NATIONAL MUSEUM
OF THE UNITED STATES AIR FORCE™

FREEFALL (MICROGRAVITY)

Students observe how microgravity is created by free-fall. Adapted from lesson plans provided by NASA.

LESSON PLAN

Learning Objectives:

The students will:

- Learn about microgravity
- Learn why astronauts appear to "float" in space
- Conduct, observe and discuss a number of demonstrations that illustrate the principle of microgravity

Background

From NASA: Gravity is a force that governs motion throughout the universe. It holds us to the ground, and it keeps the moon in orbit around Earth and Earth in orbit around the sun.

Many people mistakenly think that gravity does not exist in space. However, typical orbital altitudes for human spaceflight vary between 120 - 360 miles above Earth's surface. The gravitational field is still quite strong in these regions, since this is only about 1.8 percent the distance to the moon. Earth's gravitational field at about 250 miles above the surface is 88.8 percent of its strength at the surface. Therefore, orbiting spacecraft, like the space shuttle or space station, are kept in orbit around Earth by gravity.

The nature of gravity was first described by Sir Isaac Newton, more than 300 years ago. Gravity is the attraction between any two masses, most apparent when one mass is very large (like Earth). The acceleration of an object toward the ground caused by gravity alone, near the surface of Earth, is called "normal gravity," or 1g. This acceleration is equal to 32.2 ft/sec2 (9.8 m/sec2).

Grade Level: 6—8

Ohio Learning Standards/ Science (2018)

Expectations for Learning
Nature of Science
Ohio's Cognitive Demands for Science

Physical Science
6.PS.3: Gravitational potential energy
8.PS.1: Objects can experience a force due to an external field
8.PS.2: Forces can act to change the motion of objects

Materials Required:

- Plastic cups – one for each team plus one for the teacher – about 12 oz. size or larger
- String – about 18 inches per team
- Paper clips if needed (see directions below)
- Large wooden bead – one per team
- Hole puncher or nail
- Index card or cardstock – one for teacher
- Empty, clean pop can
- Water
- Basin (something to catch water)
- Towels

If you drop an apple on Earth, it falls at 1g. If an astronaut on the space station drops an apple, it falls too. It just doesn't look like it's falling. That's because they're all falling together: the apple, the astronaut and the station. But they're not falling towards Earth, they're falling around it.

Because they're all falling at the same rate, objects inside of the station appear to float in a state we call "zero gravity" (0g), or more accurately microgravity (1x10-6 g).

Creating Microgravity:

The condition of microgravity comes about whenever an object is in free fall. That is, it falls faster and faster, accelerating with exactly the acceleration due to gravity (1g). As soon as you drop something (like an apple) it is in a state of free fall. The same is true if you throw something; it immediately starts falling towards Earth. But how does something fall around Earth?

Newton developed a thought experiment to demonstrate this concept. Imagine placing a cannon at the top of a very tall mountain. Once fired, a cannonball falls to Earth. The greater the speed, the farther it will travel before landing. If fired with the proper speed, the cannonball would achieve a state of continuous free-fall around Earth, which we call orbit. The same principle applies to the space shuttle or space station. While objects inside them appear to be floating and motionless, they are actually traveling at the same orbital speed as their spacecraft: 17,500 miles per hour (28,000 km per hour)!

Objects in a state of free fall or orbit are said to be weightless. The object's mass is the same, but it would register "0" on a scale. Weight varies depending on whether you are on Earth, the moon or in orbit. But your mass stays the same, unless you go on a diet!

NASA uses a variety of facilities to create microgravity conditions. The most famous way is by aircraft flying in parabolic arcs to create microgravity for tests and simulations that last 20-25 seconds. NASA's Johnson Space Center, for example, operates a C-9 Low-G Flight Research aircraft also known as the "Vomit Comet." It can make several trips each year to NASA Glenn in support of ground-based microgravity research. Its predecessor, a KC-135 aircraft, was used to shoot the weightless scenes in the movie Apollo 13.

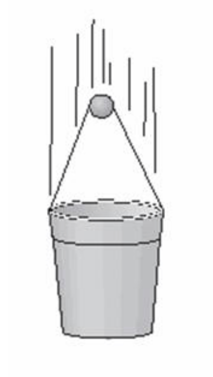
The facilities most likely to be misconstrued as "anti-gravity chambers" are NASA's drop towers. Specifically, NASA Glenn has the Zero Gravity Research Facility. It is a large shaft some 500 feet deep that allows test packages to free fall in a vacuum for just over 5 seconds. In this state of free fall, weightlessness (at or near microgravity) can be obtained. NASA Glenn also has a 2.2 second drop tower.

You may have experienced weightlessness yourself without realizing it. Many amusement park rides create brief periods of free fall. Some rides that operate vertically without any applied forces are actually classified as free fall rides. Most roller coasters have a set of parabolic (rolling) hills that also create brief periods of weightlessness. For less adventurous people, a car ride on the rolling hills of a country road or jumping on a trampoline also create brief experiences of weightlessness.

Procedures:

- Divide the students into teams to work on the first demo project. This is a very simple demonstration of freefall to get the students to start thinking about microgravity. Do this demo before introducing the concept of microgravity and freefall and have the students predict what will happen and why.

- Each team should thread an 18 inch piece of string through a large wooden bead and then attach each end of the string to a plastic cup by punching two holes on either side of the top of the cup and threading the end of the string through and knotting the ends.



- The students are to perform two variations of the demonstration. Before each demo, the team should discuss their prediction as to the outcome of the experiment and their reasons why. These should be written down on paper before carrying out the demo.

- Step one is to hold the cup in one hand with the bead in the other hand suspended at the length of the string above the cup. Drop the bead while holding the cup steady. Did they make a correct prediction? [*Gravity pulled the bead into the cup*].

- Prep in advance for step 2 by checking to see if the cup you chose for this activity will fall as quickly as the bead – you may need to add a little weight (paperclips) to the bottom of the inside of the cup to even out the weight.

- Step two is to again hold the cup in one hand with the bead in the other hand suspended at the length of the string above the cup. Drop the bead and the cup at the same time from a height of at least six feet. Did they make a correct prediction? Did the bead fall into the cup before hitting the floor? Why not? [*The bead and the cup were both in a freefall – falling at the same speed*].

- Have the class discuss as a whole the results of the test and discuss freefall and microgravity as it applies to this demo and to orbiting spacecraft. How does this explain why astronauts float and appear to be weightless? [*The astronauts and everything around them and their spacecraft are in a freefall situation – if you are falling and the floor under you is falling, all at the same speed, you will "float" above the floor as you both fall together at the same rate*]

- To reinforce the concept and to check comprehension (and for fun!), the teacher should perform the next two demonstrations for the class. Again, before each demo, have the students, in their teams, predict what will happen. Both of these demos require water and are best done in an appropriate location.

- First, fill a plastic cup with water. Ask the students what would happen if you turned the cup upside down [hopefully they will say the water will fall out towards the floor!] Then asked them what would happen if you dropped the cup while upside down? Completely cover the top of the cup with an index card or piece of cardstock and turn it upside down. Remove the card very quickly at the same time that you drop the cup. This may take a little practice. Did they correctly predict that the water will stay in the cup as it falls? Are they able to explain why it happened? [*Both the water and the cup were in a freefall – falling at the same speed*].

- For the second teacher-guided demo, prepare an empty pop can by punching two holes evenly spaced about one inch above the bottom of the can. Make sure that the holes are "clean" and completely open. Pour water into the can over a basin, demonstrating to the students that there are holes in the can. Have them predict what will happen if you drop the can when it is full of water. Hold the can in such a way as to block the holes until you are ready to drop the can. Let go above a basin, or perform the demo outside if possible! Drop the can from a height of at least 6 feet. Did the students correctly predict that the water will stay in the can and not leak out the holes? Are they able to explain why it happened? [*Both the water and the cup were in a freefall – falling at the same rate*].

- Review the concept of freefall/microgravity with the students. Check that they understand that gravity is the cause of this situation usually referred to as "zero gravity"!

- Finish by asking the students how this knowledge of freefall being the cause of a microgravity environment could be used to help train astronauts for space flight or to determine how an object or piece of equipment might react to microgravity? [*See the resources section for information on drop tower testing and the parabolic flights used to train astronauts*]

- Possible added activity: have the students videotape these demonstrations and observe the results in slow motion.

Resources:

- https://www.nasa.gov/audience/foreducators/microgravity/home/index.html
- https://www.nasa.gov/pdf/62474main_Microgravity_Teachers_Guide.pdf
- https://spaceplace.nasa.gov/how-orbits-work/en/
- https://www.nasa.gov/audience/forstudents/5-8/features/nasa-knows/what-is-microgravity-58.html
- https://www.nasa.gov/centers/glenn/shuttlestation/station/microgex.html