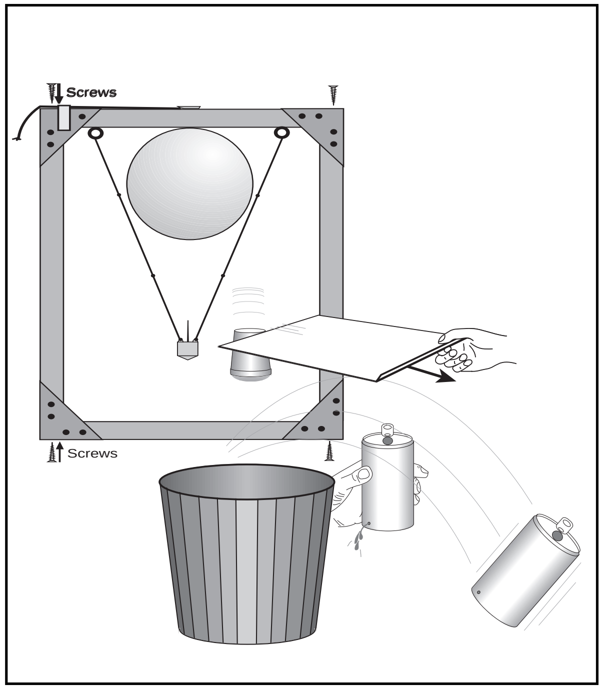
Microgravity In The Classroom

Objective:

- To demonstrate how microgravity is created by freefall.



Various objects demonstrate microgravity as they are dropped.

Science Standards:

Science as Inquiry
Physical Science
- position and motion of objects
Change, Constancy, & Measurement
- evidence, models, & exploration

Science Process Skills:

Observing
Communicating
Making Models
Defining Operationally
Investigating
Predicting
Mathematics Standards:
Computation & Estimation
Measurement

Materials and Tools

Falling weight apparatus
(see special instructions)
Plastic cup
Small cookie sheet or
plastic cutting board
Empty soft drink can
Nail or some other punch
Catch basin - plastic dish
pan, bucket, large waste
barrel
Mop, paper towels, or
sponges for cleanup

Activity Management:

This activity consists of three demonstrations that create microgravity conditions by freefall. Although the first demonstration is best done by the teacher, the other demonstrations can be done as activities by students working in groups of three or four.

Each demonstration requires a clear space where drop tests can be conducted. Two of the demonstrations require water and you should have a mop, sponges, or paper towels available to clean up any mistakes.

Begin with the Falling Weight apparatus teacher demonstration. Before dropping the device, conduct a discussion with the students to consider possible outcomes. Ask students to predict what they think will happen when the device is dropped. Students will focus on the proximity of the balloon and the needle. Will the balloon break when the device is dropped? If the balloon does break, will it break immediately or when the device hits the floor? Try to get students with different predictions to debate each other. After the debate, drop the device.

Be sure to hold the wooden frame by the middle of the top cross piece. Hold it out at arm's length in case the weight and needle bounce your way.

Discuss the demonstration to make sure the students understand why the balloon popped when it did. Before trying any of the other demonstrations, student groups should read the student reader entitled *Microgravity.*

The second and third demonstrations can also be done by the teacher or by small groups of students. One student drops or tosses the test item and the other students observe what happens. Students should take turns observing.

Assessment:

Have students write a paragraph or two that define microgravity and explain how freefall creates it.

Extensions:

1. Videotape the demonstrations and play back the tape a frame at a time. Since each second of videotape consists of 30 frames, the tape can be used as a simple timing device. Count each frame as onethirtieth of a second.
2. Replace the rubber bands in the falling weight apparatus with heavy string and drop the apparatus again to see whether the balloon will break. Compare the results of the two drops.
3. Conduct a microgravity science field trip to an amusement park that has roller coasters and other rides that involve quick drops. Get permission for the students to carry accelerometers on the rides to study the gravity environments they experience. On a typical rollercoaster ride, passengers experience normal g (gravity), microgravity, high g, and negative g.

Microgravity

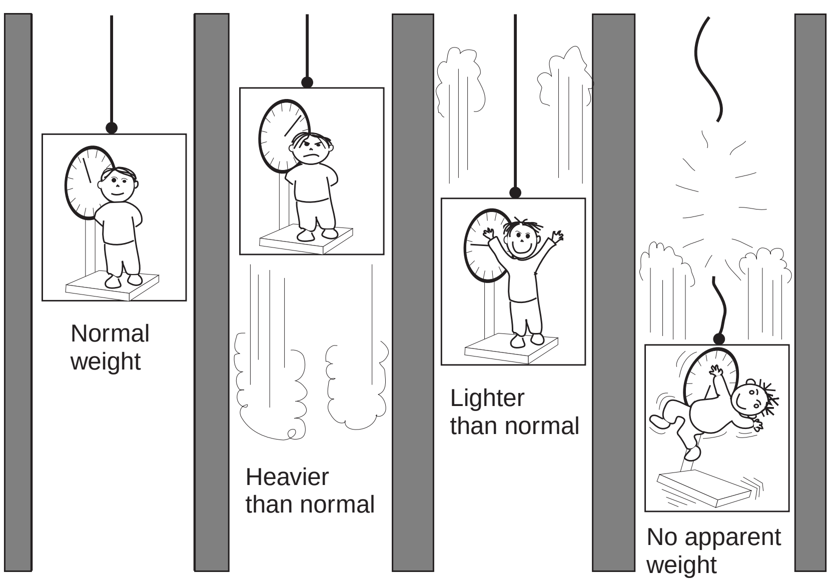
Gravity is an attractive force that all objects have for one another. It doesn't matter whether the object is a planet, a cannonball, a feather, or a person. Each exerts a gravitational force on all other objects around it.

The amount of force between two objects depends upon how much mass each contains and the distance between their centers of mass. For example, an apple hanging from a tree branch will have less gravitational force acting on it than when it has fallen to the ground. The reason for this is because the center of mass of an apple, when it is hanging from a tree branch, is farther from the center of mass of Earth than when lying on the ground.

Although gravity is a force that is always with us, its effects can be greatly reduced by the simple act of falling. NASA calls the condition produced by falling *microgravity.*

You can get an idea of how microgravity is created by looking at the diagram below. Imagine riding in an elevator to the top floor of a very tall building. At the top, the cables supporting the car break, causing the car and you to fall to the ground. (In this example, we discount the effects of air friction on the falling car.) Since you and the elevator car are falling together, you feel like you are floating inside the car. In other words, you and the elevator car are accelerating downward at the same rate due to gravity alone. If a scale were present, your weight would not register because the scale would be falling too. The ride is lots of fun until you get to the bottom.

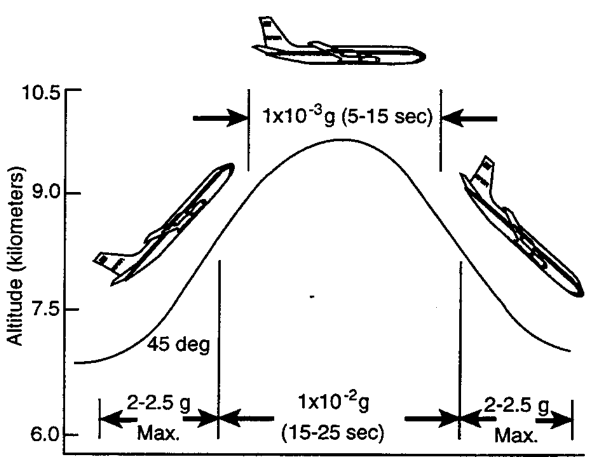
NASA uses several different strategies for conducting microgravity research. Each strategy serves a different purpose and produces a microgravity environment with different qualities. One of the simplest strategies is the use of drop towers. A drop tower is like a high-tech elevator shaft. A small experiment package is suspended from a latch at the top. The package contains the experiment, television or movie cameras, and a radio or wire to transmit data during the test. For some drop towers, when the test is ready, air from the shaft is pumped out so



The person in the stationary elevator car experiences normal weight. In the car immediately to the right, weight increases slightly in the next car because of the downward acceleration. No weight is measured in the last car on the right because of freefall.

the package will fall more smoothly. The cameras, recording equipment, and data transmitter are turned on as a short countdown commences. When T minus zero is reached, the package is dropped.

NASA has several drop tower facilities including the 145 meter drop tower at the NASA Lewis Research Center in Cleveland, Ohio. The shaft is 6.1 meters in diameter and packages fall 132 meters down to a catch basin near the shaft's bottom. For 5.2 seconds, the experiment

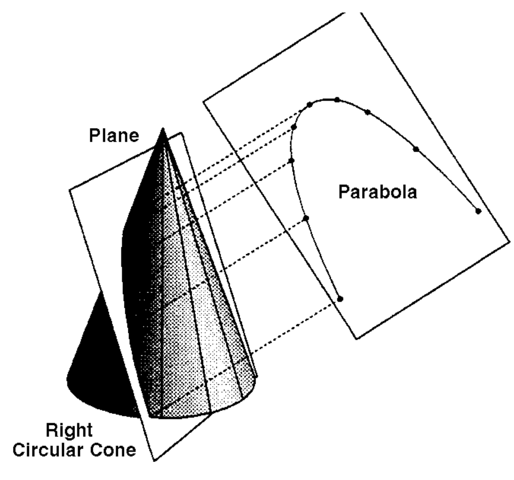


For the first few seconds of the pull up, the experiments and experimenters onboard the airplane feel a gravity force of about two times normal. During the upper portion of the parabola, microgravity is produced that ranges from one onehundredth to one one-thousandth of a g. During the pull out, the gravity force again reaches about two times normal.

experiences a microgravity environment that is about equal to one one-hundred-thousandth (lx10^{-5}) of the force of gravity experienced when the package is at rest.

If a longer period of microgravity is needed, NASA uses a specially equipped jet airplane for the job. Most of the plane's seats have been removed and the wall, floor, and ceiling are covered with thick padding similar to tumbling mats.

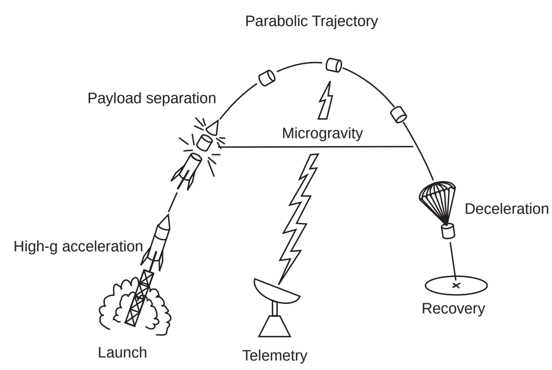
One of the advantages of using an airplane to do microgravity research is that experimenters can ride along with their experiments. A typical flight lasts 2 to 3 hours and carries experiments and crew members to a beginning altitude about 7 kilometers above sea level. The plane climbs rapidly at a 45-degree angle (pull up) and follows a path called a parabola. At about 10 kilometers high, the plane starts descending at a 45-degree angle back down to 7 kilometers where it levels out (pull out). During the pull up and pull out segments, crew and experiments experience a force of between 2 g and 2.5 g. The microgravity experienced on the flight ranges between one one-hundredth and one one-thousandth of a g. On a typical flight, 40 parabolic trajectories are flown. The gut-wrenching sensations produced on the flight have earned the plane the nickname of "Vomit Comet."



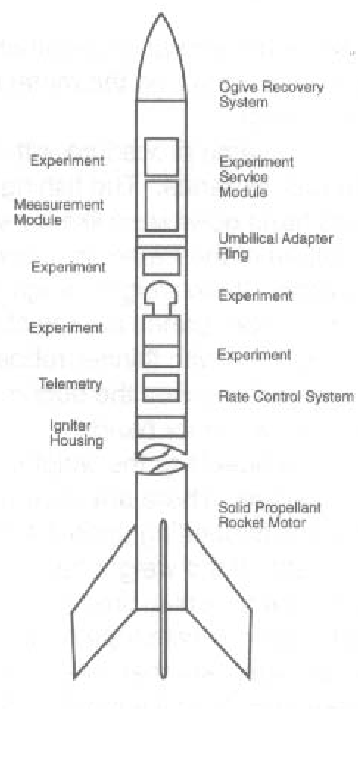
A parabola is the mathematical shape you get if you slice a cone in the way shown in the picture.

Small rockets provide a third technology for creating microgravity. A sounding rocket follows a parabolic path that reaches an altitude hundreds of kilometers above Earth before falling back. The experiments onboard experience several minutes of freefall. The microgravity environment produced is about equal to that produced onboard falling packages in drop towers.

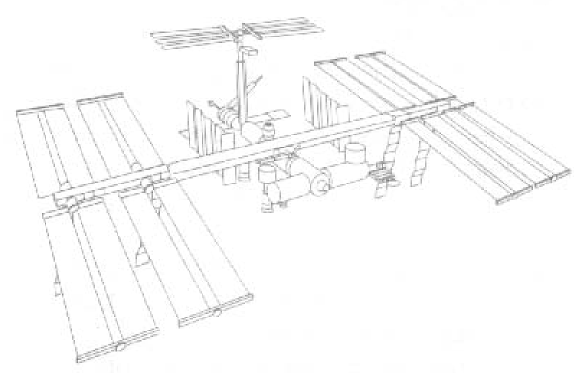
Although airplanes, drop facilities, and small rockets can be used to establish a microgravity environment, all of these laboratories share a common problem. After a few seconds or minutes of low-g, Earth gets in the way and the freefall stops. When longer term experiments (days, weeks, months, and years) are needed, it is necessary to travel into space and orbit Earth. We will learn more about this later.



Microgravity begins when the rocket arrives above Earth's atmosphere and the payload section is released. Microgravity ends when the payload falls back into the atmosphere and begins feeling atmospheric drag.

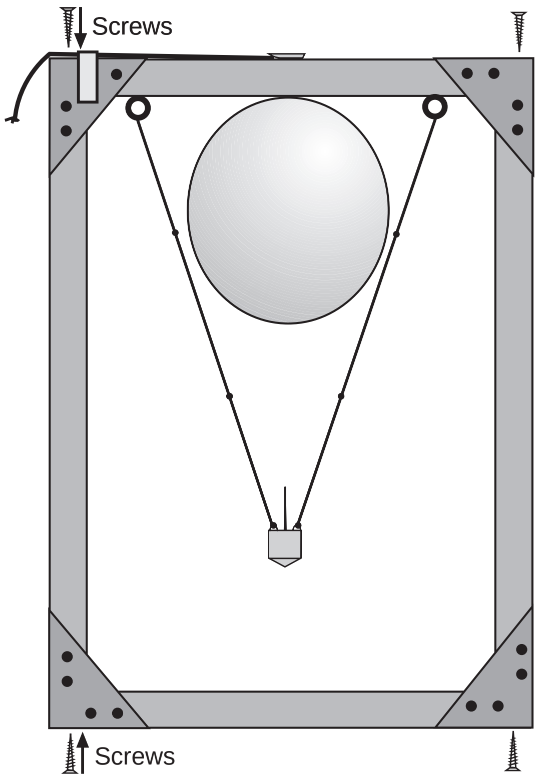


Typical design of a sounding rocket used for microgravity research.



In a few years, it will be possible to conduct sensitive microgravity experiments, lasting many months, on the International Space Station.

Falling Weight Apparatus



MATERIALS AND TOOLS	MATERIALS NEEDED: 2 pieces of wood 16x2x1 in. 2 pieces of wood 10x2x1 in. 4 wood screws (#8 or #10 by 2 in.) 8 corner brace triangles from 1/4 in. plywood Glue 2 screw eyes 4-6 rubber bands 1 6-oz fishing sinker or several lighter sinkers taped together Long sewing needle Small round balloons (4 in.) String Drill, 1/2 in. bit, and bit for piloting holes for wood screws Screwdriver Pillow or chair cushion (Optional - Make a second frame with string supporting the sinker.)

Construction:

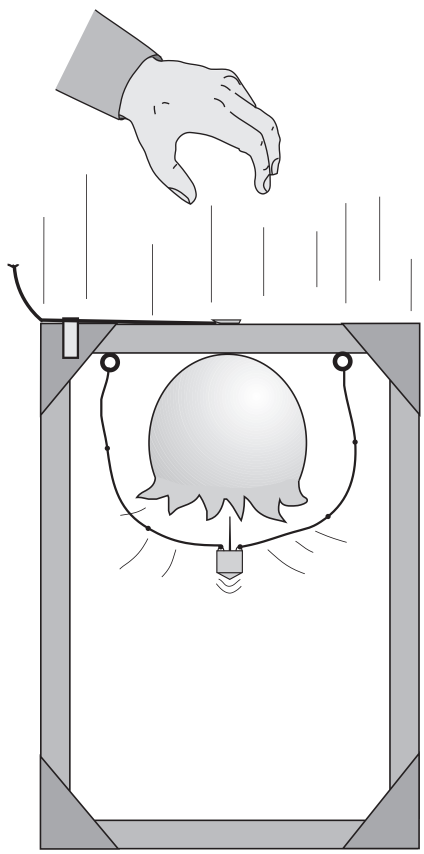
1. Assemble the rectangular supporting frame as shown in the diagram. Be sure to drill pilot holes for the screws and glue the frame pieces before screwing them together. Brace the front and back of each corner with small triangles of plywood. Glue and nail them in place.
2. Drill a 1/2 inch-diameter hole through the center of the top of the frame. Be sure the hole is free of splinters.
3. Twist the two screw eyes into the underside of the top of the frame as shown in the diagram. (Before doing so, check to see that the metal gap at the eye is wide enough to slip a rubber band over it. If not, use pliers to spread the gap slightly.)
4. Join three rubber bands together and then loop one end through the metal loop of the fishing sinker.
5. Follow the same procedure with the other three rubber bands. The fishing weight should hang downward like a swing, near the bottom of the frame as shown in the illustration. If the weight hangs near the top, the rubber bands are too strong. Replace them with thinner rubber bands. If the weight touches the bottom, remove some of the rubber bands.
6. Attach the needle to the weight, with the point upward. There are several ways of doing this depending upon the design of the weight. If the weight has a loop for attaching it to fishing line, hold the needle next to the loop with tape or low-temperature hot glue. Another way of attaching the needle is to drill a small hole on top of the weight to hold the needle.

Use:

Inflate the balloon and tie off the nozzle with a short length of string. Thread the string through the hole and pull the balloon nozzle through. Pull the string snugly and tape it to the top of the frame.

Demonstration:

1. Place a pillow or cushion on the floor. Hold the frame above the pillow or cushion at shoulder level.
2. Ask the students to predict what will happen when the entire frame is dropped.
3. Drop the entire unit onto the cushion. The balloon will pop almost immediately after release.



Explanation:

When stationary, the lead fishing weight stretches the rubber bands so the weight hangs near the bottom of the frame. When the frame is dropped, the whole apparatus goes into freefall. The microgravity produced by the fall removes the force the fishing weight is exerting on the rubber bands. Since the stretched rubber bands have no force to counteract their tension, they pull the weight—with the needle—up toward the balloon, causing it to pop. (In fact, the sinker's acceleration toward the balloon will initially be zero due to the energy released as the rubber bands relax to their normal, unstretched length.) If a second frame, with string instead of rubber bands supporting the weight, is used for comparison, the needle will not puncture the balloon as the device falls because the strings will not rebound like the rubber bands did.

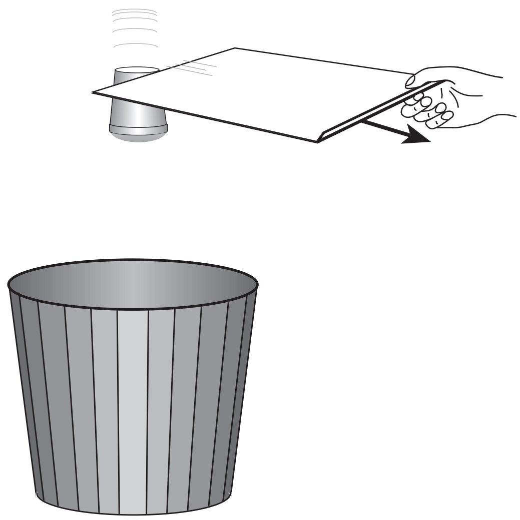
In tests of this device using a television camera and videotape machine as a timer (see extensions), the balloon was found to pop in about 4 frames which is equal to fourthirtieths of a second or 0.13 seconds. Using the formula for a falling body (see below), it was determined that the frame dropped only about 8 centimeters before the balloon popped. This was the same as the distance between the balloon and the needle before the drop.

$$d = \frac{1}{2} at^2$$

$$d = \frac{1}{2} \text{ x } 9.8 \text{ m/s}^2 \text{x}(0.13\text{s})^2 = 0\ 08m$$

d is the distance of the fall in meters
a is the acceleration of gravity in meters per second squared
t is the time in seconds

Falling Water



Materials and Tools

- Plastic drinking cup
- Cookie sheet (with at least one edge without a rim)
- Catch basin (large pail, waste basket)
- Water
- Chair or stepladder (optional)
- Towels
- Television camera, videotape recorder, and monitor (optional)

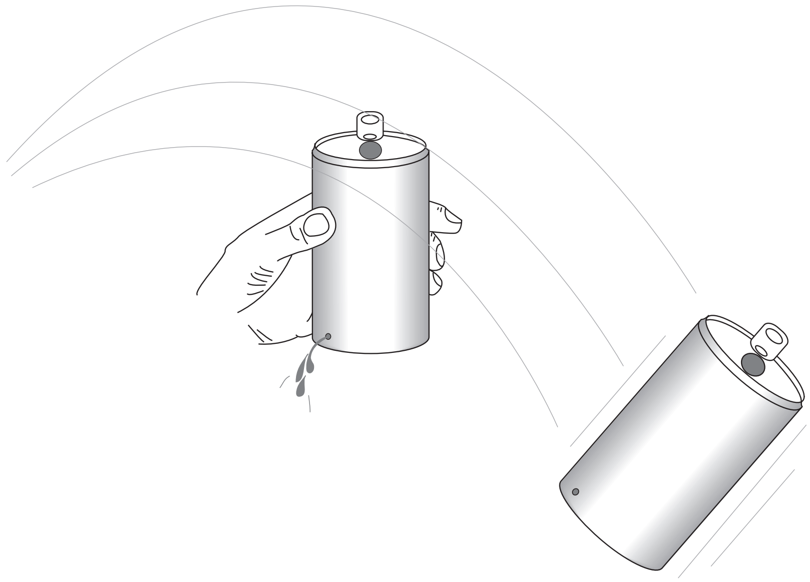
Procedure:

1. Place the catch basin in the center of an open area in the classroom.
2. Fill the cup with water.
3. Place the cookie sheet over the opening of the cup. Press the cup tight to the sheet while inverting the sheet and cup.
4. Hold the cookie sheet and cup high above the catch basin. You may wish to stand on a sturdy tahle or climb on a stepladder to raise the cup higher.
5. While holding the cookie sheet level, slowly slide the cup off the edge of the cookie sheet and observe what happens.
6. Refill the cup with water and invert it on the cookie sheet.
7. Quickly pull the cookie sheet straight out from under the cup and observe the fall of the cup and water.
8. (Optional) Videotape the cup drop and play back the tape frame-to-frame to observe what happens to the water.

Explanation:

Air pressure and surface tension keep the water from seeping around the cup's edges while it is inverted on the cookie sheet. If the cup were slowly pushed over the edge of the sheet, the water would pour out. However, when the sheet is quickly pulled out from under the filled cup, the cup and water both fall at the same time. Since they are both accelerated downward by gravity an equal amount, the cup and water fall together. The water remains in the cup but the lower surface of the water bulges. Surface tension tends to draw liquids into spherical shapes. When liquids are at rest, gravity overcomes surface tension, causing drops to spread out. In freefall, gravity's effects are greatly reduced and surface tension begins to draw the water in the cup into a sphere.

Can Throw



Procedure:

1. Punch a small hole with a nail near the bottom of an empty soft drink can.
2. Close the hole with your thumb and fill the can with water.
3. While holding the can over a catch basin, remove your thumb to show that the water falls out of the can.
4. Close the hole again and stand back about 2 meters from the basin. Toss the can through the air to the basin, being careful not to rotate the can in flight.
5. Observe the can as it falls through the air.
6. (Optional) Videotape the can toss and play back the toss frame-to-frame to observe the hole of the can.

MATERIALS AND TOOLS

Empty aluminum soft drink can
Sharp nail
Catch basin
Water
Towels
Television camera, videotape recorder, and monitor (optional)

Explanation:

When the can is stationary, water easily pours out of the small hole and falls to the catch basin. However, when the can is tossed, gravity's effects on the can and its contents are greatly reduced. The water remains in the can through the entire fall including the upward portion. This is the same effect that occurs on aircraft flying in parabolic arcs.