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ABSTRACT

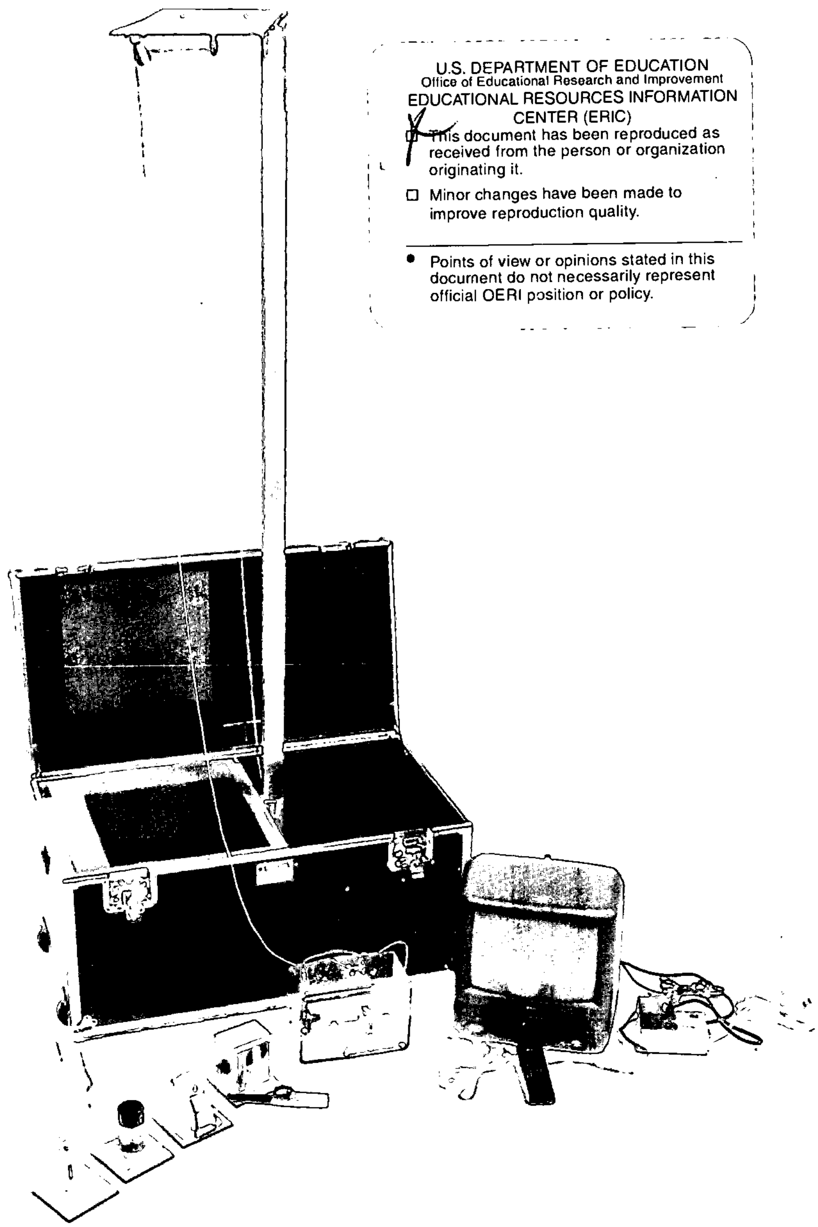
The Microgravity Demonstrator is a tool used to create microgravity conditions in the classroom. A series of demonstrations is used to provide a dramatically visual, physical connection between free-fall and microgravity conditions in order to understand why various types of experiments are performed under microgravity conditions. The manual is divided into five sections. The first section explains how to put the Microgravity Demonstrator together. The next section introduces the individual demonstrations and discusses the underlying physical science concepts. Following that are detailed steps for conducting each demonstration to make the most effective use of the demonstrator. The following section features some ideas on how to make a microgravity demonstrator. The last section contains a tips and troubleshooting guide for video connections and operations. (SAH)

National Aeronautics and
Space Administration

Marshall Space Flight Center
Huntsville, Alabama

Educational Product	
Teachers	Grades 5-12

THE MICROGRAVITY DEMONSTRATOR



THE MICROGRAVITY DEMONSTRATOR

National Aeronautics and Space Administration

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Microgravity Science and Applications Division

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How to Use this Manual

The Microgravity Demonstrator is a tool to create microgravity conditions in your classroom. A series of demonstrations is used to provide a dramatically visual, physical connection between free-fall and microgravity conditions and to understand why various types of experiments are performed under microgravity conditions. A wealth of background material on free-fall, microgravity, and microgravity sciences is available in two educational documents available through the NASA Teacher Resource Centers: Microgravity—Activity Guide for Science, Mathematics, and Technology Education, EG-1997-01-110-HQ and The Mathematics of Microgravity, EB-1997-02-119-HQ.

The remainder of this manual is divided into five sections. The first explains how to put the Microgravity Demonstrator together. The next section introduces the individual demonstrations and discusses the underlying physical science concepts. Following that are detailed steps for conducting each demonstration to make your use of the Demonstrator most effective. Next are some ideas on how to make your own Microgravity Demonstrator. The last section is a tips and troubleshooting guide for video connections and operations.

If you have one of the NASA Microgravity Demonstrators, this entire manual should be useful. If you have a copy of the Microgravity Demonstrator Videotape and would like to use that as a teaching tool, the **Demonstrations and Scientific Background** section of this manual will give you insight into the science areas studied in microgravity. If you do not currently have a Demonstrator, the **Suggestions for Making Your Own Microgravity Demonstrator** section will help you build your own Demonstrator, if you have the resources and would like to have one available all the time.

The use of company names is provided as a service and does not constitute an endorsement by NASA.

The discussions of weight and apparent weight follow the treatment of the subject in Halliday, D. and R. Resnick, Fundamentals of Physics, Extended Third Edition, John Wiley & Sons, New York, 1988.

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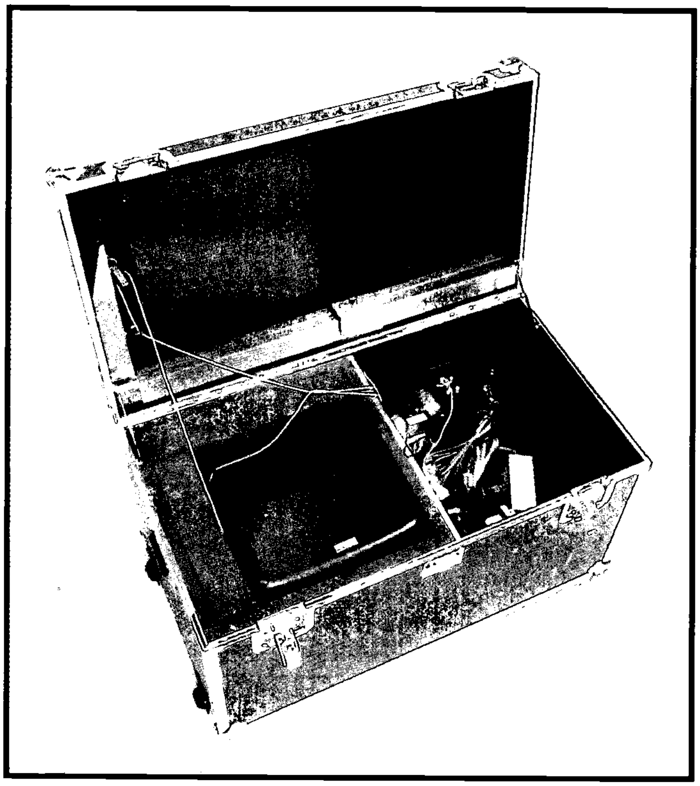
Putting Together the Microgravity Demonstrator



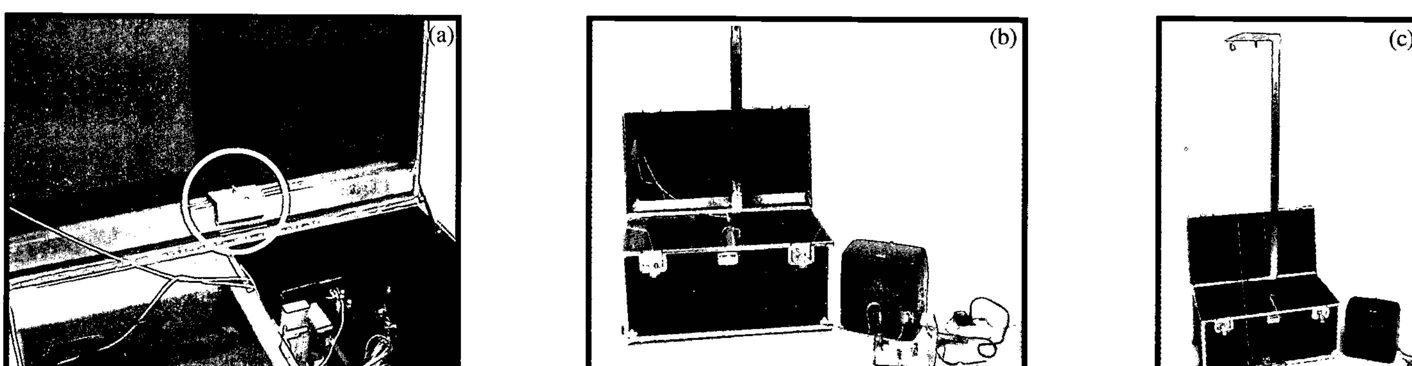
The Microgravity Demonstrator packed in its shipping container.

The Microgravity Demonstrator provided by NASA consists of four major parts: the experiments, the tower assembly, the experiment platform, and the video system. The tower assembly provides a means of raising and releasing the experiment platform and a padded catch basin to decelerate and stop the falling experiments. The two segments of the tower structure are located in the top of the shipping crate. The pieces fit together to form a tower approximately 2.5 meters high (fall distance is about 2 meters). The interior base of the crate is padded with foam to reduce the impact on the experiment platform when it hits the bottom.

The experiment platform consists of a video camera and a mounting system for the experiments. The camera should be connected to the video monitor and recorder as indicated below. This system gives the audience a steady view of an experiment as it drops. The recorder allows videotaping of the experiment so that frame-by-frame or slow-motion play back can be used for data gathering and to make sure all the effects of the drop can be observed in detail.

The Microgravity Demonstrator should be assembled as follows:

- Remove the monitor/VCR from the shipping crate.
- Remove the tower segments from the top of the shipping crate after removing the wing nut and aluminum clamp.
- Construct the tower: the straight segment fits onto the crate and the angled segment completes the tower.



Tower construction steps: (a) remove wing nut and clamp and then remove two tower pieces, (b) fit straight tower segment onto post in center of shipping crate, (c) connect crossbar piece to straight segment to complete tower. Pulley should be over padded section of crate where monitor/VCR was.

- A rope is usually attached to the top of the experiment platform, threaded through the pulley and eye hook on the cross arm and tied down to the crate. If this is not the case, tie one end of the rope securely to the eye bolt on top of the experiment platform. Thread the other end of the rope through the pulley and eye hook on the cross arm.
- You should be able to raise and lower the experiment platform by pulling on the rope.

- Connect the power and signal lines between the video camera and the video recorder. All the connections are labeled for easy set up.

  Instructions:

  (a) Place monitor/VCR on a table immediately left or right of the Demonstrator.

  (b) A single cable connects the camera to the monitor/VCR and to the power strip.

  (1) One branch of this y-cable connects to the camera in the experiment platform. Connector and port are labeled CAMERA. Four wires actually connect to the camera, two for power and two for video signal out.

  (2) One branch of this y-cable connects to the back of the monitor/VCR. Connector and port are labeled VIDEO IN.

  (3) One branch of this y-cable ends in a power supply plug. Plug and outlet are labeled PWR STRIP.

  (c) Switch off the power on the power strip.

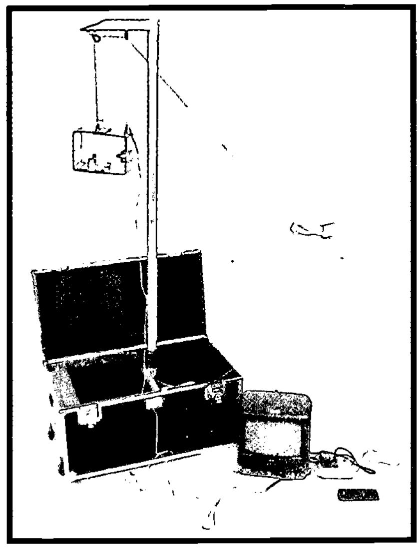
  (d) Plug the monitor/VCR power cord into the power strip. Plug and outlet are labeled PWR STRIP.

  (e) Connect the power strip to a 110 volt wall outlet, using an extension cord if necessary.

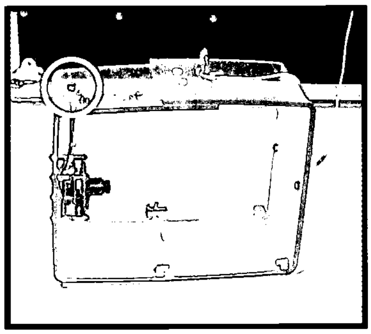
  (f) Switch on the power strip.

  (g) Switch on the monitor/VCR. Use the channel control to set the monitor on AUX rather than on a TV channel. You can escape the on-screen menu by turning the power off then on again.

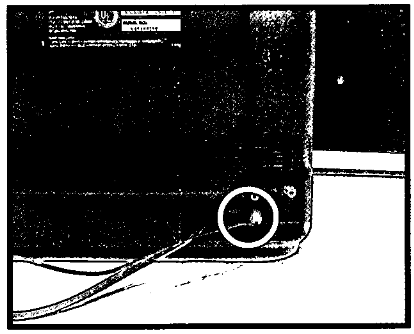
  (h) Wave your hand in front of the camera. You should be able to see it on the monitor.



Assembled Microgravity Demonstrator with experiment platform partially raised.

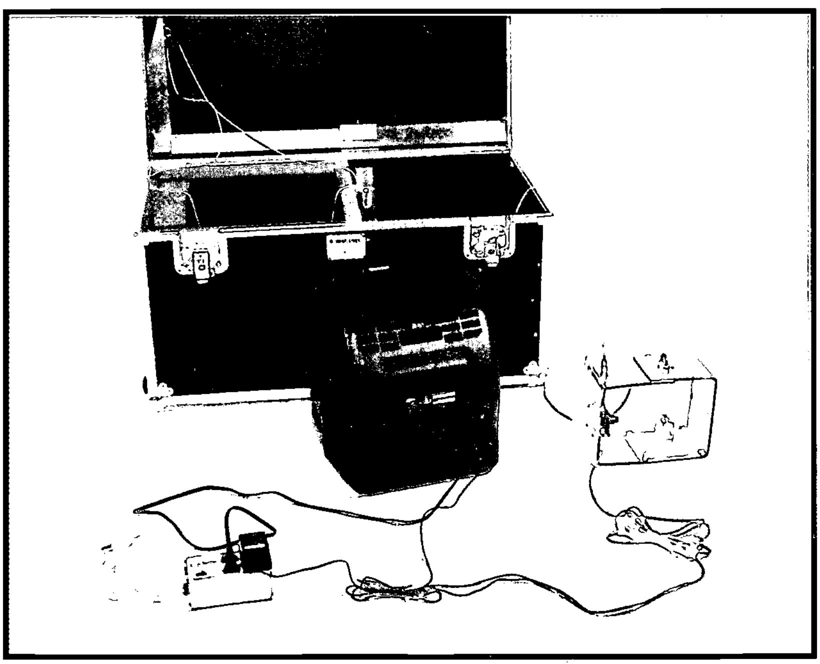


Platform with CAMERA port circled.



Monitor/VCR with VIDEO IN port circled.

- To mount the experiments, loosen the wing nut on the base of the experiment platform and slide in an experiment so that the appropriate side is facing the camera. Tighten the wing nut once the experiment is in place. Note that one corner of each experiment base has a corner cut out that should end up opposite the wing nut (in the direction parallel to the long axis of the platform). This cutout acts as a keyway for the experiments, allowing them to only be fastened correctly in one orientation.



The completed video system.

The Microgravity Demonstrator is now ready for use. The Demonstrator should be positioned so that the audience can easily see both the experiment as it is dropping and the video monitor. Be careful that the rope and video cable do not catch on anything during the drops. A few practice drops are encouraged. This will give you the opportunity to videotape one good example of each experiment. Then, when you are doing the demonstrations before an audience, you can refer to the videotape to discuss details of the observed phenomena and to collect data such as the amount of time a drop takes.

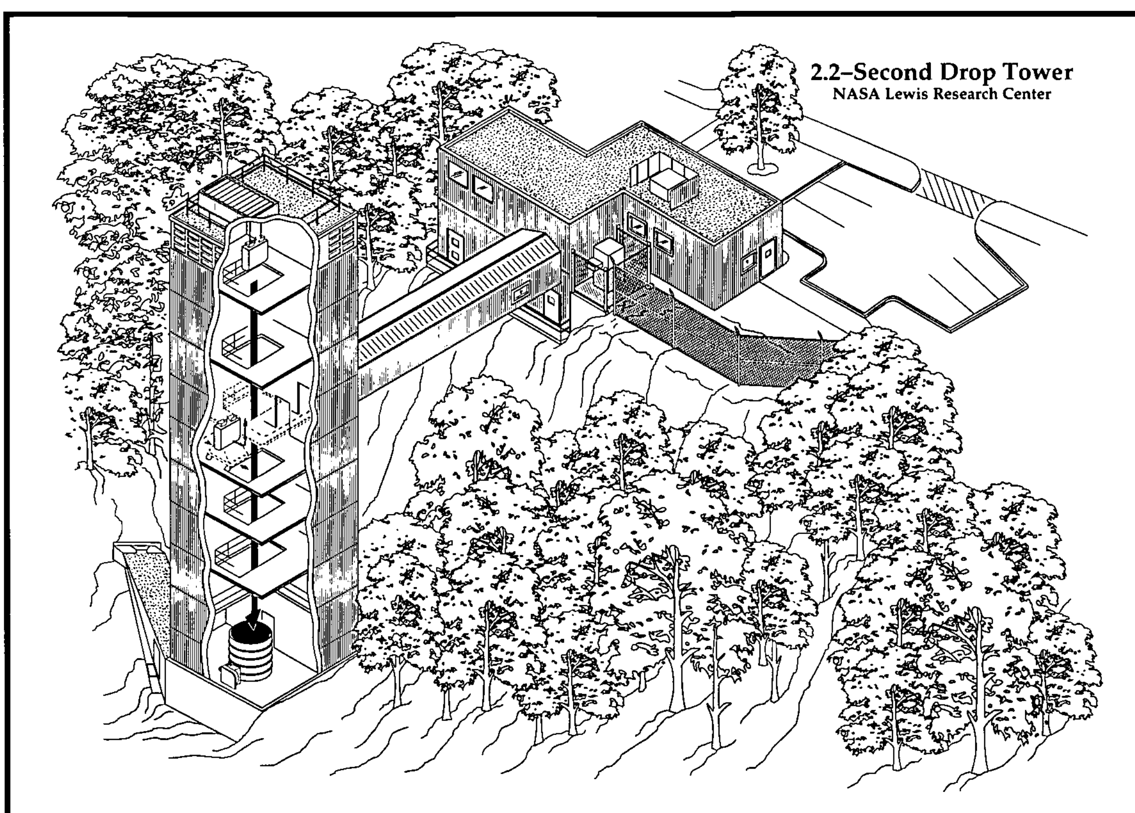
Demonstrations and Scientific Background

— *Free-Fall and Microgravity* —

Gravitational attraction is a fundamental property of matter that exists throughout the known universe. It wasn't until the twentieth century, however, that scientists realized they could actually use the Earth's gravitational field to remove the effects of gravity. The first two Microgravity Demonstrations provide visually dramatic evidence that putting an experiment into a state of free-fall reduces the effects of gravity on that experiment.

What do we mean by "a state of free-fall"? Simply put, it means dropping something within a gravitational field. When we drop something, we know by experience that it falls to Earth because of gravity. But while in free-fall, the apparent effects of gravity on the object are significantly reduced. A microgravity environment is one in which the apparent weight of a system is small compared to its actual weight, where the actual weight is that due to gravity. An in depth discussion of free-fall and microgravity can be found in Microgravity—Activity Guide for Science, Mathematics, and Technology Education, EG-1997-01-110-HQ.

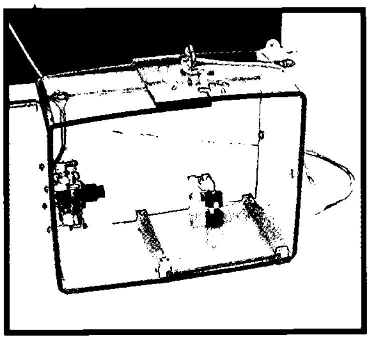
Researchers use high-tech facilities that create microgravity conditions by dropping experiment packages. The NASA Lewis Research Center has two drop facilities. One provides a 132 meter drop into a hole in the ground similar to a mine shaft. This drop provides a microgravity environment for 5.2 seconds. A tower at Lewis allows for 2.2 second drops down a 24 meter structure. The NASA Marshall Space Flight Center has a different type of microgravity facility. This 100 meter tube allows for drops of 4.5 second duration. A 110 meter tower in Bremen, Germany, allows for drops of 4.7 second duration. The longest drop time currently available is at a 490 meter deep vertical mine shaft in Hokkaido, Japan, that has been converted to a drop facility. This facility allows drops of 10 second duration.

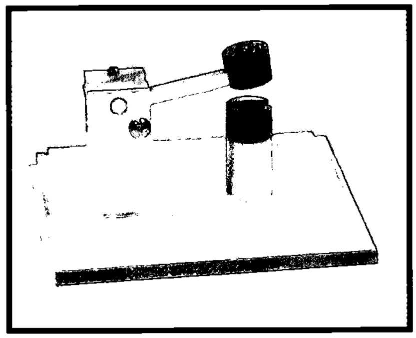


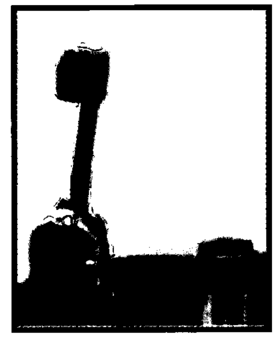
Schematic of the NASA Lewis Research Center 2.2–Second Drop Tower.

Magnet Demonstration

The Microgravity Demonstrator is a reduced scale version of these drop facilities. Its 2 meter height will allow for drops of 0.6 second duration. The first demonstration provides compelling evidence that being in free-fall removes the effects of gravity. The important scientific concept in this demonstration is the principle of balanced forces. This experiment consists of a pair of magnets: one fixed to the base of the experiment block and the other on the end of a lever arm so that it is aligned with the fixed magnet. If the magnets were configured so that their opposite poles were facing each other, the magnet on the lever arm would settle onto the fixed magnet. But the magnets are configured with their *like* poles facing each other, so the repulsive force acting between them pushes the magnet on the lever arm away from the other. Gravity, however, also acts on this system, pulling the magnet on the lever arm down toward the lower one. Where the top magnet comes to rest above the fixed magnet, the force due to gravity has the same magnitude as the force pushing them apart due to the magnetic fields.


Free-fall demonstration using concept of magnetic repulsion.

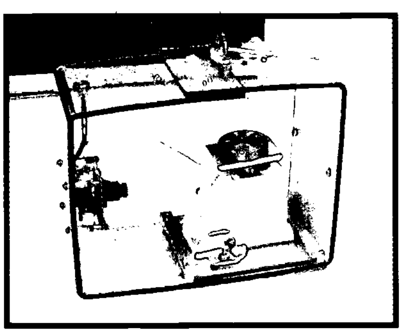

In Earth's gravity, forces due to magnetic repulsion and gravity are balanced.

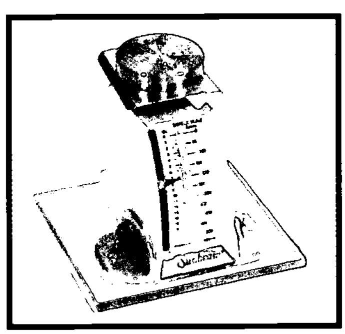

In microgravity, effects of gravity are eliminated and magnetic repulsion dominates.

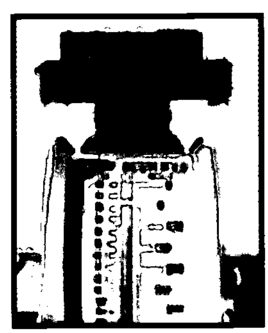
Now consider the question of what would happen to this system if we could turn off the effects of gravity. The magnetic repulsion force would no longer have gravity to compensate for it and it would become the sole force acting on the system. The magnet on the lever arm, therefore, would move as far away from the fixed magnet as the experiment configuration permits. When the magnet system is dropped, the magnet on the lever arm moves away from the fixed magnet, providing us with convincing evidence that being in free-fall removes the effects of gravity on the system.

Scale Demonstration

A second demonstration to convince you that free-fall causes a reduction in the effects of gravity uses a scale with a mass fixed to it. This demonstration also illustrates why the term weightless is sometimes used to describe objects in free-fall (including Earth orbit). The demonstration uses a spring scale with a mass attached to it. When the scale is placed on a table, the force of gravity manifests itself by pulling down on the mass. The spring in the scale pushes upward on the mass with a force equal in magnitude and opposite in sign to the force of gravity. The scale then records the magnitude of the gravitational force as the mass's weight. When this system is dropped, the effects of gravity are removed and the now unbalanced force of the spring moves the mass and scale pointer.


Free-fall demonstration using spring scale.

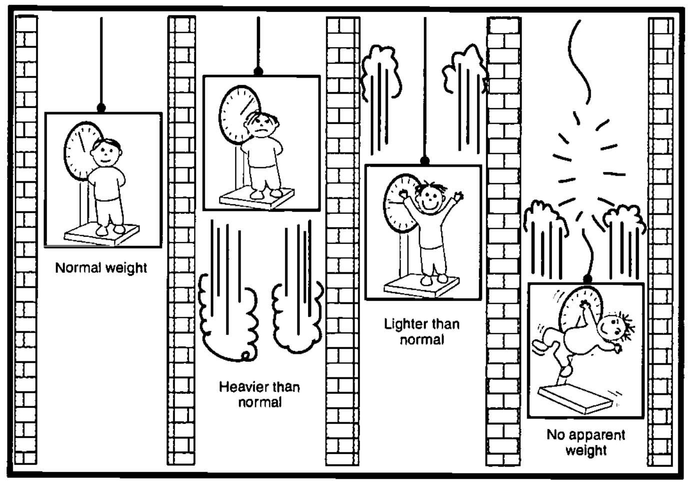

In Earth's gravity, forces due to elasticity of spring and gravity are balanced.


In microgravity, effects of gravity are eliminated and the mass's apparent weight is reduced.

Careful observation of this demonstration should raise the question, "Why does the pointer on the scale actually indicate a negative weight during free-fall?" Scales such as this one with a platen on it are set to read zero when no objects are on the platen. But the platen itself has a mass and its weight is typically referred to as the tare weight. When the scale is dropped, it's actually going back and accounting for the extra tare weight, so the scale reads negative.

It is important to realize that the **weight** of an object is the gravitational force exerted on it by Earth. The environment of an object may be changed in such a way that its **apparent weight** changes. A free-fall environment changes an object's apparent weight. Because a scale in a free-fall environment, such as the one in the demonstration, reads close to zero, the terms zero gravity and weightlessness have often been used when referring to this situation. But, because most means of producing free-fall introduce other forces such as aerodynamic drag (wind resistance) that have effects similar to gravity, a special term was created to describe these situations. A **microgravity environment** is one in which the apparent weight of a system is small compared to its actual weight.

Imagine standing on a scale in a stationary elevator car. Any vertical accelerations of the elevator are considered to be positive upwards. Your weight, **W**, is determined by your mass and the acceleration due to gravity at your location. If you begin a ride to the top floor of a building, an additional force comes into play due to the acceleration of the elevator. The force that the floor exerts on you is your apparent weight, **P**, the magnitude of which the scale will register. The total force acting on you is $\mathbf{F}=\mathbf{W}+\mathbf{P}=m\mathbf{a}_e$, where $\mathbf{a}_e$ is the acceleration of you and the elevator and $\mathbf{W}=m\mathbf{g}$. Note that if the elevator is not accelerating then the magnitudes W and P are equal but the direction in which those forces act are opposite ($\mathbf{W}=-\mathbf{P}$). Remember that the sign (positive or negative) associated with a vector quantity, such as force, is an indication of the direction in which the vector acts or points, with respect to a defined frame of reference. For the reference frame defined above, your weight in the example below is negative because it is the result of acceleration (gravity) directed downwards (towards Earth).



The person in the stationary elevator car experiences normal weight. In the car immediately to the right, apparent weight increases slightly because of the upward acceleration. Apparent weight decreases slightly in the next car because of the downward acceleration. A scale does not measure weight in the last car on the right because of free-fall.

$\mathbf{F}=\mathbf{W}+\mathbf{P}=m\mathbf{a}_e$

Rewriting yields $\mathbf{P}=m\mathbf{a}_e-m\mathbf{g}=m(\mathbf{a}_e-\mathbf{g})$.

If your mass is 60 kg and the elevator is accelerating upwards at 1 m/s^2, your apparent weight is

$\mathbf{P}=(60\ kg)(+1\ m/s^2-(-9.8\ m/s^2))=+648\ kg\ m/s^2$

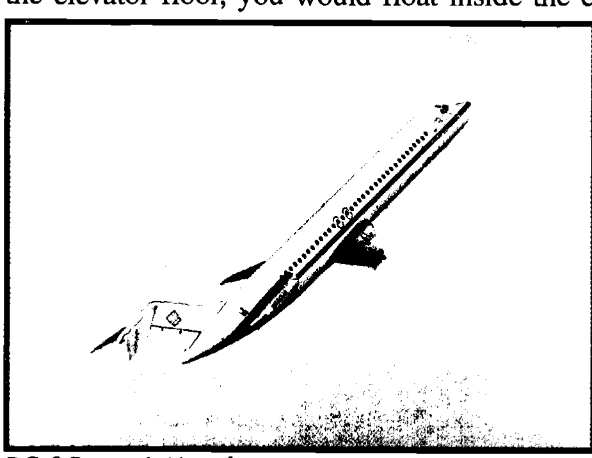
while your weight was

$\mathbf{W}=m\mathbf{g}=(60\ kg)(-9.8\ m/s^2)=-588\ kg\ m/s^2$.

If the elevator accelerates downwards at 0.5 m/s^2, your apparent weight is

$\mathbf{P}=(60\ kg)(-0.5\ m/s^2-(-9.8\ m/s^2))=+558\ kg\ m/s^2$.

Imagine now riding in the 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 towards the ground. In this example, we discount the effects of air friction and elevator safety mechanisms on the falling car. Your apparent weight $\mathbf{P}=m(\mathbf{a}_e-\mathbf{g})=(60\ kg)(-9.8\ m/s^2-(-9.8\ m/s^2)) = 0\ kg\ m/s^2$; you are weightless. The elevator car, the scale, and you would all be accelerating downward at the same rate, which is due to gravity alone. If you lifted your feet off the elevator floor, you would float inside the car. This is the same experiment that Galileo is purported to have performed at Pisa, Italy, when he dropped a cannonball and a musketball of different mass at the same time from the same height. Both balls hit the ground at the same time, just as the elevator car, the scale, and you would reach the ground at the same time.



DC–9 Research Aircraft

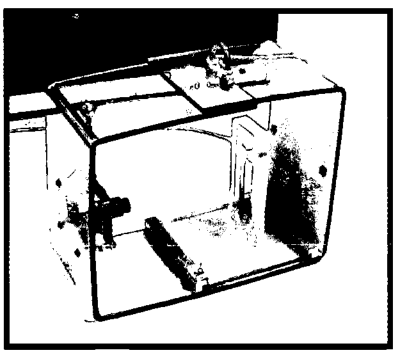
In addition to the drop facilities introduced earlier which are similar to falling elevator cars, NASA experimenters also use aircraft flying on parabolic paths, sub-orbital rockets, and orbiting spacecraft such as the Space Shuttle Orbiters and the Mir Space Station. Microgravity—Activity Guide for Science, Mathematics, and Technology Education, EG-1997-01-110-HQ gives more information about the microgravity environments provided by these vehicles.

— *Microgravity Science Experiments* —

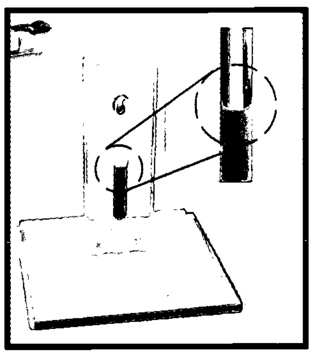
Microgravity research performed by NASA is generally divided into five categories: biotechnology, combustion science, fluid physics, fundamental physics, and materials science. Reduced gravity facilities are used when performing these types of experiments so that the scientists can study phenomena that are affected by gravity on Earth. They can also learn how to make spacecraft equipment work effectively under microgravity conditions. The remaining microgravity demonstrations provide insight into the types of research performed in microgravity environments. The Capillarity Demonstration introduces issues related to fluid physics research in microgravity. The Sedimentation Demonstration and Candle Flame Demonstration make apparent the effects of gravity when working with matter of different densities.

Capillarity Demonstration

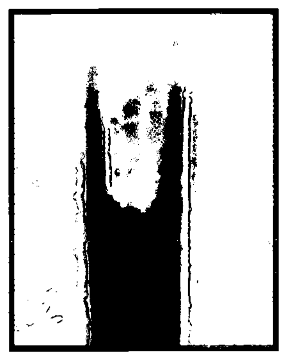
The Capillarity Demonstration shows the effects of capillary action on Earth and in a microgravity environment. The combined phenomena of surface tension, capillarity, adhesion, and cohesion have an effect on how a liquid rests in a container on Earth. The Capillarity Demonstration consists of a colored liquid in a closed container. The cross section of the container is somewhat D-shaped with two sharp corners at the front face and a curved surface at the back, see plan drawing in **Suggestions for Making Your Own Microgravity Demonstrator**. On Earth the colored fluid rests at the bottom of the container and the fluid creeps slightly upward in the sharp corners of the container. Capillary forces are stronger in narrow radius corners and in small diameter tubes. The liquid wets the container because it prefers contact with the container instead of itself. The phenomena that cause the fluid to creep up the container walls are independent of gravity. Gravity, however, keeps the liquid from rising further. In this case, the liquid only manages to rise about one millimeter into the container corners. When the system is dropped, the effects of gravity on the fluid are reduced and the capillary action pulls the fluid higher up the container corners, closer to 2 centimeters than a millimeter. If it dropped longer, the fluid would completely coat the surface of the container, leaving a bubble of air in the center.



Capillarity demonstration showing effects of microgravity on fluids.

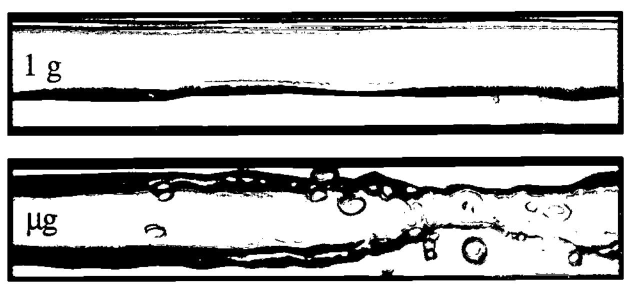


In Earth's gravity, gravity keeps the fluid in the bottom of the container with about 1 mm of capillary rise in the corners.



In microgravity, effects of gravity are eliminated and the fluid rises about 2 cm in the corners.

Scientists and engineers who design orbiting spacecraft must create systems that manage fluids effectively. A liquid that partially fills a container in space behaves differently than when it just sits in the bottom of the same container on Earth. Researchers must understand how fluids behave in Earth orbit so that astronauts can drink and liquid fuels can get to spacecraft engines when needed. In general, one of the underlying themes of microgravity research is to understand the dramatic influence on fluids that gravity has here on Earth. As we can see, being in a microgravity environment enables researchers to examine fluid phenomena such as capillary action on a centimeter scale rather than a millimeter scale. Such a change in scale makes it easier to study different aspects of fluid physics.

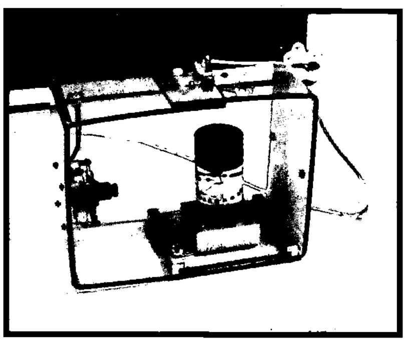


Water and air travelling in a clear pipe. In 1 g the air stays above the water. In microgravity, the air can form a core in the center of the pipe.

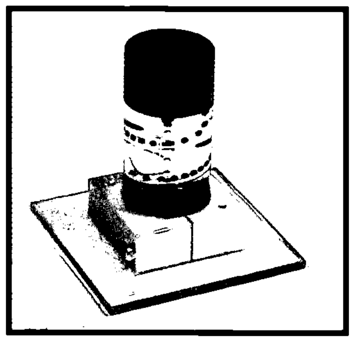
Sedimentation Demonstration

The Sedimentation Demonstration is a readily available "executive toy" containing two fluids that do not mix chemically (immiscible), one clear fluid and another, more dense, dark fluid. When the experiment is placed upright on Earth, the dark fluid drips out of the nozzle on the top of the container and the individual drops roll down the ramp through the clear fluid due to the density difference. When the container is dropped in an upright position, several effects can be observed. First, as soon as the container is dropped, the drops on the ramp slow down and stop. Gravity is no longer pulling them down through the less dense fluid. When the container is put into free-fall, the drops maintain some motion due to momentum. This motion, however, damps out quickly.

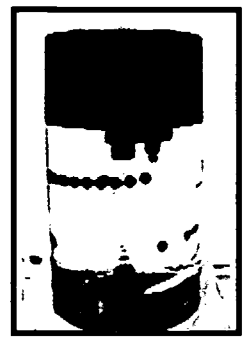
The second effect that can be observed is that the drops change shape. If you look at the drops when the container is stationary, you will see that the drops assume an ovoid or egg shape when they move down the ramp. This flattened shape is due to gravity. As soon as the container is dropped and as long as it is in free-fall, the drops assume a spherical shape. When they become spherical, they often appear to jump up and actually lose contact with the ramp. In contrast to the capillarity experiment, the dark fluid prefers to be in contact with itself. In addition, if a drop is partially out of the nozzle at the beginning of a fall, the drop will pull back into the nozzle because of surface tension; the liquid prefers to be in the reservoir.



Sedimentation demonstration showing effects of density differences in immiscible liquids.



In Earth's gravity, gravity causes the rolling drops to assume an ovoid form.



In microgravity, effects of gravity are eliminated and the drops assume spherical forms.

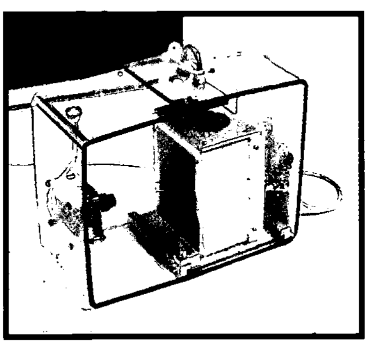
Scientists perform experiments in microgravity conditions to avoid sedimentation. Why? The formation of certain types of metallic alloys is an example. Under appropriate conditions, two immiscible liquid metals can be solidified such that one metal is imbedded in the other as a dispersion of droplets or as an aligned set of columns of one metal in the other. Imagine, for example, trying to create a block of ice with sand evenly distributed throughout the block. On Earth, the sand would settle to the bottom of the liquid water before you could freeze it. The alloys that result from such processing can have unique electrical, mechanical, and chemical properties that are vital for bearing systems and superconductivity applications. But the liquid metal components typically have different densities. Formation of such alloys under microgravity conditions allows the components to remain intermixed without the more dense metal settling.

Candle Flame Demonstration

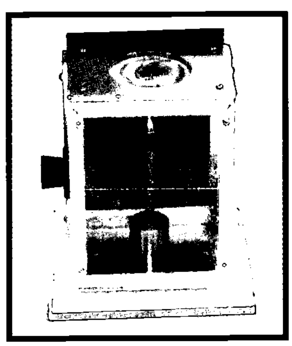
The Candle Flame Demonstration can be used to help understand how candles burn on Earth and how things burn in microgravity. When burned on Earth, notice that a candle flame assumes an immediately recognizable tear drop shape. On Earth, buoyancy-driven convection is largely responsible for the flame shape. Hot products created by the combustion are less dense than the surrounding air and move upwards. The rising hot gases pull the flame into its characteristic tip. Fresh air with more oxygen is pulled in from the side and feeds the combustion process.

When the burning candle is dropped, the candle flame quickly becomes shorter, wider, and less bright. The flame is extinguished when the candle holder hits the ground. Because buoyancy-driven convection does not play a role in the combustion process once the candle is in free-fall, heated combustion products move away in all directions equivalently and the flame becomes somewhat spherical. Fresh oxygen can now only get to the flame via diffusion. Diffusion, where species such as oxygen want to move from high concentrations to lower concentrations, is a slower process than convection, so the flame becomes less intense as less oxygen gets to it. When the candle hits the ground, the rapid deceleration of the system mimics high gravity conditions for a brief time. This causes intense convective motion of the gases around the flame to start again so rapidly that the flame is blown out by the motion of the gases.

In many drops using the Demonstrator, after the initial dimming of the flame, the flame actually gets brighter again because of the friction of the rope moving through the pulley and eye hook. Friction is proportional to the square of the velocity, so the slower the rope moves through the pulley and eye hook, the lower the friction. The lower the friction, the closer to pure free-fall. As the speed of the rope increases with time, the resistance goes up and the deviation from pure free-fall increases, causing a lowering of the quality of the microgravity conditions. The intensity of the flame serves as the indicator of an accelerometer, tracking the changing speed of the falling platform. If this experiment were run by simply dropping the experiment without the rope, the intensity of the flame would continue to get dimmer until it was totally blue.



Candle flame demonstration showing effects of gravity on combustion.



In Earth's gravity, gravity-driven convection rolls cause an easily recognizable flame shape.

In microgravity, diffusion drives the movement of gases around the flame which becomes spherical in shape.

Scientists have a good understanding of how things burn on Earth, but getting a clearer picture of the combustion process under microgravity conditions will improve that understanding. In addition, designers need to consider how things burn in the microgravity environment of spacecraft so that they can build both fire retardant components and effective fire detection and suppression systems.

Activities

Before all experiments, make sure that the Microgravity Demonstrator is assembled correctly and that the video system is configured appropriately. For all activities that suggest recording time, remember that each video frame is one thirtieth of a second.

Free-Fall Demonstration #1-Magnets

Step #	Procedure	Comments
1	Show magnet configuration to class and discuss why the magnets are not touching each other. Discuss what would happen if the effects of gravity could be turned off.	See discussion above about balance of forces.
2	Put magnet experiment into experiment platform and tighten wing nut.	Long axis of lever arm should be visible.
3	Pull experiment platform to top of tower.	Steady platform. Make sure that the cord is free from all obstacles.
4	Release the cord and watch the experiment on the video monitor as it drops.	Observe that the magnet on the lever arm moves away from the fixed magnet. Note that the lever arm has a stop built in which sometimes causes the free magnet to bounce back before the end of the drop.
5	Repeat the drop a few times if you want to watch it "live" again.	Note that the effects of gravity become dramatically reduced not after it falls for awhile but immediately.
6	Using the frame by frame play feature of the VCR, replay a recorded drop where a scale or grid system was placed behind the falling experiment. Record distance and time for several frames of the video. Discuss the non-linear nature of the relationship between distance and time for an object accelerating due to gravity.	The distance an object falls is $d=1/2\ at^2$, where a is the acceleration and t is the time. How long does the microgravity period last for this drop facility? $a=g=9.8\ m/s^2$ $=32.2\ ft/s^2$

Free-Fall Demonstration #2-Spring Scale

Step #	Procedure	Comments
1	Show the scale to the class and show that it is a working scale. Discuss the difference between mass and weight and introduce the concept of apparent weight. Discuss what would happen if the effects of gravity could be turned off.	See discussion above about balance of forces and apparent weight. See Microgravity—Activity Guide for Science, Mathematics, and Technology Education, EG-1997-01-110-HQ for more information.
2	Record the weight of the object attached to the scale.	Note that the scale should not actually be considered accurate due to potential deformation of the spring caused by repeated dropping.
3	Put the scale experiment into the experiment platform and tighten the wing nut. Make sure that the scale pointer and markings are visible on the video monitor.	
4	Pull experiment platform to top of tower.	Steady platform. Make sure that the cord is free from all obstacles.
5	Release the cord and watch the experiment on the video monitor as it drops.	Observe that the pointer on the scale moves to the negative side of the zero weight marking.
6	Repeat the drop a few times if you want to watch it "live" again.	Note that the effects of gravity become dramatically reduced not after it falls for awhile but immediately.
7	Using the frame by frame play feature of the VCR, replay a recorded drop to confirm that the pointer indicates a "negative" weight.	Again discuss the concepts of weight versus apparent weight. In addition, introduce the concept of tare weight. A common place where tare weight is encountered is in grocery stores. The scales are set to account for different tare weights when weighing a bag of potatoes or a tub of potato salad.

Capillarity Demonstration

Step #	Procedure	Comments
1	Show capillarity experiment to class. Point out that the container cross section is somewhat D-shaped and, hence, has sharp corners. Discuss the concepts of capillarity and surface tension. Discuss what would happen if the effects of gravity could be turned off.	See Microgravity—Activity Guide for Science, Mathematics, and Technology Education, EG-1997-01-110-HQ for more information. Store the experiment on its side with the curved face and the brass knob up. This will help prevent the fluid from leaking out between the two acrylic pieces.
2	Measure or make a rough estimate of how far the liquid creeps up into the corners of the container when the experiment is on a table.	
3	Put capillarity experiment into experiment platform and tighten wing nut.	Make sure that the "flat" side of the container is visible on the video monitor.
4	Pull experiment platform to top of tower.	Steady platform. Make sure that the cord is free from all obstacles.
5	Release the cord and watch the experiment on the video monitor as it drops.	Observe the reaction of the fluid during the drop.
6	Repeat the drop a few times if you want to watch it "live" again.	Note that the effects of gravity become dramatically reduced not after it falls for awhile but immediately.
7	Using the frame by frame play feature of the VCR, replay a recorded drop and measure or estimate the relative heights of the fluid in the corners before and during the drop.	What was a millimeter phenomenon when affected by gravity becomes a centimeter phenomenon when the effects of gravity are reduced.

Sedimentation Experiment

Step #	Procedure	Comments
1	"Load" experiment by placing it with the mounting plate up until the dark liquid is in the "upper" chamber.	
2	Turn the sedimentation experiment right side up and show to class. Discuss why the dark liquid does not mix with the clear liquid. Observe the drops of dark liquid and note their motion and shape. Discuss what would happen if the effects of gravity could be turned off.	See Microgravity—Activity Guide for Science, Mathematics, and Technology Education, EG-1997-01-110-HQ for more information about immiscibility and sedimentation.
3	Reload experiment.	
4	Put sedimentation experiment into experiment platform and tighten wing nut.	
5	Pull experiment platform to top of tower.	Steady platform. Make sure that the cord is free from all obstacles.
6	Release the cord and watch the experiment on the video monitor as it drops.	Observe the motion and shape of the dark drops during the free-fall period.
7	Repeat the drop a few times if you want to watch it "live" again.	It is difficult to repeat this experiment immediately because the impact tends to break up the fluid into small droplets.

This experiment can be used as a stepping stone for discussions of several topics:

1. Surface energy: Why do the drops assume a spherical shape when the effects of gravity are reduced? Why does the drop pull back into the reservoir?
2. Momentum: The drops briefly continue their motion with respect to the container.
3. Viscosity: What causes the motion of the drops to stop?

Candle Flame Experiment

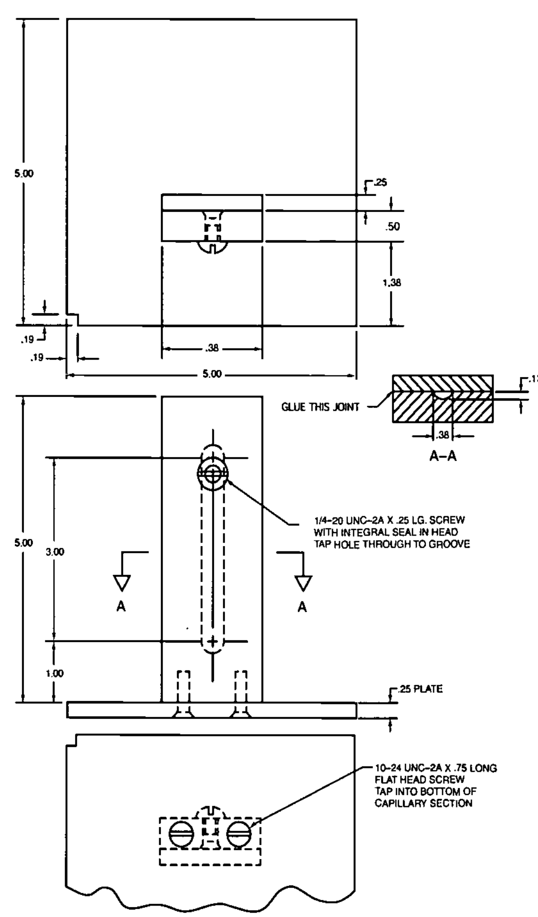
Step #	Procedure	Comments
1	Discuss how candles burn on Earth's surface and how convection causes the familiar shape of a candle flame. Discuss how a candle would burn in microgravity.	See discussion above and Microgravity—Activity Guide for Science, Mathematics, and Technology Education, EG-1997-01-110-HQ for more information.
2	Open the back door of the experiment, place a candle in holder, and tighten the door wing nut so that the door stays open. Put candle flame experiment into experiment platform and tighten wing nut on platform.	Performance of this experiment is often dependent on the length of the candle. Longer candles place the flame closer to the top vent that lets in oxygen.
3	Remove the plug from the side of the candle experiment. Light the candle and replace the plug. Turn off the room lights.	The candle flame box is plugged so that the wind that's created by the falling process doesn't influence the burning of the candle. When the back door is closed, the screened hole in the top of the box lets in enough oxygen for the candle to burn briefly. The viewing window may also fog up quickly.
4	Pull experiment platform to top of tower.	Make sure that the cord is free from all obstacles.
5	Loosen the wing nut on the back door and close the door. Steady experiment platform and make sure that flame is stable.	Flame may gutter (flicker, sputter) some when the experiment is raised and may need a moment to stabilize. Once the door is closed, the flame goes out fairly quickly.
6	Release the cord and watch the experiment on the video monitor as it drops.	Observe the shape and intensity of the flame during the free-fall period.
7	Repeat the drop a few times if you want to watch it "live" again.	You will probably have to open the door to let in fresh air and relight the candle before each drop.
8	Using the frame by frame play feature of the VCR, replay a recorded drop starting with the last frame before release.	Within the first sixth of a second (5 frames) the flame gets shorter, wider, and dimmer. In the next few frames, the flame typically gets brighter. As the platform hits the bottom, the flame gets drawn out and then extinguishes. The return of buoyancy-driven convection upon impact causes the lengthening and extinction of the flame as discussed above. It may take several drops prior to the live demonstration before you record a good occurrence of the flame lengthening at impact.

Suggestions for Making Your Own Microgravity Demonstrator

If you do not have access to a NASA Microgravity Demonstrator, or would like to create your own so that you can use it regularly, here are some ideas. Specific parts suggestions are listed in the accompanying table. The video tape recorder is not necessary, although slow motion playback does make it easier to visualize some phenomena. An experiment package can be dropped by hand, being careful not to start the package spinning or tumbling as you let go. Alternatively, pulley systems can be readily installed to allow for the hoisting of experiments. Many activities introducing the same or similar concepts to those discussed here are presented in Microgravity—Activity Guide for Science, Mathematics, and Technology Education, EG-1997-01-110-HQ.

Function of Part	Suggested Components	Comments
Support Structure	• wooden or metal pole long enough to allow drop of at least 2 m • pulley connected to ceiling of classroom • pulley attached to a basketball hoop • a person standing on a stable desk, table, or chair	The structure needs to be sturdy enough to support the experiment on the rope as it is hoisted up and during the drop.
Catch Basin	• trash can, box, or basin filled with padding material to protect experiment and camera from impact • possible padding: crumpled newspaper, polystyrene packing material, crumpled bubble wrap, foam rubber, down pillow	Longer drops make for harder impacts and an increased potential for camera damage. When designing a Demonstrator, consider the combined factors of drop time, required padding, and replacement camera costs.
Experiment Platform	• wooden or metal frame manufactured to hold experiments and camera	Platform must be sturdy enough to survive numerous falls while protecting the experiment packages and camera. Must be big enough to hold experiment and camera with camera far enough from experiment to focus properly.
Camera	• small solid state video camera, CCD camera, or chip camera; a board camera may be partially useful	These small video cameras are available in black and white and color through various electronic supply companies such as Edmund Scientific and Industrial Video. One possible manufacturer is Computar.
Video Monitor and Recorder	• a video monitor and recorder that will accept the video signal from the camera	The base band video from the camera needs to be sent to the monitor and recorder for live viewing, recording, and play back. It is good to have a recorder that can play back in slow motion. It is best to have a recorder that has a jog shuttle so that the video can be played back frame by frame.
Magnet Experiment	• one magnet should be fixed to the experiment base with the other on a lever arm such that the like poles of the magnets are repelling each other • the experiment base should mount to the experiment platform	The experiment should be designed so that the motion of the lever arm and magnet away from the fixed magnet can be seen by the camera during free-fall. Some magnets are ceramic and will break unless some padding is placed between the magnets.

Function of Part	Suggested Components	Comments
Scale Experiment	• use a small postal or dietary spring scale • attach a mass to the scale platen (the weight of the mass should fall within the marked weights on the scale) • the experiment base should mount to the experiment platform	It is a good idea to cushion the scale with some foam between the platen and the body of the scale.
Capillarity Experiment	• The container needs to be machined out of clear acrylic, see drawing below. Plexiglas™ is preferred because it can be polished well • The fluid used should be one that tends to wet the Plexiglas™, for example 1 centistoke (cS) silicone oil. • Any oil soluble dye can be used to make the fluid easier to see.	Attaching the machined parts together to make the cylinder so that the fluid does not leak out is probably the hardest part of making your own Demonstrator. Weldon 40™ was used to glue together the pieces in the Microgravity Demonstrator.
Sedimentation Experiment	• this is an "executive toy" that can be purchased at toy and gadget stores	Mount the toy onto a base such that the drops coming out of the nozzle will be visible in the video view.
Candle Flame Experiment	• a nonflammable box needs to shield the flame from wind when the experiment is in free-fall • a screened hole at the top of the box is needed to let in oxygen so that the candle will burn and to let out combustion products • access to the candle is required so that the candle can be lit (access then must be shut to prevent wind effects) • the side of the box facing the camera must be clear	The box should be mounted on the platform such that the candle flame is visible on the video during the drop.



PLAN FOR CAPILLARITY EXPERIMENT
1) MATERIAL – CAST ACRYLIC PLASTIC (PLEXIGLAS™).
2) USE WELDON 40™ TO GLUE PLASTIC (AVAILABLE FROM PLASTIC SUPPLIER).
3) ALL DIMENSIONS IN INCHES.

Tips and Troubleshooting Guide for the Video System

Tips

- Record one good example of each demonstration before you do the live drops in front of your classroom.
- To record a drop, first make sure that you have a VHS tape in the tape slot and that the tape can be recorded. Turn on the video system as instructed in the **Putting Together the Microgravity Demonstrator** section. If you have problems, refer to the Troubleshooting Guide that follows this Tips section. Begin recording after the experiment platform has been hoisted to the top of the tower and steadied. Stop recording after impact. Review the taped sequence to make sure that all the desired phenomena were captured. Rewind and repeat the process until you have a usable video sequence.
- For all activities that suggest recording time, remember that each video frame is one thirtieth of a second.
- Hint for doing frame by frame playback: Start the videotape playing and press the pause button when the experiment starts to fall. Then use the jog shuttle to step back frame by frame to just before the drop. Then you can go forward again frame by frame and observe the phenomena.

Troubleshooting Guide

Problem Encountered	Suggested Solutions
1. Monitor/VCR does not turn on.	Check that monitor/VCR PWR STRIP is plugged into power strip. Check that power strip is plugged into wall outlet. Check that power strip is turned on.
2. Video image does not show on monitor.	Check that monitor/VCR is turned on (see Problem 1). Check that VIDEO IN cable is connected correctly to monitor/VCR. Check that CAMERA cable is connected correctly to camera. Check that camera PWR STRIP is plugged into power strip. Check that power strip is plugged into wall outlet. Check that power strip is turned on. Check that monitor is set to channel AUX. Camera failure is possible.
3. VCR will not accept tape.	Make sure that a tape is not already in VCR. Make sure that there are no broken pieces on the videotape case.
4. VCR does not appear to be recording correctly.	Make sure that you have a VHS format tape. Make sure that the write protection tab is not broken off of the videotape. Make sure that the video system was set to record.
5. Videotape does not play.	Make sure that tape is of correct format. Make sure that monitor/VCR is turned on, has power, and has video feed (see Problems 1 and 2). Make sure that PAUSE button was not pushed. Make sure that jog shuttle is set as desired.
6. Jog shuttle does not appear to control tape playback.	Make sure videotape is playing. Press PAUSE button. Turn jog shuttle (dial) in direction you want tape to progress (clockwise to move forward in time, counterclockwise to move backward in time).

NASA Resources for Educators

NASA's Central Operation of Resources for Educators (CORE) was established for the national and international distribution of NASA-produced educational materials in audiovisual format. Educators can obtain a catalogue and an order form by one of the following methods:

- NASA CORE
  Lorain County Joint Vocational School
  15181 State Route 58
  Oberlin, OH 44074-9799
- Phone (440) 774-1051, Ext. 235 or 249
- Fax (440) 774-2144
- E-mail *nasaco@leeca.esu.k12.oh.us*
- Home Page: *http://spacelink.nasa.gov/CORE*

Educator Resource Center Network

To make additional information available to the education community, the NASA Education Division has created the NASA Educator Resource Center (ERC) network. ERCs contain a wealth of information for educators: publications, reference books, slide sets, audio cassettes, videotapes, telelecture programs, computer programs, lesson plans, and teacher guides with activities. Educators may preview, copy, or receive NASA materials at these sites. Because each NASA Field Center has its own areas of expertise, no two ERCs are exactly alike. Phone calls are welcome if you are unable to visit the ERC that serves your geographic area. A list of the centers and the regions they serve includes:

AK, AZ, CA, HI, ID, MT, NV, OR, UT, WA, WY
NASA Educator Resource Center
Mail Stop 253-2
NASA Ames Research Center
Moffett Field, CA 94035-1000
Phone: (650) 604-3574

CT, DE, DC, ME, MD, MA, NH, NJ, NY, PA, RI, VT
NASA Educator Resource Laboratory
Mail Code 130.3
NASA Goddard Space Flight Center
Greenbelt, MD 20771-0001
Phone: (301) 286-8570

CO, KS, NE, NM, ND, OK, SD, TX
JSC Educator Resource Center
Space Center Houston
NASA Johnson Space Center
1601 NASA Road One
Houston, TX 77058-3696
Phone: (281) 483-8696

FL, GA, PR, VI
NASA Educator Resource Laboratory
Mail Code ERL
NASA Kennedy Space Center
Kennedy Space Center, FL 32899-0001
Phone: (407) 867-4090

KY, NC, SC, VA, WV
Virginia Air and Space Museum
NASA Educator Resource Center for
NASA Langley Research Center
600 Settler's Landing Road
Hampton, VA 23669-4033
Phone: (757) 727-0900 x 757

IL, IN, MI, MN, OH, WI
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NASA Lewis Research Center
21000 Brookpark Road
Cleveland, OH 44135-3191
Phone: (216) 433-2017

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Huntsville, AL 35807-7015
Phone: (256) 544-5812

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Stennis Space Center, MS 39529-6000
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NASA Jet Propulsion Laboratory
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Phone: (818) 354-6916

CA cities near the center
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VA and MD's Eastern Shores
NASA Educator Resource Lab
Education Complex - Visitor Center
Building J-1
NASA Wallops Flight Facility
Wallops Island, VA 23337-5099
Phone: (757) 824-2297/2298

Regional Educator Resource Centers (RERCs) offer more educators access to NASA educational materials. NASA has formed partnerships with universities, museums, and other educational institutions to serve as RERCs in many states. A complete list of RERCs is available through CORE, or electronically via NASA Spacelink at *http://spacelink.nasa.gov*

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Educators and students utilizing this site will have access to a comprehensive overview of NASA's educational programs and services, along with a searchable program inventory that has cataloged NASA's educational programs. NASA's on-line resources specifically designed for the educational community are highlighted, as well as home pages offered by NASA's four areas of research and development (including the Aeronautics and Space Transportation, Earth Science, Human Exploration and Development of Space, and Space Science Enterprises).

Access these resources through the NASA Education Home Page: *http://www.hq.nasa.gov/education*

NASA Television (NTV) NASA Television (NTV) features Space Shuttle mission coverage, live special events, interactive educational live shows, electronic field trips, aviation and space news, and historical NASA footage. Programming includes a Video (News) File from noon to 1pm, a NASA Gallery File from 1-2pm, and an Education File from 2-3pm. This sequence is repeated at 3pm, 6pm, and 9pm, Monday through Friday. The Education File features programming for teachers and students on science, mathematics, and technology, including *NASA. . . On the Cutting Edge*, a series of educational live shows.

These interactive live shows let viewers electronically explore the NASA Centers and laboratories or anywhere scientists, astronauts, and researchers are using cutting-edge aerospace technology. The series is free to registered educational institutions. The live shows and all other NTV programming may be taped for later use.

NTV is transmitted on the GE-2 Satellite, Transponder 9C at 85 degrees West longitude, vertical polarization, with a frequency of 3880.0 megahertz (MHz) and audio of 6.8 MHz-or through collaborating distance learning networks and local cable providers. For more information on NASA Television, contact: NASA Headquarters, Code P-2, NASA TV, Washington, DC 20546-0001 — Phone: (202) 358-3572
NTV Home Page: *http://www.hq.nasa.gov/ntv.html*

How to Access NASA's Education Materials and Services, EP-1998-03-345-HQ This brochure serves as a guide to accessing a variety of NASA materials and services for educators. Copies are available through the ERC network, or electronically via NASA Spacelink at *http://spacelink.nasa.gov*

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