1. 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.

2. The Force of Gravity

Large bodies in the solar system 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 bodies of matter. Gravity refers to the gravitational attraction of the earth. For other celestial bodies, the term gravitation is more correct. When we think of gravity, we think of the earth, because if the earth did not exert this force on everything, we would not be here, we would be floating in space. The sun's gravitational attraction is so great that 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. The moon is in orbit around the earth because the earth's gravitational attraction is great enough to hold it in orbit. When meteors come close to the earth, the earth's gravitational attraction pulls them in and meteorites may strike the earth. The gravitational attraction of the moon is so small compared to that of the earth that the astronauts had to wear heavy boots to walk on the moon and not 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 for each other. The farther apart two bodies are, the less the gravitational attraction.

The gravitational attraction determines the weight of an object. The **weight** of an object on earth is a measure of the pull by the 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 the earth because the moon's gravity is one-sixth that of the 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 the 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 the 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 the 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 the earth. When the astronauts travel into space, they leave the earth's gravity and are almost weightless.

Because the earth is rotating, the force of gravity is not the same at all locations on the surface of the earth. The actual measured force of gravity is a combination of the gravitational attraction, or the pull of the earth on an object, and the opposing **centrifugal force** on the object due to the rotation of the 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 the earth. Another name for this force of attraction is **gravitational attraction** or **G-force**. The 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.

3. Experiments with Gravity

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

Levels 1 - VI

<u>The Downward Force</u>

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

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.

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, and try different heights of books to see if there is any change.

Free-Falling Objects

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
- paper
- pencil

Procedure:

1. Trace the coin on a piece of paper 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 2 feet. Observe.
3. Repeat step 2 with the coin directly on top of the paper.
4. Repeat steps 2 and 3 from different heights.

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.

Levels I - III

The Pendulum

Question: Can a pendulum swing back and forth forever?

Hypothesis: The pendulum will eventually stop.

Materials:

- ruler
- book
- tape
- scissors
- table
- string
- washer

Procedure:

1. Cut the string so that it is somewhat shorter than the height of the table.
2. Attach the washer to the string.
3. Tape the string to the ruler so that the string hangs over the end of the ruler.
4. Position the ruler on the table so that the pendulum hangs freely.
5. Place the book on top of the ruler so that the ruler cannot move.
6. Standing at the side of the table, grasp the washer with your fingers, pull it straight towards you, then let go.
7. Observe.

Observations: The pendulum swung back and forth, with the arc gradually decreasing until the pendulum came to a stop pointing straight downwards.

Conclusions: The earth's gravity was continuously pulling the pendulum downwards, thus gradually decreasing the arc that it made, until it stopped in a vertical position.

Discussion: As the pendulum swung back and forth, the earth's gravity continued to pull on it. The first arc that the pendulum made was the maximum distance from vertical because gravity kept pulling it towards the vertical position. Each arc the pendulum made came closer to vertical as gravity continued to pull downwards, until it stopped in the vertical position.

Further Experimentation: Try lifting the pendulum to different heights to see if the swing is affected. Also try different weights and different lengths of string.

Measure the lengths of the arcs and record. Time how long each length of string takes for the object to stop.

Attach a pencil to the pendulum. Place sand below the pendulum so that the pencil draws arcs in the sand.

Levels IV - VI

Center of Gravity

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

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. Use the figures from the geometry cabinet and find the center of gravity of each figure.
4. Cut out irregular figures and find the center of gravity of each figure.

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