NSBRI TAP Classroom Activity

Title: **FALLING WATER**

Grade Level: 5-8 and 9-12

Content Area: Physical Science

National Science Content Standards:
Standard B. Physical Science (Grades 5-8 & 9-12)

- Motion and forces

Behavioral Objectives:

- The student will know the concepts of motions and forces evident in everyday life. The student will explore acceleration and describe applications of Newton's laws.
- The student will gain an understanding of microgravity and be able to compare and contrast illustrating knowledge of the comparison of mass to weight.

Lesson Objective:

- In this lesson, the student examines the relationships among force, mass, and acceleration as described by Newton’s Three Laws of Motion and applies these relationships to gravitational acceleration and the “free fall” phenomenon. This lesson further explores how “free fall” on earth is used to simulate microgravity

Time:

- Two 45 minute class periods; One 90 minute block period

Materials:

1. One plastic drinking cup per group of two students
2. Cookie sheet (without a rim on at least one side)
3. Empty aluminum soda can
4. Nail or punch
5. Water source or container of water
6. Meter stick
7. Catch basin or large trash can
8. Drop cloth
9. Paper towels

This lesson was developed by participants and staff of the Teacher Academy Project at Texas A&M University with support from the National Space Biomedical Research Institute through NASA NCC 9-58.

<u>Procedure</u>:
Activity 1

1. Obtain a cookie sheet, a full cup of water, and a catch basin. Use extra water from the nearby bucket as needed.
2. Place the cookie sheet over the opening of the cup. Hold the cup tight to the cookie sheet and invert the sheet and cup.
3. Hold the cookie sheet and cup high above the catch basin. You may wish to stand on a sturdy table or climb on a stepladder to raise the height of the cup, which is best placed at a minimum height of 2 meters. This can be checked using a meter stick.
4. While holding the cookie sheet level, slowly slide the cup to the edge of the cookie sheet until the edge of the cup is slightly past the edge of the cookie sheet.
5. Observe what happens.
6. Refill the cup with water and once again invert it on the cookie sheet. As before, you may wish to stand on a sturdy table or climb on a stepladder to raise the cup to a minimum height of 2 meters. This can be checked using a meter stick.
7. This time, hold the cup stationary with one hand and **quickly** pull the cookie sheet straight out from under the cup.
8. Observe the fall of the cup and water.
9. If you have videotape equipment available, you may record the activity and replay the fall using the slow motion or pause control buttons to study the action at various points of the fall.
10. Draw a picture in your notebook representing what happened during both parts of this experiment. Place a descriptive caption next to your drawings.
11. Repeat these procedures until everyone in your group has individually performed this activity.

*Note: Activity can be done outside.

Activity 2

1. In your same groups, punch a small hole (5 mm in diameter) in the side of an aluminum can, approximately 1.0 cm from the bottom.
2. Cover the hole with your finger and fill the can with water.
3. While holding the can over a catch basin, remove your finger from the hole and watch what happens.
4. Cover the hole with your finger and refill the can with water.
5. Uncover the hole again, but now drop the can into the catch basin. Observe what happens.
6. If you have videotape equipment available, you may record this activity and replay the action using the slow motion or pause control buttons.
7. Draw a picture in your notebook representing what happened during both parts of this experiment. Once again, place a descriptive caption next to your drawings.

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Activity Extension:

Find a partner, refill the can with water as before, and toss the can to him/her. The throw should simulate more of a curve (similar to a McDonald's arch) instead of a "straight" throw. Note what happens in this case. This is a similar parabolic curve as flown by the KC-135A at the Reduced Gravity Program located at Ellington Field-Houston, TX

Extensions:

Note: These are possible extensions for teacher implementation.

- Read NASA article *Drop Everything*, available online at: http://www.nasaexplores.com/show2_articlea.php?id=02-006
- Have students read and learn about NASA Glen Research Center 2.2 Second Drop Tower, available online at: http://microgravity.grc.nasa.gov/drop2/
  Instructions for building a microgravity demonstrator along with classroom activities are provided on this website.

Resources:

http://www.grc.nasa.gov/WWW/K-12/airplane/newton.html - This website looks at Newton's three laws of motion in detail.

http://zerog.jsc.nasa.gov/home.html - describes the Reduced Gravity Program operated by NASA-JSC

Microgravity - Falling Water link:
http://science.nasa.gov/msl1/ground_lab/exp3.htm

Space Academy, What is Microgravity?
http://liftoff.msfc.nasa.gov/academy/space/mg.html

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Background Information:

*Note: Use the background information after the activity to explain the phenomenon that the students have observed. It may be used as a hand out.

Much of what we understand about the forces of that govern movement in our environment were developed by Sir Isaac Newton. Newton's three laws state:

- 1st Law(Law of Inertia) - Every object will remain at rest or in uniform motion in a straight line unless compelled to change its state by the action of an external force. This is normally taken as an application of the definition of inertia.

An example you may have experienced is when riding in a car and you begin to go around a curve. You "feel" your body continue moving straight ahead as you move through the curve. This is why you almost automatically lean to the outside of the curve. You can view evidence of inertia during your ride by placing keys on a string on the rearview mirror and watching them as you round a curve, speed up, or slow down.

- 2nd Law (Law of Acceleration) – Net force is equal to the change in momentum per change in time **(F_{net} = ?p/?t)**. **It has also been commonly stated as "A net force causes an object to accelerate in the direction of the net force. This acceleration is directly proportional to the net force and inversely proportional to the object's mass.** For a constant mass, force equals mass times acceleration. F = m x a.

Newton's second law tells us how we can measure various forces in the environment by measuring an object's mass and its acceleration. Force can only be measured if acceleration is occurring and therefore constant movement. We can find the force of gravity on an object, commonly known as the objects weight, by multiplying its mass by its free fall acceleration towards the center of the earth (taken to be approximately 9.8 m/s^2).

- 3rd Law (Law of Interaction) -For every action (force) in nature there is an equal and opposite reaction. **It may also be stated as "When one object puts a force on a second object, the second object puts a force back on the first object that is equal in magnitude (strength) but opposite in direction."**

With Newton's third law we can see how rockets work. As the action force of hot gases being released from the rocket engine creates a force downward, the reaction force pushes the rocket upward.

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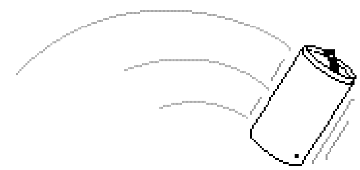
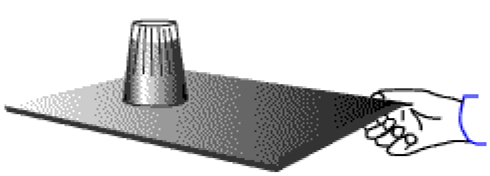
In this activity we look mainly at Newton's second law, F = m x a. The falling can, for a moment, demonstrates microgravity (which is sometimes incorrectly referred to as weightlessness or zero-g). Any object in freefall experiences microgravity conditions, which occur when the object falls toward the Earth with an acceleration equal to that due to gravity alone (approximately 9.8 meters per second squared or 1 g at Earth's surface). When the can is stationary, water freely pours out of the can. If the can falls, the water remains inside the can for the entire fall. Even though the water remains inside, it is still attracted to Earth by gravity and ends up in the same place that the water from the first experiment did.



Weight is a measure of gravitational force on an objects mass. An object at rest on Earth will weigh only one-sixth as much on the Moon because of the lower gravitational attraction. That same object will weigh almost three times as much on Jupiter because of the giant planet's greater gravitational attraction. The "apparent" weight of the object can also change on Earth simply by changing its acceleration. If the object were placed on a fast elevator accelerating upward, its apparent weight would increase. However, if that same elevator were accelerating downward, the object's apparent weight would decrease. Finally, if that elevator were accelerating downward at the same rate as a freely falling object, the object's apparent weight would diminish to near zero.

Free fall is the way scientists create microgravity for their research. Various techniques, including drop towers, airplanes, sounding rockets, and orbiting spacecraft achieve different degrees of perfection in matching the actual acceleration of a free-falling object.



In this demonstration, a water-filled cup is inverted and dropped. Before release, the cookie sheet counteracts the forces on the cup and water (their weight, caused by Earth's gravity). On release, if no horizontal forces are exerted on the cup when the sheet is removed, the only forces acting (neglecting air) are those of gravity. Since Galileo demonstrated that all objects accelerate similarly in Earth's gravity, the cup and water move together. Consequently, the water remains in the cup throughout the entire fall.

To make this demonstration possible, two additional scientific principles are involved. The cup is first filled with water. A cookie sheet is placed over the cup's mouth, and the sheet and the cup are inverted together. Air pressure and surface tension forces keep the water from seeping out of the cup. Next, the cookie sheet is pulled away quickly, like the old trick of removing a tablecloth from under a set of dishes. The inertia of the cup and water resists the

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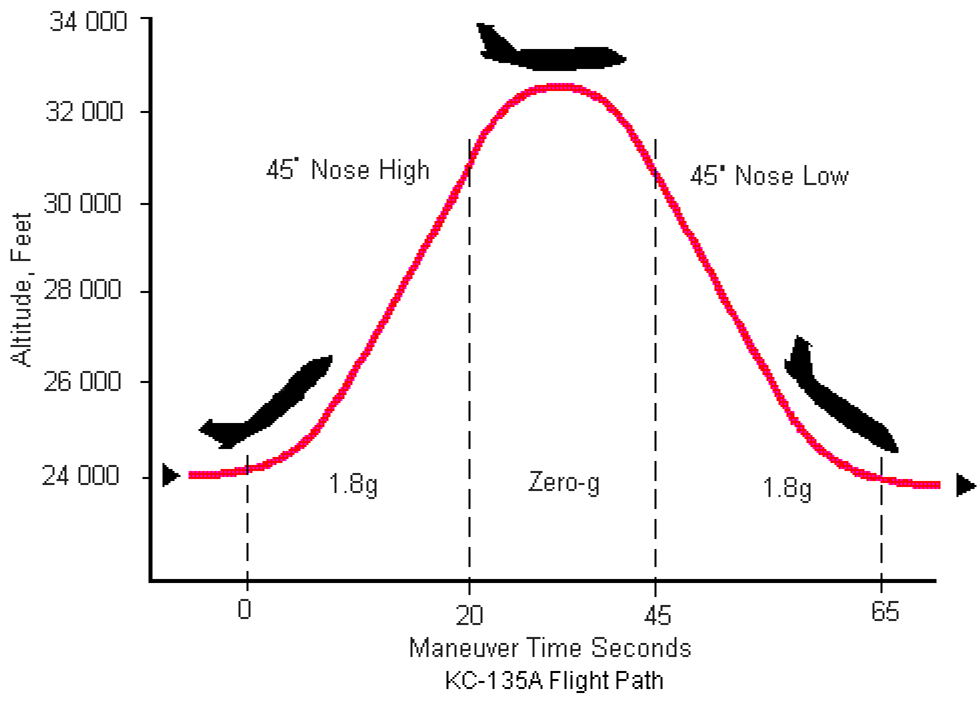
movement of the cookie sheet so that both are momentarily suspended in air. The inverted cup and the water inside fall together.

Earth-orbiting spacecraft experience a condition described as **microgravity**. The spacecraft is in a state of free-fall as it orbits. If the spacecraft has astronauts on board, the astronauts are able to move about with ease because they too are in a state of free-fall. In other words, everything in their immediate world is falling together. This creates the microgravity condition. Crewmembers and all the other contents of the spacecraft seemingly float through the air.

On Earth, momentary microgravity can be created in a number of ways. Some amusement parks achieve a second or two of microgravity in certain wild high-tech rides. A springboard diver feels a moment of microgravity at the top of a spring just as the upward motion stops and just before the downward tumbling motion to the water below begins. As the diver falls, friction with air quickly offsets the microgravity sensation and produces drag that returns at least a portion of the diver's weight before the water is struck. NASA eliminates the air friction problem and achieves about 30 seconds of microgravity with a special airplane. High above Earth, the plane begins a long arc-like dive downward at a speed equal to the acceleration of a falling object. After 30 seconds, the plane pulls out of the dive and climbs back to the high altitude to begin another microgravity cycle. The airplane's skin and engine thrust during the dive totally negates air friction on the people and experiments in the plane.



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<u>Student Assessment (Student Copy)</u>

Title: **FALLING WATER**

1. Explain what is meant by microgravity.

2. What are some examples in which brief periods of microgravity can be experienced on Earth?

3. State Newton's Three Laws.

4. In the falling can experiment explain why no water comes out of the hole of the can while it is falling?

5. Compare and contrast weight and mass.

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Student Assessment

Title: **FALLING WATER**

1. Explain what is meant by microgravity.

   Ans: Microgravity is a condition in which the effects of gravity are greatly reduced, sometimes described as "weightlessness". Any object in freefall experiences microgravity conditions, which occur when the object falls toward the Earth with an acceleration equal to that due to gravity alone (approximately 9.8 meters per second squared [m/s^2], or 1 g at Earth's surface).

2. What are some examples in which brief periods of microgravity can be experienced on Earth?

   Ans:
   - Objects falling from tall structures-NASA's 2.2 second drop tower.
   - The Reduced Gravity Program's KC-135A
   - Amusement parks in certain high-tech rides.
   - Springboard divers at the top of a spring just as the upward motion stops and just before the downward motion to the water below begins.

3. State Newton's Three Laws.

   Ans:
   - 1st Law - Every object will remain at rest or in uniform motion in a straight line unless compelled to change its state by the action of an external force.
   - 2nd Law - Force is equal to the change in momentum per change in time. For a constant mass, force equals mass times acceleration (F=m x a).
   - 3rd Law - For every action (force) in nature there is an equal and opposite reaction.

4. In the falling can experiment explain why no water comes out of the hole of the can while it is falling?

   Ans: The can and water fall at the same rate. It is similar to the space shuttle and crew falling at the same rate around the Earth or the International Space Station and its crew.

5. Compare and contrast weight and mass.

   Ans:
   - Compare-Weight and mass are both considered measures
   - Contrast- Mass measure the true amount of matter in a object where weight measures the gravitational attraction on the matter.

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