Physics of Air

1: Expanding and contracting

Purpose

In this activity you will observe how a gas behaves when its temperature changes.

Materials

Hot water, ice water, balloon, string, length measuring device (ruler, meter stick, tape measure), large plastic cups, thermometer

Overview

You will observe how the volume of a gas changes with temperature. You will use an inflated round balloon as a convenient sample of air and keep track of its volume as it is placed in hot water and ice water.

Procedure

1. Predict: Will the volume of an air-filled rubber balloon change if it is heated or chilled?

2. Blow up a balloon, not too full. Measure its size somehow. Record it here.

3. Place the balloon and the thermometer in hot water. Try to keep the balloon as completely submerged as possible. (I recommend using something besides your hand to hold the balloon.) After it has been there for at least five minutes, remove it and *immediately* measure its size. Don't give it a chance to return to room temperature! Record the temperature and the balloon's size here.

4. Dunk the balloon and the thermometer in ice water. After the balloon has been there for at least five minutes, remove it and *immediately* measure its size. Record the temperature and the balloon's size here.

5. Clean up any water or other mess from the table.

2. Convection

Purpose

In this activity you will observe the principal way that heat moves through liquids and gases.

Materials

Cold water, hot water, food coloring, 4 clear glass jars, funnel, cardboard pieces, bucket, Lava Lamp

Overview

In this activity you will observe the vertical mixing of hot and cold water between two pairs of quart jars.

Procedure

1. Completely fill two bottles with hot colored water and two bottles with clear cold water.

1. Hold a card over the mouth of a bottle of hot water and invert the bottle. Place it atop a bottle of cold water. Carefully remove the card so that the hot-water bottle sits inverted atop the cold-water bottle, mouth-to-mouth.

2. Repeat the process with the other pair of bottles, but with the bottle of cold water inverted atop the bottle of hot water.

3. Observe the water in both bottles for a few minutes. What happens to the colored water in each case? If any water moves, describe its motion.

4. Carefully empty the four bottles. Clean up all spills from the area.

Questions

1. Why is the movement of water different in the two situations?

3. Adiabatic Compression and Expansion

Purpose

You will observe how changing the pressure of a gas affects its temperature.

Materials

basketball pump, hose, rubber stopper, 2-L PETE bottle with LC thermometer strip inside

Overview

Gases change temperature when they do work or when work is done on them. **Work** occurs when a force is applied to a moving object: it is the change wrought by the force. Static forces do not do work. It takes energy to do work. In fact, one of the more popular definitions of **energy** is the ability to do work.

When a sample of gas expands, such as blowing up a balloon, it does work on its surroundings. Conversely, when the surroundings push on a sample of gas, causing it to contract, the surroundings do work on the gas.

In this activity you will add air to a 2-L bottle already full of air. The added air takes up space in the bottle, compressing the air that already was there. When the bottle is vented, air escaping from it does work on the air outside the bottle.

Procedure

1. Because this activity involves gases under pressure and small objects that may fly through the air, *all members* of a group working on this activity MUST WEAR SAFETY GOGGLES. True, goggles are neither comfortable nor stylish. However, neither is a black eye or worse. So, put on a pair of safety goggles.

2. Predict: If air is pumped into a bottle, how does its temperature respond? What if compressed air is released from a bottle?

3. Read the temperature of the thermometer inside the bottle. Record it here. ______

4. If it is not already assembled, connect the hose to both the pump and the rubber stopper so that air expelled from the pump comes out through the narrow end of the stopper. Place the stopper securely in the mouth of the bottle. It is best if one person holds the stopper in the mouth of the bottle and another operates the pump.

5. Pump a few strokes of air into the bottle until you feel resistance. Wait 30 seconds for the thermometer to equilibrate and read its temperature. Record it here. ____________

6. Pump more air into the bottle until it is noticeably pressurized. Wait 30 seconds for the thermometer to equilibrate and read its temperature. Record it here. ___________

7. Pump still more air into the bottle, until it feels about as pressurized as a soda bottle on the grocery store shelf. Wait 30 seconds for the thermometer to equilibrate and read its temperature. Record it here. ____________________

8. Now *gradually* vent the air from the bottle by *gently* releasing the stopper. Wait 30 seconds for the thermometer to equilibrate and read its temperature.
Record it here.______

Questions

1. What happens to the temperature of a gas as its pressure is increased?

2. What happens to the temperature of a gas as its pressure is decreased?

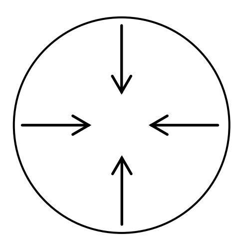
3. How does the temperature of a gas change when the gas *does* work?

4. How does the temperature of a gas change when work is *done on* the gas?

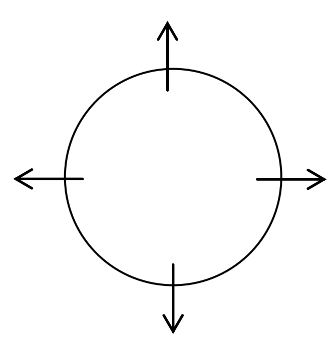
5. Doing work *on* a gas *raises* its energy. When a gas *does* work, its energy is *depleted*. How is the gas's temperature related to its energy?

4. Coriolis Force

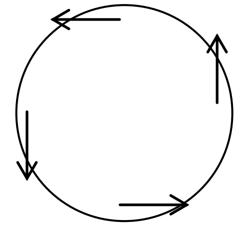
1. Have 2–4 people stand evenly distributed on the carousel at its outer edge.
2. (0.2 point) Spin the carousel at a moderate speed (none of the riders should have any difficulty standing up, holding on, or keeping lunch down). Have a person on the ground maintain the carousel's constant rotational speed.
3. While riding on the moving carousel, drop a ball. Watch the ball's path. How does the ball behave?
4. Place a ball at rest (relative to the carousel) on the carousel, about at the 1/2 tape mark. Release the ball. How does it roll? Describe the path it takes.
5. Swing the plumb bob like a pendulum. (You may want to secure the pendulum to one of the rails on the carousel.) What sort of path does the weight follow as it swings?
6. Stand near the rim of the carousel facing inward. Throw the ball toward the opposite rider. What path does the ball appear to take?



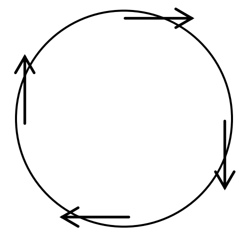
7. Now stand near the center of the carousel facing outward. Hold one arm out in front of you as a sighting guide and throw the ball outward. Compared to the sight line of your arm, what path does the ball take?



8. Now stand near the rim and face right (counterclockwise from above). Hold one arm out in front of you as a sighting guide and throw the ball to the right (the direction you are facing). Compared to the sight line of your arm, what path does the ball take?



9. Now face the opposite direction (clockwise from above) and throw the balls that way. Compared to the sight line of your arm, what path does the ball take?



10. Repeat observations 6–9, with the carousel rotating in the opposite direction.
    a. inward throw:

    b. outward throw:

    c. counterclockwise throw:

    d. clockwise throw:

11. Play catch with the other people riding the carousel. How do you need to throw the ball so that it reaches the other person?

12. From the perspective of the people standing on the ground: When a carousel rider throws a ball, is its path straight or curved? Does the direction the ball is thrown affect whether the path is straight or curved, or the direction it curves?