Purpose of Experiments with Gravity

The children have already done several experiments with gravity from *Functional Geography* and learned about its importance in the formation of the Universe. This chapter will include more experiments to aid in their understanding of the force of gravity.

The Force of Gravity

Large bodies in solar systems have **gravity** or **gravitational attraction** or **gravitation**, the force that pulls objects on or near them towards the center of the body. Gravity is the property of mutual attraction possessed by all matter. Gravity refers to the gravitational attraction of Earth. Gravity is what keeps us on Earth; it is a principle affecting us and the planet on which we live. For other celestial bodies, we use the term gravitational attraction. The Sun's gravitational attraction is so great that it exerted more force than either Mercury or Venus could to pull bodies into their orbit. Therefore, Mercury and Venus were not able to capture moons. The gravitational attraction of the larger planets such as Jupiter and Saturn is so great that they were able to capture many moons. Our Moon is in orbit around Earth because Earth's gravitational attraction is great enough to hold it in orbit. When meteors come close to Earth, Earth's gravitational attraction pulls them in and then meteorites may strike Earth. The gravitational attraction of our Moon is so small compared to that of Earth that astronauts have to wear heavy boots to walk on our Moon, otherwise they would float away.

The English physicist, Sir Isaac Newton, developed his **law of gravitation** in 1684. This law states that the gravitational attraction between two bodies is directly proportional to the product of the masses of the two bodies and inversely proportional to the square of the distance between them. Thus bodies with larger mass have a greater gravitational attraction towards each other. The farther apart two bodies are, the less the gravitational attraction.

The gravitational attraction reflects the weight of an object. The **weight** of an object on Earth is a measure of the pull by Earth's gravity on a given mass. The **mass** of an object is the quantity of matter that it contains. The mass is constant and will not change with different gravities. The weight of an object is less with lower gravity and more with higher gravity. Thus the weight of an astronaut on the Moon is six times less than that on Earth because our Moon's gravity is one-sixth that of Earth.

Activity: The children do the long jump. The children jump as far as they can. Then they multiply by six to find out how far they could jump on the moon.

Free-falling objects always fall straight down towards the center of Earth. For every second of falling time, the speed of the fall increases at a rate of 32 feet per second. This rate is the same for all objects regardless of the weight. Skydivers are able to reach a terminal velocity of 120 mph, the maximum speed for humans in a free-fall.

The strength of the pull of gravity on an object depends on its weight and its distance from Earth's surface. The pull of gravity will be greater on a heavier object (the definition of weight). The farther away the object is from Earth's surface, the less the gravity. The difference in the force of gravity between sea level and the top of Mt. Everest is negligible because the distance is so small compared to the distance to the center of Earth. When the astronauts travel into space, they leave Earth's gravity and become almost weightless.

Because Earth is rotating, the force of gravity is not the same at all locations on the surface of Earth. The actual measured force of gravity is a combination of the gravitational attraction, or the pull of Earth on an object, and the opposing **centrifugal force** on the object due to the rotation of Earth. The centrifugal force at the equator is relatively large, making the measured gravitational force relatively small. The centrifugal force at the poles is zero, making the measured gravitational force relatively large. Therefore, when we use the term **'force of gravity'**, we refer to a force that is a combination of gravitational and centrifugal forces.

The **center of gravity** is the point at which the weight of an object is equally distributed. All parts of the object exactly balance each other at this point. All objects can be balanced, and, if it is supported at its center of gravity, it will be balanced. Natural bridges and balanced rocks are good examples of objects balanced at their center of gravity.

A **spring scale** is an instrument used to measure the weight of an object, or the force of attraction between the object and Earth. Another name for this force of attraction is **gravitational attraction** or **G-force**. Earth's gravity is a G-force of 1 and is equal to the free-fall rate of 32 feet per second per second.

A **balance** is an instrument that compares the masses of two objects. The mass of an object does not change with gravity, just the weight. On Earth, mass and weight are the same number.

Gravity affects plant growth. **Geotropism** is the movement of a plant due to the pull of gravity. Plants contain a growth hormone called **auxin** that is pulled downward by gravity, resulting in the auxin collecting in the lower part of the plant. In the stem, the cells grow longer on the side where there is more auxin and the stem bends upward. Root cells grow longer on the side where there is a smaller amount of auxin, and the root bends downward. No matter how the plant is turned, the roots always grow downward and the stem always grows upward.

Experiments with Gravity

Repeat experiments 2 and 4 from the *Functional Geography Manual* that demonstrate centrifugal and gravitational forces.

Levels I - VI

- The Downward Force
- Free-Falling Objects

Levels IV - VI

- Center of Gravity

The Downward Force

Experiment #6

Question:

Do hanging objects always point in the same direction?

Hypothesis:

Yes, objects always point downward.

Materials:

- 2 large books the same height
- ruler
- plumb line from the geometry stick box
- goggles
- Science notebook and pencil

Procedure:

1. Tie the end of the plumb line to the center of the ruler.
2. Stand the two books on end about 10 inches apart.
3. Position the ruler on top of the books.
4. Observe the position of the plumb line.
5. Elevate one end of the ruler and hold it.
6. Observe the position of the plumb line.
7. Draw a picture of the experiment with its title in your science notebook. Write your observations.

Observations:

No matter what position the ruler was in, the plumb line always pointed directly downward or vertically.

Conclusions:

Hanging objects will always point directly downward toward the center of the earth.

Discussion:

The earth's gravity will always pull objects on or near the surface of the earth directly downward towards the center of the earth.

Further Experimentation:

- Shorten the length of the plumb line.
- Try different objects tied to the ruler.
- Try different heights of books to see if there is any change.

Free Falling Objects

Experiment #7

Question:

Do objects of different weights free-fall at the same rate?

Hypothesis:

All objects have the same rate of free-fall.

Materials:

- quarter coin
- scissors
- 3 x 5 card
- pencil
- goggles
- Science notebook and pencil

Procedure:

1. Trace the coin on the 3 x 5 card and cut it out, ensuring that the paper is exactly the same size as the coin.
2. Place the paper circle directly on top of the coin and drop them together at a height of about 4 feet. Observe.
3. Repeat step #2 with the coin directly on top of the paper.
4. Repeat steps #2 and #3 from different heights.
5. Observe.
6. Draw a picture of the experiment with its title in your science notebook. Write your observations.

Observations:

The paper and coin always fell together. They separated only after they hit the floor.

Conclusions:

In a free-fall, all objects fall at the same rate.

Discussion:

The weight of an object does not affect the rate of free-fall.

Further Experimentation:

- Drop the objects separately and observe. The coin hits the floor first because air resistance holds the lighter paper circle up. In a vacuum, the two objects would hit the floor at the same time.

Center of Gravity

Experiment #8

Question:

How do you find the center of gravity of an object?

Hypothesis:

The center of gravity is at the center of the object where all its weight is evenly distributed.

Materials:

- 3 x 5 card
- plumb line
- paper
- geometry cabinet
- pencil
- modeling clay
- scissors
- goggles
- Science notebook and pencil

Procedure:

1. Place the pencil, point down, in the clay so that the pencil is vertical. Test vertical with the plumb line.
2. Place the 3 x 5 card on the pencil eraser and move it around until the card is balanced. Observe.
3. Cut out irregular figures and find the center of gravity of each figure.
4. Use the figures from the geometry cabinet and find the center of gravity of each figure.
5. Draw a picture of the experiment with its title in your science notebook. Write your observations.

Observations:

The center of gravity of the 3 x 5 card was the center of the card. The center of gravity for the irregular figures was different for each figure. The center of gravity for the regular figures was the center of the figure.

Conclusions:

The center of gravity of a regular figure is the center of the figure because the weight of the object is equally distributed from this point. The center of gravity of an irregular figure will be the point from which the weight of the object is equally distributed.