is equal to the volume of the body submerged in the liquid. If the force of gravity pulling the object down which is equal to the total weight of the object, is less than the buoyant force, the body floats in the liquid.

Buoyancy is the tendency of an object to float in a fluid. It is controlled by differences in **density** between the object and the fluid. Since salt water is more dense than fresh water, an object will float "higher" in salt water (less of its mass will be submerged.) This is particularly noticeable when floating in hyper-saline waters such as the Great Salt Lake or the Dead Sea. You can't sink!!

Air is a fluid, and also has buoyancy effects and can rise and sink depending on density differences. Air moves vertically for one of two reasons: It is forced to rise mechanically (when it encounters a mountain, for instance), or because of changes in buoyancy.

If an air mass is heated without changing the number of gas molecules present, the air mass will expand. When the air mass expands, it occupies more volume but has the same number of air molecules as before. This means that the air density is less than before.

This air mass becomes positively buoyant and will rise because it is less dense than the air surrounding it.

If the air mass is more dense than the surrounding air, the mass would sink because it would have negative buoyancy. Cooling a parcel of air causes it to be more dense and therefore less buoyant.

Hot air balloons rise into the air because the density of the air (warmer air) inside the balloon is less dense than the air outside the balloon (cooler air). The balloon and the basket displaces a fluid that is heavier than the balloon and the basket, so it has a buoyant force acting on the system. Balloons tend to fly better in the morning, when the surrounding air is cool.

Cartesian Diver

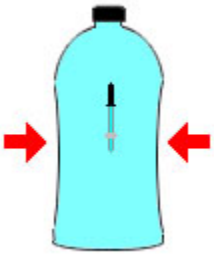
The Cartesian diver can also be made with a pen cap and some clay, a balloon and weight or even condiment packages such as ketchup or soy sauce.

MATERIALS

- One or two liter plastic soft drink bottle with cap
- Plastic eye dropper
- Small washer or clay
- Water

QUESTIONS

- What determines how an object floats in a fluid?



PROCEDURE

Step 1
Slide the washer up the end of the eye dropper till it stops. This will be used to weight the diver down so it should be fairly close to the end of the dropper. You may use clay in place of the washer. This is your Cartesian Diver. Fill the soft drink bottle to the very top with water. Draw up some of the water with the eye dropper and place the diver in the bottle with the washer end down. Cap the bottle tightly. Squeeze the bottle and observe what happens. If you use a clear plastic dropper, you will be better able to see all that happens.

Step 2
If it doesn't work, vary the amount of water you draw into the dropper or add more weight to the dropper with clay or a bigger heavier washer.

CONCLUSION

- What happens to the water pressure when the bottle is squeezed?
- Describe what happens to the air volume in the dropper when the bottle is squeezed?
- Answer the question posed in the beginning of the activity.

Floating Balloons

MATERIALS

- Three balloons
- Tank filled with water
- Water faucet

QUESTIONS

- What determines how high the balloon will float?

PROCEDURE

Step 1
When filling the balloons, be sure to fill them to the same size. Fill one balloon with just water. Fill a second balloon with water and air. Fill a third balloon with just air.
Step 2
Place the balloons in the tank of water.

CONCLUSION

- Describe the difference in the three balloons in terms of mass and density.
- Discuss why the balloons "floated" where they did.
- Discuss how this relates to the size of the ULDB and its payload.
- Answer the question posed in the beginning of the activity.

ACTIVITY FOUR

What will happen to the ULDB as it rises in the atmosphere?

QUESTIONS

- What is the relationship between the radius of a spherical balloon and its circumference, surface area and volume?
- How do the characteristics of a scientific balloon change as it is filled?

MATERIALS

- spherical balloon
- string
- meter stick

PROCEDURE

Blow air into the balloon so that it is still small but **spherical**. (you may have to push the bottom up a bit to make it more spherical) Measure the **diameter** of the balloon using the meter stick. Measure the **circumference** of the balloon by wrapping the string once around the balloon and then measuring the length of the string using the meter stick. Blow into the balloon again, making it a little bigger and record the diameter and circumference. Repeat 4 more times recording the data in Data Table 1.

Data Table 1

Balloon Trial	Diameter	Radius	Circumference
1			
2			
3			
4			
5			
6			

Data Table 2

Balloon Trial	Total Surface Area $S = 4\pi r^3$	Volume $V = \frac{4}{3}\pi r^3$	Total Surface Area to Volume Ratio S/V
1			
2			
3			
4			
5			
6			

CONCLUSION

- Describe the relationship between the surface area and the volume.
- Discuss which measurement in **Data Table 2** represents the "skin" of the balloon?
- As the balloon gets bigger, does the surface area to volume ratio increase or decrease?
- As payloads for NASA balloons increase in weight, scientist have to use bigger and bigger balloons to carry the payload. What eventually happens to a balloon if you keep blowing it up?
- Is it feasible for NASA scientist to keep increasing the size of their balloons?
- Discuss some possible changes necessary in order to increase the size and carrying capacity of a balloon.

EXTENDED ACTIVITY

Shape of the World

The ULDB is a pumpkin shaped balloon. Pumpkins do not have one smooth shape. They have lobing or bumps evenly spread out around the shape. However, the shape and volume of the ULDB can be approximated by using an ellipsoid. Discuss with students different shapes in nature and the world around them. Have them come up with shapes and an object of that shape.

ACTIVITY FIVE
Where is the ULDB today?

TEACHER PREPARATION

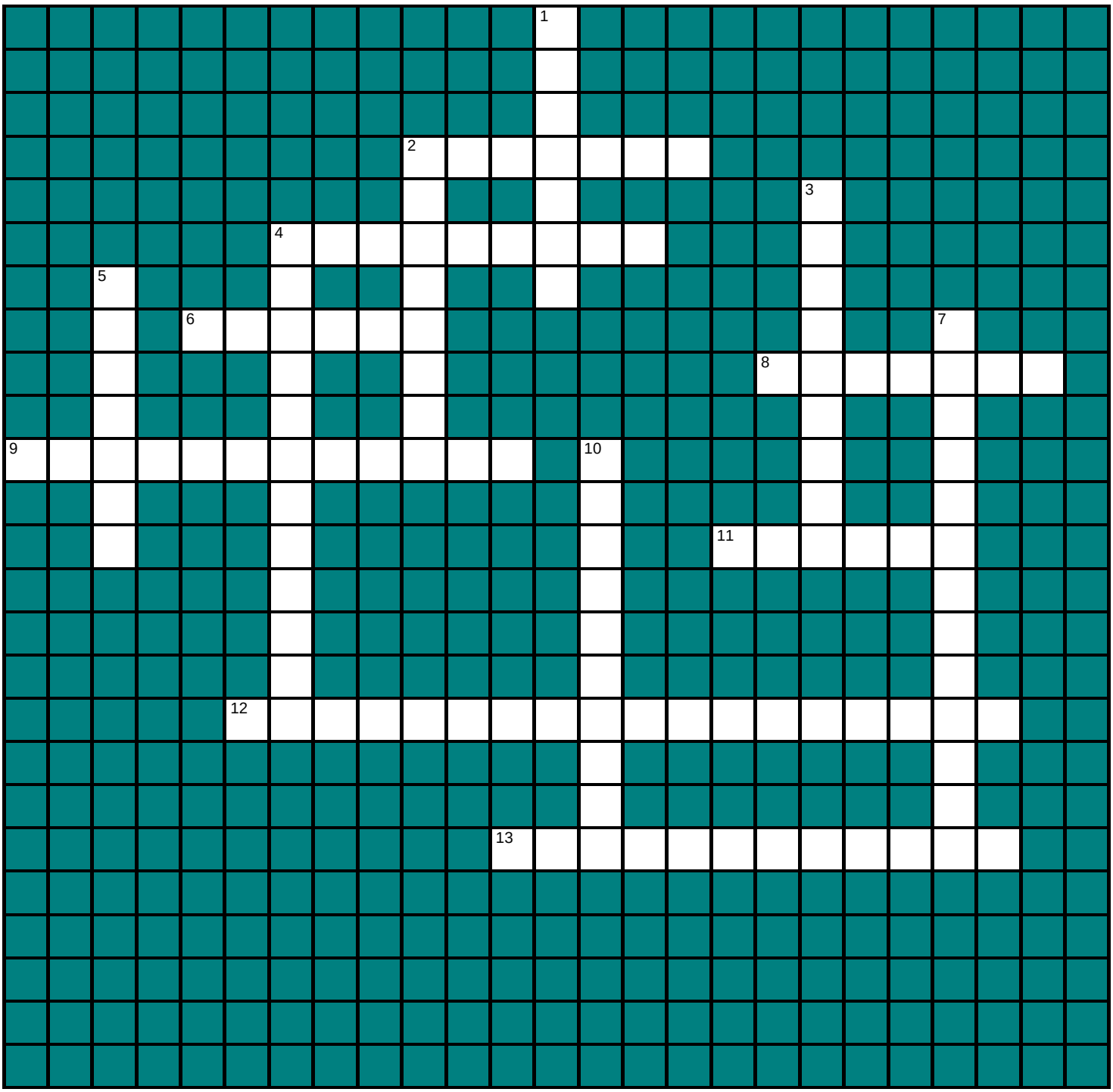
The Ultra Long Duration Balloon will be launched from Alice Springs, Australia in late January. The flight of the balloon will take it mostly over the Australia, the Antarctic Ocean, the southern tip of South America and Africa. The latitude and longitude for the ULDB will be available on the ULDB website.
http://www.wff.nasa.gov/pages/scientificballoons.html

Have the students track the ULDB on a global map or globe. They can also make a three dimensional map of the balloon location and altitude using toothpicks and clay.

Have the students write a journal of a mouse caught in the payload of the ULDB. What would it see and what would it learn about Earth below?

Have student use an Internet "Weather Browser" to find temperature readings, air pressure (barometric) readings and other weather information of the various regions the balloon will be traveling over to make predictions about weather conditions associated with certain temperatures and air pressures. Have them chart this information and draw conclusions on how temperature and air pressure affects the weight of the air (light or heavy); molecule activity (far apart or close together); and then predict the change in weather. They can later use a weather map to check the accuracy of their predictions. Have students use chart headings similar to the following: Location-Region, Barometric Reading, Temperature Reading, and Weather Conditions.

ULDB



ULDB Clues

Across

2. the amount of mass contained in a volume space

4. The skydiver opened her _____ and floated to the ground

6. the big box had more _____ than the small box

8. Earth's attraction to all objects

9. ships are kept afloat by a _____

11. a gas used in balloons

12. a device used to measure temperature

13. the measurement system used most throughout the world

Down

1. temperature scale in the metric system

2. distance across a circle or sphere

3. round; like a ball

4. thin plastic material used for balloon

5. the balloon lifted the _____ up in the air

7. the distance around a circle or sphere

10. English scale in the metric system