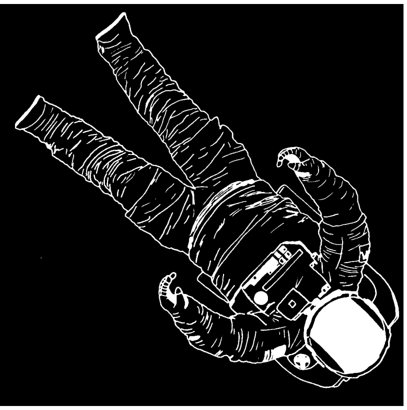
Classroom Activities



The activities and related student projects that follow emphasize hands-on involvement of the students. Where possible, they make use of inexpensive and easy-to-find materials and tools. The activities are arranged into four basic units, each relating to a different aspect of spacesuits and spacewalking.

Unit 1: Investigating the Space Environment

Objectives: To demonstrate how very different the space environment is from the environment at the surface of Earth.

To illustrate why spacesuits must be worn by astronauts going on a spacewalk.

Unit 2: Dressing for Spacewalking

Objectives: To demonstrate how spacesuits create a livable environment for astronauts.

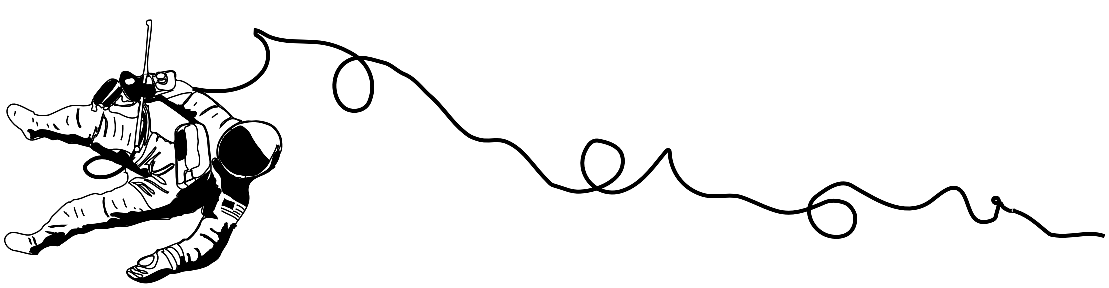
To illustrate some of the complexities involved in constructing a usable spacesuit.

Unit 3: Moving and Working in Space

Objective: To experience the problems astronauts face when trying to move and work in space and understand how those problems are solved.

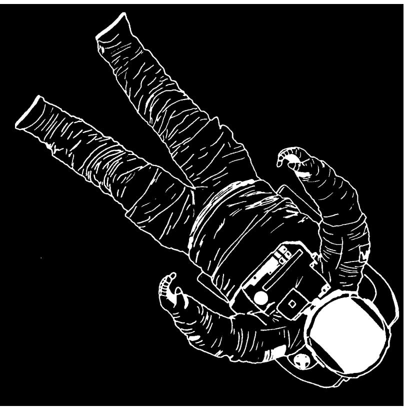
Unit 4: Exploring the Surface of Mars

Objective: To design, through a team effort, a spacesuit for future use on the planet Mars.



Unit 1

Investigating the Space Environment



Activity 1: A Coffee Cup Demonstrates Microgravity

Topic: Microgravity in space

Description: A stream of water coming out of a hole in a cup stops when the cup is dropped.

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Materials Needed:
Styrofoam or paper coffee cup
Pencil or other pointed object
Water
Bucket or other catch basin

Procedure:

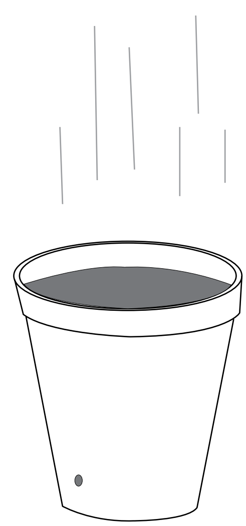
Step 1. Punch a small hole in the side of the cup near its bottom.

Step 2. Hold your thumb over the hole as you fill the cup with water. Ask students what will happen if you remove your thumb.

Step 3. Remove your thumb and let the water stream out into the catch basin on the floor.

Step 4. Again seal the hole with your thumb and refill the cup. Ask students if the water will stream out of the hole if you drop the cup.

Step 5. Drop the filled cup into the catch basin. The demonstration is more effective if you hold the cup high before dropping it.



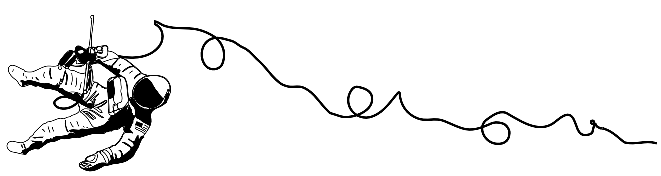
Discussion:

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.

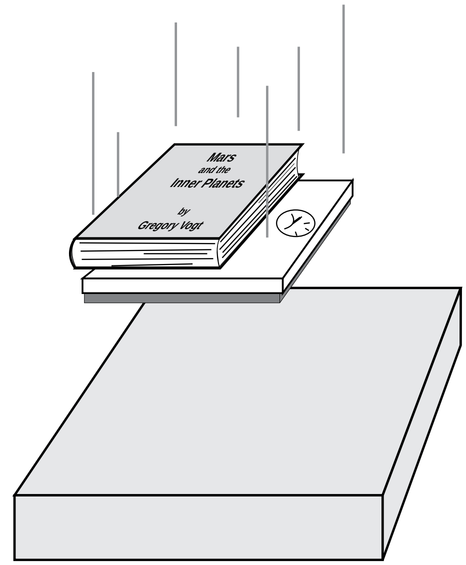
On Earth, momentary microgravity can be created in a number of ways. Some amusement parks achieve a second or two of microgravity in certain wild high-tech rides. A springboard diver feels a moment of microgravity at the top of a spring just as the upward motion stops and just before the downward tumbling 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 negate air friction on the people and experiments in the plane.

The falling cup for a moment demonstrates microgravity (or sometimes incorrectly referred to as weightlessness or zero-g). When the cup is stationary, water freely pours out of the cup. If the cup falls, the water remains inside the cup 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.

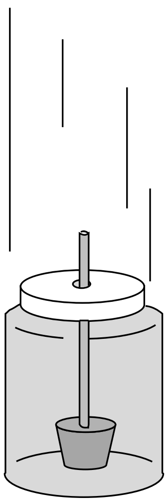
The demonstration works best when students are asked to predict what will happen when the cup is dropped. Will the water continue to pour out the hole as the cup falls? If your school has videotape equipment, you may wish to videotape the demonstration and then use the slow motion controls on the playback machine to replay the action.



Additional Demonstrations on Microgravity:

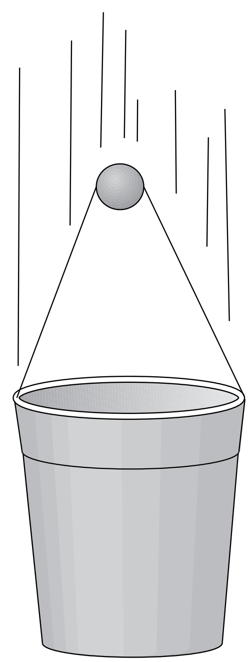


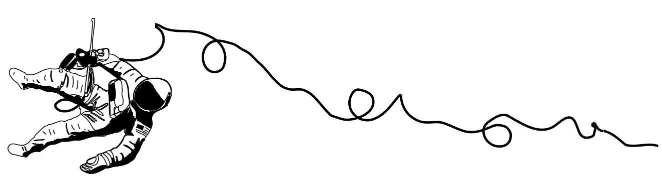
• Place a heavy book on a bathroom scale. Note the book's weight. Drop the book and scale together from a height of about a meter on to a mattress or some pillows. As it drops, quickly observe the book's weight. (The book's weight becomes zero as it falls.)



• Cut a small hole in the lid of a clear plastic jar. Drill a hole into a cork stopper and insert one end of a drinking straw into the stopper. Fill the jar with water and place the cork inside the jar with the straw extending through the hole. Push the cork to the bottom. Hold the jar a couple of meters off the floor and drop it into someone's hands. As it falls, watch the cork and straw. (During free-fall, the buoyancy of the cork disappears.)

• You can show how objects appear to float in microgravity by tieing a wooden bead to a paper cup with thread and dropping them together. Assemble the demonstration as shown in the illustration. Because of air friction, it may be necessary to add a few paper clips to the bottom of the cup to make it fall as fast as the bead. Hold the cup high in the air by the bead and drop it to the floor. Observe the bead and cup as they fall. Try letting go of the bead again, but this time hold on to the bottom of the cup. How does this demonstration show that freefall creates microgravity?





Activity 2: Meteoroids and Space Debris

Topic: Potential hazard to spacewalkers from meteoroids and space debris

Description: The penetrating power of a projectile with a small mass but high velocity is demonstrated.

Materials Needed:
Raw baking potato
Large-diameter plastic straw

Procedure:

Step 1. Hold a raw potato in one hand. While grasping the straw with the other hand, stab the potato with a quick, sharp motion. The straw should penetrate completely through the potato. **Caution: Be careful not to strike your hand.**

Step 2. Again hold the potato and this time stab it with the straw using a slow push. The straw should bend before penetrating the potato very deeply.

Discussion:

Astronauts on spacewalks are likely to encounter fast-moving rocky particles called meteoroids. A meteoroid can be very large with a mass of several thousand metric tons, or it can be very small—a micrometeoroid about the size of a grain of sand. Every day Earth's atmosphere is struck by hundreds of thousands or even millions of meteoroids, but most never reach the surface because they are vaporized by the intense heat generated when they rub against the atmosphere. It is rare for a meteoroid to be large enough to survive the descent through the atmosphere and reach solid Earth. If it does, it is called a meteorite.

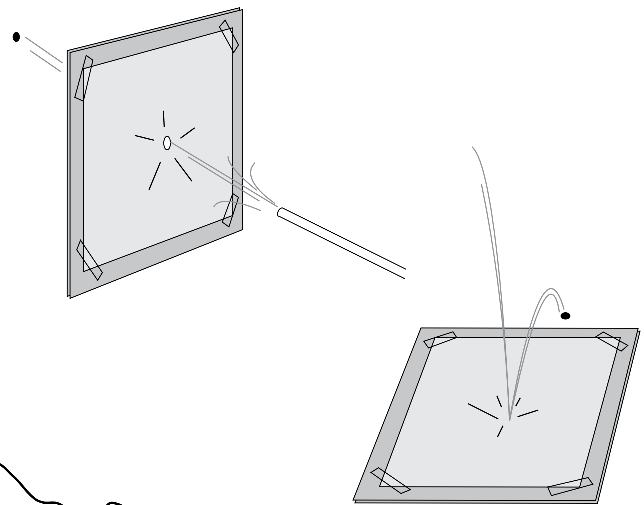
In space there is no blanket of atmosphere to protect spacecraft from the full force of meteoroids. It was once believed that meteoroids traveling at velocities averaging 80 kilometers per second would prove a great hazard to spacecraft. However, scientific satellites with meteoroid detection devices proved that the hazard was minimal. It was learned that the majority of meteoroids are too small to penetrate the hull of spacecraft. Their impacts primarily cause pitting and sandblasting of the covering surface.

Of greater concern to spacecraft engineers is a relatively recent problem—spacecraft debris. Thousands of space launches have deposited many fragments of launch vehicles, paint chips, and other "space trash" in orbit. Most particles are small, but traveling at speeds of nearly 30,000 kilometers per hour, they could be a significant hazard to spacecraft and to astronauts outside spacecraft on extravehicular activities.

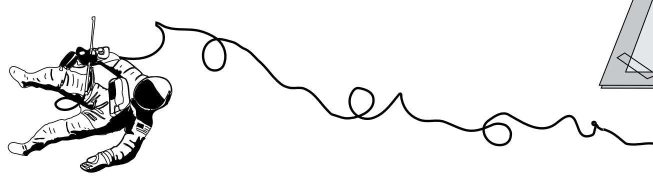
Engineers have protected spacecraft from micrometeoroids and space trash in a number of ways, including construction of double-walled shields. The outer wall, constructed of foil and hydrocarbon materials, disintegrates the striking object into harmless gas that disperses on the second wall. Spacesuits provide impact protection through various fabric-layer combinations and strategically placed rigid materials.

Although effective for particles of small mass, these protective strategies do little if the particle is large. It is especially important for spacewalking astronauts to be careful when they repair satellites or do assembly jobs in orbit. A lost bolt or nut could damage a future space mission through an accidental collision.

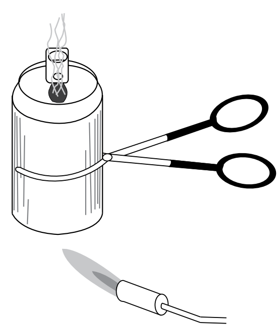
Additional Demonstration on Meteoroids and Space Debris:



• Aim a pea shooter at a piece of tissue paper taped to a cardboard frame. Aim the shooter at the tissue paper and blow hard into the shooter to accelerate the pea to the tissue at a high velocity. Drop the pea on to the tissue paper from a height of two meters. In the first demonstration the pea will penetrate the tissue, but in the second the pea will bounce.



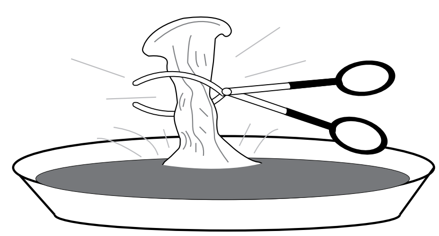
Activity 3: Air Pressure Can Crusher



Topic: Vacuums

Description: Air pressure exerts a force that crushes an aluminum beverage can.

Materials Needed:
Aluminum beverage can
Tongs to hold the can
Dish of cold water
Heat source (propane torch set at low flame, alcohol lamp)
Eye protection for demonstrator
Towel for cleanup



Procedure:

Step 1. Place approximately 30 ml of water in the can and heat it to boiling. Permit the water to boil for at least 30 seconds before removing it from the heat.

Step 2. Immediately invert the can and thrust its top (end with the opening) a short distance into the cold water. The can will collapse implosively. **Caution: Avoid splashing the boiling water.**

Discussion:

The crushed can in this activity demonstrates the force of air pressure. An absence of pressure is a deadly hazard of space flight.

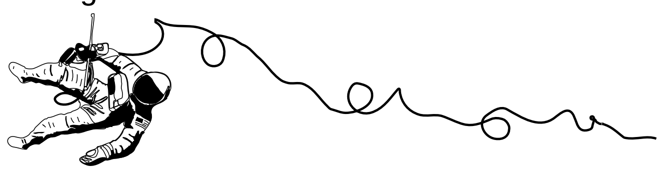
The can collapses because a partial vacuum has been created inside and its metal walls are not strong enough to sustain its original shape against the outside air pressure. The first step in creating the vacuum is to boil the water inside the can to produce steam. After approximately 30 seconds of boiling, the air in the can is replaced by the steam. When the can is inverted into the cold water, a rapid temperature drop takes place, causing the steam to return to water drops. What is left is a vacuum. Since the opening of the can is sealed with water in the dish, the can collapses before water in the dish has a chance to fill the void.

The amount of air pressure on the can may be calculated by determining the surface area of the can and multiplying this by a sea-level air pressure of 101 kilopascals:

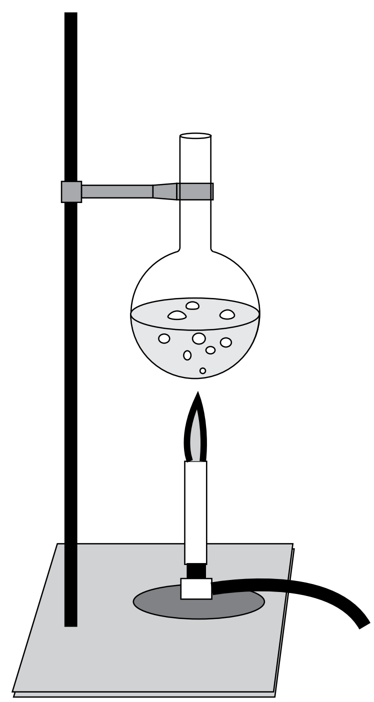
Surface area of can = area of cylinder + area of 2 ends

or

Surface area of can = $2\pi r$ x length + $2 \times \pi r^2$



Activity 4: Boiling Water With Ice



Topic: Vacuums

Description: A sealed flask of hot water is brought to a boil by immersing it in ice water.

Materials Needed:
- Pyrex glass boiling flask (round or flat bottom)
- Solid rubber stopper to fit flask
- Bunsen burner or propane torch (flame spreader optional)
- Ring stand and clamp
- Aquarium filled with ice water
- Eye protection for anyone standing near the boiling flask

Procedure:

Step 1. Fill the flask to about one-third capacity with water and attach to the ring stand.

Step 2. Heat the bottom of the flask until the water begins to boil.

Step 3. Remove the heat source. When the boiling stops, insert the stopper.

Step 4. Free the clamp from the stand and immerse the entire flask in the aquarium. Be sure the side of the aquarium is wiped free of condensation so that the flask can easily be seen. Observe what happens to the water in the flask.

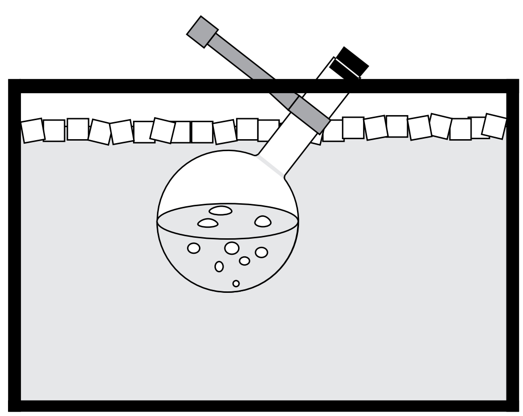
Discussion:

Water boils when its temperature reaches 100 degrees C. The act of boiling changes the state of matter from liquid into gas. In doing so, heat is carried away by the gas, so that the remaining liquid cools below the boiling point. Consequently, continuous heating is necessary until all the liquid is converted to gas.

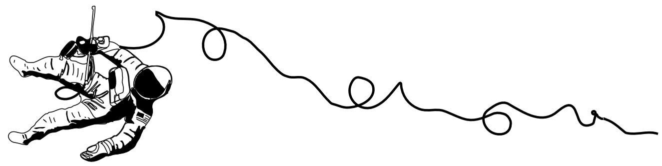
Although the boiling temperature of water appears to be fixed, it is not. It varies with air pressure. Water boils at 100 degrees C at a sea-level pressure of 101 kilopascals. However, water's boiling temperature drops as air pressure drops, and air pressure drops with elevation above sea level. (Because of depressed boiling temperatures at higher elevations, many commercial cake mixes come with instructions for increasing baking times if the cake is going to be baked in a mountain home.)

At very low atmospheric pressures, such as those encountered at elevations higher than 18 km above sea level, water boils spontaneously even at room temperature. This creates a problem for pilots of high-altitude research planes and astronauts in space. The human body is approximately 60% water. At very low atmospheric pressures, body water contained within the skin would begin to boil, and the skin would start inflating. Needless to say, this is a very unpleasant experience and one that can be fatal if it persists for too many seconds. High-altitude pilots and astronauts on extravehicular activity require pressure-suit protection for survival.

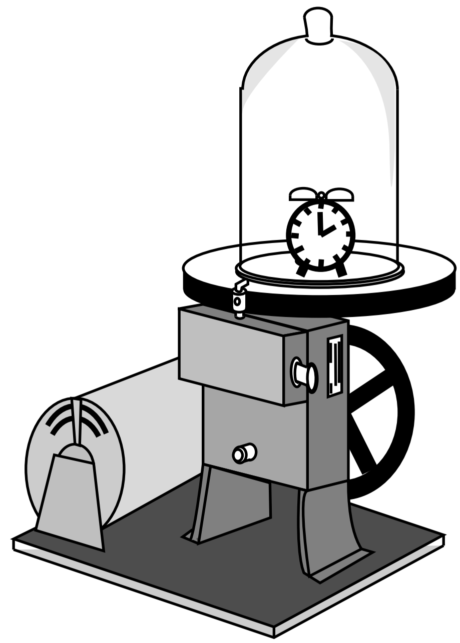
This demonstration shows the effect of lowered pressure on the boiling point of water. When the water has stopped boiling and the flask is sealed, it is thrust into chilled water. The temperature of the hot, moist air above the water in the flask is quickly lowered and it contracts, thereby lowering the pressure inside the flask. With the lowered pressure, the water, even though its temperature has actually lowered, begins boiling again. Boiling will stop shortly as the pressure in the flask increases due to newly released gas.



Note: The rubber stopper may be difficult to remove from the flask once the water inside the flask has cooled. Simply reapply heat to the flask and remove the stopper as air pressure inside increases. **Be sure to wear eye protection while doing this.**



Additional Demonstrations on Vacuums:



Additional demonstrations on the properties of the vacuum found in space can be done with a vacuum pump, vacuum plate, and bell jar. This apparatus is available through science supply catalogs, and many schools have them in their equipment inventories. If your school does not have this equipment, it may be possible to borrow it from another school.

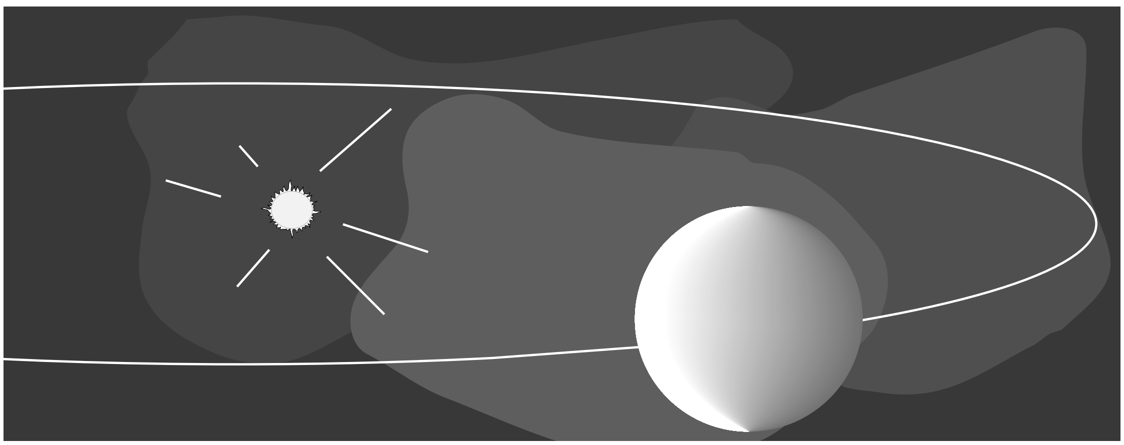
- Set the alarm on a windup alarm clock to ring in a few minutes. Place the clock on the vacuum plate, cover with the bell jar, and evacuate the air. When the alarm goes off, it will be possible to see but not hear the clock ring. There is no air inside the chamber to conduct the sound waves from the ringing of the bell. Some sound may conduct through the vacuum plate, however, through its contact with the clock feet. This demonstration illustrates why radios are built into spacesuits. Contrast this demonstration with science fiction movies in which sounds from explosions are heard through space.

- Obtain a clear balloon or a clear plastic freezer bag. Put water in the balloon or bag and seal. Place the balloon or bag on the vacuum plate, cover with the bell jar, and evacuate the chamber. Observe the boiling that takes place in the water and how the balloon or bag begins to inflate. The inflation provides an analogy to the way exposed skin will inflate in a vacuum because of the gas bubbles that form in the liquid contained in cells.

Student Project 1: **Earth Is a Spaceship**

Topic: Earth as a life-support system for travel through space

Background Information: Every 365 days, 5 hours, and 46 minutes, Earth completes an orbit around the Sun. To do so, it travels at a speed of 109,500 km per hour. At the same time this is happening, our Sun and all its planets are traveling in the direction of the star Vega at a speed of 20 km per second. As a part of the Milky Way galaxy, we are also orbiting the galactic center at a speed of about 250 km per second. Finally, the Milky Way is on its own voyage through the universe at a speed of 600 km per second. Combining all these motions together, we discover that Earth is actually a spaceship, hurtling us through space at the incredible speed of approximately 900 km per second, or nearly 30 billion km per year!



Writing Assignment: Like astronauts traveling on rockets or moving about through outer space in their spacesuits, earthling astronauts need protection from the hazards of space.

- Write an essay about spaceship Earth. What "services" does Earth provide for human life-support? How do the ways Earth provides these services compare with the way the life-support system of a spacesuit functions? Why is it important to protect our life-support systems?
- Write a short story on what might happen to our spaceship if we do not take care of it.

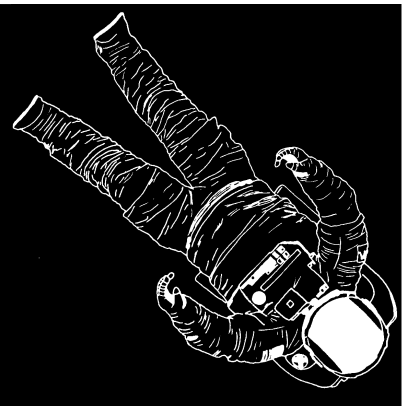
Art Project: Create a mural, collage, or mobile that illustrates the spaceship Earth concept.

Mathematics Assignment: Compare the travel of spaceship Earth with terrestrial locomotion–such as walking, running, automobiles, trains, airplanes–and with the Space Shuttle. How long would it take a person in an automobile (train, plane, etc.) to travel the distance Earth travels through space in just one hour?

Historical Research: Try to learn who first proposed the concept of Earth as a spaceship and the event that led to the development of this environmental concept.

Unit 2

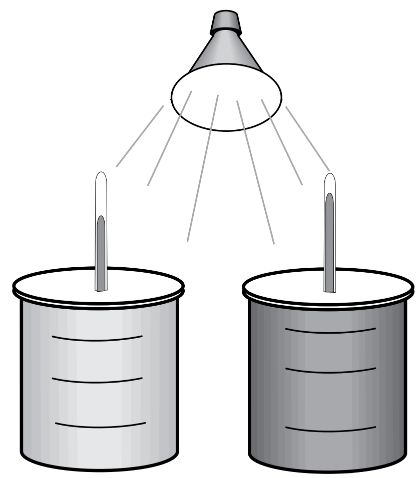
Dressing for Spacewalking



Activity 1: Choosing the Right Color

Topic: Spacesuit design

Description: The relative effects of light versus dark surfaces on heat absorption and radiation are investigated.



Materials Needed:
2 Coffee cans with plastic snap lids
2 Thermometers (dial or glass)
Spray paint (white and black)
Flood lamp and light fixture
Stopwatch or watch with a second hand
Graph paper

Procedure:

Step 1. Spray-paint the outside of one coffee can black and spray the other white.

Step 2. Snap on the plastic lids and punch a hole in the center of each lid. Insert one thermometer into each lid.

Step 3. Direct the light from a flood lamp at the sides of the two cans. Make sure it is equidistant from both cans.

Step 4. Begin recording temperatures starting with an initial reading of each thermometer, and take readings thereafter every 30 seconds for the next 10 minutes. Extend the time beyond 10 minutes if you wish.

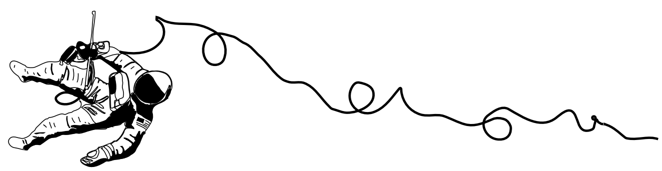
Step 5. Plot the temperature data on graph paper, using a solid line for the black can and a dashed line for the white can. Construct the graph so that the data for temperature are along the Y (vertical) axis and for time along the X (horizontal) axis.

Step 6. Compare the slope of the temperature plots for the white and black cans.

Discussion:

It is not by chance or for aesthetics that the outer layer of a spacesuit is constructed of a durable white fabric. Environments in outer space fluctuate from shade to full sunlight. In full Sun, the temperature will rise to 120 degrees C and in shade drop to minus 100 degrees C. Such extremes are constantly being encountered by astronauts out on extravehicular activities. The side of the astronaut facing the Sun cooks while the side in shade freezes.

One of the challenges in spacesuit design is to maintain a comfortable working temperature inside. A liquid cooling-unit inside the suit helps moderate body heat caused by the astronaut's physical exertion, but the heat coming into the suit from the outside and the heat escaping from the suit to the outside must be moderated as well. Several inside layers provide insulation, but that is not enough to protect the crew member. White fabric on the outside of the suit is used because it absorbs less heat than does dark fabric.

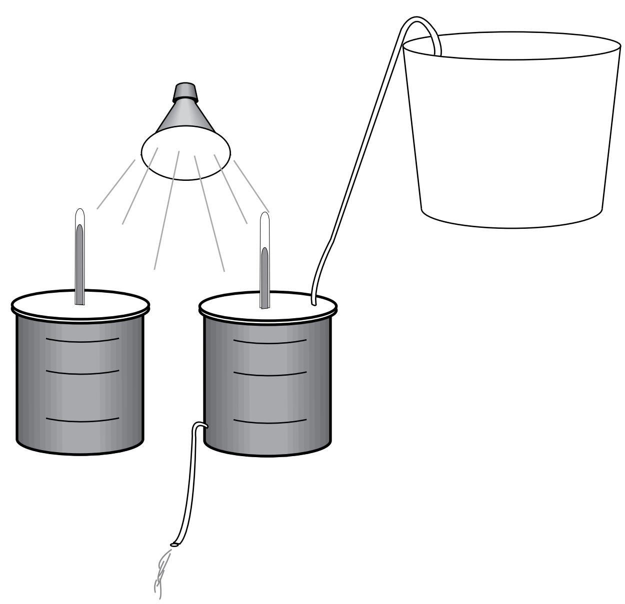


Activity 2: Keeping Cool

Topic: Spacesuit design

Description: The functioning of the liquid cooling-garment of spacesuits is demonstrated.

Materials Needed:
- 2 Coffee cans with plastic snap-on lids
- 2 Thermometers (dial or glass. Must be able to read a full range of temperatures from freezing to boiling.)
- Spray paint (black)
- Floodlight and light fixture
- Plastic aquarium tubing (6 meters)
- Masking tape
- 2 Buckets
- Ice
- Water
- Stopwatch or watch with a second hand
- Graph paper
- Metal punch or drill



Procedure:

Step 1. Spray-paint the outside of both cans black and permit them to dry.

Step 2. Punch a hole in the center of each lid and insert a thermometer. Punch a second hole in one of the lids large enough to admit the aquarium tubing. Also punch a hole in the side of one of the two cans near its base.

Step 3. Form a spiral coil with the plastic tubing along the inside wall of the can with the hole punched in its side. Do not pinch the tube. Extend the tube's ends out of the can, one through the hole in the can and the other through the hole in the lid. The upper end of the tube should reach into the elevated water bucket and the other should hang down from the side of the can toward the lower bucket.

Step 4. Set up the floodlight so that it shines on the sides of the two cans. Make sure the light is equidistant from the two cans.

Step 5. Fill one bucket with ice and water. Make sure there is enough ice to chill the water thoroughly.

Step 6. Elevate the ice water bucket on a box or some books next to the can with the tubing.

Step 7. Insert the long end of the aquarium tubing into the ice water bucket to the bottom. Using your mouth, suck air from the other end of the tube to start a siphoning action. Permit the water to drain into a second bucket on the floor.

Step 8. Immediately turn on the floodlight so that both cans are equally heated.

Step 9. Begin recording temperatures, starting with an initial reading of each thermometer just before the light is turned on and every 30 seconds thereafter until the water runs out.

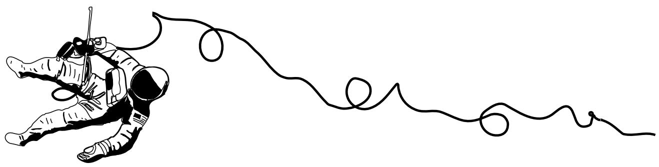
Step 10. Plot the temperature data on graph paper, using a solid line for the can that held the ice water and a dashed line for the other can. Construct the graph so that the temperature data are along the Y (vertical) axis and those for time along the X (horizontal) axis.

Step 11. Compare the slope of the plots for the two cans.

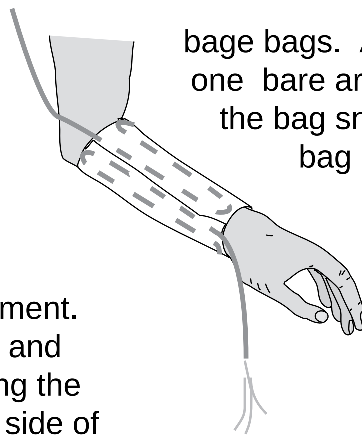
Discussion:

Astronauts out on extravehicular activity are in a constant state of exertion. Body heat released from this exertion can quickly build up inside a spacesuit, leading to heat exhaustion. Body heat is controlled by a liquid cooling-garment made from stretchable spandex fabric and laced with small-diameter plastic tubes that carry chilled water. The water is circulated around the body. Excess body heat is absorbed into the water and carried away to the suit’s backpack, where it runs along a porous metal plate that permits some of it to escape into outer space. The water instantly freezes on the outside of the plate and seals the pores. More water circulates along the back of the plate. Heat in the water is conducted through the metal to melt the ice directly into water vapor. In the process, the circulating water is chilled. The process of freezing and thawing continues constantly at a rate determined by the heat output of the astronaut.

This activity demonstrates how chilled water can keep a metal can from heating up even when exposed to the strong light of a floodlight.

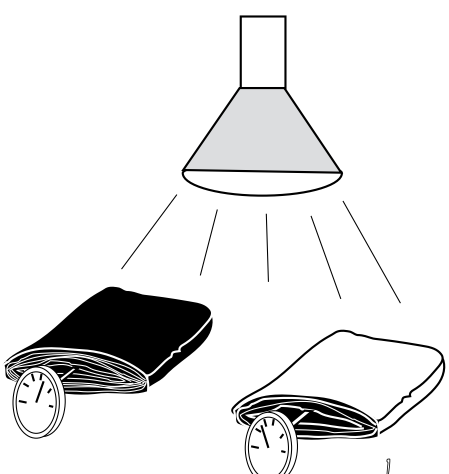


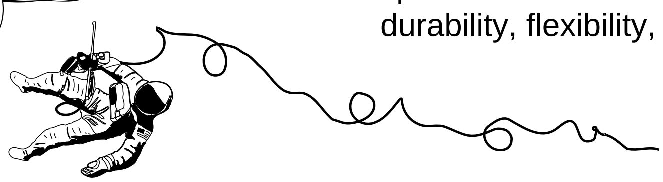
Additional Demonstrations on Cooling:



- Make a sleeve of spandex (stretchable) fabric. Lace the sleeve with plastic aquarium tubing as shown. Circulate cold water through the sleeve with a siphoning action to demonstrate the cooling effects of the Shuttle EMU's liquid cooling-and-vent-garment. Discuss how the water is recycled and rechilled. **Note:** To assist in placing the sleeve on different people, slit the side of the sleeve from one end to the other and attach Velcro strips.
- To help students understand the importance of liquid cooling in the space suit, obtain some tall kitchen plastic garbage bags. Ask each students to place one bare arm inside the bag and wrap the bag snugly around the arm. The bag represents the restraint layer of a space suit. After a minute or two, ask the students to compare how their covered arms feels to the uncovered arms (warm, sweaty, etc.). Why is there a difference? How would they feel if their entire bodies were covered like this?

- Make small bags of various materials to test their insulating properties. Slip a thermometer into each bag and measure the bags' temperature rise when exposed to a heat source such as a floodlight or sunlight. Try using fabrics, paper, aluminum foil, and plastics as well as commercial insulating materials such as rock wool and cellulose. Also experiment with multilayered materials. Compare the bulk and weight of different insulators with their effectiveness. What criteria must spacesuit designers use in evaluating spacesuit insulation? (Weight, bulk, durability, flexibility, flammability.)





Activity 3: Oxygen for Breathing

Topic: Spacesuit life-support

Description: The lung capacity of an average student is determined and related to the oxygen supply carried in the portable life-support system of a spacesuit.

Materials:
- Large glass cider jug
- Rubber or plastic hose
- Basin
- Measuring cup
- Permanent marking pen
- Water
- Hydrogen peroxide or other nontoxic disinfectant
- Exercise device such as a stationary bike (optional)
- Stop watch or clock with a second hand

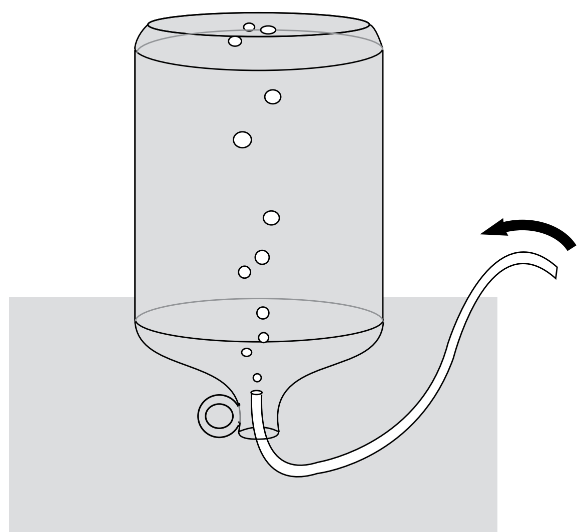
Procedure:

Step 1. Calibrate the glass jug in units of liters. Pour 1 liter of water into the jug and mark the water level on the side of the jug. Add a second liter and again mark the level. Repeat twice more.

Step 2. Completely fill the jug with water and invert it into a basin of water so that air pressure causes the water to remain in the jug. Insert one end of the tube into the jug.

Step 3. Invite several student volunteers, one at a time, to exhale through the tube into the jug. Water will be expelled from the jug. Students should breathe normally when doing this. Count how many breaths it takes to empty the water from the bottle. Also, determine the number of breaths each student takes during one minute. Record the two measurements on a chart under the headings "Breathing Volume" and "Breaths per Minute." **Caution: Be sure to disinfect the end of the tube between student participations.**

Step 4. After all volunteers have participated in the first measurements, run



the experiment again, but this time have each student engage in vigorous exercise for 1 minute before breathing into the tube. Using an exercise bike or running in place should be sufficient to promote heavy breathing. Again measure how many breaths are required to empty the jug. Also measure the number of breaths each student takes during a period of one minute.

Keep a record of these numbers under the headings of “Breathing Volume II" and "Breaths per Minute II.”

Step 5. Calculate averages for each of the four columns on the data chart. Use the first set of measurements to determine what volume of air an average student will consume per minute during normal activity. Next, calculate how much air is needed for one hour by that average student under normal activity and under heavy work.

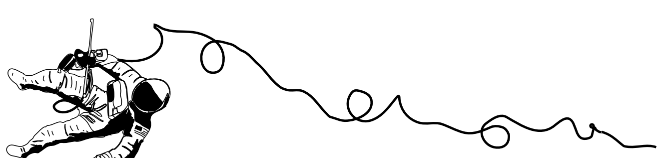
Step 6. Ask the students to calculate how much air would be needed by an average student-astronaut on a six-hour spacewalk. Typically, spacewalks involve both light and heavy exertion.

Discussion:

It is of obvious concern to spacewalking astronauts to have enough oxygen to breathe while they are conducting a mission. They need enough oxygen to complete their assigned tasks and additional oxygen in case of unforeseen problems and emergencies. How much oxygen they carry with them is determined by their oxygen use rate and the time length of their mission. Physically difficult tasks cause astronauts to use oxygen more rapidly than do physically simple tasks.

To provide enough oxygen for spacewalk missions, NASA has had to determine oxygen use rates for different levels of physical activity. Oxygen use is measured rather than air use because it was determined early in the space program that using air for spacewalks would be inefficient because air would require very large holding tanks. Air is approximately 80 percent nitrogen and 20 percent oxygen. By eliminating the nitrogen and providing pure oxygen, much smaller tanks can be used.

In this activity, students have determined the amount of air an average student breathes during rest and during heavy physical activity. They have calculated how much air would be needed for a six-hour spacewalk. If no one thinks of it, suggest they consider using pure oxygen instead of air. Have your students calculate the volume of pure oxygen that would satisfy the needs of the average student for the six-hour mission and compare this to the quantity of air that would be required for the same mission.

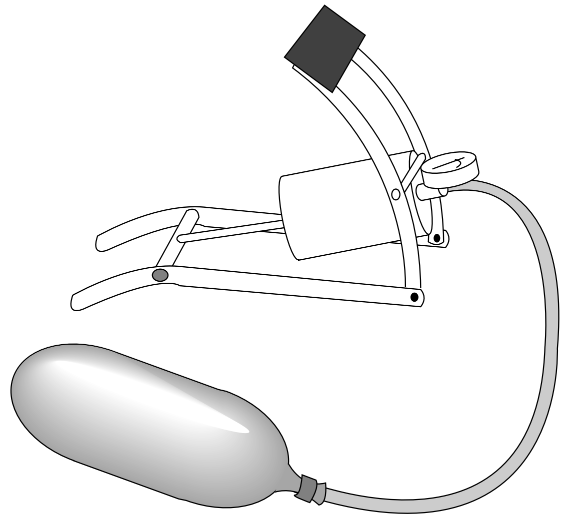


Activity 4: Keeping the Pressure Up

Topic: Spacesuit life-support

Description: How spacesuits maintain a safe pressure environment is demonstrated.

Materials Needed:
- Bicycle or automobile foot pump (with pressure gauge)
- Gear type of hose clamp (small size—available from hardware store)
- Helium quality balloon—30 to 40 cm diameter (several)
- Ripstop nylon (about 45 cm from fabric-store bolt)
- Thread
- Sewing machine
- Scissors
- Screw driver



Procedure:

Step 1. Use the pattern on the next page to make the nylon restraint layer bag.

Step 2. Slide the pump nozzle entirely into a balloon. The valve should almost touch the other side of the balloon.

Step 3. Slip the hose clamp over the balloon nozzle and tighten it over the air hose.

Step 4. While watching the pressure gauge, pump up the balloon until it breaks. Make a note of the maximum pressure attained.

Step 5. Slip a second balloon over the nozzle as before.

Step 6. Insert the balloon and nozzle into the nylon bag. The nozzle of the balloon should lie just under the nozzle of the bag.

Step 7. Use the hose clamp to seal both the balloon and the bag around the air hose.

Step 8. While watching the pressure gauge, pump up the balloon. Stop pumping when the gauge reaches 35 to 70 kilopascals (5 to 10 lbs per square inch if pump gauge is in English units). Feel the bag.

Note: The balloon can be deflated by loosening the hose clamp.

Discussion:

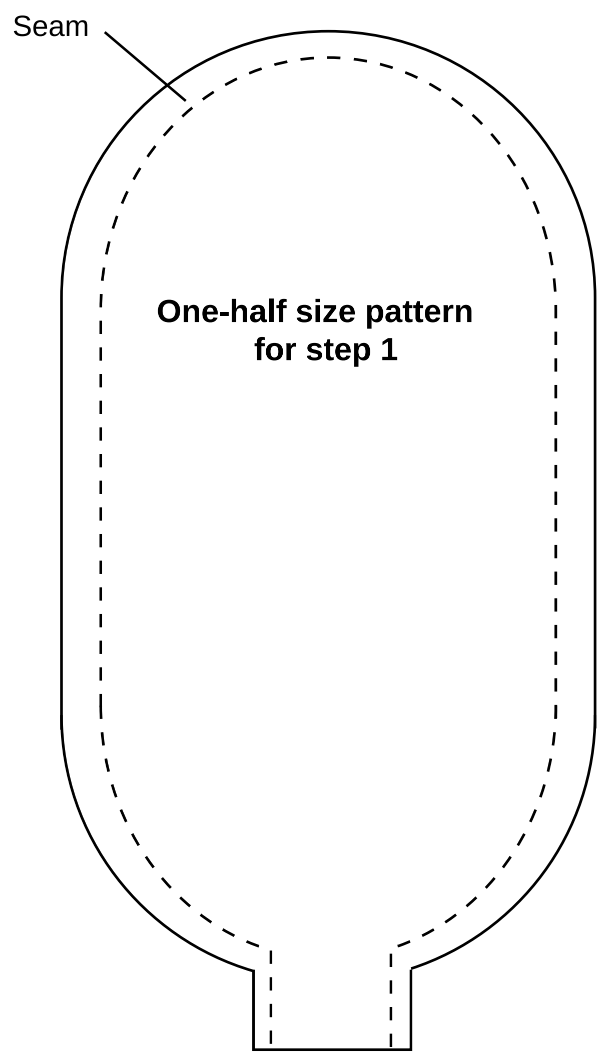
Pressure is essential to human survival in space. Spacesuits provide pressure by enclosing an astronaut inside an airtight bag. A spacesuit is made up of many layers. The pressure-containing portion of the suit is a nylon layer coated on the inside with rubber. The rubber, by itself, acts like a balloon to contain oxygen. This would be fine except that balloons expand when they are pressurized. A spacesuit with just a rubber layer would grow bigger and bigger until it popped. However, the nylon or restraint layer prevents this from happening by permitting expansion to go only so far. Any additional oxygen added to the inside increases the pressure that is exerted on the astronaut wearing the suit.

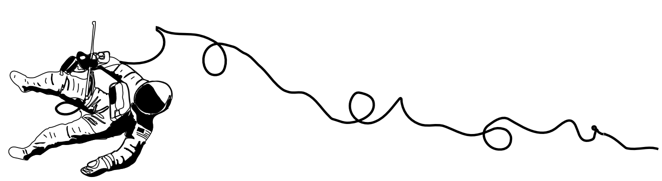
In this activity, the balloon simulated the rubber layer of a spacesuit, and the nylon bag simulated the restraint layer. When an unrestrained balloon was pumped up, it just increased in size until it popped. Even at the moment of popping, the pressure gauge barely moved. With the restraint layer over the balloon, the balloon could expand only so much, and then additional air pumped inside increased the internal pressure. Thereupon, the bag became very hard and stiff.

The safe operating pressure inside a Shuttle spacesuit is about 29.65 kilopascals. Although this pressure is about one-third that at sea level on Earth, the astronaut wearing the suit experiences no difficulty in breathing, for the gas inside is pure oxygen rather than the approximately 20 percent concentration of oxygen in normal air. Even at the lower pressure, the astronaut takes in more oxygen with each breath inside a spacesuit than on Earth while breathing a normal air mixture.

Sewing Instructions:

Cut out two layers of ripstop nylon according to the pattern and stitch up along the sides indicated. Provide a 1 cm seam allowance. Restitch the seam with a zigzag stitch for reinforcement. Turn the bag inside out. You may wish to hem the open end of the bag to prevent fraying.

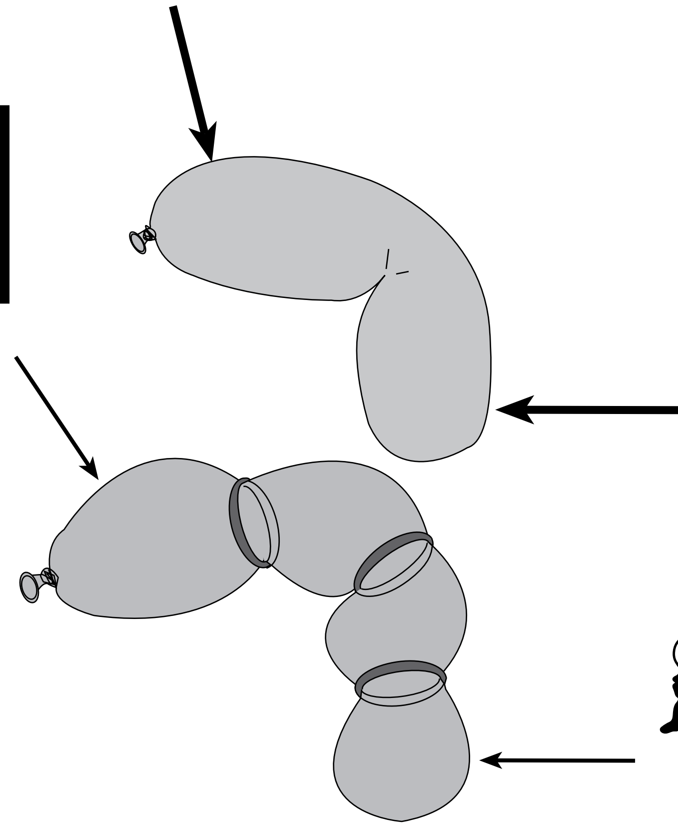




Activity 5: **Bending Under Pressure**

Topic: Spacesuit mobility

Description: Students compare the ability of inflated balloons to bend in an analogy to the arm of a spacesuit.



Materials Needed:
2 Long balloons
3 Plastic bracelets, metal craft rings, or thick rubber bands

Procedure:

Step 1. Inflate one balloon fully and tie it.

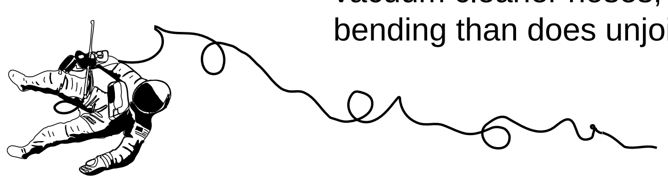
Step 2. Inflate the second balloon, but while it is inflating, slide the bracelets, craft rings, or rubber bands over the balloon so that the balloon looks like sausage links.

Step 3. Ask the students to compare the "bendability" of the two balloons.

Discussion:

Maintaining proper pressure inside a spacesuit is essential to astronaut survival. A lack of pressure is fatal. Pressure, however, produces its own problems. An inflated spacesuit can be very difficult to bend. In essence, a spacesuit is a balloon with the astronaut inside. The rubber of a balloon keeps in air. But, as pressure inside the balloon builds up, the balloon's walls become stiff and hard to bend. It would be impossible for an astronaut to function effectively in a stiff suit.

Spacesuit designers have learned that strategically placed breaking points (the rings in this demonstration) at appropriate points outside the pressure bladder (the balloon-like layer inside a spacesuit) makes the suit become more bendable. The breaking points help form joints that bend more easily than unjointed materials. The same thing happens with the balloon and rings. Further spacesuit research has determined that there are other techniques for promoting bending. Built-in joints, like ribs on vacuum cleaner hoses, also promote easier bending than does unjointed material.



Activity 6: Getting The Right Fit

Topic: Spacesuit design

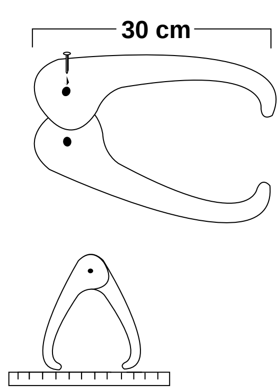
Description: Students design and build space helmets that can be used by anyone in class.

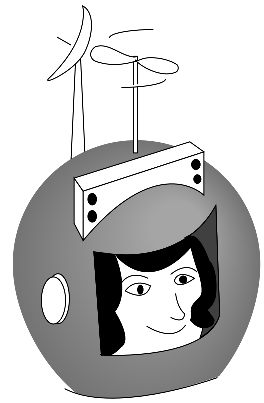
Materials Needed:

Several cloth tape measures (metric)
Metric rulers
Cardboard calipers (see diagram)
Brass paper fasteners
Pencil and paper
Calculator (optional)
Large, round balloons
Papier-mâché paste and newspaper
String
Graph paper
Field-of-view measurement device
- Plywood board 60x30 cm
- White poster board
- Thumbtacks
- Marking pen
- Protractor

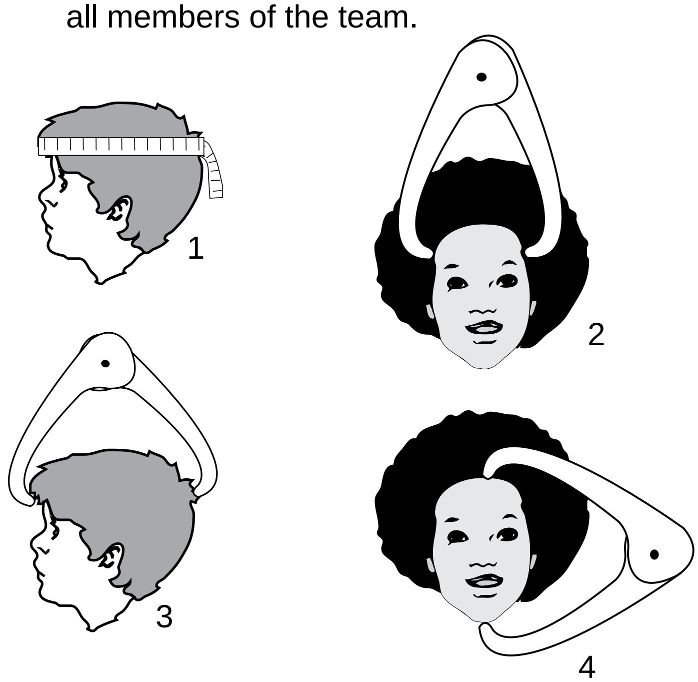
Procedure: Head Measurements

1. Divide the students into groups of three to five.
2. Working as teams, the students should take four separate measurements of each member's head in centimeters, and tally the data. The measurements will be: (1) Head Circumference, (2) Head Breadth, (3) Head Depth, (4) Chin to Top of Head. Refer to the diagram in the next column. Use calipers and cloth tape measures for the actual measuring. Be sure the students check each other's work.





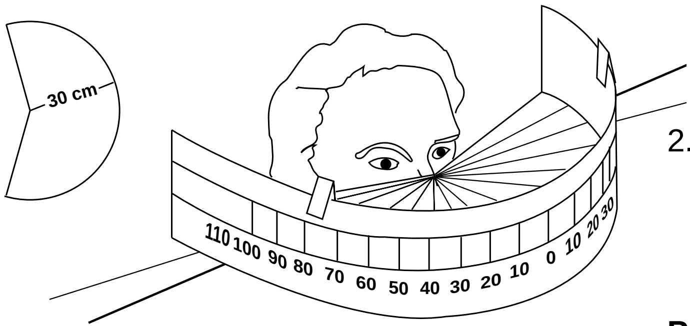
3. After the measurements are taken, the teams should practice calculating averages by averaging the measurements for all members of the team.



4. Tally the results for all the groups in the class and calculate averages for each measure.

Procedure: Field of View

1. Construct a field-of-view measurement device out of wood and poster board. Cut a partial circle (220 degrees) with a radius of at least 30 cm out of plywood. Refer to the pattern on the next page for



details. Tack or glue a strip of white poster board to the arc. Using a protractor and a marking pen, measure and mark the degrees around the arc as shown in the illustration.

2. Place the device on the edge of a table so that it extends over the edge slightly. Begin measuring the field of view by having a student touch his or her nose to the center of the arc and look straight ahead. Have a second student slide a marker, such as a small strip of folded paper, around the arc. Begin on the right side at the 110-degree mark. The student being tested should say, “Now,” when he or she sees the marker out of the corner of the eye. Record the angle of the marker on a data table for the right eye. Repeat for the left eye.
3. Take the same measurements for the other students. When all the data have been collected, calculate the average field of view for all the students.

Procedure: Designing a Space Helmet

1. Working in the same teams as before, have the students draw sketches on graph paper of their ideas for a space helmet that could be worn by anyone in class. The students should determine a scale on the graph paper that will translate into a full-size helmet. In designing the helmet, three considerations must be met. First, it must fit anyone in the class. Second, it must provide adequate visibility. Finally, it must be made as small as possible to reduce its launch weight and make it as comfortable to wear as possible.
2. Students may wish to add special features to their helmet designs such as mounting points for helmet lights and radios.

Procedure: Building a Space Helmet

1. Have each team inflate a large round balloon to serve as a form for making a space helmet. Tie the balloon with a string.
2. Using strips of newspaper and papier mâché paste, cover the balloon except for the nozzle. Put on a thin layer of newspaper and hang the balloon by the string to dry.
3. After the first layer of papier mâché is dry, add more layers until a rigid shell is formed around the balloon. Lights, antennas, and other appendages can be attached to the helmet as the layers are built up.
4. Using a pin, pop the balloon inside the paper mâché shell. According to the design prepared in the earlier activity, cut out a hole for slipping the helmet over the head and a second hole for the eyes.
5. Paint the helmet and add any designs desired.
6. When all helmets are completed, evaluate each one for comfort and utility. Have students try on the helmets and rate them on a scale that the students design. (For example: on a scale of 1 to 5, with 1 the best, how easy is it to put the helmet on?)

Discussion:

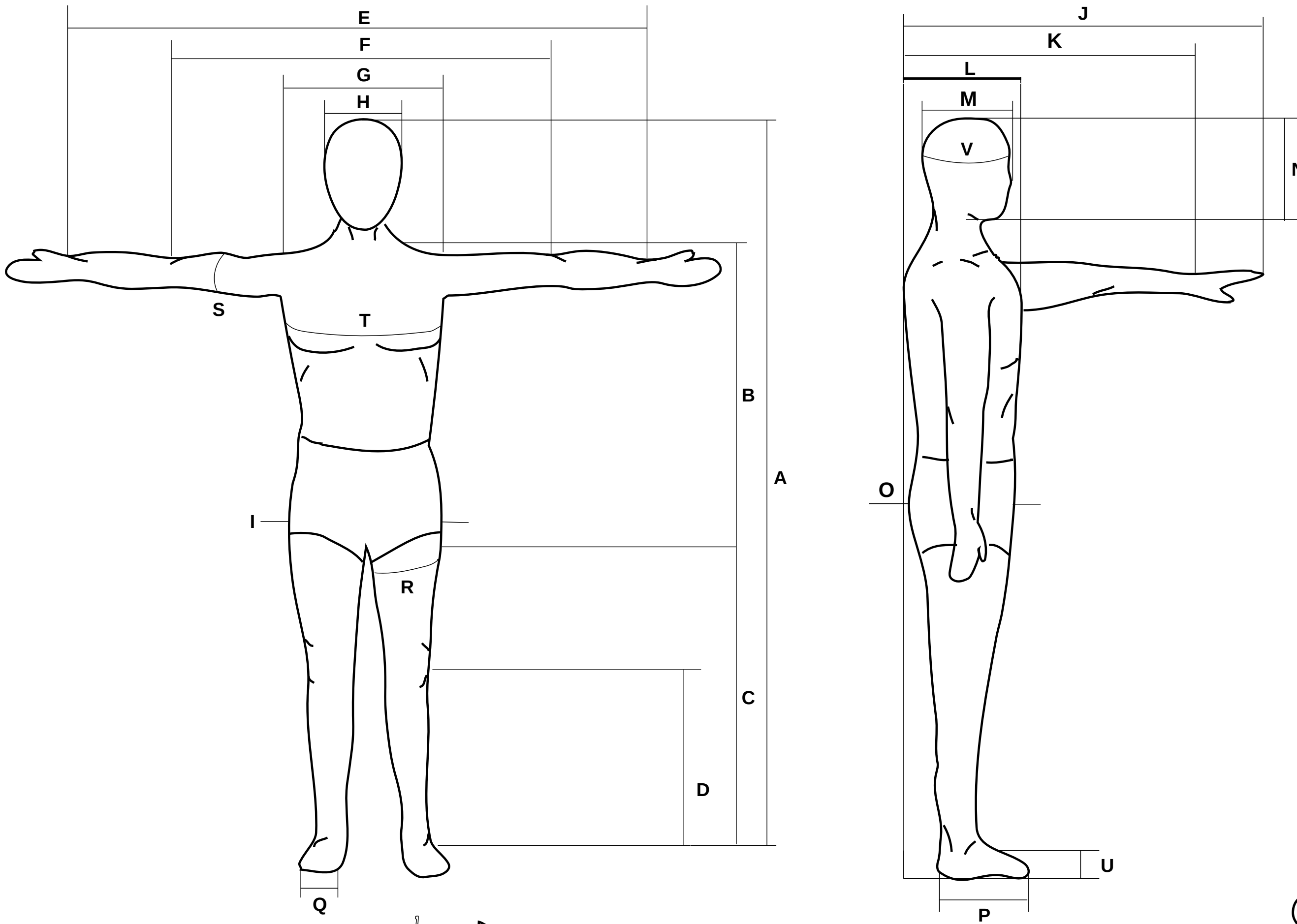
Spacesuit designers have expended great energy to make sure spacesuits fit their wearers properly. It is essential that suit joints line up with the wearer's joints. A mismatched elbow can make it very difficult for the wearer to bend an arm.

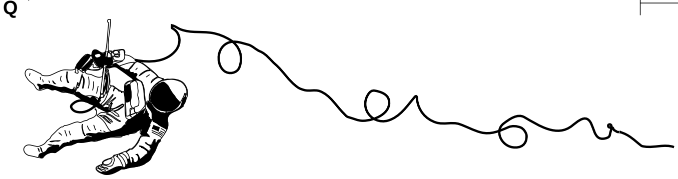
To save on spacesuit construction costs, designers have sought to develop common parts that can be worn by the greatest number of people. To do so has required careful evaluation of the human form. Many different people have been measured to determine the ranges of sizes that a spacesuit must fit comfortably. In the present activity only a few head measurements were taken, but in designing complete spacesuits many different measurements are necessary. The dimensions below are based on a spacesuit designed to fit astronauts having this range of measurements.

	Category	Minimum (cm)	Maximum (cm)
A.	Stature*	162.1	187.7
B.	Vertical trunk dimension	64.3	74.4
C.	Knee height	32.3	38.9
D.	Crotch height	74.4	91.9
E.	Wrist to wrist distance	131.6	167.1
F.	Elbow to elbow distance	85.9	106.2
G.	Chest breadth	27.9	36.6
H.	Head breadth	12.7	16.5
I.	Hip breadth	32.3	38.9
J.	Arm reach	80.5	94.2
K.	Shoulder to wrist reach	62.2	73.7
L.	Chest depth	21.3	27.7
M.	Head depth	18.3	21.6
N.	Chin to top of head	21.8	24.4
O.	Hip depth	24.1	29.2
P.	Foot length	21.1	27.4
Q.	Foot width	8.9	10.7
R.	Thigh circumference†	52.1	67.1
S.	Biceps circumference (flexed)	27.4	36.8
T.	Chest circumference	89.2	109.7
U.	Instep	NA	8.3
V.	Head circumference	55.5	60.2

* Stature increases approximately 3 percent over the first three to four days in microgravity. Because almost all the change appears in the spinal column, other dimensions, such as vertical trunk dimension, increase selectively.

† Thigh circumference will significantly decrease during the first day in orbit due to the shift of fluid to the upper torso.





Student Project 2: Spacesuit History

Topic: How spacesuits evolved into their present design

Background Information: The Extravehicular Mobility Unit worn by Space Shuttle astronauts is the result of decades of research and testing. The introductory material in this activity guide provides a brief history of its development.

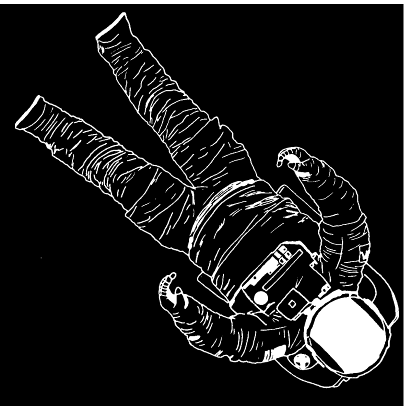
Research and Writing Assignment: Ask students to research spacesuit history and write reports on specific topics. Students might choose from the following topics:

- Project Mercury Spacesuits
- Project Gemini Spacesuits
- Project Apollo Spacesuits
- Skylab Spacesuits
- Soviet Cosmonauts' Spacesuits
- High-Altitude Aircraft Pressure Suits
- Comparison of Spacesuits with Deep Sea Divers' Suits
- Spacesuits in Science Fiction Stories and Film

Art Project: Create a mural of the evolution of spacesuit design.

Unit 3

Moving and Working In Space



Activity 1: Spinning Chair

Topic: Moving in space

Description: Students sit, one at a time, on a swivel chair and try to make the chair turn without touching the floor or other furniture with their hands or feet.

Materials Needed:
Swivel stool or desk chair with a good bearing mechanism that permits smooth motion
2 Sandbags made from canvas sacks (about 2 kg each)

Procedure:

Step 1. Ask for a volunteer student to sit on the chair or stool.

Step 2. Instruct the student to make the chair or stool turn in a circle. The student must not touch the floor or anything else except the chair's seat. Stand back and watch.

Step 3. Permit other students to try.

Step 4. Help students out by giving them sandbags to hold in their hands. If no student thinks to toss the bags, suggest that he or she do so at an angle perpendicular to their extended arms (tangential direction).

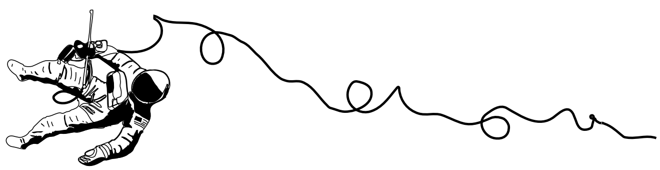
Caution: Do not use a stool or chair that tips easily. Stand nearby to keep the student from falling. The student should toss the bags gently at first.

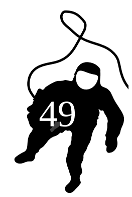
Discussion:

Although very difficult, some circular motion may be possible with the chair. Astronauts away from the inside walls of the Space Shuttle orbiter quickly learn that through awkward twisting, it is possible to change their direction. However, the moment they stop the twisting, the movement they had achieved stops as well. In spite of the movement, center of mass is exactly in the same place as it was before. They learn that to achieve movement from place to place it is necessary to have something to push against to start and something else at the other end to push against to stop.

Outside the orbiter, the problem of movement becomes even more difficult. If an astronaut bumps something and is not attached to the orbiter by a tether, the astronaut will simply drift away in the opposite direction, and no amount of twisting and turning will reverse or stop the drift.

In the demonstration, the swivel chair illustrates the manner in which astronauts can change the direction they face but cannot move away without having something to push against. The sandbags, however, do permit real movement through the action-reaction principle stated by English scientist Sir Isaac Newton. The chair continues to spin for a time after the movement stops. Astronauts take advantage of this principle when they wear the Manned Maneuvering Unit while on extravehicular activity. The unit releases compressed nitrogen gas to propel the astronaut along, just as air escaping from a balloon propels it along.

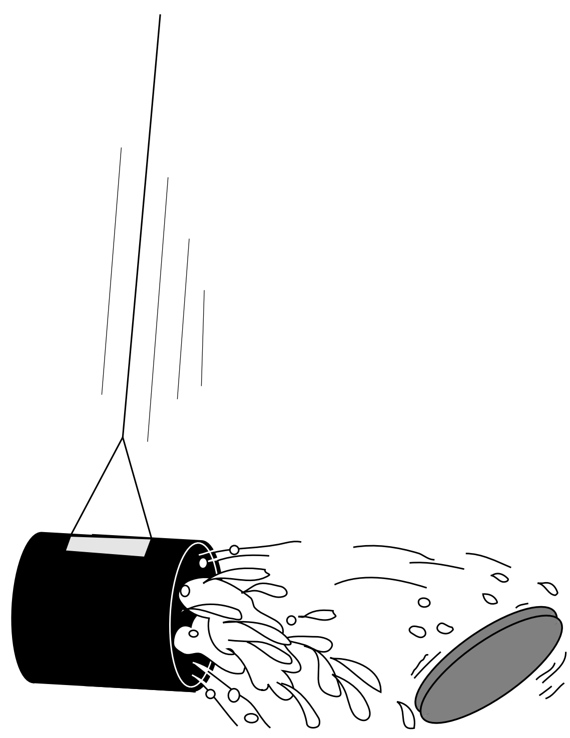




Activity 2: **Fizz, Pop!**

Topic: Moving in space

Description: Action-reaction demonstration using "antacid power."



Materials Needed:
Plastic 35-mm film canister
Masking tape
String
Water
Effervescent antacid tablet
Eye protection for demonstrator
Towel for mop up

Procedure:

Step 1. Attach a string to the side of a plastic film canister with tape as the canister from the ceiling, waist-high above the floor.

Step 2. Make a small tape loop and press it to the inside of the film canister cap. Press an effervescent antacid tablet to the tape.

Step 3. Hold the canister upright and fill it halfway with water. Snap the cap, with the tablet, onto the canister snugly.

Step 4. Tip the canister to its side and suspend it from the string. Prevent it from swinging. Stand back and watch. **Note:** Some film canisters don't work as well as others. It is advisable to have a backup in case the first one fizzles.

Caution: Although this activity does not present a significant eye hazard, eye protection is recommended for the demonstrator.

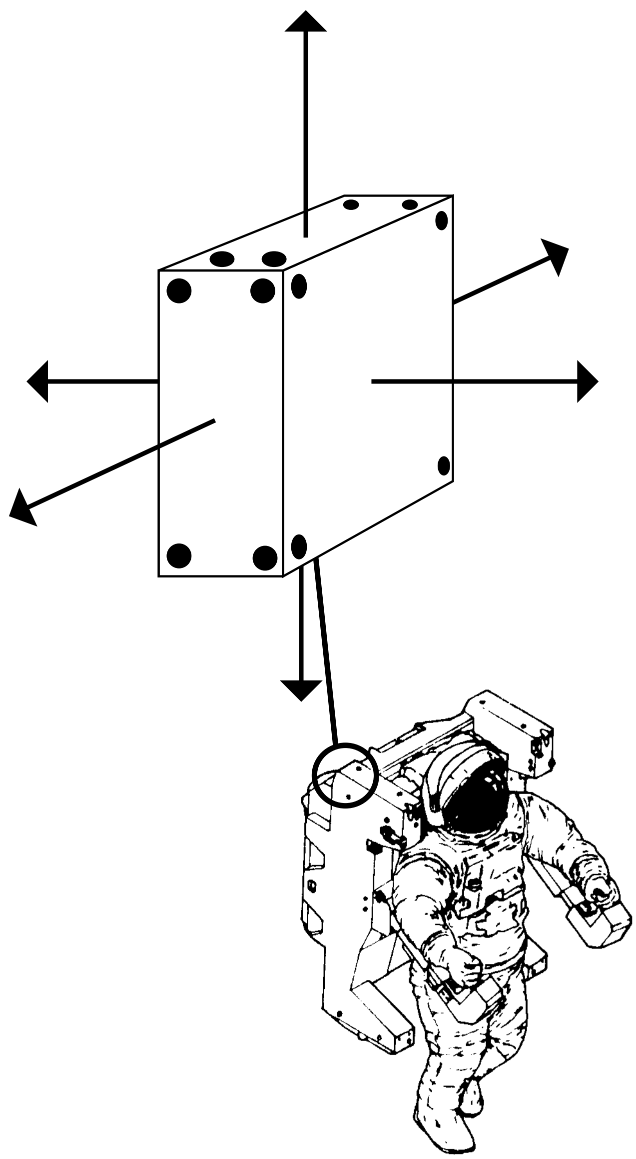
Discussion:

Immediately upon contact with water, the tablet begins effervescing. Because the cap is snapped onto the film canister, gas pressure builds up. Eventually, the cap pops off the end of the canister, releasing the water and gas inside.

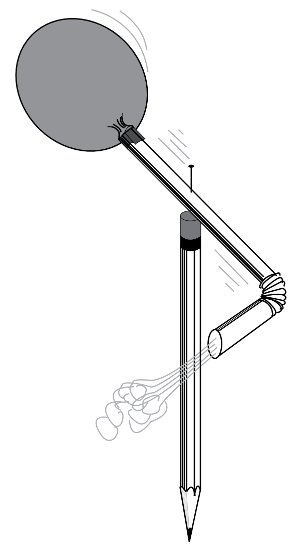
The explosive separation of the lid from the canister provides an action force that is balanced with a reaction force that causes the canister to swing the other way. This is a simple demonstration of the action-reaction principle described in Newton's Third Law of Motion.

In space, any deviation of a spacecraft's motion from its orbit requires an action-reaction force to be expended. An astronaut on a spacewalk can accomplish the same end by pushing against the spacecraft. The action-reaction force will propel the astronaut in the opposite direction.

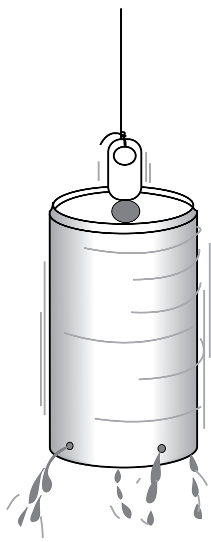
Precise movements in space by spacewalkers can be achieved with the Manned Maneuvering Unit. Although it operates by the same principle as does the popping film canister, the MMU is propelled by compressed nitrogen gas. The MMU is far more controllable than the canister because it has 24 nozzles instead of just the one opening. Shaped like a box with arms, the MMU has nozzles arranged in clusters of three at each corner. Controls on each arm permit sequential firing of pairs of nozzles for precise movements.



Additional Demonstrations on the Action-Reaction Principle:



• Tape a round balloon to the end of a flexible soda straw. Push a pin through the straw into a pencil eraser. Inflate the balloon through the straw and let the air escape.

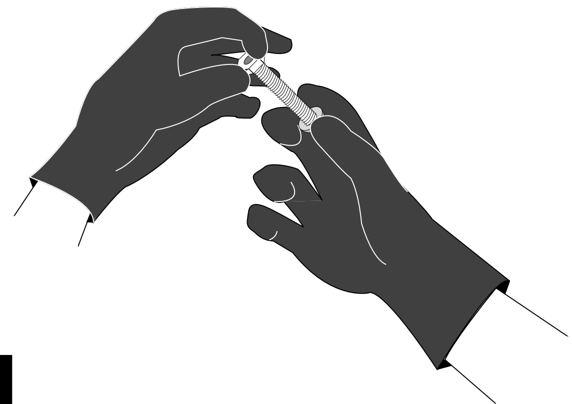


• Make a Hero engine from an aluminum beverage can. Punch angled holes around the base of the can and suspend the can with a piece of string. Fill the can with water by immersing it in a bucket of water. Raise the can out of the water by lifting it with the string. Observe what happens.

The Hero engine was invented by Hero (also called Heron) of Alexandria sometime around the first century B.C. His engine was a sphere connected to a water-filled kettle heated from below. Steam produced by boiling water escaped through two L-shaped tubes and caused the sphere to spin. Remarkably, the Hero engine was considered a novelty and, reportedly, no attempt to harness its power was made at that time.

The principle behind the engine is simple. Steam from the boiling water inside the kettle pressurizes the sphere. The steam rapidly escapes through the tubes, producing an action-reaction force that causes the sphere to spin. The action-reaction principle of the Hero engine is the same that is used to propel airplanes and rockets.

Activity 3: **Space Tools**



Topic: Space tools

Description: Students practice using tools while wearing heavy gloves that represent the gloves worn by astronauts on spacewalks.

Materials Needed:
Several sets of thick insulated ski gloves or heavy rubber work gloves
Miscellaneous tools and items such as
- Needle-nose pliers
- Socket wrenches
- Small machine screws and nuts
- Lamp cord and plug
- Tinker Toys™ or Legos™
- Perfection™ game

Paper and pencil

Procedure:

Step 1. Instruct students to put on the gloves and begin working with the tools and other items. The gloves represent the stiff, bulky gloves astronauts wear while on space-walks.

Step 2. Have your students compare the difficulty of doing a particular task such as wiring a lamp cord to a plug, assembling a structure out of construction toys, or writing a message, with and without gloves.

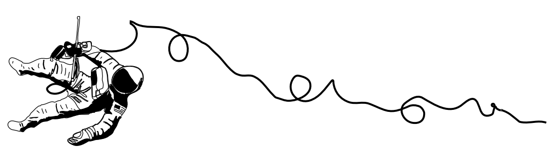
.

Step 3. Ask your students to try to design tools that could help them do their work in space if they were repairing a satellite.

Discussion:

Spacesuit gloves can be stiff and hard to work in. The gloves worn by Apollo astronauts on the Moon caused much finger fatigue and abrasion during long Moon walks. Designers for the Shuttle spacesuit have placed special emphasis on making pressurized gloves more flexible and easy to wear. This is not a simple task because, when inflated, gloves become stiff just like an inflated balloon. Designers have employed finger joints, metal bands, and lacings to make gloves easier to use.

A second effort is underway to create design tools for use with spacesuit gloves. Even with very flexible spacesuit gloves, small parts and conventional tools can be difficult to manipulate. This activity illustrates the problem of manipulating objects and encourages students to custom-design tools to help spacewalkers do their jobs.

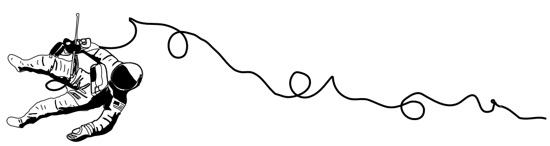


Student Projects 3: EVA Tools and Workstations

Topic: The design of EVA tools and workstations for future space stations

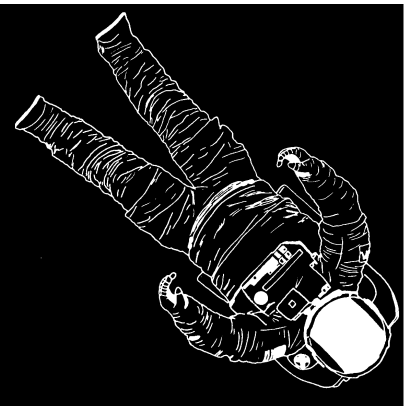
Background Information: When future space stations are constructed, astronauts may have to don their spacesuits and participate in a variety of assembly tasks to bring its parts together. After the stations become operational, EVAs will be necessary for periodic space station maintenance, unscheduled repairs, and to service payloads. Years of EVA experience have shown that even simple jobs, such as turning a screw with a screwdriver, can be very difficult in space if no anchor point is available for the astronaut to brace against. Much research has been invested in the creation of special tools and workstations to make EVA jobs easier. The screwdriver problem is solved with an electric screwdriver that pits the astronaut's inertia against the friction of the screw. Bracing an astronaut for work is solved with workstations—platforms with footholds and tool kits.

Design Project: Ask students to design tools and a workstation that can be used by astronauts assembling a space station. The workstation should have provisions for holding the astronaut in place, holding tool kits, providing adequate lighting, and being moved around the outside of the Space Station to different work sites. The tools should make possible a variety of tasks such as screwing screws, tightening bolts, cutting and splicing wires, and transferring fluids. Students should include in their designs provisions for preventing the tools from drifting off if they slip out of an astronaut's hand and for extending the reach of an astronaut. Have your students illustrate their designs and present oral or written reports on how their tools and workstation will be used. If possible, have them build prototype tools for testing in simulated EVAs.



Unit 4

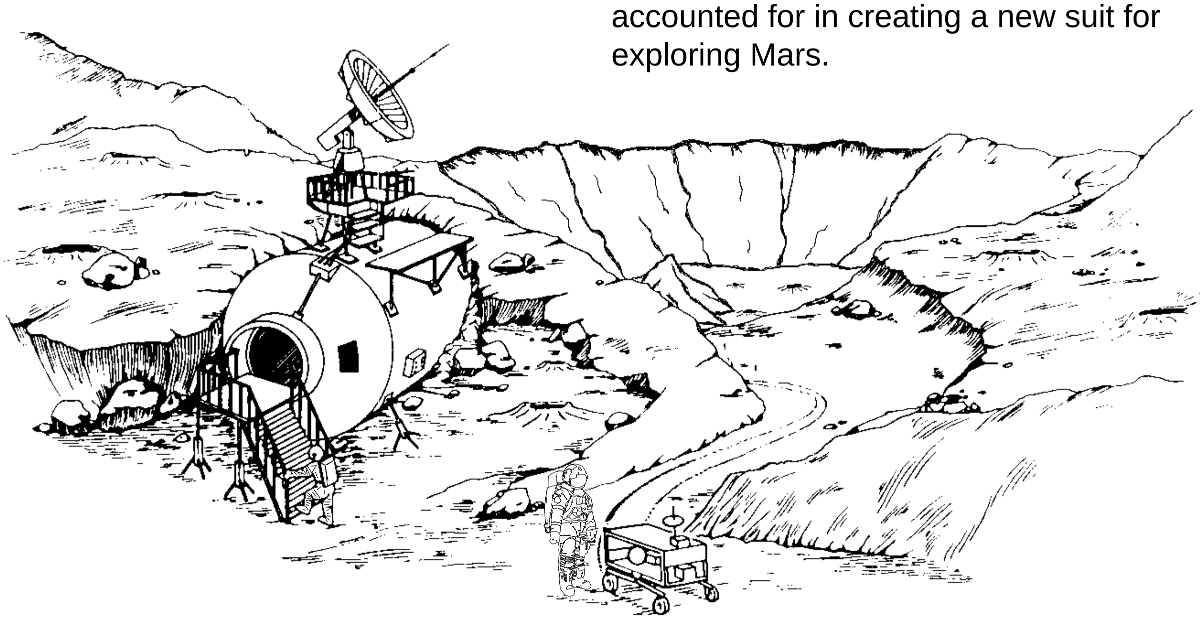
Exploring the Surface of Mars



Group Project: Exploring the Surface of Mars

Objective: This project encourages students to work cooperatively in the development of a spacesuit for the exploration of the surface of Mars and to conduct a simulated EVA on the surface of the planet.

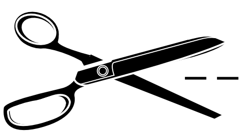
Background Information: Although NASA is not actively planning at this time for crewed space missions to Mars, it is inevitable that rockets will someday carry astronauts to the "red planet." Making this great adventure possible will require the development of many new technologies, including suits for exploring the Martian surface. The Martian environment, although less hostile than that of outer space, is such that a human could not survive there without protection. Although NASA has extensive experience with spacesuits used on the Moon and with suits used on the Space Shuttle, Mars offers new challenges in suit design. Mars has a gravitational pull equal to almost four-tenths that of Earth. This means that new, lightweight structures will be needed to minimize the load the wearer will have to bear. Other factors to be accounted for include: a thin atmosphere that will require a new kind of suit-cooling system, wind-blown Martian dust, and a temperature range that is similar to Earth's. These and many other factors must be accounted for in creating a new suit for exploring Mars.



Teacher's Instructions: Divide your students into working groups that will each work on some aspect of the design of new Martian exploration suits. Each group should select a group leader who will keep track of the activities of the group and report on accomplishments and problems encountered. Also select one or more students as mission managers to see that all groups are working smoothly and on time. Working with the mission managers, develop a schedule for the completion of each group's assigned task. When the suits have been designed and constructed, conduct a simulated mission on the surface of Mars to evaluate the design of the suits.

This activity offers students many opportunities for important lessons in problem solving. For example, one problem is that not everyone can become an astronaut. When the time comes for the actual exploration of Mars, only a tiny fraction of the people on Earth will be able to go. In this activity, only two of the students will wear the suits in the simulation. How should those students be selected? What criteria should be used? What about the people left behind? The important lesson is that everyone's job is important and that teamwork is essential or else the mission would not be possible. The success of the Martian explorers is the success of everyone involved.

Another of the opportunities offered by this activity is the involvement of parents and community members. Parents and community members may be willing to donate suit construction materials and help with the sewing and other tasks of fabrication.



Student Challenge:

You have been assigned to work on one of the teams that will design and test new exploration suits for use on the surface of the planet Mars. You will be given a specific assignment as part of one of several working groups. The goal for all working groups is to bring the components of two prototype suits together so that they can be tested on a simulated Martian mission. Because you will be developing prototype suits for testing on Earth, these suits will not have to be sealed and pressurized.

Working Group Assignments

Working Group 1: Research

What is the environment of Mars like? Go to astronomy books and encyclopedias to find out such important environmental characteristics of Mars as its surface gravity, atmospheric pressure, atmospheric composition, temperature range, and surface composition. Also determine the average size of the students in the class so that the group working on the design and construction will know how large to build the prototype suits. Determine the range and average of your classmates' measurements, including their body height and arm and leg length.
(**Teacher's Note:** Because of sensitivity to weight, measuring waists and chests is not recommended. The prototype suits should be made in a large or extra large size to fit any of the students.)

Working Group 2: Design

What will the Martian suit look like? To answer this question, network with the research working group to find out what the Martian environment is like. The research working group can also tell you how big to make the suits. Contact the life-support working group for details on how the suit will provide a suitable atmosphere, temperature control, and food and water. Furthermore, consider what kinds of tools the Martian explorers are likely to need. Create drawings of the Martian suits and patterns for their construction.

Working Group 3: Life Support

How will you keep the Martian explorers alive and safe in their exploration suits? What will you do to provide air for breathing, provide pressure, and maintain the proper temperature? How will you monitor the medical condition of the explorers? Contact the research working group for details on the environment of Mars. Make drawings of the Mars suit's life-support system and write descriptions of how it will work. Share your plans for life-support with the design working group.

Working Group 4: Construction

From what will you build the Martian exploration suits? Contact the design and life-support working groups for the suit components you must build. Obtain suit patterns from the design working group and collect the necessary construction materials. Build two Mars exploration suits. You may be able to get donations of construction materials from community businesses and the assistance of parents in fabricating the suits.

Working Group 5: Astronaut Selection and Training

Who should be selected to be the astronauts in the simulated mission? Create application forms for interested students who wish to become Martian explorers. Give an application to every interested student. Conduct interviews and select prime and backup crews for the simulated mission. Design a simulated Mars mission that will last 15 minutes. What should the explorers do on Mars? Obtain materials to create a mini-Martian environment in one corner of the classroom. Contact the research working group to learn what the surface of Mars looks like. Develop training activities so that the prime and backup crews can practice what they will do when they test the suit. Create emergency situations of the kind that might be encountered on Mars so that the crews can practice emergency measures. One emergency might be a dust storm.

The Simulation:

Prepare a small test area in one corner of the classroom or in a separate room. Decorate the test area to resemble a portion of the Martian environment. Also prepare a Mission Control center where the test conductors can observe the simulated mission and communicate with the astronauts. If video equipment is available, set up a television camera on a tripod in the test area and stretch a cable to a television monitor in Mission Control. To add additional realism, communicate with the astronauts using walkie-talkies. During the simulation, one very important communication issue will have to be set aside. Communication between Mission Control and the astronauts during the simulation will be instantaneous. During the actual mission to Mars, one-way communication time between Mars and Earth will be at least 20 minutes. If an astronaut asks a question of mission control, 20 minutes will elapse before the message will reach Earth and another 20 minutes will elapse before the answer can be returned. Consequently, the Martian explorers will have to be very well trained to meet every kind of emergency imaginable.

Additional Activities:

- Create a mission patch.
- Publish a project newsletter filled with stories about working group activities, Mars, and other space exploration information.
- Invite parents and community members to observe the simulation.
- Let every student try on the suits and take photos for keepsakes.

Curriculum Application

The chart below is designed to assist teachers in integrating the activities contained in this guide into existing curricula.

Subjects

Activities	Page Number	Art	Biology	Earth Science	English	Environmental Science	History	Mathematics	Physical Science	Social Studies	Technology Education
	Unit 1: Investigating the Space Environment										
A Coffee Cup Demonstrates Microgravity	**26**					X			X		
Meteoroids and Space Debris	**29**			X		X					X
Air Pressure Can Crusher	**30**			X		X			X		
Boiling Water with Ice	**31**			X		X			X		
Earth is a Spaceship	**34**	X	X	X	X	X	X	X	X	X	X
	Unit 2: Dressing for Spacewalking										
Choosing the Right Color	**35**			X		X		X	X		X
Keeping Cool	**36**			X		X		X	X		X
Oxygen for Breathing	**39**		X					X			X
Keeping the Pressure Up	**41**								X		X
Bending Under Pressure	**43**								X		X
Getting the Right Fit	**44**	X	X					X			X
Space Suit History	**47**	X			X		X		X		X
	Unit 3: Moving and Working In Space										
Spinning Chair	**48**								X		X
Fizz, Pop!	**49**								X		X
Space Tools	**52**								X		X
EVA Tools and Workstations	**53**	X							X		X
	Unit 4: Exploring the Surface of Mars										
Exploring the Surface of Mars	**54**	X	X	X	X	X	X	X	X	X	X