BioEd℠

# Think Like an Astronaut

By
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Baylor College of Medicine

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**TEACHER RESOURCES FROM THE CENTER FOR EDUCATIONAL OUTREACH AT BAYLOR COLLEGE OF MEDICINE**

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# Think like an Astronaut
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Always follow district and school laboratory safety procedures. It is a good idea for students to wash their hands with soap and water before and after any science activity.

Unless noted, each activity in this guide is designed for students working in groups of four (see "Using Cooperative Groups in the Classroom").

## Using Cooperative Groups in the Classroom

Cooperative learning is a systematic way for students to work together in groups of two to four. It provides organized group interaction and enables students to share ideas and to learn from one another. Students in such an environment are more likely to take responsibility for their own learning. Cooperative groups enable the teacher to conduct hands-on investigations with fewer materials.

Organization is essential for cooperative learning to occur in a hands-on science classroom. Materials must be managed, investigations conducted, results recorded, and clean-up directed and carried out. Each student must have a specific role, or chaos may result. The Teaming Up! model* provides an efficient system for cooperative learning. Four "jobs" entail specific duties. Students wear job badges that describe their duties. Tasks are rotated within each group for different activities, so that each student has a chance to experience all roles. For groups with fewer than four students, job assignments can be combined.

Once a cooperative model for learning is established in the classroom, students are able to conduct science activities in an organized and effective manner. The job titles and responsibilities are as follow.

Principal Investigator
- Reads the directions
- Asks questions of the instructor/teacher
- Checks the work

Maintenance Director
- Ensures that safety rules are followed
- Directs the cleanup
- Asks others to help

Reporter
- Records observations and results
- Shares results with group or class
- Tells the teacher when the investigation is complete

Materials Manager
- Picks up the materials
- Directs use of equipment
- Returns the materials

* Jones, R.M. 1990. Teaming Up! LaPorte, Texas: ITGROUP.



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Think Like an Astronaut

# Materials Sheet

for class of 24 students in groups of 4

**Activity 1A – Modeling Day and Night**

Per Group
- Large paper clip
- Table tennis (ping pong) ball or round foam ball (diameter of 1.5 in. or 40 mm)
- Permanent marker
- Sheet of cardstock (8.5 in. x 11 in.)
- 2-3 strips of masking or clear tape
- Copy of student sheets "Earth Model" and "Rotation Observations"
- Flashlight

**Activity 1B – Modeling the Seasons**

Per Class
- Earth globe (with axial tilt) on a portable stand
- Yellow ball, about 8 in. diameter, to serve as a sun model
- 2 small, blue glass "pony" beads (available from craft stores)
- 2 toothpicks or wooden skewers
- Twine or string, approximately 75 ft
- Glue
- Flashlight

**Activity 2A – Air Model**

Per Class
- 30 cups of popped popcorn (see Setup for alternatives)
- 3 clear resealable plastic bags, 1-gal size (12 in. x 15 in.)
- Clear plastic bag, 15-gal size (or a bag from the cleaners)
- Dry soft drink mix: 2 pkgs of yellow, 1 pkg each of green and red

Per Student Group
- Clear resealable plastic bag, 1-gal size (12 in. x 15 in.)
- Measuring cup, 8-oz size
- Copy of "Let's Measure" student sheet

**Activity 2B – Atmosphere Model**

Per Class:
- Large sheet of white or brown wrapping or banner paper, 1 m x 3 m (approx.)

Per Student Group:
- 6 sheets of construction paper, assorted colors
- Crayons or markers
- Glue stick or roll of tape
- Pair of scissors
- Job cards from "Atmosphere Model" student sheets

**Activity 3A – Gravity and Objects**

Per Student Group:
- water
- snack-size plastic zip-top bag
- food coloring
- clear container with straight sides that holds at least 1 liter of water, or a glass aquarium in a central location
- paper towels
- copy of "The Shape of Things" sheet

**Activity 3B – Supporting Structures**

Per Student Group
- sealable plastic bag or plastic wrap to use as skin or outer covering
- 10 straws
- Play dough, 1/4 cup
- scissors
- 15 paper clips
- 2 sheets of cardstock
- tape
- ruler
- copy of "From the Outside In" student sheet

**Activity 3C – Making Microgravity**

Per Class
- Large beach ball or Earth globe
- Small wastebasket or box
- Small ball (hardball or other ball of similar size and weight)
- 3 meters of cotton string
- Plastic drinking cup
- Cookie sheet or smooth plastic cutting board
- Large plastic lined wastebasket or kiddy pool
- Water
- Towels for cleanup

Per Student:
- Styrofoam coffee cup

**Activity 4A – Modeling the Solar System**

Per Class
- 8-inch diameter ball or seedless melon that size
- 12-inch diameter beach ball or 12-inch Earth globe



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- Small glass bead
- Tennis ball
- Access to computer
- Calculators (optional)
- 30 meters (100 ft) of string
- Meter sticks, tape measures, or yardsticks
- 3x5 Index cards (9 per solar system model students make)
- Marker

*Per Student Pair*

- Solar System Model Planner sheet

For supplemental activity

- Roll of register tape
- 5 round stickers, ¼" size or dime as template
- 5 round stickers, ½" or quarter as template

**Activity 4B – How Big is the Sun?**

*Per Class*

- butcher paper
- yellow, orange, red, and black tempera paint
- pencil or marker
- white construction paper cut into 2 in. x 4 in. pieces for labels
- tape
- sponges and brushes
- half-inch round Avery adhesive labels (blue)
- 4 small pins with round heads to place across the half-inch round label

**Activity 4C – The Size of Celestial Objects**

*Per Group*

- 3 pounds of play dough (see recipe)
    - 2 cups flour
    - 1 cup salt
    - ½ cup cornstarch
    - 1 tbsp alum or cream of tartar
    - 2 cups water
    - 2 tbsps oil
    - 2 packages of Kool Aid mix and/or food coloring
- Plastic knife
- Wax paper
- Instruction sheet
- Planet name worksheets

**Activity 4D – Analyzing Craters**

*Per Class*

- Play box sand
- Large tray, copy paper box lid
- Talcum powder
- Glass marbles, large ball bearings, or small rounded pebbles
- Bicycle pump
- Small balloons
- Rubber bands on masking tape
- Video camera or telephone video camera
- Safety goggles

**Activity 5A – Why Explore Space?**

*Per Class*

- Clock with second hand

*Per Student*

- Copies of the student pages
- Markers or pencils

**Activity 5B – Launching Rockets**

*Per Launcher:*

- ½" PVC pipe (about 6 feet per launcher)
- 2x ½" PVC caps
- 2x ½" PVC tee connectors
- 1x ½" connector
- duct or masking tape

*Per Student:*

- 12" long ½" PVC pipe piece
- 2 liter soft drink bottle (have spares)
- copy paper
- clear tape
- scissors
- rulers
- metric tape measure or meter stick and marker
- copies of altitude tracker pattern on cardstock
- string
- large paper clips
- straws
- eye protection

**Activity 5C – Reentry Capsule**

*Per teams of 2 or 3 students*

- Cotton string (2 yards)
- 1 9-ounce clear plastic cup
- Masking tape (about 2 feet)
- Styrofoam food tray
- 1 Raw egg
- Scissors

For all teams to share

- Paper punch (can be shared between teams)
- Plastic bag, sealable
- Packing materials – cotton or paper towel
- Kiddy Swimming Pool
- Water
- Package of small thin trashcan bags

**Activity 5D – Working in Space**

*Per Group*

- Copy machine paper box with lid and hand holes pre-cut (see instructions)
- Razor knife for cutting holes
- Pair of long kitchen plastic gloves

- 4 Plastic cups, 18-ounce
- Masking tape
- Aluminum foil
- Plastic kitchen wrap
- Clear plastic tape
- 2 large #64 rubber bands
- 1 Alka Seltzer tablet
- 16 ounce plastic bottle with lid
- Graduated cylinder or beaker
- funnel
- 250 ml cooking oil
- 125 ml water
- small bottle food coloring
- foil pie pan or another container to catch any spillover
- copy of "How Dense Is It?"
- flashlight (optional)

**Activity 5E – Interplanetary Travel**

*Per Class*

- clothesline (about 40 meters total)
- Meter stick
- Black marker pen
- Basketball or beach ball
- Small bell (optional)

**Activity 5F – Glider Design**

*Per Class*

- Tape measure

*Per Student Pair*

- 2 unused styrofoam food trays (about 15 by 8 inches)
- Scissors
- 3 3/8ths inch metal washers (measurement refers to hole size)
- 2 sheets of copy machine paper for each student
- Marker pens
- (Optional) Low-temperature glue guns and glue
- Medium grade sandpaper squares (3"x3") - 1 per team
- Mars Airplane Design page

**Activity 6A – Space Suit Safety**

*Per Class*

- Paper mache paste (see recipe)
- White paper or newsprint (if using newsprint you may want to add white tempera paint to cover the newspaper inks.)
- Spacesuit design PowerPoint
- 2-4 sets of calipers and field of vision devices (see notes about construction)
- Additional materials such as: marker pens, colored tape, pencils, cardboard, pipe cleaners, etc.

*Per Student*

- twelve-inch round balloons
- sheet of white paper (such as white butcher paper) that is slightly longer than the student is tall
- scissors
- empty 2-liter soft drink bottles (straight-sided, not bumpy)
- 2 brads (brass paper fasteners)
- Styrofoam soup bowl

**Activity 6B – Fluid Shift in Microgravity**

*Per Class*

- Digital camera with card reader or other way of downloading the images to a computer
- Computer
- (Optional) LCD projector and screen or Smart Board
- Meter or yardstick
- 4 or 5-inch-diameter balloon
- (Optional) Aquarium - 10 gallon
- Water
- (Optional) 8-foot folding banquet table (legs folded) and box or some other support to hold up one end at about a 6 to 10 degree angle
- Cloth tape measure
- Marker pen

**Activity 6C – Gravity and Muscles**

*Per Group*

- light-weight chair
- copies of "Balancing You!" sheet

*Per Student Pair*

- copy of "Balancing Act" student sheet
- meter stick
- standard weight items such as heavy coins, washers, etc.
- masking tape
- copy of "Balancing Act" student sheet

**Activity 6D – Space Flight Fitness**

*Per Class*

- sample exercise gear
- internet access

*Per Student Pair*

- miscellaneous materials determined by student teams, such as weights, elastic bands, springs, etc.
- design sheets for the teams


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**Activity 6E – Building Strength**

*Per Class*

- overhead projector and screen
- clock with second hand or timer

*Per Group*

- 2 transparent plastic knives

*Per Student*

- spring-hinge clothespin
- copy of "Stress This!" student sheet

**Activity 6F – Eating in Space**

*Per Class*

- bathroom scale
- metric ruler or metric tape measure
- 1 butane lighter – long (for teacher to use)
- Can opener
- Needle nose pliers
- Scissors

*Per Teams of 3 students*

- 2 small aluminum pot pie pans
- 2 small binder clips
- Solid copper wire (about 15 cm) or large paper clip
- Empty soft drink can
- 50 ml of water for each calorimeter test (use graduated cylinder for measuring)
- Safety goggles
- Thermometers
- Cheerios® breakfast cereal (four pieces)
- ¼ of a pecan half
- Optional: Ziploc vacuum bags, vacuum pump, and assorted snack food and mixes

**Activity 7A – Careers in Space Exploration**

*Per Class*

- Item

*Per Student Pair*

- Astronaut cards for the NASA 20th Astronaut Group
- video camera
- simulated TV studio (chairs, backdrop, props, etc.)
- internet access



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# 1) Where Are We?

## 1A) Modeling Day and Night: *Our Spinning Earth*

Students make a "mini-globe" to investigate the causes of day and night on our planet. Earth rotates completely on its axis about every 24 hours. This rotation, in combination with Earth's position relative to the sun, produces the cycles of day and night.

## 1B) Modeling the Seasons: *Our Tilted Earth*

Students plot the path of the sun's apparent movement across the sky on two days, with the second day occurring two or three months after the first.

The inclination of Earth's axis to its orbit creates the four seasons. Days are longer and sunlight more direct in summer than in winter. At any given time of year, the northern hemisphere experiences seasons opposite to those being experienced in the southern hemisphere.


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# 1A) Modeling Day and Night

*Our Spinning Earth*

### Time Needed

1 session

### You Need This Stuff

<u>*Per Student Pair*</u>

- Large paper clip
- Table tennis (ping pong) ball or round foam ball (diameter of 1.5 in. or 40 mm)
- Permanent marker
- Sheet of cardstock (8.5 in. x 11 in.)
- 2-3 strips of masking or clear tape
- Copy of student sheets "Earth Model" and "Rotation Observations"
- Flashlight

#### Speed of Rotation

Earth rotates at a speed of about 1,600 kilometers per hour at the equator. As it rotates, our planet also revolves around the sun. Both of these movements d*etermine day length*.

*Each day on Earth lasts about 24 hours, when measured according to the position of the sun* in the sky. Day lengths are different on other planets, depending on the velocity with which the planet spins on its axis. On Mars, one rotation (day) takes 24.6 Earth hours; one rotation of Jupiter is 9.9 Earth hours; and one rotation of Venus takes 243 Earth days!

#### A Matter of Degrees

Rotation (turning around a center point or axis) is measured in degrees. One complete rotation is 360°. As seen from the North Pole, the Earth rotates in a counterclockwise direction—from west to east.

### What It's About

Our lives, and those of other organisms on Earth, are shaped in countless ways by the cycle of day and night. This repeating sequence of light and darkness is caused by the spinning of our planet and its position relative to the sun.

Earth, like other planets in our solar system, revolves around the sun in a slightly elliptical orbit. It takes about 365 days—one year—for Earth to go around the sun. Other planets require more or less time to complete their orbits, and their years are correspondingly longer or shorter than Earth's. In any case, a year is defined as the amount of time it takes a planet to make one complete revolution around the sun.

As Earth orbits the sun, it also rotates, or spins, on its axis. It takes about 24 hours—one day—for Earth to complete a single rotation.

During each 24-hour period, most locations on Earth will experience several hours of sunlight (day) followed by a period of darkness (night). Solar noon is the moment at which the sun reaches its highest point in the sky in a given location. It rarely coincides with the "noon hour" on a clock. Many factors—location (longitude) on Earth, time of year, time zone, and whether daylight savings time is in effect—influence what "clock time" it will be when solar noon occurs. Midnight occurs 12 hours before and after noon.

As viewed from the North Pole, Earth spins counterclockwise. This is why the sun appears to rise in the east and set in the west. In reality, of course, the sun remains relatively stationary, while Earth rotates in its orbit. The following activity uses a simple model to help students visualize Earth's rotation about its axis, the slight tilt in Earth's axis, and the cycle that produces day and night.

### What's The Question

Where are we in the Universe? Why do we experience day and night?

### Before You Start

Before the activity, follow the instructions on the "Earth Model" to build a demonstration "mini-globe." If using table tennis balls for the activity, use a pushpin to make a small hole in the bottom of each ball before distributing to students.

Place the materials in a central location for materials managers to pick up.



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## What To Do

1. Challenge students to think about what causes night and day on Earth. Conduct a discussion and list students' ideas on the board.
2. Ask students, *Is day always followed by night? Does the sun shine at night? Why does the sun appear in the east in the morning and disappear in the west in the evening? Do the combined hours of light and darkness in a day always equal 24?* List any other questions posed by students. Tell students they will be conducting an investigation that will help answer many questions about day and night on Earth. Explain that each group will construct a model Earth and investigate what happens when light shines on the model.
3. Show students the globe model you made in advance (see Setup). The model can be as simple or as elaborate as you choose. Tell students they will create similar models for their investigations. Distribute the "Earth Model" sheets and ask materials managers to pick up their supplies.
4. Have groups follow the instructions and build their models.
5. Next, have students identify which end of the model Earth represents the North Pole. Then, have them determine the direction in which their model Earth must spin if it is to rotate counterclockwise when viewed from above the North Pole. (To review clockwise and counterclockwise, have the class stand and face the same direction, and then turn in place, first clockwise, then counterclockwise.)
6. Distribute copies of the "Rotation Observations" page and have each group work through the questions.
7. Point out how the Earth models appear slightly tilted. This tilt in Earth's axis affects day length throughout the year and causes the seasons, which are explored in Activity 1B, *Modeling the Seasons*.
8. Prompt students to reconsider the questions asked at the beginning of the activity, and to use their Earth models to obtain the answers. Ask, *Is day always followed by night?* Yes, in most locations. However, during the summer at the North and South Poles, the sun is visible all day long. *Does the sun shine at night?* Yes, the sun always is shining, even when your part of the planet is in darkness. Similarly, one part of Earth always is facing away from the sun and in darkness. *Why does the sun appear in the east in the morning and disappear in the west in the evening?* The direction of Earth's rotation creates the illusion that the sun rises in the east and sets in the west. In fact, the sun remains relatively still, while Earth rotates. *Do the combined hours of light and darkness in a day equal 24?* Yes, because the Earth rotates completely relative to the sun once every 24 hours.

## Extras

- Have students track the times of sunrise and sunset in their town for several weeks. This information is available from newspapers, weather broadcasts or the Internet. Have students compare these times to those for a city in the southern hemisphere at the same south latitude.
- Have students find the latitude, longitude and time zone of the location in which they live. Then, lead a class discussion about the importance of standardized time zones. Students can find the times of solar noon and

### Time to Travel

The moon is about 226,000 miles from Earth at its closest point. The distance from Earth to Mars is about 35 million miles. It takes astronauts about three days to reach the moon, and it is estimated that it would take at least six months to travel to Mars.

### Biological Clocks and Human Health

Research on biological clocks inside cells is helping to improve treatments for many diseases, including cancer. Physicians now are able to time the administration of chemotherapy drugs with points in the day when cancer cells are least likely to be able to reverse the medications' action.

### Ancient Beliefs

Over the course of history, different civilizations explained the cycle of night and day in different ways. For example, some ancient priests of India believed that Earth is supported by 12 huge pillars. At nighttime, the sun was believed to pass beneath our planet.

Aristotle, a Greek philosopher, was certain that the entire sky revolved around the Earth. This Earth-centered view of the universe prevailed in Europe until the 16th Century.

Copernicus, a Polish clergyman and scientist, is credited with providing the world with a more accurate theory of the solar system, in which planets (including Earth) revolve around the sun.

apparent sunrise and sunset in their location—and other places around the world—with the Sunrise/Sunset Calculator created by the National Oceanic and Atmospheric Administration (NOAA):

*www.srrb.noaa.gov/highlights/sunrise/sunrise.html*

This would be a good time to explain the difference between solar noon and chronological noon.

- Astronauts on the space station orbit Earth every 90 minutes. Have students calculate the number of day/night cycles that a crew in orbit experiences during a 24-hour period.

**Astronaut Jeffrey S. Ashby**, Mission Commander, STS-112, and crewmembers sleep in special sleeping bags while in orbit. Since the day/night cycle is only 90 minutes long, astronauts sleep poorly, averaging about two hours less sleep each day while in orbit.

(photo courtesy of NASA)



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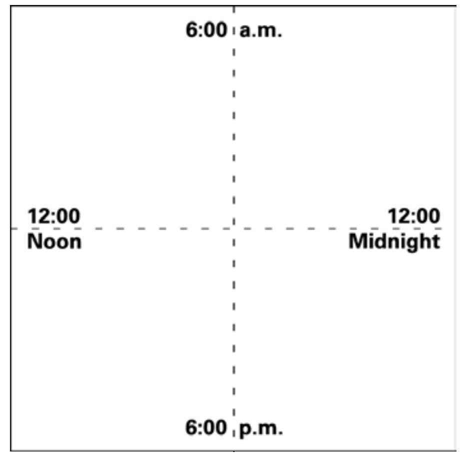
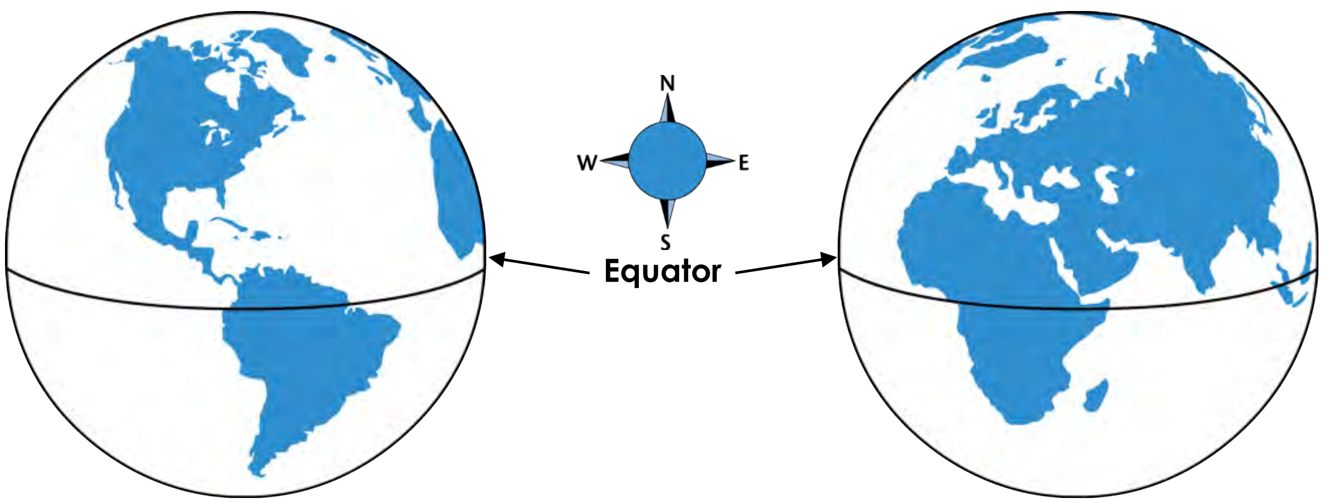
# Earth Model

Make a model of Earth by following the steps below. You will need a table tennis (ping pong) ball or foam ball, permanent marker, a sheet of heavy paper or cardstock, a large paper clip and several pieces of tape.

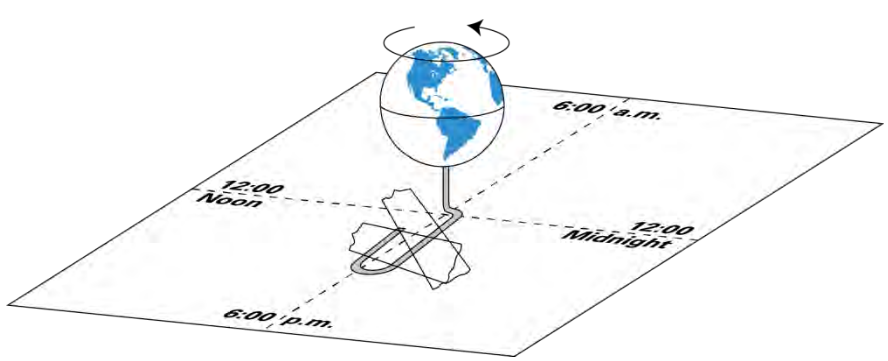



**Instructions**

1. Fold the heavy paper in half twice. This will make four equal sections. Then, smooth the sheet back out and label the folds, as shown to the right.
2. Draw a line around the widest part of the ball using a pencil or marker. This represents the equator on your Earth model.
3. Draw the continents on your "Earth," using the diagrams below as guides. Write an "N" at the North Pole and an "S" at the South Pole.




4. Straighten (unfold) one loop of the paper clip. Tape the other half onto the center point of the folds of your paper.
5. Push your Earth globe over the straightened part of the paper clip, with the North Pole facing almost upward. Your model should look like the drawing below.



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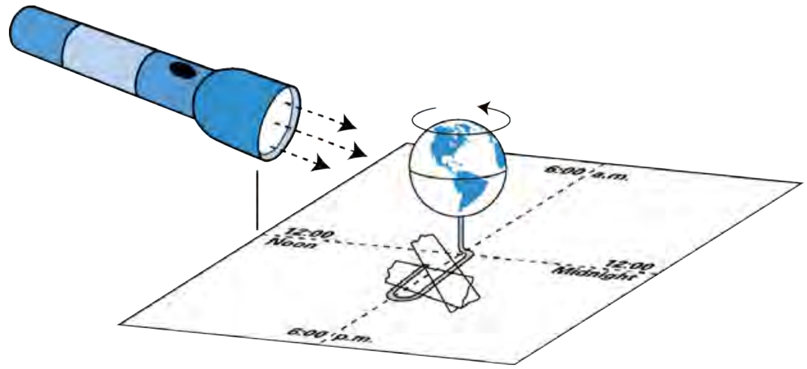
# Rotation Observations

You will use your group's Earth model and a flashlight to demonstrate how the sun shines toward Earth. Follow the directions and answer the questions below.




1. Place a small dot on the Earth model to show where you live. You will observe what happens to this dot as the Earth model rotates.

2. Hold the flashlight so that it points toward your Earth model along the marking for 12:00 noon.

3. Rotate the Earth model counterclockwise until the dot is at 6:00 a.m. This represents early morning in your location. Notice where the sun (flashlight) is at this time.

   a. Is the dot in the light or in the dark? ........................................................ ________________

   b. Does the light shine directly toward the dot, or to one side? .................... ________________

4. Rotate the Earth model 90 degrees (1/4 of a circle) in a counterclockwise direction. Notice where the sun (flashlight) is.

   a. What is the time in your location when the model is at this position? ...... ________________

   b. Is the dot in the light or in the dark? ........................................................ ________________

   c. Does the light shine directly toward the dot, or to one side? .................... ________________

5. Rotate the Earth model another 90 degrees (1/4 of a circle) in a counterclockwise direction. Notice where the sun (flashlight) is.

   a. What is the time in your location when the model is at this position? ...... ________________

   b. Is the dot in the light or in the dark? ........................................................ ________________

   c. Does the light shine directly toward the dot, or to one side? .................... ________________

6. Rotate the Earth model another 90 degrees (1/4 of a circle) in a counterclockwise direction. Notice where the sun (flashlight) is.

   a. What is the time in your location when the model is at this position? ...... ________________

   b. Is the dot in the light or in the dark? ........................................................ ________________

   c. Does the light shine directly toward the dot, or to one side? .................... ________________

7. Based on your observations, write a paragraph describing why the sun appears overhead at noon, is visible in the western part of the sky in the evening, and cannot be seen at midnight. Use the back of this sheet or a separate sheet of paper to record your answer.



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# 1B) Modeling the Seasons

*Our Tilting Earth*

### Time Needed

Part 1: 1 session
Part 2: 1 session

### You Need This Stuff

*Per Class*

- Earth globe (with axial tilt) on a portable stand
- Yellow ball, about 8 in. diameter, to serve as a sun model
- 2 small, blue glass "pony" beads (available from craft stores)
- 2 toothpicks or wooden skewers
- Twine or string, approximately 75 ft
- Glue
- Flashlight

### What It's About

Many students (and adults) mistakenly believe the seasons are due to the changing distance between Earth and the sun as our planet progresses in its orbit. According to this (incorrect) scenario, Earth experiences summer when it is closer to the sun and winter when it is farther away. Earth's distance from the sun does vary over the course of a year.

At its near point (perihelion), Earth is 147.9 million kilometers from the sun; at its far point (aphelion), it is 152.09 million kilometers away. However, the difference between the perihelion and aphelion is small—less than 3%.

In fact, the varying distance between Earth and the sun has little impact on our seasons. Perihelion (when Earth is closest to the sun) occurs in early January, when it is winter in the northern hemisphere. Aphelion (when Earth is furthest away) occurs in early July, during summer in the northern hemisphere. But remember, summer in the northern hemisphere occurs when it is winter in the southern hemisphere, and vice versa. Since Earth experiences winter and summer simultaneously, the seasons must not be determined by Earth's distance to the sun.

The seasons are caused by Earth's rotation around an axis, an imaginary line through the center of Earth that connects the North Pole to the South Pole. This axis is tilted about 23.5° from a vertical position, relative to its orbit around the sun. During summer in the northern hemisphere, Earth's North Pole leans toward the sun, while the South Pole leans away. When it is winter in the northern hemisphere, the South Pole leans toward the sun and the North Pole leans away. In between winter and summer, when Earth experiences spring and fall, neither Pole leans toward the sun.

The tilt of Earth's axis alters the hours of daylight and the apparent angle of the sun in the sky. During summer, there are more of hours of daylight and the sun is higher in the sky than during winter. Thus, summer brings more heating, longer days, and more intense light. Conversely, winter is characterized by fewer hours of daylight and a lower angle of the sun, which combine to produce cooler, shorter days.

#### Seasonal Daylight Effects

**Summer:** Longer days with more direct rays from the sun mean more heating.

**Winter:** Shorter days with less direct rays from the sun mean less heating.

**Spring/Fall:** Medium length days with medium direct rays from the sun mean medium heating.

The hours of nighttime also affect the seasons. In winter, days are shorter than nights, so there is more time for Earth's surface to radiate heat back into space. This causes a net decrease in heat in locations experiencing winter. But in summer, days are longer



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than nights, so there is a net increase in heat in Earth's surface.

In the northern hemisphere, the longest day of summer, known as the summer solstice, occurs around June 21; the shortest day, or winter solstice, occurs on or around December 21. Between summer and winter, during the seasons of spring and fall, neither of Earth's poles leans toward the sun. Days and nights are exactly 12 hours long on both the first day of spring (spring equinox) and the first day of fall (autumn equinox).

### Perihelion and Aphelion

**Perihelion:** The point at which Earth is at its nearest orbital point to the sun. Earth's perihelion is reached during the northern hemisphere winter and southern hemisphere summer.

**Aphelion:** The point at which Earth is at its farthest orbital point to the sun. Earth's aphelion is reached during the northern hemisphere summer and southern hemisphere winter.

## What's The Question

Why do we experience seasonal changes in the weather and in the day/night cycle?

## Before You Start

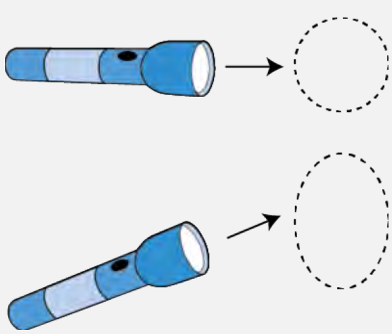
<u>Part 1:</u> Prepare two small Earth models ahead of time, each comprised of a single blue "pony" bead glued to the end of a toothpick or wooden skewer. To conduct the activity, you will need an open space about 75 feet long (e.g., a long hallway, football field, etc.).

### Modeling Distances

Wrapping the string around the sun model 33.5 times illustrates the ratio of the sun's circumference to the distance between Earth and the sun, when Earth is at the perihelion of its orbit. In other words, the distance at perihelion is approximately 33.5 times the circumference of the sun. [Perihelion distance (147.09 million km)/sun circumference (4.39 million km) = 33.5.] The ratio at aphelion (farthest from the sun) is 34.6.

### Direct and Indirect Rays

Use a flashlight to demonstrate how and why direct rays are more efficient than indirect rays in heating Earth. Darken the room and aim the light directly at a wall. Observe the brightness of the flashlight circle on the wall. Redirect the flashlight at an angle and shine the beam on the same location. The beam will spread out and the indirect beams of light will form an elliptical shape. Again, observe the brightness of the spot. It will be dimmer. In a similar way, direct rays concentrate the sun's heat, while indirect rays spread the heat.



## What To Do

<u>Part 1: Earth and Sun Models</u>

1. Take your students into an open area (long hallway, open outdoor area, etc.), and ask one student to hold the 8-inch yellow ball. This represents the sun. Then, ask a second student to hold an Earth model.

2. Tell your students the two models are to scale (the sun's diameter is 110 times that of Earth). Ask, To show proper scale, how far apart should the sun and Earth models be from each other? Encourage students to discuss their ideas.

3. Wrap the string around the sun model 33.5 times (see "Modeling Distances," sidebar). Then hold one end of the string next to the sun and have the "Earth" student take the other end of the string and walk away from the "sun" student until the string is fully extended. At that point, you have created an accurate scale model—size and distance—of Earth and the sun.

4. Give another student the second Earth model. Have him or her walk to the first "Earth" student, and then step about 60 centimeters (2 feet) further away from the sun.

5. Have students observe the positioning of the three models. Explain that the two blue beads represent Earth, the yellow ball represents the sun, and the positioning of the models represents the nearest and furthest distances between Earth and the sun. Explain perihelion and aphelion to your students. Mention that the bead closer to the sun represents Earth at the near point (perihelion) in its orbit, which occurs during the northern hemisphere winter/southern hemisphere summer. The more distant bead represents Earth at its far point (aphelion), which occurs during the northern hemisphere summer/southern hemisphere winter.



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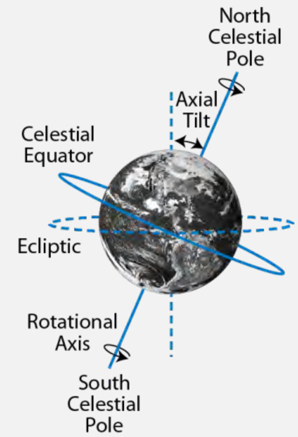
6. Ask, Does the distance between Earth and the sun cause the seasons? You may help your students visualize the question by giving the "perihelion Earth" student a small sign that reads "Northern Hemisphere Winter" and the "aphelion Earth" student a sign that reads "Northern Hemisphere Summer."

**Effects of 23.5°**




The tilt of Earth's axis alters the hours of daylight and the apparent angle of the sun in the sky.

Illustration courtesy of Dna-webmaster, Wikimedia Commons, http://commons.wikimedia.org. Earth photo courtesy of NASA

Part 2: Tilted Earth

1. Return to the classroom with your students. Place the yellow ball representing the sun on a stool in the center of the classroom. Ask for a volunteer to hold the Earth globe that shows the tilt of the axis. Point out that the distances and sizes of the sun model and Earth globe will not be to scale in this part of the activity.

**Seasonal Tilt**

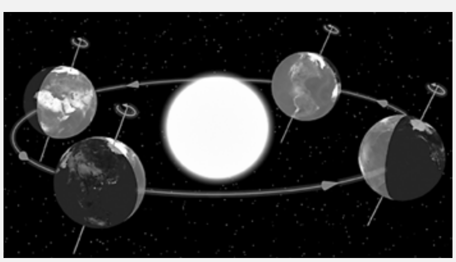
When Earth's North Pole leans toward the sun, it is summer in the northern hemisphere and winter in the southern hemisphere.

Three months later (one-quarter of the way through Earth's orbit), neither Pole leans toward the sun. It is spring in the northern hemisphere and fall in the southern hemisphere.

Three months after that, (one-quarter turn in orbit), the North Pole leans away from the sun. It is winter in the northern hemisphere and summer in the southern hemisphere.

Three months later, (one-quarter turn in orbit), neither Pole leans toward the sun. It is the autumn in the northern hemisphere and spring in the southern hemisphere.

Finally, another three months brings Earth back to its starting point. A full year has passed, and the North Pole once again leans toward the sun.



Earth's seasons as seen from the north.

Illustration courtesy of Tau'olunga, Wikipedia Commons, http://commons.wikimedia.org.

2. Have the student holding the globe walk in a circular counterclockwise pattern around the sun. This pattern represents Earth's orbit. At all times during the "orbit," the student should ensure that the globe's North Pole axis is pointing in the same direction (i.e., toward the same side of the room). Also, have the student gently spin the globe while he or she "orbits," to remind the class that Earth rotates while it circles the sun.

3. Over the course of several complete orbits, have all students observe how Earth's axis always leans in the same direction. At one point during Earth's orbit, the northern end of the axis will lean toward the sun, and the southern end will lean away. Stop the student who is carrying the globe and make sure everyone notes the position of the northern axis at this time. Then, have the "orbiting" student continue. Stop him or her again when he or she reaches the opposite side of the sun. Students now will observe that the north axis leans away from—while the southern axis leans toward—the sun. In between these two positions, the northern and southern axes lean neither toward nor away from the sun.

4. Review the seasons with your class as the student and Earth "globe" orbit the sun (see "Seasonal Tilt," sidebar, p. 7).

5. Discuss as a class how Earth's tilt affects the seasons. Give students a list of cities around the world (e.g., Minneapolis, Sydney, Beijing, Buenos Aires, and Moscow). Have students predict whether residents of each city experience winter or summer in July. Then, have students use the globe to locate each city and verify their predictions.

## Extras

- Challenge students to provide possible reasons why portions of the Arctic are known as the "Land of the Midnight Sun." Help them understand that, during summer in the northern hemisphere, the North Pole and Arctic regions face the sun. At this time of year, areas above the Arctic Circle experience continuous light throughout the day and night (including midnight). Have students hypothesize what happens when the South Pole and Antarctic regions are tilted toward the sun, and what happens in



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these regions during winter months. Ask students what it would be like to live in continuous light or dark for several months.



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# 2) Exploring the Atmosphere

## 2A) Air Model: *The Air Around Us*

Students use different colors of popcorn to model the composition of air.

## 2B) Atmosphere Model: *The Air Above Us*

By creating a scale model of the atmosphere, students learn about its composition and structure.


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# 2A) Air Model

## *The Air Around Us*

### Time Needed

Preparation: 10 minutes
1 Session

### You Need This Stuff

Per Class

- 30 cups of popped popcorn (see Setup for alternatives)
- 3 clear resealable plastic bags, 1-gal size (12 in. x 15 in.)
- Clear plastic bag, 15-gal size (or a bag from the cleaners)
- Dry soft drink mix: 2 pkgs of yellow, 1 pkg each of green and red

Per Student Group

- Clear resealable plastic bag, 1-gal size (12 in. x 15 in.)
- Measuring cup, 8-oz size
- Copy of "Let's Measure" student sheet

**Components of Dry Air**

| | |
|---|---|
| Nitrogen ($N_2$) | 78% |
| Oxygen ($O_2$) | 20% |
| Argon | < 1% |
| Carbon dioxide | < 0.04% |
| Other Gases | < 1% |

### What It's About

About 78% of the volume of dry air is nitrogen gas ($N_2$). Oxygen ($O_2$), the component of air required by our bodies, comprises about a fifth of dry air. Argon, a non-reactive gas, makes up slightly less than 1% of dry air. Carbon dioxide ($CO_2$), a gas released from our bodies when we exhale, is present in even smaller quantities (less than 0.04%). Very minute amounts of many other naturally-occurring gases (such as neon, helium, methane and ammonia), as well as gases resulting from pollution, are present in air. Water vapor, when present, can occupy up to 5% of the total volume of air. When we breathe, nitrogen, oxygen and all the other components of air enter and exit our lungs.

### Before You Start

You will need to pop and tint three small batches of popcorn before you begin this activity. First, pop the corn. To tint it, measure 6 cups of popcorn into a sealable plastic bag. Add a tablespoon of yellow soft drink mix and 1–3 teaspoons of water. Seal the bag and shake to distribute the color. Repeat the tinting process with the red, and again with the green mix—but use only 1 cup of white popcorn with each of these colors. Ultimately, you should have 6 cups of yellow popcorn in the first bag, 1 cup of red popcorn in the second bag, and 1 cup of green popcorn in the third bag. Let the popcorn dry by spreading it on a paper towel or leaving the bags open.

When dry, put each color of popcorn in separate containers. You also will need about 22 cups of white popped corn.

As an alternative, you may use purchased popcorn. Select different flavors to represent three colors. You also can use different colored styrofoam packing peanuts or small balls of crumpled paper in different colors.

If you would like to create a larger model of air, multiply the materials by two or more.

### What's The Question

What is air?

### What To Do

1. Divide the students into six small groups.

2. Have the Materials Manager from each group collect a measuring cup and a sealable plastic bag. Give three groups approximately 7 cups of white popcorn each. Give 1 bag of colored popcorn to each of the remaining three groups.



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3. Review the "Let's Measure" student sheet as you explain that each group with white popcorn will measure 5 cups of popcorn into its bag; the group with yellow popcorn will measure 4 cups; the group with red popcorn will measure 1/4 cup; and the group with green popcorn will place only one kernel in its bag.
4. When the students have finished measuring, ask one student from each group to empty the popcorn from the group's bag into the large, clear plastic bag (which you will hold in a central location).
5. Shake the large plastic bag. Ask, *What do you think I'm doing?* Lead the students to understand that the popcorn is being mixed. Ask, *Are the colors of popcorn arranged in a special way in the bag?* Students should note that the colors are mixed randomly.
6. Have the students identify which color of popcorn is represented by the most kernels in the bag, by the second-most kernels and so on, until you mention the single kernel of green popcorn. Follow by asking students to name other kinds of mixtures (e.g., fruit salad, crayons of different colors in a container, etc.).
7. Explain that air also is a mixture, made up of different kinds of gases. The different colors of popcorn in the large bag are present in the same proportions as the different gases in air. (Some students already will know that oxygen and carbon dioxide are involved in breathing. If the class is not familiar with this information, point out that the gas we take out of air when we breathe in is known as oxygen, and the gas we release when we breathe out is carbon dioxide.) Ask students to guess which color of popcorn represents oxygen molecules (yellow) and carbon dioxide molecules (green) in air.
8. Finally, point out that air is mostly nitrogen, represented by the white popcorn. The red popcorn corresponds to argon, gases present in air, but not absorbed by the body during breathing.

**Fiesta Popcorn**

8 cups of popped popcorn

1/4 cup of sugar

6 tbs of butter

3 tbs of light corn syrup

1/4 tsp of baking soda

Food coloring

In a 2-quart saucepan, combine sugar, butter and corn syrup. Cook and stir over medium heat until mixture comes to a boil. Cook without stirring for 5 minutes. Remove from heat and stir in baking soda and food coloring. (If more than one color is desired, separate mixture into containers before adding food coloring.) Pour mixture over popcorn and stir gently to coat. Bake in a 300°F oven for 15 minutes. Stir, and then bake for 10 more minutes. Place popcorn in a large bowl to cool.

## Extras

• Make your own colored and flavored popcorn using the "Fiesta Popcorn" recipe.



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# Let's Measure

| Color of Popcorn | Cups of Popcorn |
| --- | --- |
| White |  |
| White |  |
| White |  |
| Yellow |  |
| Red |   |
| Green |  |


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# 2B) Atmosphere Model

## *The Air Above Us*

### Time Needed

1 – 2 Sessions

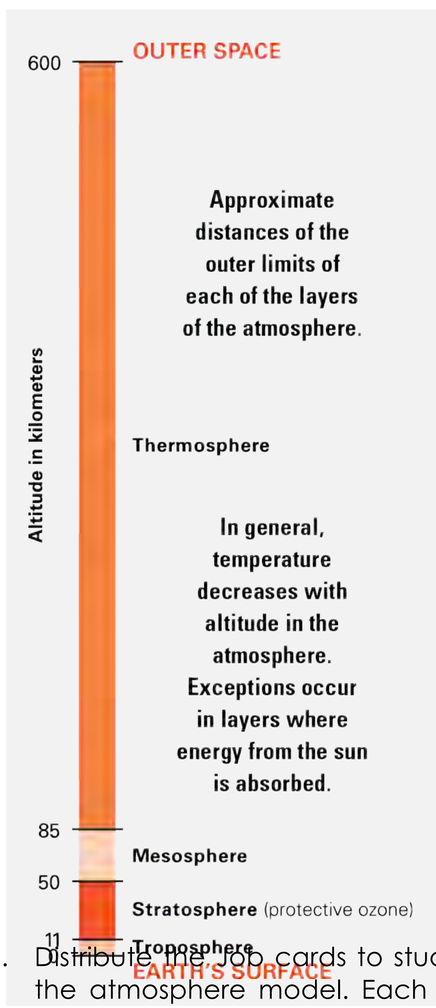
### You Need This Stuff

Per Class:

- Large sheet of white or brown wrapping or banner paper, 1 m x 3 m (approx.)

Per Student Group:

- 6 sheets of construction paper, assorted colors
- Crayons or markers
- Glue stick or roll of tape
- Pair of scissors
- Job cards from “Atmosphere Model” student sheets




### What It’s About

The air surrounding Earth is known as the atmosphere. Gas molecules in the atmosphere are held relatively close to Earth’s surface by gravity. The atmosphere is mostly nitrogen (78%) and oxygen (20%). The amount of water vapor in the atmosphere varies, but can be as much as 5% by volume. Other gases, present in much smaller amounts, also are extremely important parts of the atmosphere. Carbon dioxide ($CO_2$), methane ($CH_4$) and other gases, including water vapor, help radiate heat back toward Earth’s surface, thus keeping it much warmer than it would be otherwise. Ozone, which is present in tiny amounts in part of the atmosphere, filters out most of the harmful ultraviolet radiation from the sun.

Life on Earth would not be possible without the atmosphere, which protects the planet’s surface from extremes of temperature and harmful radiation, and also provides essential water, carbon dioxide, oxygen and nitrogen. This activity helps students learn about Earth’s atmosphere by creating a scale model.

### What’s The Question

What is the atmosphere and why is it important?

### Before You Start

Divide the class into six groups of four students. Each group will be responsible for creating a different part of the model, which should be assembled and displayed on the floor or the wall. Copy and cut out the Job cards prior to class.

### What To Do

1. Ask students if they ever have seen pictures of astronauts in space. Ask, Why do the astronauts wear special suits? Mention that the space suits keep astronauts warm, provide them with air to breathe and protect them from harmful rays from the sun. Follow by asking if we need to wear space suits on Earth. Help students recognize that the thin layer of gases surrounding Earth—the atmosphere—provides protection for all of the planet, as space suits protect the astronauts.

2. Mention that, as a class, the students will create a scale model of Earth’s protective layer of gases. Lay a sheet of brown or white paper (at least 2.5 m long) on the floor where students can work on it. Discuss the scale of the model with students (1 cm = 1/2 km; 2 cm = 1 km).

3. Distribute the Job cards to student groups. Each group will create and decorate a different part of the atmosphere model. Each student should measure and draw their own lines on the model. To



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facilitate work in groups, you may want students to cut off their sections of the model to complete in separate locations. (Groups 1 and 2 work on the same section.) Once completed, the sections can be taped together.

Group 1–Planet Earth. Draws a vertical line about 15 cm from the bottom of the sheet of paper (this line represents the Earth's surface); creates figures (mountains, forests, cities, etc.), using construction paper or other materials and adds them to the model. Remind students that the figures they create should be no more than 5 cm tall.

Group 2–First layer of the atmosphere (troposphere). Draws a line about 22 cm from the line designating Earth's surface (represents the upper limit of the first layer); adds figures of weather phenomena (clouds, rain, lightning, etc.), as well as low-flying aircraft and hot air balloons. Point out to students that much of the pollution produced by burning wood and fossil fuels remains in the troposphere. The gases responsible for keeping Earth warm (greenhouse gases) are found in this layer. Temperatures within the troposphere decrease with altitude.

Group 3–Second layer of the atmosphere (stratosphere). Draws a line about 100 cm from the line for the Earth's surface (represents the upper limit of the second layer); adds figures of storm clouds, jet aircraft, wind, and a representation of the protection provided by ozone molecules in this layer. The stratosphere is warmer due to absorption of UV light by ozone.

Group 4–Third layer of the atmosphere (mesosphere). Draws a line about 170 cm from the line for the Earth's surface (represents the upper limit of the third layer); adds figures of feathery ice clouds and weather balloons. The mesosphere is very cold.

Group 5–Fourth layer of the atmosphere (thermosphere). Adds figures of spacecraft, satellites and meteors (shooting stars) to the model. If students were to draw a line, the upper limit of the thermosphere would be 1,200 cm (12 m) from the baseline of the model. This group may use the remainder of the space on the sheet. This layer is very hot in some parts—up to 1,700°C or more—due to absorption of radiation by different atoms and molecules.

Group 6–Space outside Earth. Creates figures representing other components of the solar system and universe, and places them around the room. The exosphere contains very small amounts of hydrogen and helium, and continues until it merges with space.

4. Have each group label its layer on the model. Display the model somewhere in the classroom. Encourage students to note that most activities involving the atmosphere occur very close to Earth's surface. Leave the model available for students to refer to throughout the unit.

**Modeling**

In the atmosphere model created by students, 1 cm represents 0.5 km. Based on these proportions, the diameter of the Earth would have to be drawn as approximately 25,000 cm. The sun would be positioned 300,000,000 cm away!

**Etymology**

The word "atmosphere" comes from the Greek word *atmos* (vapor) and the Latin *sphaera* or Greek *sphaira* (ball). The names of the layers are based on *tropos* (to turn), or *stratum* (layer), *mesos* (middle) and *therme* (heat).

**Ozone**

Ozone, a highly reactive gas molecule made of three oxygen atoms, is found naturally in the stratosphere. Even though it is present only in tiny amounts, ozone is vital to the planet. It absorbs most of the harmful ultraviolet radiation emitted by the sun and prevents it from reaching Earth's surface.

Near the ground, ozone often is produced as a byproduct of burning fossil fuels. Unfortunately, in this instance, ozone is very harmful. It can damage lungs and is harmful to other living things, such as plants.



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# Atmosphere Model Job Cards

### Group 1 — Surface of Planet Earth

1. Draw a line across one end of the sheet of paper, about 15 cm from the bottom. This line represents Earth's surface.

2. Make figures that show different things found on the surface of Earth (like mountains, oceans, forests and buildings). The figures should be no taller than 5 cm. Glue or tape your figures onto the model.

### Group 2 — First Layer of the Atmosphere: The Troposphere

1. Draw a line about 22 cm above the line for Earth's surface. This line represents the top of the first layer of the atmosphere.

2. Make figures to represent weather (like clouds, rain, lightning and wind), as well as low-flying aircraft and hot air balloons. Glue or tape your figures onto the model within the troposphere.

### Group 3 — Second Layer of the Atmosphere: The Stratosphere

1. Draw a line about 100 cm above the line for Earth's surface. This line represents the top of the second layer of the atmosphere.

2. Make figures of storm clouds, jet aircraft, winds, and the protection provided by ozone. Glue or tape your figures onto the model within the stratosphere.

### Group 4 — Third Layer of the Atmosphere: The Mesophere

1. Draw a line about 170 cm above the line for Earth's surface. This line represents the top of the third layer of the atmosphere.

2. Make figures of feathery ice clouds and weather balloons. (Temperatures in this layer are very cold.) Glue or tape your figures onto the model within the mesophere.

### Group 5 — Fourth Layer of the Atmosphere: The Thermosphere

1. Use the remaining portion of the sheet to represent the thermosphere.

2. Make figures of spacecraft, satellites and meteors. (This layer is very hot.) Glue or tape your figures onto the model.

### Group 6 — Space Outside Earth's Atmosphere

1. Make figures representing other parts of the solar system and universe.

2. Place your figures anywhere around the room.


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# 3) Exploring Gravity

## 3A) Gravity and Objects: *The Shape of Things*

Students compare and contrast the behavior of a water-filled plastic bag, both outside and inside of a container of water, to begin to understand the differences between environments with gravity and environments with reduced gravity.

## 3B) Supporting Structures: *Skeletons*

Students design and build an exoskeleton or an endoskeleton for an animal of their own invention to understand how organisms' structures counteract the force of gravity.

## 3C) Making Microgravity: *Free fall*

Students explore microgravity by creating and observing free-falling water in a coffee cup.


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# 3A) Gravity and Objects

## *The Shape of Things*

**Time Needed**
1 Session

**You Need This Stuff**
*Per Student Group:*
- water
- snack-size plastic zip-top bag
- food coloring
- clear container with straight sides that holds at least 1 liter of water, or a glass aquarium in a central location
- paper towels
- copy of "The Shape of Things" sheet

Imagine you are on an elevator that begins to fall freely toward the ground. You and the elevator car would be moving toward the Earth at the same velocity, and you would be able to "float" within the elevator car. You would be weightless compared to the car, which is falling along with you. This is similar to what astronauts experience when they orbit the Earth.

The amount of gravity experienced while in orbit is about one-millionth of the normal gravity we feel at the Earth's surface. The gravity experienced in space is so weak that it is called microgravity.

### What It's About

All organisms on our planet are adapted to living with gravity, the force that pulls objects toward the center of the Earth. Gravity keeps objects from floating into space and it is the reason why "what goes up must come down." It is not exclusive to the Earth. Amazingly, all objects in the universe attract each other. The force of the attraction depends on the distance between the two objects and their masses. Gravitational forces are normally too tiny to notice, unless one of the objects has a lot of mass (such as a planet or moon).

Many students have difficulty with the concepts of mass and weight. For a quick refresher on mass and weight check out http://vimeo.com/47606857 All objects in the universe have mass, which can be understood as a measurement of how difficult it is to set an object in motion or to stop it once it is moving. The mass of an object, measured in kilograms, is constant no matter where the object is.

Weight, on the other hand, varies with the amount of gravity and can be measured in units called "newtons" (named after the famous physicist). On Earth, something with a mass of 1 kg weighs about 10 newtons. On the Moon, where gravity is less, the same object still has a mass of 1 kg but weighs less than two newtons. It is important to note, however, that in everyday language people are much more likely to say that "something weighs two kilograms." For ease of understanding, in this guide we use the words "weigh" and "weight" in their everyday sense instead of their strictest scientific interpretation.

Understanding the difference between mass and weight is important if you go into space. Deep in space, something can be virtually weightless because it is too far away from other objects to be affected by their gravity. An object in orbit around Earth (or other celestial body) also is weightless, but for a different reason. Though this object is close to the Earth, it circles the planet at a velocity that overcomes the downward pull of Earth's gravity. In other words, orbiting bodies fall freely toward the Earth, but because they have so much forward speed, their trajectories follow the curvature of the Earth's surface.

This activity allows students to observe and compare the pull of gravity on water contained within a plastic bag when the bag is standing alone and when it is submerged in water, at which time, the force of gravity is counteracted by buoyancy.

### What's The Question

How does gravity affect life on earth?


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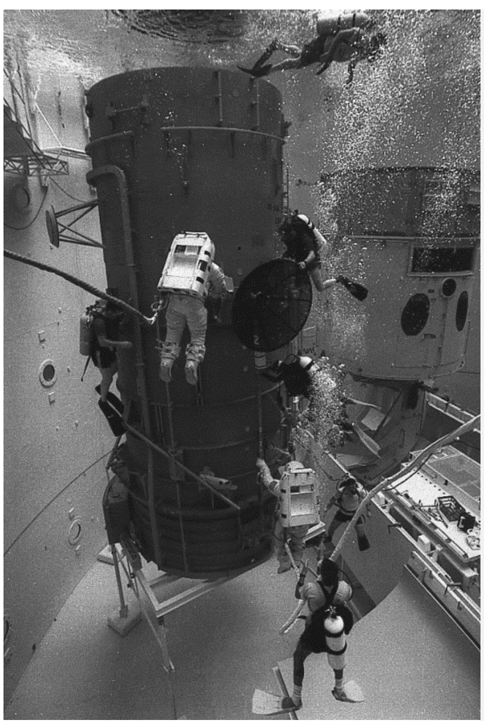
## Before You Start

Students will observe a water-filled bag. Depending on time, you may want to fill the bags for students. Fill each bag with as much water as it will hold and add a drop of food coloring. Zip the top tightly closed, while removing as much air as possible. Place the bags and other materials in a central location.

## What To Do

1. Begin a class discussion of gravity by asking questions such as, *What keeps us and other objects from floating off the Earth and into space? What happens when you throw a ball into the air? Does it fly into outer space? How could we explore the pull of the Earth on objects near its surface?* Tell students that they will be investigating gravity in action.
2. Have the Materials Manager from each group collect a container of water and a water-filled plastic snack bag, or have students fill the bags following the directions given under Set-up and Management.
3. Tell students that they will be investigating the behavior of the water bag in two different environments: resting on a flat surface and floating in water. They should record their predictions and observations with a labeled drawing.
4. Have each group predict what will happen to the shape of the bag when it is placed on a hard, flat surface. Let each group set its bag on the table and record the bag's appearance. Groups may choose any orientation for their bags (on the side or with zip top "up" works best). Students will note that the bottom of the bag is flattened. Ask, Why do you think the bottom of the bag is flat? What would happen to the water if it wasn't in the bag? What would happen to the bag if it wasn't filled with water?



To practice for space walks, astronauts work under water in a giant swimming pool at the Neutral Buoyancy Lab at NASA. The pool, which holds enough water to fill about 60 Olympic-sized pools, is so huge that astronauts can rehearse complicated repair and assembly tasks on life-sized sections of the International Space Station.

For work in the pool, astronauts wear special suits that are similar to those worn in space. Once underwater, the suits are weighted to prevent them from sinking or rising in the pool. This condition, which is called "neutral buoyancy," reduces the sensation of gravity and simulates the feeling of working in microgravity.

Working under water on Earth, however, does not completely mimic the conditions in outer space. Even though the astronauts float freely, the water offers resistance to their movements. This doesn't happen in space. In addition, even though they feel weightless, gravity is still acting on the astronauts under water. If they work upside down, for example, blood still rushes to their heads.

On average, each astronaut spends eight to ten hours practicing in the giant pool for every hour that he or she will be expected to work in space outside the shuttle or space station.

*(Photos courtesy of NASA)*

5. Next, have the students predict what might happen when the bag is placed in the water. They should consider where they think the bag will sit in the container (floating on the surface, at the bottom, etc.), and what shape they think the bag might have.

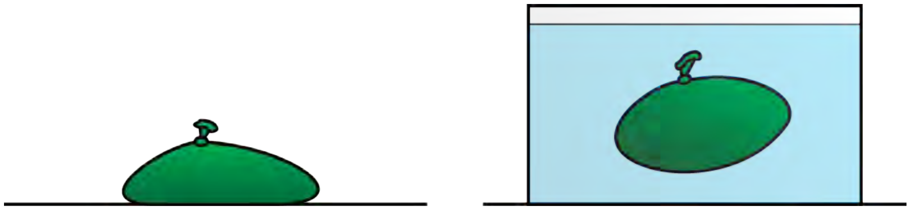
**Floaties!**

An object will float on top of a liquid if it is less dense than the liquid. An object close to the same density as the liquid will float under the surface. An object will sink if it is more dense (weighs more) than the liquid it displaces.

A boat will float even though its walls are very heavy, because the total volume of the boat is made up mostly of air. The combined density of the sides of the boat and the air inside is less than the density of the water that has been moved aside.

Something that floats is said to be buoyant ("buoy" = float).

6. After they have made their predictions, direct students to place the bags gently in the containers of water. They should orient their bags in the same position that was selected for the observations on the table.



7. After each group records its observations, ask, *What happens to the shape of the bag in the water?* Students will observe that the lower surface of the bag is not flattened in the water. Also ask, *Where does the bag rest in the water?* Unless the bags contain large air bubbles, they will float completely or almost completely submerged in an upright or sideways position. Help students understand that the bags float freely under water because buoyancy counteracts the downward pull of gravity. On the table, however, gravity is able to pull the water within the bag toward the Earth's surface without the counteraction of buoyancy (ignoring the slight buoyancy of air).

8. Conclude by leading students in a discussion of what the water in the bags might look like in a microgravity environment, such as in space. Help them understand that water bags in space probably would look similar to the bags as they floated under water OR discuss what might happen if they tried to weigh the bags under water, using a small scale. Students should be able to predict that they would be unable to weigh the floating "underwater" bag.

## Extras

- Challenge students to come up with other examples in which gravity's pull is counteracted. Examples include: flight of birds and insects, hot air balloons, kites and airplanes, jumping into the air (temporarily overcomes gravity), fish swimming upward, etc.
- Have students visit NASA's web site (www.nasa.gov) to investigate how astronauts practice tasks underwater to prepare for future work in space.
- If students have not investigated buoyancy prior to this activity, help them understand concepts related to floating and sinking by using snack bags filled with sand, water, air and any other substances. Students should weigh each bag, including the one with water, and predict which bags will float and which will sink. Any bags that weigh more than the bag of water will sink. Bags that weigh less than the bag of water will float on the surface. You can also view a quick refresher on floating and sinking at http://vimeo.com/47606858.

Human physiology changes as a person goes from the Earth to outer space. As we move away from the surface of the Earth, the gravitational pull of the Earth decreases. The human body is designed to operate in the gravitational field of the Earth. When the body no longer experiences the Earth's gravitational force, complex changes begin to occur as the body adapts to microgravity conditions.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# The Shape of Things

You will be investigating the shape and position of a water bag when it is in two different environments. You will need a sealed snack bag filled with colored water and a clear, straight-sided container filled with about 1 liter of water.

**What happens to the bag when it is placed on a hard surface?**

1. Predict what the bag will look like when it is placed on a table or desk. Write or draw your prediction in the left column of the box labeled "Hard Surface."

2. Carefully put the bag on your table or desk. How does the bag look? Write or draw your observations in the right column.

**Hard Surface**

| Prediction | Actual |
|---|---|
| | |

**What happens to the bag when it is placed on top of the water in the container?**

3. Predict what the bag will look like when it is placed on the water. Think about the shape of the bag and the place in the water where it will end up. Write or draw your prediction in the left column of the box labeled "Container of Water."

4. Carefully put the bag on the water in the container. How does the bag look? Where is the bag? Write or draw your observations in the right column.

**Container of Water**

| Prediction | Actual |
|---|---|
| | |

5. How did the water bags in the two investigations look alike? How were they different?

______________________________________________

______________________________________________

6. What forces were acting on the water bags in the two different investigations?

______________________________________________

7. What do you conclude happened in each investigation?

______________________________________________

______________________________________________



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# 3B) Supporting Structures

## *Skeletons*

### Time Needed

1 – 2 Sessions

### You Need This Stuff

<u>*Per Student Group*</u>

- sealable plastic bag or plastic wrap for skin or outer covering
- 10 straws
- Play dough
- scissors
- 15 paper clips
- 2 sheets of cardstock
- tape
- ruler
- copy of "From the Outside In" student sheet

### What It's About

Living things support and move their bodies against the pull of Earth's gravity in many different ways. Tree trunks, lobster shells, floating lily pads and snake backbones all represent different solutions to this problem.

An animal's support structure depends upon the size and shape of its body and also the environment in which it must live. Support structures can be inside (internal) or outside (external) of the body. External supports (exoskeletons) usually consist of hard plates or tubes that cover most or all of the body. Insects, spiders, clams and crabs all have exoskeletons. Exoskeletons protect internal organs, prevent water loss from the body surface and provide a protective shield from enemies/predators. However, since they encase the body, some kinds of exoskeletons must be shed and remade as an animal grows. Endoskeletons are located inside the body. Humans, mice, frogs, snakes, birds and fish all have endoskeletons. An endoskeleton grows along with the body but provides incomplete protection. Endoskeletons are living tissues that can have several functions. Some of these include storage of red bone marrow where red blood cells are made, storage of fat and minerals, and regulation of calcium distribution between bone and other tissue.

Most skeletons have one or more rigid sections connected at joints to allow movement. In endoskeletons, bones are connected across joints by tough fibrous ligaments. Muscles, which usually are attached to bones by tendons, make movement possible and also help support the body.

### What's The Question

How do organisms counteract the effects of gravity?

### Before You Start

Place the plastic wrap, straws, play dough, paper clips, tape, cardstock and scissors in a central location.

### What To Do

1. Ask students to remember what happened to the plastic bag filled with water that they examined the last activity. Ask, *Did the bag have the same shape in water as on the table?* Students should be able to report that the bag was much flatter on the table. Follow by asking, *Why don't you and I flatten out on the floor, the way the bags did on the table?* Use students' answers to guide them into a discussion of support structures for living things, particularly animals. You might ask questions such as, *Do all animals have some kind of support for their bodies? When present, what do we call these supports?* (skeletons). *Are all*



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*skeletons the same? How are skeletons different?* (some are internal and some are external; some consist of many parts, others do not; some grow with the organism, others must be shed and replaced).

2. After students have had opportunities to think about the variety of support structures for animal bodies, challenge them to invent an animal using the "From the Outside In" sheet as a guide. Depending on your students, you may want them to investigate different types of animal bodies using the internet or the library before they proceed further.
3. Each group of students will need to decide where its animal lives and how it looks (especially body shape). Once groups have discussed their ideas, they should decide which type of skeleton (external or internal) would serve their animals best. Finally, each group should draw a design or plan for its animal. Encourage students to be creative. Show students the supplies (see materials list) that will be available for creating their animals OR ask students to make a list of materials to bring from home to build their animals.
4. Once the groups' plans are completed, have the Materials Managers collect straws, plastic bag/plastic wrap, tape, scissors, play dough, paper clips and cardstock for their groups from a central area in the classroom.
5. Have each group create its imaginary animal. Designate a time frame for this work.
6. Ask groups to display their animals and to describe how they designed their skeletons.
7. Draw a chart on the board with "Similarities" at the top of one column and "Differences" at the top of a second column. Ask the students to think about and discuss the similarities and differences of the various internal and external skeletons created by the groups.
8. Extend the discussion by drawing two more charts on the board: "Internal Skeleton—Advantages and Disadvantages," and "External Skeleton—Advantages and Disadvantages." Work with one chart at a time and ask students to respond.

### Wrapping Up

- Conclude by asking students to share their ideas about how their animals might move. Ask, *What allows us to move? What would we need to add to our animals so that they could move?* Help students understand that, in most cases, muscles and joints are necessary, in addition to endo- or exoskeletons, to achieve movement of a body.

### Extras

- Human Bone Facts:

  Human bones are about half water and half solid material.

  The smallest bones in your body are in your ear. They are the malleus (or hammer), incus (or anvil), and stapes (or stirrup).

  Half of your bones are in your hands and feet.

  Humans and giraffes each have seven neck bones.
- Some plants and animals (like water lilies and jellyfish) are adapted to float in water and survive without a rigid support system. Earthworms use water pressure instead of a hardened skeleton to provide support and strength to their bodies.
- Internal Skeletons
    - Advantages:
        - Grow with organism.
        - Can be stronger and thicker than external plates or tubes.

    - Store or manufacture other materials inside bones.
    - Can support a large-sized body.
    - Store minerals, like calcium.
  - Disadvantages
    - Provide only limited protection of internal organs.
    - Do not prevent water loss from body.
- External Skeletons
  - Advantages
    - Serve as protection for soft body (except during molting).
    - Prevent water loss from body.
  - Disadvantages
    - Can make an animal temporarily vulnerable if old skeleton must be shed to accommodate growth.
    - Limit animal size because the skeleton has to be very strong and heavy to support a large body. (The largest animals with exoskeletons, such as lobsters, are found where water helps support their weight.)

# From the Outside In

You will be creating a skeleton for an imaginary animal, using the following materials or materials from home.

| | | | |
|---|---|---|---|
| 15 paper clips | 10 straws | 2 pieces cardstock | tape |
| Play dough | plastic bag or wrap | scissors | |

1. Imagine that the plastic bag is the body of your animal. Think about the shape that your animal might have. Draw the shape in the box labeled "Shape" below.
2. Make a skeleton for your animal, using any of the materials listed above. First, you must decide whether the skeleton will be inside (endoskeleton) or outside (exoskeleton) the animal's body. Next, think about how you will support the animal's shape by designing a skeleton. Make a plan for the skeleton in the box labeled "Skeleton" below or use the back of this sheet.

| Shape | Skeleton |
|---|---|
| | |

3. Now build the skeleton in or around your plastic-bag animal.
4. How does the skeleton change the animal?

_______________________________________________

_______________________________________________

5. What advantages does this skeleton give your animal?

_______________________________________________

_______________________________________________

_______________________________________________

6. What disadvantages does this skeleton give your animal?

_______________________________________________

_______________________________________________

_______________________________________________

7. How would you make your animal move?

_______________________________________________

_______________________________________________

_______________________________________________



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# 3C) Making Microgravity

*Free fall*

### Time Needed
1 Session

### You Need This Stuff
<u>*Per Class*</u>
- Large beach ball or Earth globe
- Small wastebasket or box
- Small ball (hardball or other ball of similar size and weight)
- 3 meters of cotton string
- Plastic drinking cup
- Cookie sheet or smooth plastic cutting board
- Large plastic lined wastebasket or kiddy pool
- Water
- Towels for cleanup

<u>*Per Student:*</u>
- Styrofoam coffee cup

Isaac Newton's concept for orbiting Earth.

### What It's About

Because gravity is such a predictable and ever present part of life, watching astronauts and objects float and tumble seemingly weightless is fascinating and exciting. Large drops of water don't fall to the ground, but instead shimmer as they seem to hover in midair. A handful of M&Ms scatter in three dimensions when released. These strange effects are due to microgravity.

Microgravity is created by letting things fall freely. Imagine riding in an elevator and the cables snap. The elevator plunges toward the bottom of the shaft (we are ignoring air friction and brakes in this imaginary ride). Inside the car, it feels like gravity has disappeared. It hasn't, as you shortly will be reminded. Inside the elevator car, objects, including you, appear to float about as everything falls together.

What if that falling experience could be extended? What kinds of science experiments could be conducted if gravity could be hidden for days, weeks, months, or years? The way to do that is with orbiting spacecraft.

To understand how microgravity is created by orbiting it is necessary to understand what keeps a spacecraft in orbit. Ask just about anybody what keeps satellites in orbit and you will probably hear, "There is no gravity in space." This is simply not true. Gravity is what keeps the International Space Station from drifting off into space. It does this by bending an orbiting object's path into a elliptical (flattened circle) shape. To explain how this works, we can use the example presented by English scientist Sir Isaac Newton. In *Philosophiae Naturalis Principia Mathematica* (Mathematical Principles of Natural Philosophy. Published in 1673), Newton explained how a satellite could orbit Earth.

Newton envisioned a very tall mountain on Earth whose peak extended above Earth's atmosphere. This was to eliminate friction with Earth's atmosphere. Newton then imagined a cannon at the top of that mountain firing cannonballs parallel to the ground. As each cannonball was fired, the cannonballs were acted upon by two forces. One force, due to the explosion of the black powder, propelled the cannonballs straight outward. If no other force were to act on the cannonballs, they would traveled in a straight line and at a constant velocity. But Newton knew that a second force would also act on the cannonballs: Earth's gravity would cause the path of the cannonballs to bend into an arc ending at Earth's surface.



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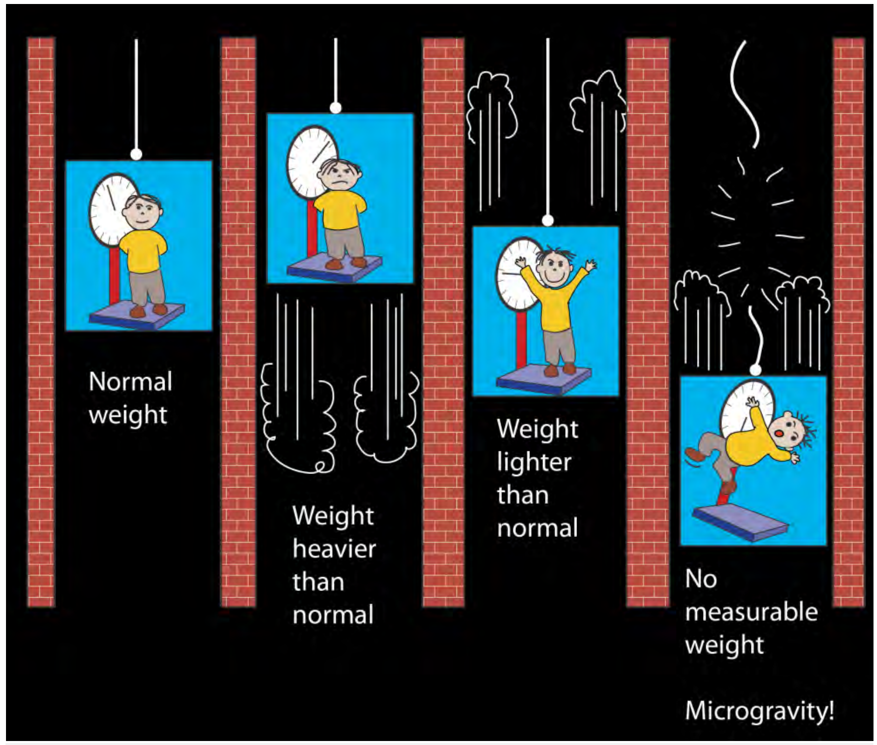
Newton demonstrated how additional cannonballs would travel farther from the mountain if the cannon were loaded with more black powder each time it was fired. With each shot, the path would lengthen and soon the cannonballs would disappear over the horizon. Eventually, if a cannonball were fired with enough energy it would fall entirely around Earth and come back to its starting point. This would be one complete orbit of Earth. Provided no force other than gravity interfered with the cannonball's motion, it would continue circling Earth in that orbit. In essence, this is how the International Space Station stays in orbit. The ISS was launched on a path arcing above Earth at a speed (about 27,650 kph or 17,180 mph) that enables it to orbit Earth continuously. Because the ISS is freefalling (like in the short elevator car fall), a microgravity environment is created.




The elevator on the left is stopped. The middle two cars are in motion. The car on the right is falling down the elevator shaft after the cables broke. The perception of weight changes in each case due to motion of lack of motion.

### What's The Question

How can microgravity be demonstrated?

### Before You Start

Practice each activity prior to demonstrating them to your students.

### What To Do

1. Ask your students to explain how satellites orbit Earth? *Why do astronauts appear to float inside their orbiting spacecraft?* Most students will probably say that there isn't any gravity in space. Follow up the question, with another. *What keeps the Moon in orbit?* Most students will probably say that its gravity. Give students a moment to digest the contradiction (Gravity shuts off for astronauts and satellites but "turns on" again for the Moon?)
2. Show your students the Satellite Orbit Demonstration that follows. Have students experiment with launching the ball satellite around the globe. Discuss their observations. Ask them, *What happens to the satellite as it slows down?* (It falls to Earth.) *What caused the fall?* Explain that gravity keeps satellites in orbit. Without gravity, satellites would shoot off into space. The trick (as students will discover with the demonstration) is to make the satellite travel at the right speed and direction so that its falling path carries it around the Earth. The main point is that satellites need gravity. Gravity bends their falling path into an orbit.

<u>**Demonstration - Satellite Orbit Demonstration**</u>

This demonstration of a satellite orbiting around Earth is effective for teaching some fundamentals of orbital dynamics. A large beach ball, placed in a waste basket or box as a stand or an Earth globe is set on the floor. This represents Earth. A small ball, representing a satellite, is suspended from the



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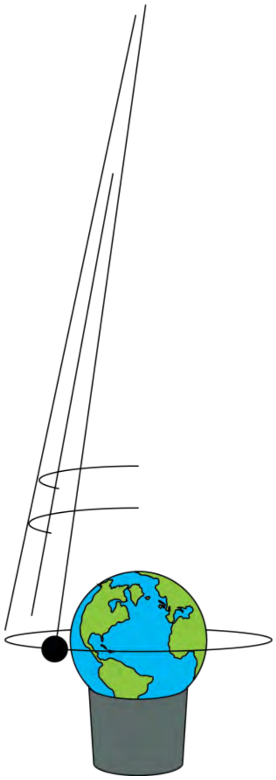
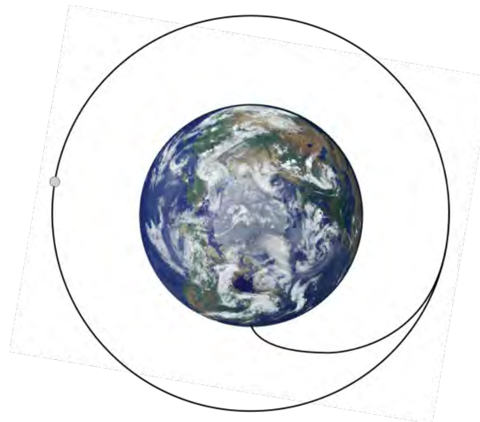
ceiling by a string directly over Earth. Students will attempt to launch a satellite into orbit around Earth. In a short time, they will discover that launching the ball straight out will cause it to fall back to Earth's surface. Instead, the ball has to be launched in a curving path as shown in the diagram. The speed of the ball determines how it will move. If the ball moves too slowly, it will arc "down" to Earth's surface. Too fast and it will move away from Earth. To make the ball orbit Earth, it has to move in the correct speed.



NASA launches orbital spacecraft on a spiraling path. At first, the rocket launches vertically but it then arcs over, traveling almost parallel to Earth's surface. It's speed increases and the rocket moves further from Earth. When the correct altitude and speed are achieved, the satellite is released from the rocket to continue in orbit. The rocket body reenters Earth's atmosphere and disintegrates due to heat generated by atmospheric friction.

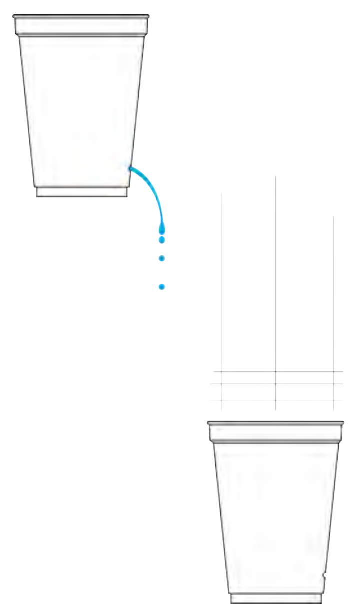


Unlike Isaac Newton's concept for orbiting Earth in which the cannon is already at orbit altitude, today's satellites have to be launched from Earth's surface, carried to the right altitude, with the right speed, and aimed in the right direction.

The speed is determined by the desired altitude for the satellite. Satellites in low orbits must travel faster than satellites in higher orbits because gravity is stronger in lower orbits. In the model, the small ball and string become a pendulum. If suspended properly, the at-rest position for the pendulum is at the center of the large ball. When the small ball is pulled out and released, it swings back to the large ball. Although the real direction of gravity's pull is down, the ball seems to move only in a horizontal direction. Actually, it is moving downward as well.

Note: In order to demonstrate a high orbit (the ball farther away from Earth), the string needs to be lengthened. When doing so, the speed needed to maintain the ball is noticeably lower than the speed for the low orbit.

3. Distribute styrofoam coffee cups to each of your students. Using the point of a ballpoint pen, pairs of students should poke a small hole through the side of the cup near its bottom. If your school has a balcony, stage, or elevated location, place the large waste basket or kiddy pool on the floor so that dropped cups will land in it. Have one student stand in the elevated place and hold the cup with a thumb covering the small hole. Add water to the cup to the half way point. The student should extend his or her arm over the catch basin. With partner students watching, slip the thumb off the hole so that water can stream out. After a few moments, the student should drop the cup. Be sure the partner students are watching to see what happens to the water. Does it continue to stream out of the hole? Switch partner students and do the drop again.



4. Hold a debriefing discussion of what students observed. Ask them to explain their observations. (When the cup was dropped, falling created microgravity and the water stopped steaming through the hole. When the cup was still, water pressure, due to gravity, caused the streaming. During the drop, the pressure was greatly reduced because both the cup and the water fell at the same rate.)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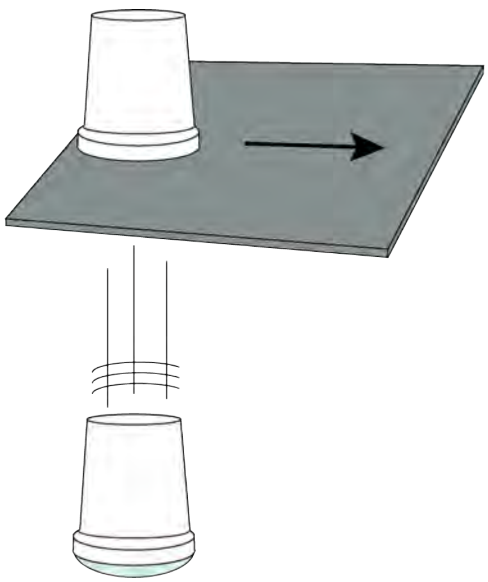
## Optional Demonstration #1 – Falling Water Cup

This optional demonstration can be used in conjunction with the falling water cup activity. It is similar to the old trick of pulling a silk table cloth out from a place setting. Instead of a silk table cloth and fine china, silver flatware, and wine glasses, a plastic cup will be filled with water and inverted on to a cookie sheet or a plastic cutting board. The cookie sheet or cutting board will be yanked out from under the cup and the cup permitted to fall into a catch basin.

Begin by filling up the cup with water to its brim. Place the cookie sheet or cutting board over the cup. Press the two together as you invert them. The water will remain in the cup because of outside air pressure.



Tell your students that you will be yanking the sheet or board out from under the cup. Inertia of the cup and water will cause it to remain in place momentarily. What will happen? Will the water fall out of the cup?

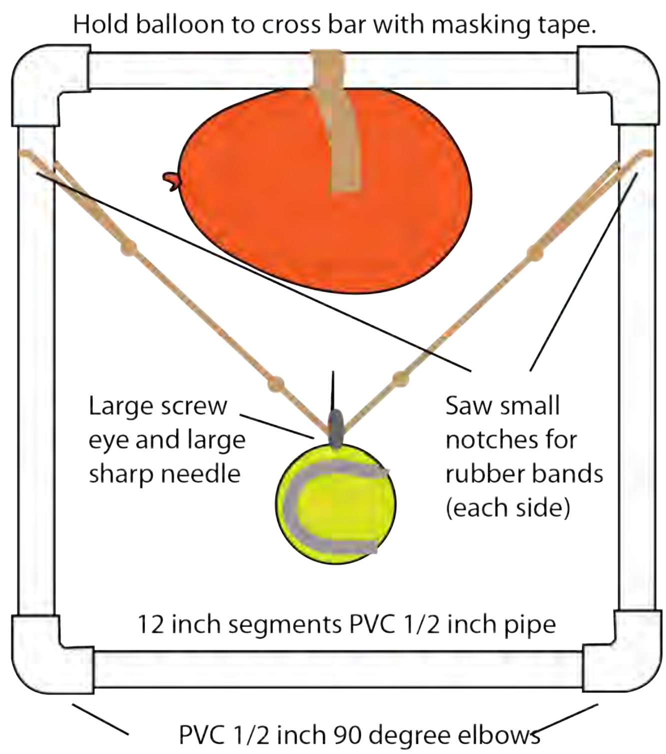
When all ideas have been offered, extend the cup and sheet or cutting board over the catch basin. Do a brief countdown and yank the cookie sheet or cutting board away.

Ask students to describe and explain what they observed. (This demonstration is very similar to the falling coffee cups. Microgravity is created during the fall and the cup and water fall together.) Students may notice that the water in the cup bulges outward. This is due to the surface tension of the water trying to gather the water into a large spherical shape. Repeat the demonstration and have all students watch for the surface tension effect.

## Optional Demonstration #2 – PVC Microgravity Demonstrator

1. Prior to starting the activity, construct the microgravity drop demonstration. Cut four 12 inch pieces of 1/2 inch PVC pipe. Notch two of the pipes as shown in the diagram with the saw. Screw a large screw eye into the tennis ball and shove the blunt end of a needle into the ball along side the screw eye. Use a hard surface to press the needle into the ball. Loop together 5 rubber bands and thread the chain through the screw eye. Slip the ends into the notches. Assemble the frame as shown. Friction will hold the pieces together. Using masking tape, hold the inflated balloon securely beneath the top cross bar and directly in line with the needle's point.

2. Test the demonstration a couple of times to make sure all parts are assembled properly. Hold the frame by the top cross bar at arm's length over some sort of cushion on the floor. Drop the frame straight down. The balloon should pop right after release. If not, make sure that the needle and the balloon are exactly aligned and try again.




Suspend tennis ball with 5 or 6 #19 rubber bands looped together. Slip the ends of the rubber bands into the notches to hold them.

3. Exhibit the microgravity demonstrator to your students. (See instructions for how to make it.) Point out its parts. Hold the demonstrator and ask students to predict what will happen if you drop the frame. List their ideas.

   Potential student answers:

   - The frame will fall to the floor.
   - The balloon will pop when it hits the floor.
   - The balloon will not pop.
   - The balloon will pop half way down to the floor.
   - Etc.

   Have students explain their answers. Take a show of hands to learn the opinions of the entire group.

4. Hold the frame in one hand and extend your arm so that the frame is over a cushion of some sort. Make sure the needle is aligned with the balloon. Do a short count down and drop the frame. Ask for student observations and explanations.

   (The balloon will pop immediately upon release (less than 0.2 seconds).

   What happened? The frame is similar to the example of the elevator car in which the cables break. In the moment it enters free-fall, a microgravity environment is created. Prior to the drop, the tennis ball weight stretched the rubber bands. At the moment of the drop, the weight no longer exerted a force on the rubber bands and the rubber bands contracted to their normal length. In the process the needle, attached to the weight, is drawn into the balloon. To confirm that this is what is happening, replace the rubber bands with string and again drop the frame. Because the string did not stretch with the weight prior to the drop, it will not contract during the fall and the needle will not contact the balloon. (The needle may hit the balloon when the frame lands.)

5. Summarize what happened and compare it to the falling coffee cup demonstration. Ask your students what word describes what happened. (Microgravity)

### Extras

- Ask your students to imagine what would happen to a balloon filled with water if it were popped? What would happen if it were popped in microgravity?
- Show your students the Microgravity Water Balloon video.
  http://spaceflightsystems.grc.nasa.gov/WaterBalloon/
- Conclude the session with this. “Now that we know what microgravity is, what can we do with it?”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# 4) Beyond the Atmosphere

## 4A) Modeling the Solar System: *Relative Scaling*

Students create a physical model to illustrate distances among objects in the solar system.

## 4B) How Big is the Sun? *Size and Scale*

Students explore the relative sizes of the Sun, Earth and Moon as they make an impressive large-scale model for classroom use throughout the unit.

## 4C) The Size of Celestial Objects: *Worlds in Comparison*

Students compare the size of planets size using play dough.

## 4D) Analyzing Craters: *Impact or Collapse?*

Students examine, create, and analyze craters on Earth and the moon.


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# 4A) Modeling the Solar System

## *Relative Scaling*

### Time Needed

1 – 2 Sessions

### You Need This Stuff

*Per Class*

- 8-inch diameter ball or seedless melon that size
- 12-inch diameter beach ball or 12-inch Earth globe
- Small glass bead
- Tennis ball
- Access to computer
- Calculators (optional)
- 30 meters (100 ft) of string
- Meter sticks, tape measures, or yardsticks
- 3x5 Index cards (9 per solar system model students make)
- Marker

*Per Student Pair*

- Solar System Model Planner sheet

For supplemental activity

- Roll of register tape
- 5 round stickers, ¼" size or dime as template
- 5 round stickers, ½" or quarter as template

### What It's About

Many books and posters feature diagrams showing the Sun and the planets. These illustrations try to give students a sense of the relative sizes and distances of objects in our solar system. Unfortunately, the extreme distances and sizes of objects in the actual solar system make it impossible to depict them accurately. Most illustrations resort to lining up the Sun and planets, a perfect arrangement that never happens in the real solar system. The planets may be shown in their approximate relative sizes and correct order but they have to be squeezed together to fit the paper. Other illustrations may show the relative distances of the planets from the Sun but their diameters have to be greatly inflated just to be visible. For example, if a poster shows the Sun as a circle 10 cm across, Earth would be only 0.08 cm across, hardly larger than a pinpoint. Using a 10 cm Sun, Neptune, the farthest planet from the Sun would be 321 meters away. Consequently, a poster with a 10 cm Sun would be larger in area than a football stadium.

In this activity, students create true scale models of objects in the solar system.

### What's The Question

How big and how far apart are the Sun and the planets?

### Before You Start

Load the Solar System Model Calculator by scanning the QR code to the left or going to http://goo.gl/hH4q6. Alternatively you can download the Excel spreadsheet from http://goo.gl/zAGMy.

### What To Do: Part One – Sun and Earth

Note: You will need to do this in a very large room, hallway, or outside. This demonstration will stretch out about 75 feet.

1. Begin the activity by finding out what students know about the solar system. Ask students to list all of the objects in our solar system. In a round robin discussion, have students share their lists. Make a master list on the board. Use this discussion to identify and correct misconceptions. Their biggest misconceptions are likely to be the size and arrangement of solar system objects. For example, stars (except for the Sun), nebulae, and galaxies should not be included.

2. Tell your students you will begin making a model of the Sun and Earth. Select two volunteers. Present the ball to one volunteer and tell everyone that the ball represents the Sun. Give the second volunteer the bead. The bead represents Earth. The



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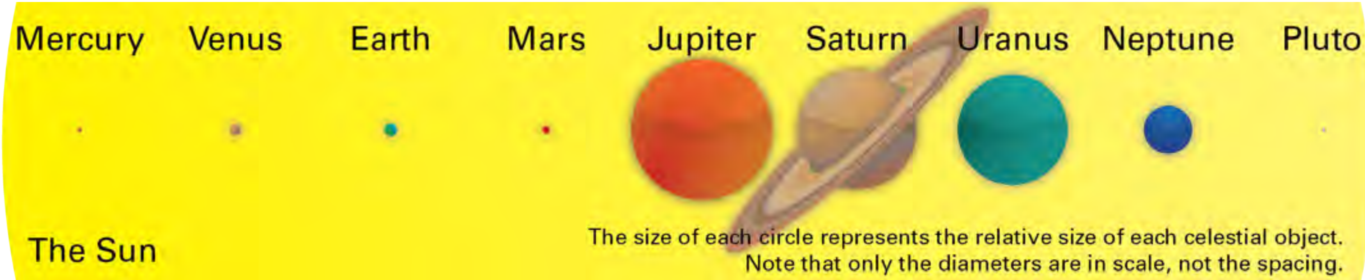


ratio of the two sizes is approximately the same as the real size difference of the Sun and Earth (about 110:1).

3. Call for a third volunteer and present that volunteer with a 30 meter length of string. Have the volunteer wrap the string around the Sun model 34 times. When the volunteer finishes, grasp the string at the end of the 34th wrap. Tie a small knot at that spot and place bead at this point.

4. Give the volunteer with the Earth bead the marked end of the string or twine and tell that person to walk away from the Sun as the wraps are pulled off the Sun ball. When the string is stretched straight, have the Earth volunteer stop. Announce that if the ball were the Sun and the bead were Earth, this is how far apart they would be from each other. Discuss student impressions of the model. Did they expect this?

   Math Note: The number 34 is the quotient of the Sun's circumference (4,400,000 km or 2,700,000 miles) divided into Earth's distance from the Sun (150,000,000 km or 93,000,000 miles). It doesn't matter if you use a much larger or smaller ball to represent the Sun. Wrap the line around it 34 times to get the correct scale distance to Earth.


In this depiction of the solar system planets are correctly shown in many different directions from the Sun. However, The Sun should be about 70 times larger than it is and planet orbits are not uniformly spaced.

**What To Do: Part Two – Earth and Moon**

Note: You will need to do this in a very large room, hallway, or outside. This demonstration will stretch out about 40 feet.

1. Pick two volunteers and give one the 12 inch beach ball and the other the tennis ball. Announce that the large ball represents Earth and the small ball represents the Moon.

2. Tell the volunteers to stand apart from each other at a distance representing how far the real Earth and Moon are from each other. Invite other students to offer their ideas how far the two balls should be apart.

3. When everyone is satisfied, give a third volunteer string (or twine) and have that person wrap the line around the Earth ball 9.5 times. Mark or hold the line and stretch it out. The line shows how far Earth and Moon should be from each other in this model. Students will be surprised.

   Math Note: The number 9.5 is the quotient of the Earth's circumference divided into Earth's distance from the Moon. It doesn't matter if you use a much larger or smaller ball to represent the Earth. Wrap the line around it 9.5 times to get the correct scale distance from the Earth to the Moon. The beach ball or globe is about 4 times larger across than the tennis ball. Different sized balls can be used but the ratio of 4:1 should be maintained to ensure accuracy.

### What To Do: Part Three – Make Your Own Solar System

Note: Depending on the scale students choose for their model, you will need a large space to create model (long hallway, playground, football field, etc.)

1. Organize your students into teams. Challenge each team to create an accurate model of the solar system. The Sun and planets must be arranged in their correct order, correct distances, and sizes.
2. Demonstrate the Solar System Model Calculator using a computer and LCD projector. Show that all they have to do is enter a number for the size of the Sun and press the return key. The page will automatically calculate the sizes and distances of the planets. Suggest that teams should think carefully about how large to make the Sun. A 10-meter-diameter Sun sounds great but the planet Neptune will be almost 33 kilometers away.

   Math Note: The Solar System Model Calculator does not present measurement units. If millimeters or inches are chosen by teams as the unit they are working in, then the calculated values in the spreadsheet will be in millimeters or inches.
3. Have teams select their Sun diameters and copy the planet distances and diameters given onto the Solar System Model Planner sheet.
4. Challenge teams build a solar system model with the numbers they have chosen. Starting with the Sun, have teams draw a circle representing the Sun on a file card and write "Sun" on the card. Have the teams measure out to Mercury and place a file card with a dot representing Mercury and the name "Mercury" at that location. Continue measuring outward until the solar system model is created.

   Example: The Sun is 1 cm in diameter. Mercury will be 41 cm away. Venus will be 77 cm away and Earth 107 cm away. Each planet will be about the size of a pinpoint.
5. After finishing their models, have teams start at the Sun and take a planetary tour by walking from planet to planet.

   Note: If space permits, a more accurate model of the solar system can be constructed by measuring outward in different directions for each planet. Planets orbit the Sun at different distances and at different speeds. They are never in a perfectly straight line from the Sun

### Wrapping Up

- Ask students if their ideas about the solar system have changed. How? Have them draw pictures of the solar system or parts of the solar system on the board.
- Talk about the 1969 Apollo 11 space mission to the Moon. Astronauts took three days to get to the Moon. Would they like to go on a mission to Mars, Jupiter, Uranus, or Neptune? How long do you think a flight to Neptune would take? (Remember that astronauts expect to come home after they have accomplished their mission. Double the travel time.)
- Why isn't Pluto a part of the models they made? (Pluto is no longer considered a planet because the International Astronomical Union in 2006 adopted a definition of planets that excludes Pluto and a few other moon-sized objects - Ceres, Haumea, Makemake, and Eris. These bodies are considered dwarf planets. The technical term is plutoid. Astronomers estimate that the solar system may contain 100 to 200 dwarf planets, most yet to be discovered.)

## Alternate / Supplemental Activity: Solar System in Your Pocket

### You Need This Stuff

Per Student:

- 1 meter length of cash register tape
- 5 round stickers, ½" (or quarter as template for tracing)



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- 5 round stickers, ¼" (or dime as template for tracing)
- Pencil or marker

### What It's About

You will build a portable model of the Solar System by folding a piece of register tape. The relative distances between the orbits of the planets will be illustrated. Images in textbooks often depict the planets squeezed together, but this model shows how far apart they are, especially beyond Mars.

### Before You Start

Pre-cut 1m strips of register tape and divide out groups of stickers for each team. If you wish, practice the steps a few times so you don't have to refer to your notes.

### What To Do

Pull out a folded completed sample of the model from your pocket. Point out that the planets never appear in a straight line like this in order out from the Sun, but this is just a reminder of the radius of the orbits. The planets would be found somewhere along a circle this far from the Sun. If you have a board with a thumbtack, you can tack it to the board at the Sun and show or draw out the orbits.

Now have the students create their own Pocket Solar System models. Lead them through the following steps:

1. Place a sticker on each end of the tape, one large and one small, right at the edge. Label the large one Sun and the small one Pluto (dwarf planet). Note that while Pluto is no longer considered a planet, it is the 10th largest body orbiting the Sun and we will use it for measuring purposes.

2. Fold the tape in half, crease it, unfold and lay flat. Place a large sticker at the half-way point. You can ask for guesses as to which of the remaining 8 planets might be at this half-way point. Label the sticker Uranus.

3. Fold the tape back in half, then in half again. If there are mixed ages, give those with some knowledge of fractions the opportunity to show off by asking "What is half of a half?" Unfold and lay flat. Place large stickers at the quarter mark and 3/4 marks and label as Saturn (closer to the Sun) and Neptune (closer to Pluto).

4. Fold back into quarters, then in half one more time. This will give you eighths. Unfold and lay flat again. Place a large sticker for Jupiter at the 1/8 mark (between the Sun and Saturn), and label.

5. No need to fold the whole thing up again. If you take a look, you've got the 4 gas giants and Pluto all on there. For the remaining terrestrial planets, you'll only need 1/2 of the first 1/8th! That's the inner 1/16th of your meter. Fold the Sun out to meet Jupiter to mark the 1/16th spot. A planet does not go here, but the Asteroid Belt does.

6. At this point, things start getting a little crowded and folding is tough to get precise distances, so fold the remaining 1/16th in half and crease at the 1/32nd spot. Place a small sticker for the Earth just inside this fold (between the Sun and Asteroid Belt) and a small sticker for Mars just outside the fold (closer to the Asteroid Belt) and label them.

7. Place small stickers for Mercury and then Venus, between the Earth and Sun, pretty much dividing the space into 1/3rds and label them as Mercury closest to the Sun and Venus closest to the Earth.

### Wrapping Up

At the end of the discussion, be sure to have everyone put their names on their tapes and fold them up to put it in their pockets. But before you put them away, here are some questions you might ask to get participants thinking about insights they can get from building this model.

1. Are there any surprises? Look how empty the outer solar system is: there is a reason they call it space! And how crowded the inner solar system is (relatively speaking).

2. Do you know anything about the physical properties of the ones that are spread out versus the ones that are crowded in close to the Sun? All the inner ones are small and rocky and the outer ones are gassy giants (except small icy Pluto).

3. Given this spacing, why do you think little rocky Venus can outshine giant Jupiter in the night sky? Both are covered with highly reflective clouds and although it is much smaller Venus is also much, much closer.

4. Does anyone know where the next known planet, 2003UB313, will go? At 97 A.U., it would more than double the size of the model. Pluto is on average 40 A.U. (A.U. stands for Astronomical Unit, roughly the mean distance from the Earth to the Sun. 1 AU = 149,597,870.691 kilometers, or about 93 million miles.)

5. On this scale (1m = 40a.u) where would the nearest star be? After some guesses you could bring out your pocket calculator to use in getting how far away the star would be. This allows you to talk about how far is a light year and do the calculations to find that the next nearest star is about 7km (4.2miles) away. They could then take out a local map to see what is that far away from where the presentation is happening.

[Calculations: A light year, the distance light travels in one year, is about 63,240 A.U. (about 9,460,000,000,000 km). The nearest star is Proxima Cantauri (visible from the Southern Hemisphere), at 4.2 light years. So, 4.2 ly x 63,240 A.U./ly x 1 m/ 40 A.U. = 6640.2 m = about 7 km.]

*Original activity developed by Amie Gallagher and adapted for Astronomy from the Ground Up by Suzanne Gurton and Anna Hurst*


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# Solar System Model Planner

Measurement Unit (circle one): millimeter centimeter meter inch foot

Sun Diameter = ______

| | Distance from the Sun | Diameter |
|---|---|---|
| Mercury | | |
| Venus | | |
| Earth | | |
| Mars | | |
| Jupiter | | |
| Saturn | | |
| Uranus | | |
| Neptune | | |
| Pluto (optional) | | |


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# 4B) How Big is the Sun?

## *Size and Scale*

**Time Needed**
3 Sessions

**You Need This Stuff**
*Per Class*

- butcher paper
- yellow, orange, red, and black tempera paint
- pencil or marker
- white construction paper cut into 2 in. x 4 in. pieces for labels
- tape
- sponges and brushes
- half-inch round Avery adhesive labels (blue)
- 4 small pins with round heads to place across the half-inch round label

Original activity from Eye on the Sky used with permission from the University of California Center for Science Education.

### What It's About

Earth's nearest star, the Sun, is extremely large relative to the Earth and its moon. The Sun has a diameter of about 1,392,684 km, which is about 109 times that of the Earth (around 6,371 km). The moon has a diameter of about 1,737 km.

### What's The Question

How big are the Sun, Earth, and Moon?

### Before You Start

Outline a large circle with a diameter of 54.5 inches to represent the Sun for this activity.

### What To Do

Part One

1. Show students images of the sun at http://umbra.nascom.nasa.gov/images/
2. Discuss features to be included on the model they will be creating and write them on the board. These words are a good place to start: corona, moon, magnetic loop, solar flare, earth, diameter, sunspot, prominence, gas.
3. Students may take turns painting the Sun with yellow, red and orange tempera to create the surface of the sun. Start with the lightest paint for optimal effects. You can save some time by starting with yellow butcher paper and painting with red and orange tempera.

Part Two

1. Continue with painting or drawing. If painting, the granules of the Sun's surface can be achieved by sponging darker colors across the painting.
2. Encourage students to paint or draw details such as sunspots, prominences, and solar flares.
3. After completing painting, ask students to write vocabulary words on the 2-inch x 4-inch labels.
4. After model has dried, cut it out and display on the wall.
5. Students take turns gluing the vocabulary labels to the Sun.
6. The model can be the focal point for your expanding "Science Word Wall" with new vocabulary displayed around and on the Sun.


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Part Three

1. Discuss the enormous size of the Sun in contrast to the Earth and the Moon.
2. Ask students to imagine that one round blue label is the Earth.
3. Ask a group of students to place the round labels across the diameter of the Sun.
4. After placing the labels, ask students to count them in intervals of ten.
5. Mark each group of ten.
6. You will find that approximately 109 Earths span the diameter of the Sun.
7. Explain that it takes four Moons to cover the diameter of the Earth.
8. Tell students that one small pin represents the Moon. Ask how many pins are needed to span the diameter of Earth. Note: You can make 4 equal size circles instead.
9. Place four small pins with round white heads across the blue label.

   HINT: Be sure to start the labels at the edge of your 54.5-inch circle—otherwise you may end up with more than 109 "Earths" spanning the diameter!
10. "Signs" for reinforcing the comparative sizes of the Sun, Earth and Moon can be printed and displayed near your Sun model.

**Wrapping Up**

- Have a whole-class discussion of the Sun and its size relative to the Earth and Moon can be started with the following discussion questions:
    1. What is bigger, the Earth or the Sun?
    2. How many “Earths” does it take to cover the diameter of the Sun?
    3. What is bigger, the Earth or the Moon?
    4. How many Moons does it take to cover the diameter of the Earth?
    5. How many Moons do you think it will take to cover the Sun?

Original activity from Eye on the Sky used with permission from the University of California Center for Science Education.

# 4C) The Size of Celestial Objects

## *Worlds in Comparison*

### Time Needed

1 Session

### You Need This Stuff

*Per Group*

- 3 pounds of play dough (see recipe)
    - 2 cups flour
    - 1 cup salt
    - ½ cup cornstarch
    - 1 tbsp alum or cream of tartar
    - 2 cups water
    - 2 tbsps oil
    - 2 packages of Kool Aid mix and/or food coloring
- Plastic knife
- Wax paper
- Instruction sheet
- Planet name worksheets

### What It's About

This activity allows students to develop an understanding of the relative sizes (volumes) of the planets in our solar system. Students start with a big ball of play dough and divide it up following the steps on the instructions sheet. When they are done, they see how the planets vary in size. By the time they get to tiny Pluto, they are typically quite amazed.

### What's The Question

What are the comparative sizes of the planets (and Pluto!) in our Solar system?

### Before You Start

This activity works best if the worksheets with the planet names are placed side-by side on a table, and are arranged to match the order from the Sun. In front of these sheets place the instruction sheet and the play dough and plastic knife on a work surface. Be sure there is enough room in front of the table for the group to work together. It is crucial to have the indicated amount of play dough for each group. If there is less than three pounds, the Pluto piece will be too small to see!

### What To Do

This activity is designed as a self-guided station activity. Nevertheless, if you choose to do so, it can also be a facilitated activity from the beginning. If you facilitate this activity from the start, begin by asking the students which planet they think is the largest. Which is the smallest? For whatever planet they say is the largest (it will most likely be Jupiter), ask them the following question: If we could combine all the planets together into a big ball, what fraction of that ball would the largest planet be? Might it be 1/9 or 1/5, for example? End the introduction by telling them they will get a better idea after completing this activity.

Note: If people will be using previously used play dough of various colors, you can reassure participants that mixing colors is fine (after all, many planets are multicolored!).

Students begin by reading the instructions. They should follow the instructions as to how to divide up their play dough, placing the parts in the proper planet boxes. Each time the play dough is divided up and parts are combined to make a planet, be sure students roll the combined parts around in their hands until the planet has a ball shape.

### Wrapping Up

- Start by asking about some of the discoveries they made regarding the sizes of the planets. Were there any surprises? Ultimately direct the discussion so that they realize the smaller planets (except Pluto) are the inner planets, while the larger planets are the outer planets. You may also want to note that more than 96% of the combined volume of the planets is in Jupiter and Saturn (approximately 60% in Jupiter and 36% in Saturn). Those giant planets really ARE giants.

Originally developed by Dennis Schatz and adapted by Anna Hurst for Astronomy from the Ground Up.

**Extras**

- Recipe for Play Dough
  2 cups flour
  1 cup salt
  ½ cup cornstarch
  1 tbsp alum or cream of Tartar
  2 cups water
  2 tbsp oil
  2-3 packs of Kool-Aid mix and/or food coloring

  For microwave directions use large microwave-safe bowl. For stove-top directions use appropriate pot.

  Thoroughly mix dry ingredients. Add water, stir. Add oil, stir. Add food coloring (if applicable), stir.

  **Stove Top:** Heat and stir mixture constantly until it forms a ball. Knead until smooth.

  **Microwave:** Heat mixture 2 minutes, stir thoroughly. Heat 1 minute, knead until smooth. If needed: heat 30 more seconds, knead again. If dry add a bit more oil.


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# Worlds in Comparison, Instruction Sheet

**What's This About?**
This activity demonstrates the different sizes of the nine planets in our solar system. Follow the steps outlined below to see the relative size (volume) of each planet. Start with a big 3-pound ball of play dough, which represents the volume of all the planets combined.

1. **Divide the Entire Ball of Play dough into 10 Equal Parts**
   *You may find it easiest to start by rolling the ball into one big hot dog shape.*
   - Combine 6 parts together, roll them into a ball, and put the ball into the Jupiter box.
   - Similarly combine 3 parts and put them into the Saturn box.

2. **Cut the Remaining Part Into 10 Equal Parts**
   - Take 5 parts and combine them with the ball in the Saturn box.
   - Combine 2 parts to put into the Neptune box.
   - Put 2 parts into the Uranus box.

3. **Cut the Remaining Part Into 4 Equal Parts**
   - Take 3 parts and combine them with the ball in the Saturn box.

4. **Cut the Remaining Part Into 10 Equal Parts**
   - Put 2 parts into the Earth box.
   - Put 2 parts into the Venus box.
   - Take 4 parts and combine them with the ball in the Uranus box.

5. **Combine the Remaining 2 Parts and Cut Into 10 Equal Parts**
   - Put 1 part into the Mars box.
   - Take 4 parts and combine them with the ball in the Neptune box.
   - Take 4 parts and combine them with the ball in the Uranus box.

6. **Cut the Remaining Part Into 10 Equal Parts**
   - Put 7 parts into the Mercury box.
   - Take 2 parts and combine them with the ball in the Uranus box.

7. **Cut the Remaining Part Into 10 Equal Parts**
   - Take 9 parts and combine them with the ball in the Uranus box.
   - Put 1 part into the Pluto box.

**And Now...**
Now that you have divided the play dough to represent the planets by volume, roll the pieces in each planet's box into balls to best represent the shapes of the planets.

| |
|---|
| **Mercury** |
| **Venus** |
| **Earth** |


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**MARS**

**JUPITER**

**SATURN**



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| |
|---|
| **URANUS** |
| **NEPTUNE** |
| **PLUTO**<br>(Dwarf Planet) |



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# 4D) Analyzing Craters

## *Impact or Collapse?*

### Time Needed

1 – 2 Sessions

### You Need This Stuff

*Per Class*

- Play box sand
- Large tray, copy paper box lid
- Talcum powder
- Glass marbles, large ball bearings, or small rounded pebbles
- Bicycle pump
- Small balloons
- Rubber bands on masking tape
- Video camera or telephone video camera
- Safety goggles

### What It's About

The large solid bodies of our solar system - terrestrial planets and moons - are peppered with craters. Most of these craters are due to impact of large meteors, asteroids, and comets traveling across the solar system. We can readily see the result of these impacts when turning a telescope on the Moon. The Moon's surface is covered with millions of impact craters. For the most part, impact craters are bowl-shaped depressions formed by the energy release that occurs during the moment of impact. Lunar craters range in size from microscopic pits in rock to basins hundreds of kilometers across.

The planet Mercury is also covered with craters, so much so that it resembles the surface of the Moon. Mars is heavily cratered but Mars has had large lava flows and wind erosion that has obliterated its most ancient craters. The thick atmospheres of Earth and Venus have also obliterated many of their craters. Wind and water erosion on Earth wipes away the surface marks of all but the largest of the ancient craters. Still, there are hundreds of more recent impacts that have scarred Earth's surface. Venus's thick atmosphere (90 times thicker than Earth's) heats and destroys most incoming objects so that its surface is nearly crater free. Venus does have places where the surface is jumbled from the low altitude explosion of incoming objects.

Craters from impacts aren't the only craters found on the planets. Craters can also produced by volcanic activity. Molten material wells up from planet interiors and spews out on to the surface. Large cones may be produced as the result of successive eruptions. Eventually, lava chambers are formed inside volcanoes. From time to time, the lava will erupt to the surface or drain back down, leaving the chamber unsupported. The chamber ceiling may then collapse forming a broad circular crater. Large volcanoes may also explode forming giant craters called calderas.

In this two-part activity, students will first investigate two ways craters on the surface of planets and moons are made. They will study the shapes of the craters and learn how to interpret the history of impacts. In the second part of the activity, students will begin geological training for a mission to Mars. They will learn how to interpret satellite pictures of craters on Earth and determine whether they are impact or volcanic. They will then be challenged to determine the origin of several craters on the Mars.

### What's The Question

Is it an impact event or a volcanic collapse?



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## Before You Start

Download the free software Google Earth to the computers students will use.

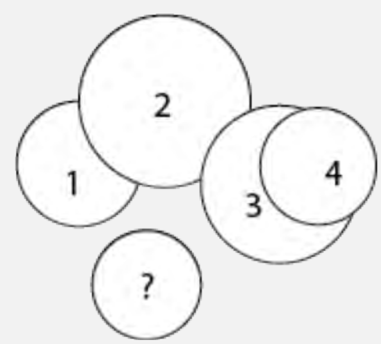
http://www.google.com/earth/index.html

## What To Do: Part One – Impacts

Note: This activity involves dropping or throwing marbles and other small objects into dry sand. If a balcony is available, excellent impact craters will be produced. If it is necessary to throw the "impactors" into the sand, be sure to place the tray with the sand in a clear location so that if students miss, which they sometimes will even though they are standing next to the tray when they make the throw, the "impactors" will not bounce into somebody. Eye protection is mandatory.

**Crater Sequence**

When a crater overlaps another, the overlapping crater is more recent. Determining when an outlying (not overlapping) crater occurred is more difficult. Radioactive age dating techniques will yield an age if samples from the crater can be collected. This works for Earth but if the crater is on Mars, dating the crater is more difficult. However, craters with sharp features tend to be young. Craters that are filled in and worn are old.




1. Engage your students by showing them pictures of craters (find on Google). Ask your students what these are, have they seen them before? Where? What might have caused them? Some may have visited Crater Lake in Oregon or Meteor Crater in Arizona but all have seen craters on the Moon. What is a crater? What does it look like? List student ideas on the board. Explain that craters are generally made in two ways. The first, is by impacts caused by large space rocks, such as asteroids and meteorites, and comets (ice and rock) falling on to the surface of Earth and other bodies in our solar system. The second main way craters can be formed is by volcanic explosions or the collapse of volcanic cones. Tell your students that they will be experimenting with how craters are formed.
2. Set up the sandbox or tray in a suitable area and explain that they will be dropping or throwing "space rocks" into the sand to see what happens. Have them make a folding storyboard as shown in the directions on the next page. Ask them to draw a picture of how they think a crater will look on the first panel of the storyboard.
3. Select a student to create the first crater. Be sure the student wears eye protection. Smooth the sand surface and sprinkle talcum powder over the surface like a thin dusting of snow. Have the student throw (or drop) the "impactor" (marble, etc.) into the center of the sand while other students stand back. Have students examine the crater produced. The combination of the sand and the talcum powder makes it easy to see how sand from the crater is thrown outward to form a spatter pattern. Have students to sketch the shape of the crater on panel 2 of their storyboard and compare it with their predicted crater drawing in step 1. Ask students, *What are similarities and differences?*
4. Select another student to throw a second "impactor" into the sand. Do not smooth over the sand first. Compare the second crater to the first one. Did the spatter from the second crater alter the appearance of the first crater? Draw the new crater and its effects on the first crater on panel 3 of the storyboard.
5. Repeat with more impacts thrown by other students. Eventually, the earliest craters will start filling in from the spatter of subsequent impacts. Have students sketch the collection of craters. Can they tell which crater came first and which last? Ask them to explain.

## What To Do: Part One – Volcanic Explosion Demonstration

Note: Use the same sandbox set up as in the previous activity – cover the immediate area with newspaper



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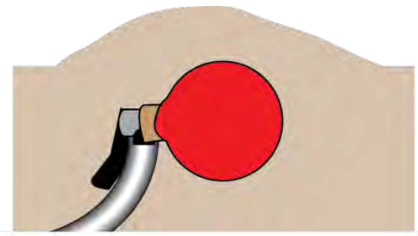
Remember to use eye protection.



1. Prepare the bicycle pump by stretching a small balloon over the valve at the end of the hose. The balloon should be pulled snugly over the valve and taped. The object is not to inflate the entire balloon but only a part of it. When the latex expands to about 5 cm in diameter, it should burst, creating the explosion needed for the activity.
2. Bury the pump valve with the balloon about 2-3 cm deep in the center of the sandbox. Prepare the sand as before by smoothing and coating with talcum powder.
3. Explain how a volcanic explosion will be simulated. Ask students to speculate on what the crater produced will be like. Will it look the same or differently from impact craters.
4. Slowly begin pumping. When the latex reaches its maximum expansion, an explosion will occur, blasting out a crater in the same way a volcano creates a crater through an explosion.
5. Have students observe and sketch the crater that is produced. Is there a difference between the craters produced in the two different ways? Describe.

How to Capture the Impact/Explosions with a Camera

If you have a video camera available, this is an excellent extension to the cratering activity. Have another student operate the camera from a short distance away from the sandbox. This student should wear eye protection too. The camera operator should focus the camera on the middle of the sand surface and start recording the video. The other student waits 2 seconds and throws the "impactor" into the sand or pumps the air to create the explosion. Transfer the video to a computer and watch the crater form. Using the motion controls with the video software on the computer, move the video back to just before the impact or explosion. Slowly, frame by frame, advance the video forward and watch the crater form in slow motion. View this several times and have students analyze the crater forming process.

### What To Do: Part Two – Astronaut Training, Geology of Impacts

Note: This part requires computer access.

1. Inform your students that prior to space flights, astronauts are trained in many scientific disciplines including geology. Because many planetary surfaces are riddled with craters, it is important to know what their features are and how they formed. Therefore, your students will be trained in geology for a mission to Mars. The training will begin with examining satellite crater pictures of Earth. Some will be of impact origin and others volcanic. They will learn to differentiate between the two kinds.
2. Begin by training your students to use the computer program Google Earth. Load up the program on the computers students will be using. Turn the "Grid" control on. You will find Grid under View in the menu bar. This control displays longitude and latitude lines on the globe. Explain how the lines are used to locate places on Earth. You may need to review longitude and latitude with your students. See below.

   Longitude and Latitude

   Longitude and Latitude lines are a grid system for locating places on Earth. Latitude lines are horizontal lines that run parallel to Earth's equator. Lines north of the equator are called north latitude lines and lines running south of the equator are south latitude lines. Longitude lines are vertical lines that intersect at the north and south poles like pie slices. The base line or prime meridian for longitude runs through Greenwich England. Lines to the east of the prime meridian are called east longitude and lines running to the west are west longitude lines. The spacing between latitude and longitude



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lines is measured in degrees and fractions of degrees called minutes and seconds. If you have the coordinates, you can locate any place on the surface of Earth. For example, Washington DC is located a Longitude N38 degrees 53 minutes latitude W77 degrees 2 minutes. Using Google Earth, you can fly immediately to the tidal basin in Washington DC by entering the following into the "Fly To" space in the "Search" menu (upper left corner): N38 53 W77 2

3. Demonstrate how to use Google Earth.

   <u>Entering Longitude and Latitude</u>

   Students enter coordinates in the search "Fly To" (upper left corner) space and hit return. Google Earth will automatically rotate the globe to the right place and zoom in to a close up. Move the mouse to the upper right of the screen. A slider bar appears. Moving the slider upward zooms in image and moving downward zooms out. Clicking and holding enables you to move the view and explore the area around the chosen scene.

   <u>Measuring Crater Size</u>

   Go to the icon menu bar above the globe. Click on the ruler icon. A small pop-up menu appears that offers the choice of "Line" and "Path." Click on Line if not already selected. If in the way, the menu can be dragged to the side by clicking its menu bar and dragging. To measure the size of a crater, click on one crater rim. A dot will appear. Move across the crater to the other rim. A line will appear. Click on the other rim at the desired point. The distance will be given. Measurement units can be changed. Select "kilometers."

   Google Earth has many controls that are easy to figure out and exploration should be encouraged.

4. Give students working individually or in small teams, the Earth Crater Table. The table features craters produced by impacts and by volcanic explosions and collapses. Coordinates are given for each crater. Students should enter the coordinates exactly as shown in the "Fly To" search space and press return. If entered properly, the coordinates will take them to the exact location of the crater. Encourage students to use the in and out zoom control to study the crater. Have them write down their observations of the crater in their log books. What features does each crater have that indicate the process by which it formed? Some will be easy to tell and others will be more difficult because of erosion. All of the craters have diameter measurements provided. Have students practice making the measurements. They will need this skill later.

5. When students have studied several impact and volcanic craters, hold a discussion and have students report on their observations. *What are the characteristics of impact craters? What are the characteristics of volcanic craters?* Make a list or a T-chart.

6. When students have developed proficiency in crater identification, tell them that they have been selected as the crew for a mission to Mars. As a part of their pre-launch training, they will have to study the geology of Mars. The training will focus on Mars craters. Show students how to go to Google Mars. One of the icons along the top of Google Earth shows a ringed planet. This will bring up a small menu. Click on "Mars" to go to Google Mars to begin the training. All Google Earth controls work as well for Google Mars.  Give students the Mars coordinate table have them measure crater diameters and determine the process by which they formed and enter their answers in the blanks on the table

## Wrapping Up

- Hold a post-training debriefing. Pick students to describe one Martian crater to the group. How big is it? What process created it? Why did they arrive at this conclusion (what are their supporting observations)?
- Ask students why doesn't the Mars crater data base have numbers for age measurements? Age measurements are given in BP which means before present. Age determinations on Earth are possible because of established radioactive element age dating techniques. Geologists collect samples of the rocks making up the craters and they can use these techniques to determine the ages of the rocks and when the cratering event took place. Samples are not available from the Martian craters.



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Geologists can make guesses. Like Earth, Mars has erosion. The older a crater is, the more it is worn. Very sharply-defined craters are younger than worn down craters.

## Mars Crater Answer Key

| MARS CRATER NAME | LOCATION | COORDINATES | DIAMETER km | AGE | BP | PROCESS |
|---|---|---|---|---|---|---|
| **(no name)** | Mars | N21 30 W86 30 | 80 | ? | | Impact |
| **Olympus Mons** | Mars | N18 30 W133 30 | 70 | ? | | Volcanic |
| **Ascraeus Mons** | Mars | N11 15 W 104 30 | 48 | ? | | Volcanic |
| **Schiaparelli** | Mars | S2 30 E16 30 | 400 | ? | | Impact |
| **Lohse** | Mars | S43 30 W16 30 | 135 | ? | | Impact |
| **Pavonis Mons** | Mars | N0 30 W113 0 | 47 | ? | | Volcanic |
| **Barnard** | Mars | S61 0 E 61 0 | 114 | ? | | Impact |


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## Earth Crater Table

| EARTH CRATER NAME | LOCATION | COORDINATES | DIAMETER km | AGE BP | PROCESS |
|---|---|---|---|---|---|
| **Pingualuit Crater lake Also called "New Quebec"** | Quebec, Canada | N61 16 W73 40 | 3.44 | 1.4 million | Impact |
| **Couture** | Quebec, Canada | N60 09 W75 18 | 8 | 430 million | Impact |
| **Shoemaker** | Western Australia | S25 52 E120 53 | 30 | 1,630 million | Impact |
| **Upheaval Dome** | Canyonlands National Park, Utah, USA | N38 26 W109 56 | 10 | 170 million | Impact |
| **Deep Bay** | Saskatchewan, Canada | N56 24 W102 59 | 13 | 99 million | Impact |
| **Meteor Crater (also known as "Barringer")** | Arizona, USA | N35 2 W111 1 | 1.2 | 50,000 | Impact |
| **Lake Bosomtwe Crater (also spelled (Bosomtwi")** | Ghana | N6 30 W1 25 | 10.5 | 1 million | Impact |
| **Serra da Cangalha** | Brazil | S8 5 W46 52 | 12 | 300 million | Impact |
| **Vredefort Dome** | South Africa | S27 0 E27 30 | 160 | 2 billion | Impact |
| **Lac Manicougan** | Quebec, Canada | N57 26 W68 42 | 85 | 214 million | Impact |
| **El'gygytgyn** | Russia | N67 30 E172 5 | 18 | 3.5 million | Impact |
| **Kara-Kul** | Tajikistan | N39 1 E73 27 | 52 | 5 million | Impact |
| **Oasis** | Libia | N24 35 E24 24 | 18 | 120 million | Impact |
| **Lonar** | India | N19 58 E76 30 | 1.8 | 52,000 | Impact |
| **Aorunga** | Chad | N19 6 E19 15 | 13 | 345 million | Impact |
| **Crater Lake National Park** | Oregon, USA | N42 56 W122 6 | 8.5 | 5,677 | Volcanic |
| **Mt. Pinatubo** | Philipines | N15 8 E120 21 | 2.5 | (1991) | Volcanic |
| **Ngorongoro Crater** | Tanzania | S3 12 0 E35 34 | 18 | 2-3 million | Volcanic |
| **Valles Caldera** | New Mexico | N35 54 W106 32 | 18 | 1.25 million | Volcanic |
| **Lake Rotorua** | New Zealand | S38 5 E176 16 | 10 | 240,000 | Volcanic |
| **El Chichón** | Mexico | N17 21 W93 13 | 1 | (1982) | Volcanic |
| **Lake Avernus (also called Lago di Averno)** | Italy | N40 50 E14 05 | 2 | | Volcanic |
| **Mt. Vesuvius (also called "Via delle Margherite")** | Italy | N40 49 E14 25 | .5 | 17,000 | Volcanic |
| **Mount Aniakchak National Monument and Preserve** | Alaska, USA | N56 54 W158 9 | 9.5 | 3,700 | Volcanic |


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## Mars Crater Table

| MARS CRATER NAME | LOCATION | COORDINATES | DIAMETER km | AGE | BP | PROCESS |
|---|---|---|---|---|---|---|
| **(no name)** | Mars | N21 30 W86 30 | | ? | | |
| **Olympus Mons** | Mars | N18 30 W133 30 | | ? | | |
| **Ascraeus Mons** | Mars | N11 15 W 104 30 | | ? | | |
| **Schiaparelli** | Mars | S2 30 E16 30 | | ? | | |
| **Lohse** | Mars | S43 30 W16 30 | | ? | | |
| **Pavonis Mons** | Mars | N0 30 W113 0 | | ? | | |
| **Barnard** | Mars | S61 0 E 61 0 | | ? | | |


## Mars Crater Table

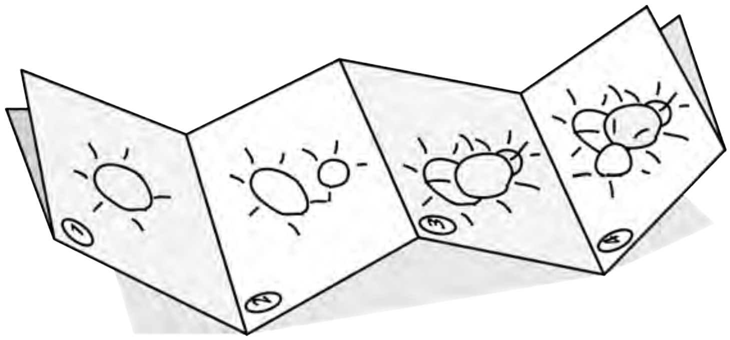
| MARS CRATER NAME | LOCATION | COORDINATES | DIAMETER km | AGE | BP | PROCESS |
|---|---|---|---|---|---|---|
| **(no name)** | Mars | N21 30 W86 30 | | ? | | |
| **Olympus Mons** | Mars | N18 30 W133 30 | | ? | | |
| **Ascraeus Mons** | Mars | N11 15 W 104 30 | | ? | | |
| **Schiaparelli** | Mars | S2 30 E16 30 | | ? | | |
| **Lohse** | Mars | S43 30 W16 30 | | ? | | |
| **Pavonis Mons** | Mars | N0 30 W113 0 | | ? | | |
| **Barnard** | Mars | S61 0 E 61 0 | | ? | | |

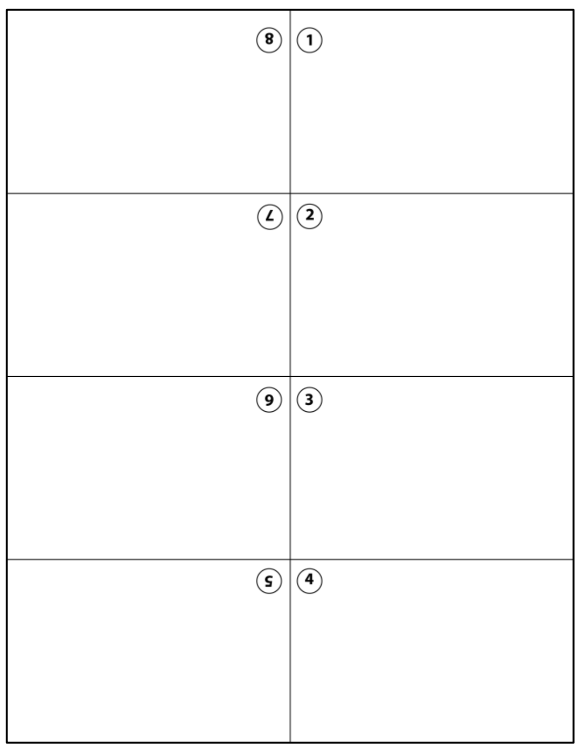
## Mars Crater Table

| MARS CRATER NAME | LOCATION | COORDINATES | DIAMETER km | AGE | BP | PROCESS |
|---|---|---|---|---|---|---|
| **(no name)** | Mars | N21 30 W86 30 | | ? | | |
| **Olympus Mons** | Mars | N18 30 W133 30 | | ? | | |
| **Ascraeus Mons** | Mars | N11 15 W 104 30 | | ? | | |
| **Schiaparelli** | Mars | S2 30 E16 30 | | ? | | |
| **Lohse** | Mars | S43 30 W16 30 | | ? | | |
| **Pavonis Mons** | Mars | N0 30 W113 0 | | ? | | |
| **Barnard** | Mars | S61 0 E 61 0 | | ? | | |

## How to Make a Folding Storyboard

Using a full sheet of paper, have students make a folding storyboard of the impact sequence starting with panel 1 for their drawing predicting what a crater would look like. As each impact occurs, students should make new drawings showing what happened. The folding storyboard has room for the prediction (panel 1) and 7 panels for drawings of the impact students create.






To make a folding storyboard, divide the paper into 8 rectangles by folding. Make the first fold along the vertical line shown. Make the second fold along the top horizontal line. Fold the top two panels up. Fold the next two down and the last up. This creates the accordion fold as shown above. Number the panes as shown. Note that the numbers on the left side are upside down. When unfolded (like reading pages of a book), the panels will go from 1 to 4. Then the story board is turned upside down and the "pages" are opened from 5 to 8.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# 5) Why Venture into Space?

## 5A) Why Explore Space? *The Great Debate*

Students make paper rockets and construct air-powered launchers. They will determine the maximum altitude their rockets reach.

## 5B) Launching Rockets: *Reach for the Stars*

Students make paper rockets and construct air-powered launchers. They will determine the maximum altitude their rockets reach.

## 5C) Reentry Capsule: A Spinoff from Space Exploration

Students learn about the challenges of returning from space by constructing their own reentry capsule and test their designs by dropping their spacecraft into a pool of water.

## 5D) Working in Space: *Glove Box*

Students create a simulated work environment as they perform an investigation inside a glove box.

## 5E) Interplanetary Travel: *Mars or Bust*

Students simulate the relationship of the orbits of Earth and Mars to discover the trajectory a space craft must make to travel between the two planets.

## 5F) Glider Design: *Wings over Mars*

Students will design and build gliders to simulate the type that could be used to explore Mars.


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# 5A) Why Explore Space?

## *The Great Debate*

### Time Needed

1 – 2 Sessions

### You Need This Stuff

*Per Class*

• Clock with second hand

*Per Student*

• Copies of the student pages
• Markers or pencils

### What It's About

> *The greatest gain from space travel consists in the extension of our knowledge. In a hundred years this newly won knowledge will pay huge and unexpected dividends.*"
>
> - Professor Werner von Braun

Ever since the first rockets escaped Earth's atmosphere to explore the mysteries of outer space, people have debated the value and wisdom of doing so. Exploring space is expensive. In 2012, the United States invested $16 billion dollars in sending spacecraft to other planets and supporting astronauts on the International Space Station. Proponents of space exploration where thrilled at the many successes. The Mars Curiosity rover safely landed on Mars. The Hubble Space Telescope continued to send fantastic pictures of the most distant objects in space. Earth orbiting satellites continued collecting data about the environment. Astronauts continued using the International Space Station to study fundamental science.

On the other hand, opponents point to the great expense and dangers of exploring space. Earth and its people have many serious problems. The money spent on space exploration could be spent solving these problems.

In this activity students will explore the pros and cons of space exploration. They will begin by taking a 20 question opinion survey. The survey has no right or wrong answers. They will then analyze their results and come up with a graphical measure of their opinions about space exploration. If desired, the survey can be used as the first step in a formal debate about space exploration.

### What's The Question

Should we continue to explore outer space?

### Before You Start

Collect some space pictures from the internet.

### What To Do: Part One – The Survey

1. Give each student the first two student pages. Page 1 states the issue and provides some facts. The space exploration pro-con survey starts at the bottom of page 1 and ends on page 2.
2. When all students have taken the survey, give them page 3. Page 3 provides instructions for how to analyze the survey. Students create a bar graph showing the numbers of pro and



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con responses. Whether or not a student is in favor of space exploration will be displayed by the heights of the bars.

### What To Do: Part Two – The Debate

1. Select two teams of 3 students to compete in a debate on whether or not we should continue to explore outer space. Randomly pick one team to take the pro side and the other the con side. Designate the remaining students to be a judging panel
2. Give the two teams 15 minutes to prepare their arguments.

**Debate Rules**

1. A coin flip will determine which side speaks first. The first team will get 3 minutes to state their case.
2. Team 2 will get 1 minute to respond to what was said.
3. Team 2 will get 3 minutes to state their case.
4. Team 1 will get 1 minute to respond to what was said.
5. Team 2 will get 1 minute for closing remarks.
6. Team 1 will get 1 minute for closing remarks.

3. While the debate teams are preparing, hold a discussion with the remaining students about how they will judge the winners of the debate. Have them create a simple 1 to 5 scoring scale with 5 the highest score. Designate one student to be the official time keeper. Pick another student to average the scores.
4. Hold the debate and select the winning team.

### Wrapping Up

Have students examine the budget figures for the 2012 US budget. Not all items are listed. One of the arguments against space exploration is that the money should be spent to solve problems on Earth. Ask students to compare the $16 billion in the NASA budget to other programs. For example, how much is spent on education and social services. How much for defense, etc. Over $2 trillion is already spent on domestic programs. Will an extra $16 billion make much of a difference? What does spending on space exploration get us? Here are a few benefits of space exploration.

computer technology
cell phone calls via satellites
accurate weather forecasting and severe storm warnings
many medical technologies
environmental monitoring from space
many consumer and sporting products
food technology
water treatment technology
basic knowledge about Earth and the solar system
radiation protection
alternate energy technologies
improved aircraft engines
safer highways

### Extras

• Visit hubblesite.org


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## The United States Should Explore Space
OR
## The United States Should Stop Exploring Space

What do you think? Should we explore space or should we use the money allotted for exploration for other purposes?? Before deciding, look at the facts below. Where does our money go?

UNITED STATES BUDGET FOR 2012
The total budget for the government of the United States of America in 2012 was $3,796 billion (3.796 trillion dollars).

Within that budget are many governmental agencies and programs. Some of them are:

| | |
|---|---|
| National Defense | $716 billion |
| International Affairs | $56 billion |
| Justice | $62 billion |
| Agriculture | $20 billion |
| Social Security | $778 billion |
| Health | $347 billion |
| Medicare | $482 billion |
| Transportation | $103 billion |
| Income Security | $579 billion |
| Veterans Benefits | $129 billion |
| Education/Social Services | $139 billion |
| Space Exploration | $16 billion |

**Where Do You Stand?**

Answer the 20 questions below. There are no right or wrong answers. It is what you believe that counts. Place an X in the box for your answer.

| | Agree | Disagree |
|---|---|---|
| 1. We should explore space because humans are curious. | [ ] | [ ] |
| 2. Space exploration is too expensive. | [ ] | [ ] |
| 3. Space exploration is too dangerous. | [ ] | [ ] |
| 4. Space exploration develops new technologies that can help people on Earth. | [ ] | [ ] |
| 5. Space exploration inspires people to learn about the universe and themselves. | [ ] | [ ] |
| 6. Space exploration diverts our attention from the real problems on Earth. | [ ] | [ ] |
| 7. Searching for life on other worlds is important. | [ ] | [ ] |


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| | Agree | Disagree |
|---|---|---|
| 8. We should solve the problems of people on Earth before exploring space. | [ ] | [ ] |
| 9. Space exploration helps us to find resources needed on Earth. | [ ] | [ ] |
| 10. Space exploration wastes money because it doesn't help people. | [ ] | [ ] |
| 11. Space exploration is dangerous because it could serve military purposes like orbiting weapons in space. | [ ] | [ ] |
| 12. Space exploration could save the human race by protecting Earth against asteroids and other space objects. | [ ] | [ ] |
| 13. Satellites are a waste of money. | [ ] | [ ] |
| 14. Learning how to care for astronauts in space helps doctors care for patients on Earth. | [ ] | [ ] |
| 15. Satellites help us by enabling better weather forecasts and improving communications. | [ ] | [ ] |
| 16. Space exploration provides useless information like water on Mars or of what the rings of Saturn are made. | [ ] | [ ] |
| 17. Instead of learning about life on other worlds, we should learn about life on Earth. | [ ] | [ ] |
| 18. Satellites provide information that enables us to protect our environment on Earth. | [ ] | [ ] |
| 19. Space exploration enables different nations to work together peacefully. | [ ] | [ ] |
| 20. Technology developed by space exploration could have been developed on Earth without expensive rockets. | [ ] | [ ] |

What do you really think? To find out, compare your answers using the table on the next page.



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Instructions: Color in one square for each answer in the columns to the right. Start at the bottom and work upward. Use the key below to determine which square to color in for each question.

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**Start Here**

1. Agree - column 1 square, Disagree - column 2 square
2. Agree - column 2 square, Disagree - column 1 square
3. Agree - column 2 square, Disagree - column 1 square
4. Agree - column 1 square, Disagree - column 2 square
5. Agree - column 1 square, Disagree - column 2 square
6. Agree - column 2 square, Disagree - column 1 square
7. Agree - column 1 square, Disagree - column 2 square
8. Agree - column 2 square, Disagree - column 1 square
9. Agree - column 1 square, Disagree - column 2 square
10. Agree - column 2 square, Disagree - column 1 square
11. Agree - column 2 square, Disagree - column 1 square
12. Agree - column 1 square, Disagree - column 2 square
13. Agree - column 2 square, Disagree - column 1 square
14. Agree - column 1 square, Disagree - column 2 square
15. Agree - column 1 square, Disagree - column 2 square
16. Agree - column 2 square, Disagree - column 1 square
17. Agree - column 2 square, Disagree - column 1 square
18. Agree - column 1 square, Disagree - column 2 square
19. Agree - column 1 square, Disagree - column 2 square
20. Agree - column 2 square, Disagree - column 1 square

How do you feel about the original statements?

"The United States Should Explore Space" or "The United States Should Stop Exploring Space"

The number of squares in each column express how you feel. More squares colored in for column 1 than column 2 indicates that you favor exploring space. More squares colored in for column 2 than column 1 means that you don't favor exploring space.



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# 5B) Launching Rockets

*Reach for the Stars*

### Time Needed

2 – 3 Sessions

### You Need This Stuff

*Per Launcher:*

- ½" PVC pipe (about 6 feet per launcher)
- 2x ½" PVC caps
- 2x ½" PVC tee connectors
- 1x ½" connector
- duct or masking tape

*Per Group:*

- 12" long ½" PVC pipe piece
- 2 liter soft drink bottle (have spares)

*Per Student:*

- copy paper
- clear tape
- scissors
- rulers
- metric tape measure or meter stick and marker
- copies of altitude tracker pattern on cardstock
- string
- large paper clips
- straws
- eye protection

### What It's About

To be an astronaut, you have to have a way of getting to outer space. Throughout history, people have dreamt of fantastic vehicles that could carry them on voyages to the Moon and stars. Thrones carried by tethered eagles, cannon shell spacecraft, sleighs propelled by giant springs, balloons, and sailing ships were all thought of as methods for space travel. None of these ideas ever got off the ground because early dreamers didn't understand what space was like or understand basic principles of force and motion.

Space is a vacuum and without air, balloons, sails, and wings don't work. Objects in space are much farther away from Earth than anyone believed and gravity was much stronger than anyone thought.

Today, one has to expend a great force just to travel 100 kilometers above Earth where outer space begins. To reach the Moon, 380,000 kilometers away, a far greater force has to be expended. Everything else in space is much farther away.

Genuine space travel did not become a possibility until the invention of the rocket. The first real rockets appeared about 1,000 years ago. No one knows for sure who invented them but it was probably Chinese fireworks makers. Rockets were initially used for fireworks but later became weapons of war. About 900 years after their invention, rockets had become large enough and powerful enough to reach outer space.

Today, rockets are still the only way of reaching space and traveling through it. Rocket science is explained by Isaac Newton's three laws of motion.

The first of these motion laws is also called the law of inertia. Inertia is a property of all objects that causes them to resist changes in motion. The greater the mass of an object, the greater its inertia.

> First Law: Objects at rest and objects in motion remain in their state of rest or motion unless acted upon by an unbalanced force.

The first law refers to unbalanced force. It means a force exerted on an object that is not balanced by an equal opposing force. Think of two people of equal size pushing on each other with equal force. The forces are balanced and no change in motion takes place. Replace one person with someone who is stronger and the forces become unbalanced. The two start moving in the direction of the stronger force.

When it comes to rockets, the first law means that the rocket will remain on a launch pad (all forces balanced) until an unbalanced force lifts it upward. The unbalanced force comes



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from the firing of its engines.

Second Law: Force is equal to mass times acceleration.

This law refers to the force produced by the rocket's engines. Rocket propellant is burned and the expanding hot gases accelerate out the engine nozzle. The more propellant burned, and the faster the gases (mass) produced by the burning is sent out of the nozzle (acceleration) the greater the force acting on the rocket.

Third Law: For every action there is an equal and opposite reaction.

The third law simply states that the action force produced by downward gases, escaping the engine nozzle, is accompanied by a reaction force that propels the rocket the other way.

To sum the three laws up. It takes an unbalanced force of sufficient strength to start a rocket moving (First Law). The magnitude of the force is determined by the mass of gases and the acceleration of the gases coming out of the engine (Second Law). The downward force from the engines produces an equal and opposite reaction that sends the rocket upward (Third law).

One more thing needs to be mentioned about rockets. There are many other factors affecting rocket flight. For example, rockets that are excessively heavy require a greater force to lift off. Rockets that are poorly designed will experience a great deal of friction (drag) with the atmosphere. This exerts a retarding force that impacts the rocket's flight. In other words, lightweight rockets that are streamlined to smoothly slip through the air, work best.

### What's The Question

How can astronauts travel to space?

### Before You Start

Construct a rocket launcher. See instructions.

### What To Do – Building the Launcher

The rocket launcher uses air as the propulsive gas. A tube arrangement connects to an empty soft drink bottle. When the bottle is stomped upon, air is forced through the tubes and launches the rocket.

PVC cutter

1. Obtain the launcher parts from a hardware store. The launcher requires 6 feet of 1/2" PVC pipe. The pipe usually comes in 10-foot lengths. A cutter tool is available or the tubes can be cut with a saw. The 10-foot pipe is enough PVC to make one launcher and four additional 12 inch pipes used as forms for constructing the rockets.
2. Cut the pipe to the lengths shown in the diagram towards the end of the activity.
3. Assemble the parts as shown. Friction will hold the parts together.
4. Tape a 2 liter bottle to the launcher as shown.
5. The middle tee connector permits the launch rod to be aimed straight up or tilted to either side.
6. After the bottle has been stomped upon, re-inflate it by blowing through the tubes.

Tip: Leave the label on the bottle. Have students aim their stomps for the label. The bottle is hard to re-inflate if students stomp on the bottle end. Tape a spare bottle to an extra pipe to make changing bottles quick and easy.

TIP: Have students assemble the launcher using the diagram. Make a copy of the diagram for students to follow. Have students slip the end of the 18" pipe a short distance into the bottle and wrap tape around the bottle neck to hold in place.



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### What To Do – Building the Rockets

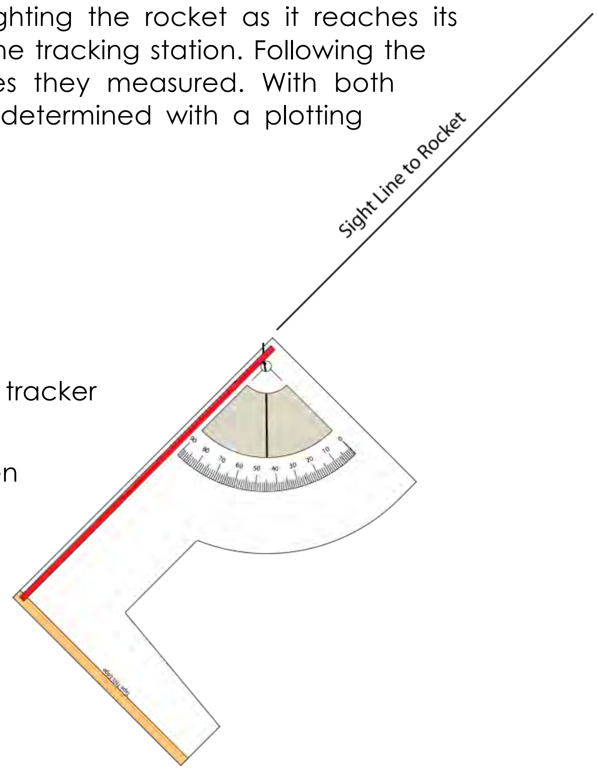
1. Hold a class discussion about rockets. Next, introduce the website http://legospace.com/en-us/Games/LegoSpaceLaunch.aspx and demonstrate creating a rocket. Discuss the process and have students work in teams and use the website to make their own rockets. Engage the students by launching a paper rocket. (See detailed instructions on the pages that follow.) Paper rockets can be safely launched in the classroom. Aim the launcher away students and do a short countdown. Strike the 2 liter bottle lightly.

   What are rockets? What do they do? How do they work? Have students list their ideas on the board. Tell your students that they each will be designing, building, and launching a rocket. Their rockets will go much faster than the one you demonstrated because they will be stomping on the bottle and exerting a much greater launch force. Their objective will be to have their rockets fly as high as possible. Tell them the height each rocket reaches will be measured and compared to its design.

2. Distribute the materials for constructing the rockets. Each group of students will share 1 tube to make their rockets on. Each student will receive one sheet of paper for their rocket. Building a rocket around the tube enables students to construct rockets that fit the launch rod on the launcher. Scissors and tape can be shared between small groups of students.
3. Provide students with the "Making a Rocket" instructions or project them on a screen.
4. If using colored paper, students can swap scraps from their rocket with other students that have different colors to make contrasting nose cones and fins.
5. Permit students to design their rocket fins in any way they want and in any number they want. They can place their fins anywhere on the rocket.
6. Other than checking to see that the rocket tubes slide easily on the launch rod, do not offer any suggestions or help to the students. Students will evaluate their own rockets based on flight results and make any modifications they think necessary.

### What To Do – Making the Altitude Tracker and Setting Up Tracking Stations

Determining the maximum altitude the rockets reach requires two altitude trackers and two tracking stations, each 30 meters in opposite directions from the launch site. Altitude trackers are protractor quadrants with a plum weight on a string. Sighting the rocket as it reaches its maximum altitude provides an angle measurement from the tracking station. Following the launch, each tracking station should call out the angles they measured. With both measurements, the altitude the rocket reached can be determined with a plotting board.




1. Print the altitude tracker pattern on cardstock paper.
2. Cut out the window.
3. Fold the tracker in half and tape the edge indicated.
4. Use a hole punch and punch a hole at the apex of the tracker quadrant. Go through both layers of the paper.
5. Tie a string through the holes so that the string is between the two paper layers.
6. Tie a paperclip to the other string end just below the window.
7. Tape or glue a sighting straw where shown. The tracker is finished.



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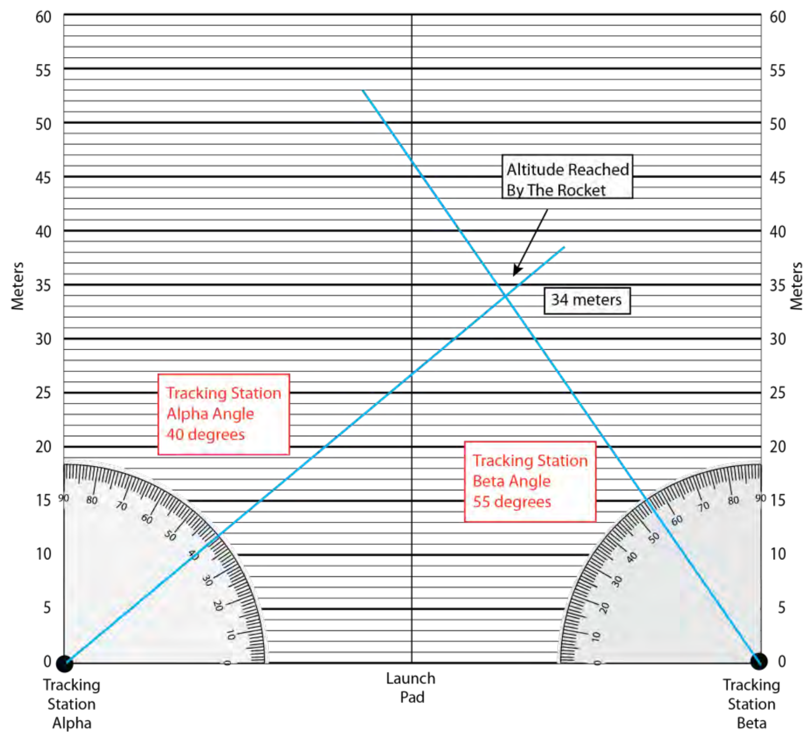
8. To use the tracker, sight the rocket along the straw. When the rocket reaches its maximum altitude, squeeze the two paper layers together to hold the paperclip in its position. The degree marking where the string crosses the window is the angle of the rocket as seen from the tracking station.

### What To Do – Plotting Rocket Altitude




For every launch, a minimum of two measurements must be taken, one from each of the two tracking stations. Each tracking station will need at least one student tracking the launch. More than one student can measure the launch angle at each station and their results can be averaged for greater accuracy.

Have students work out a system for plotting rocket altitude.

- The trackers need to be alert and ready to take measurements. How will the trackers be alerted that the launch is about to take place?
- The measurements need to be given to the rocketeer that launched the rocket. How will the trackers communicate their measurements to the rocketeer?
- How will the trackers rotate their jobs so all get experience tracking and all get to launch their rockets?

Plotting Altitude

1. Tracking stations Alpha and Beta take the measurements and give them to the rocketeer.
2. The rocketeer records the measurements for his or her rocket flight on the Altitude Plotting Page.
3. Using a pencil and the straight edge of a ruler, a line is drawn from the dot on the lower corner for the Tracking Station Alpha across the protractor at the right angle and across the page. A second line is drawn from Tracking Station Beta across the protractor and across the page.
4. The intersection point of the two line is the altitude the rocket reached. Read the altitude from the scales on the sides of the page.

### What To Do – Launch Day

1. Organize students into launch teams of 5 or 6 students. Teams will perform different jobs at different times.
2. Have teams lay out the base line for the two tracking stations and launch site. The base line should be 60 meters long and parallel to the wind direction. Designate one tracking station Alpha and the other Beta. Place the launch site at the midpoint between the tracking stations.
3. Unless launching or tracking rockets, teams should remain in the viewing site.
4. Students launching rockets must wear eye protection.
5. Provide scissors, tape, and extra paper for students to modify their rockets between launches.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6. Permit students to launch their rockets at least three times.

### What To Do – Launch Plan

1. Have all students launch their rockets once to familiarize themselves with the launch procedures. Be sure students observe the flight performance of their rockets.

2. Hold a short debriefing session where students describe their flights. Challenge students to measure the altitude their rockets reach. Assign teams to each tracking station to measure the angle to the highest point reached by each rocket. Assign the remaining teams to the launch site.

3. When all rockets for a particular team have launched, have the two tracking teams combine their angle measurements so that the altitudes reached can be determined.

4. Rotate the teams so that every team gets a chance to launch their rockets and track the rockets of other students.

5. After all rockets have been launched again, permit students to modify their rockets to improve their performance. (Note: The greatest improvements in the rockets have to do with the sizes of the fins. Large fins and crooked fins produce more drag, reducing flight performance.)

### Wrapping Up

- Hold a debriefing session following the rocket launch. Have students report on the altitudes their rockets reached. Did they do anything to modify their rockets for their second or third flights? How did the changes affect their flight performance? Why?

### Extras

- Challenge students to redesign their rockets so that they can carry a payload or have a parachute or streamer that deploys in flight.
- Website to check out: European Space Agency Launchers:
  http://www.esa.int/esaKIDSen/SEMYWIXJD1E_Technology_0.html


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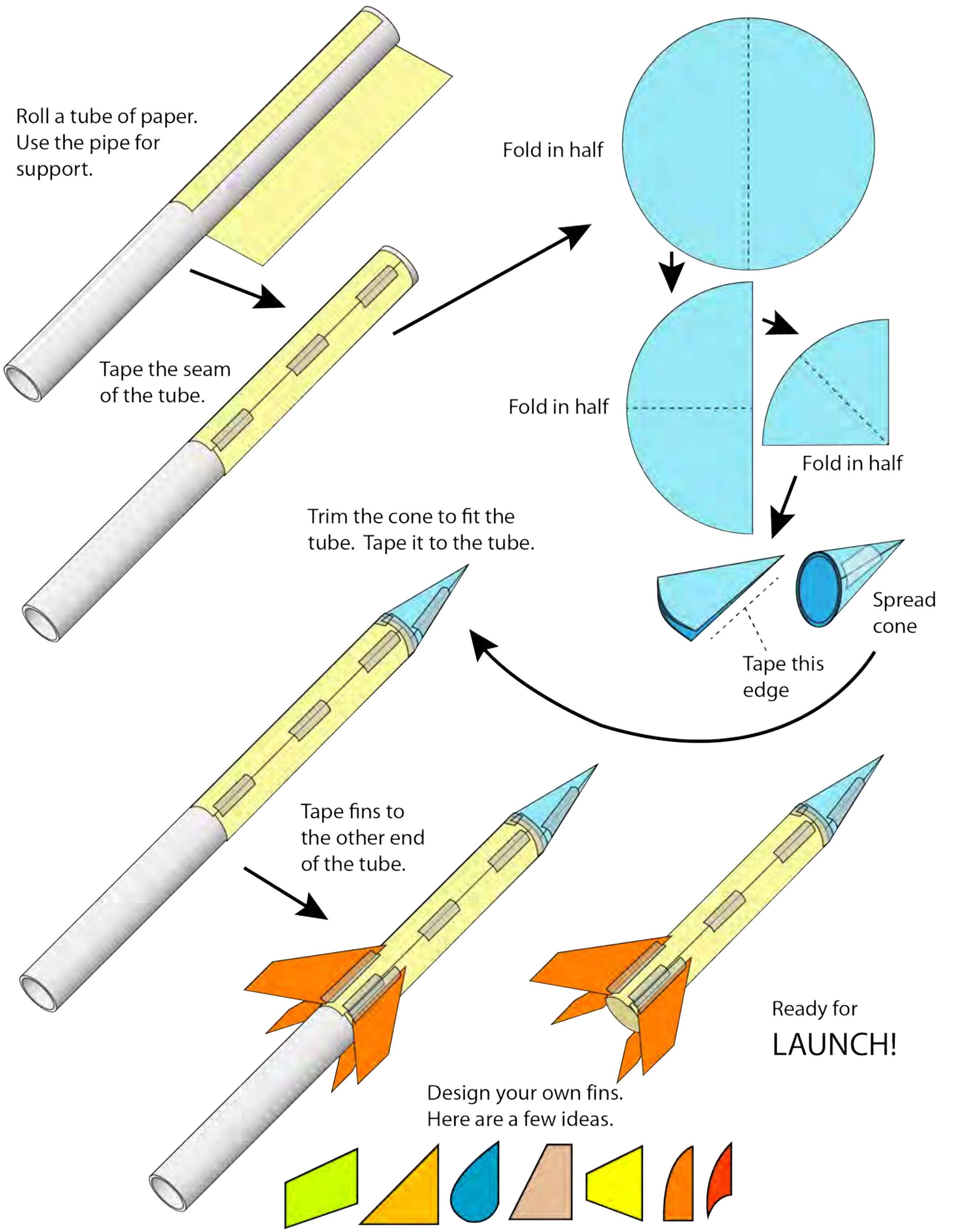
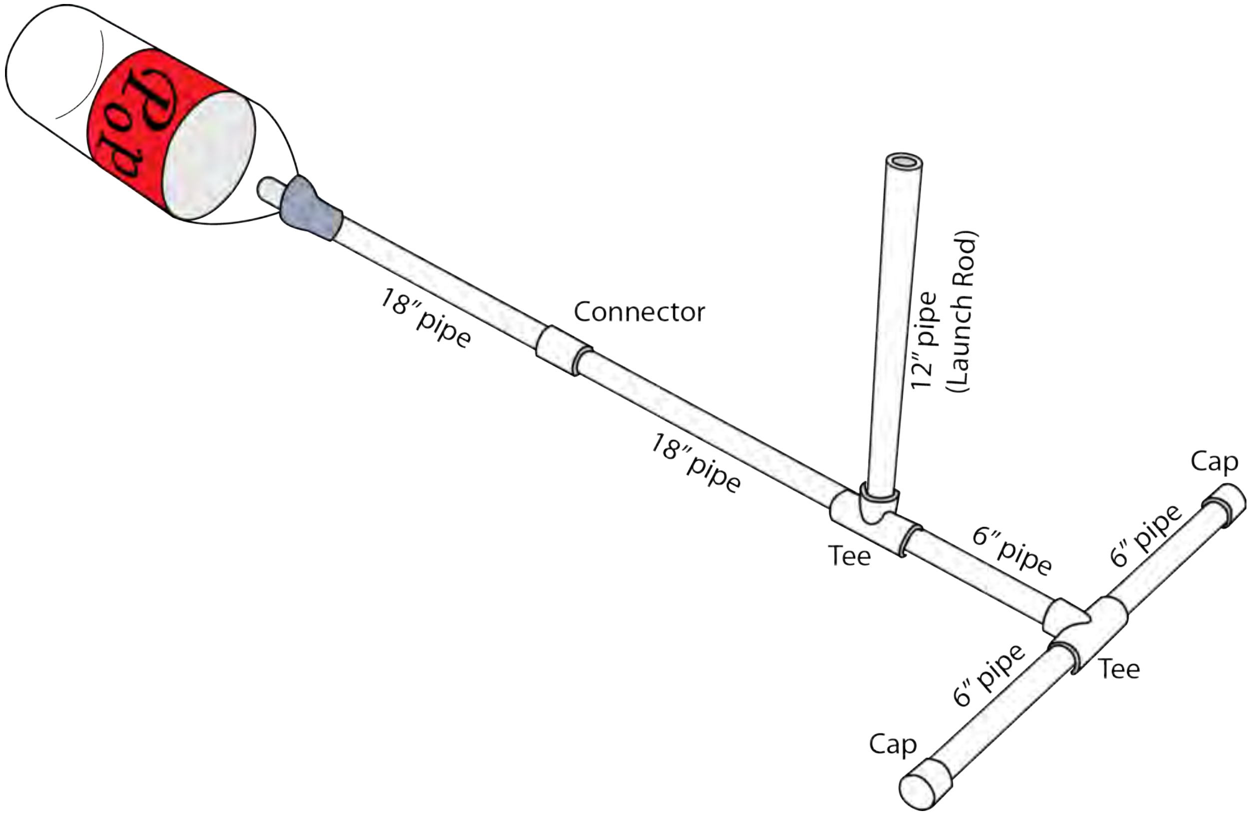
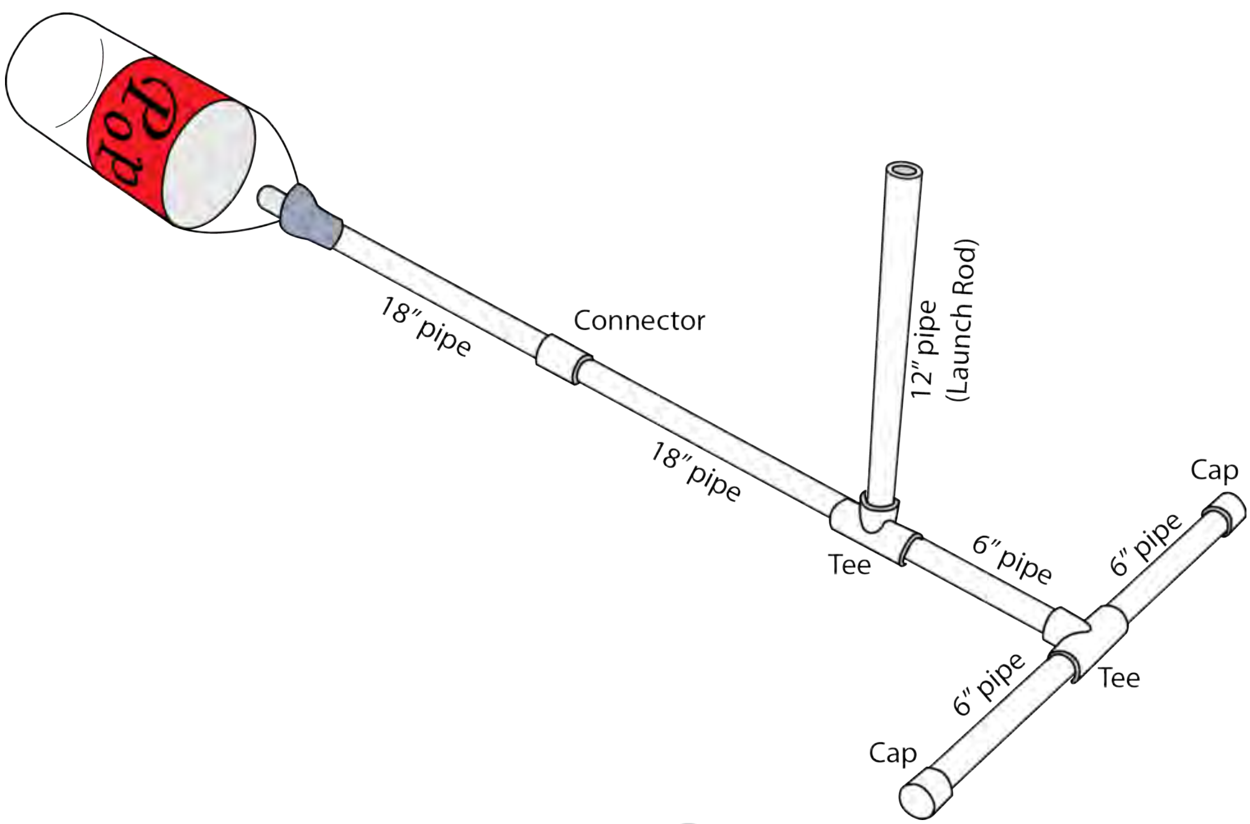
# Make A Rocket



## Rocket Launcher Construction





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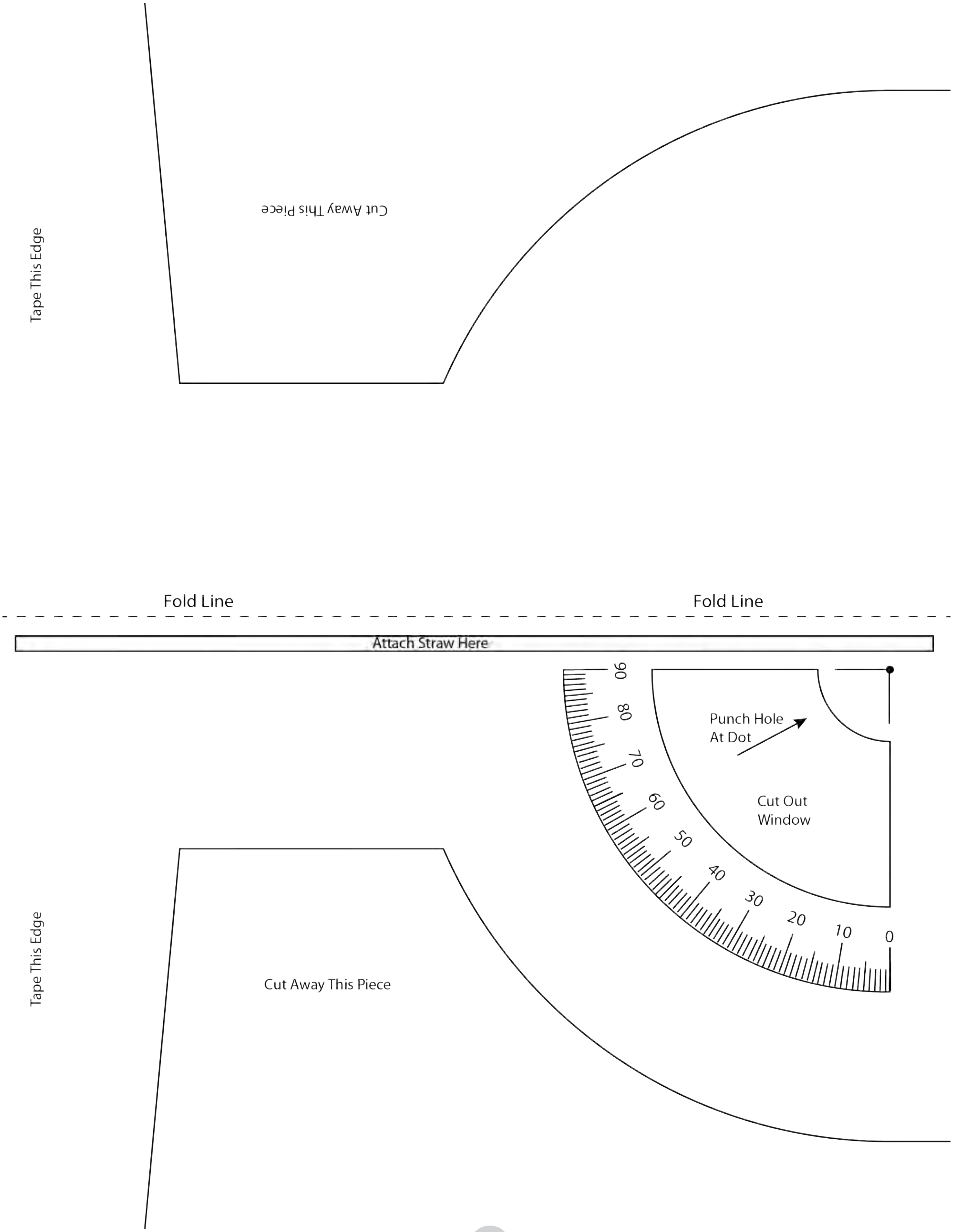
## Altitude Tracker Template





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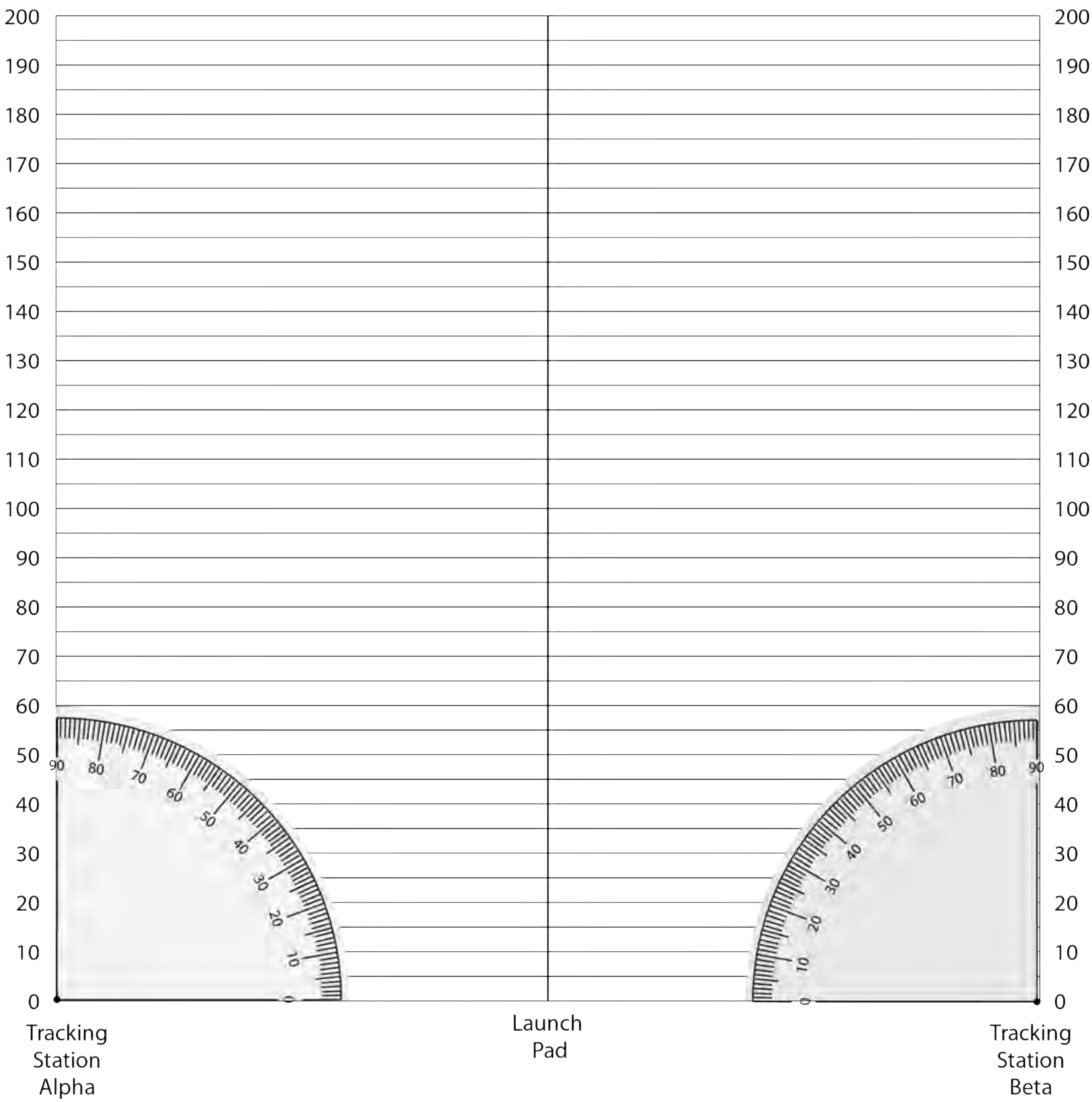
**Plotting Altitude**



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# 5C) Reentry Capsule

## *A Spinoff from Space Exploration*

**Time Needed**
2 Sessions

**You Need This Stuff**
<u>*Per teams of 2 or 3 students*</u>
- Cotton string (2 yards)
- 1 9-ounce clear plastic cup
- Masking tape (about 2 feet)
- Styrofoam food tray
- 1 Raw egg
- Scissors

<u>For all teams to share</u>
- Paper punch (can be shared between teams)
- Plastic bag, sealable
- Packing materials – cotton or paper towel
- Kiddy Swimming Pool
- Water
- Package of small thin trashcan bags

Tip: The styrofoam tray covers the bottom of the capsule. One tray can be divided into several squares for multiple teams.

Orion capsule during a parachute drop test.

### What It's About

OK, so we get to space. How do we get back? That's a question that should be answered before volunteering for a space mission.

There are a couple of ways to get back from space. You can land on land or you can land on water. It's easier to land on water because water is softer than land and Earth's surface is about 3/4 water and 1/4 land. It is hard to miss the water.

Still, land landings have been done many times. All Space Shuttle missions landed on land (1981-2011). The spacecraft, called the orbiter, was shaped like a delta wing (triangular shape) aircraft. It glided to the ground and landed on a long runway. Space capsules launched by Russia also land on land. They come down by parachute and moments before touchdown, a blast from small rocket engines below the capsule, cushions the impact. Still, its a pretty good thump. Chinese space capsules also return that way.

Space capsules from the American Mercury, Gemini, and Apollo missions (1961-1975) all landed in either the Atlantic or Pacific Oceans. They descended by parachute and splashed down in water for a relatively soft landing. The capsules were designed to float and had inflatable bags for extra buoyancy just in case.

The new spacecraft the National Aeronautics and Space Administration is building for the future is also a capsule. It has a bell shape much like the Apollo Capsule but it is much larger. It too will splash down in the ocean.

All space vehicles, upon their return to Earth, have to first reenter Earth's atmosphere. They do so at a speed of around 32,000 kilometers per hour (20,000 mph). Friction with the atmosphere raises the temperature of the spacecraft's skin several thousand degrees. Special materials are needed to withstand this temperature and capsules are usually blunt in shape to distribute the pressures and heat generated. Pointed space capsules reach extreme temperatures and are likely to burn up.

As the air thickens and speed and temperature drops, space capsules pop out drogue chutes. These are small parachutes that stabilize the capsule so they don't tumble. Next, out pops the large parachutes (usually three) that bring the capsule to the ocean surface.


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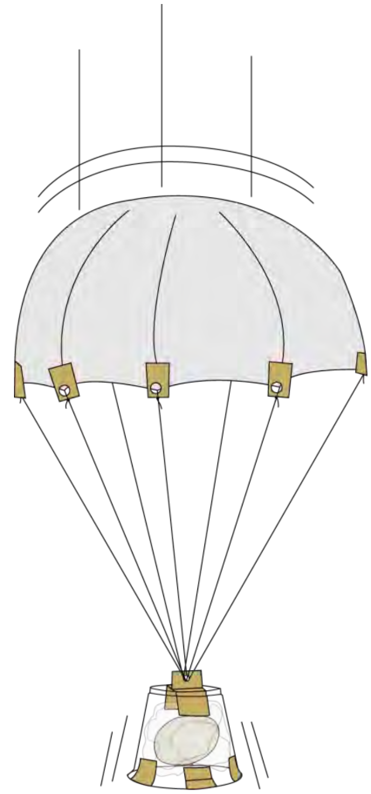
Just in case things really go wrong and the capsule ends up on land or there are parachute failures, the capsules have lots of cushioning inside to protect the crew.



### What's The Question

How do I get back from space?

### Before You Start

Collect all the materials. Locate a place to do drop tests. It can be a second floor window, rooftop, balcony, or just a high-ceiling room like a gym or cafeteria.

### What To Do

1. Download the following NASA video to your computer and project for your students.

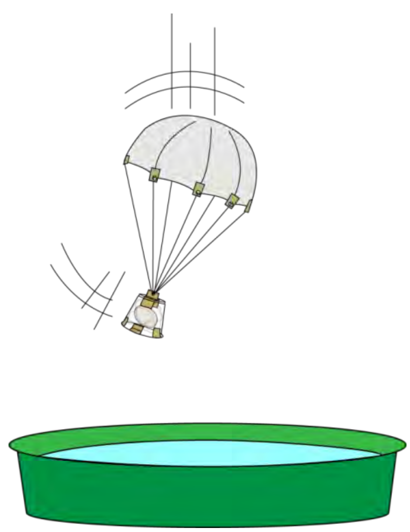
   http://www.nasa.gov/multimedia/videogallery/index.html?media_id=114569411#

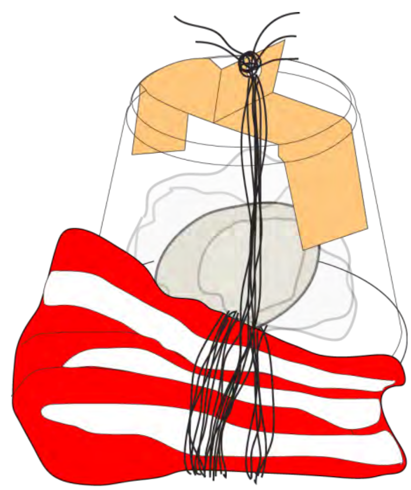
   Ask your students if they have ever seen a something like this in the night sky. *What is it? It is a meteor or shooting star*. Meteors are bits of space rock that fall towards Earth at very high speeds and burn up because of friction with the atmosphere. As the rock is heated, it creates a bright streak of light that we can see from Earth. Larger meteors may even explode into a shower of sparks.

   Ask your students to imagine being astronauts returning from space. They could burn up too but spacecraft are protected by heat shields. But burning isn't the only danger they face on their return from space. Their spacecraft have to slow from about 32,000 kilometers per hour to about 35 kilometers per hour when they reach the surface of Earth. Landing at 35 kilometers per hour would feel like a car crash unless the craft lands in the ocean. Water will help cushion the impact.

2. Organize your students into teams of three. Challenge them with an important job. NASA is building a new spacecraft called Orion. It is bell-shaped and will ride on top of new rockets being built to send astronauts to the International Space Station, to the Moon, and eventually to Mars. The spacecraft will need parachutes to bring the capsule safely to a water landing. It will be up to the teams to first build a capsule with a dummy test subject inside. Then, they will design, construct, and test their parachutes to see how effective they are in bringing astronauts safely back to Earth. Provide each team with an instruction sheet.

3. When all teams are ready with their capsules, prepare the drop zone. For the first drop, you'll only need an open space. For the second drop set the kiddy pool in the drop zone below a second floor window, balcony, or some other area where the capsules can be dropped from about 4 to 5 meters (about 12 - 15 feet). Fill the pool with water. Have teams select one member to do the dropping. That person's objective is to have the capsule splash down in the pool. During the drop, other members become the observers. If





Parachute folded and ready to toss



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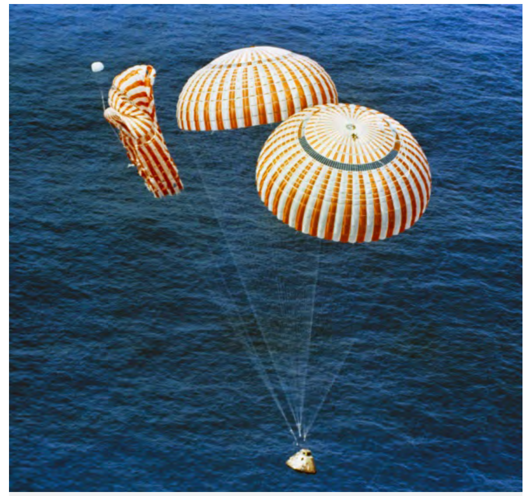
the capsule and egg survives the landing, more tests can be run with other team members doing the dropping.

Tip: If there isn't time to run the drop tests, collect the spacecraft and parachutes and place them in a refrigerator until the next meeting.

Tip: If you don't have a high place to drop the capsule, the capsule can be tossed upward into the air. The parachute will have to be folded and wrapped in the shroud lines to make this possible. See illustration of a folded parachute on the next page.



Apollo 15 Moon mission capsule during descent. One parachute failed on the way down.

### Wrapping Up

- Hold a mission debriefing. Have each team describe their strategy designing their parachute. Have them report on the success or failure of their drops. Did the egg astronaut survive? Would they be willing to ride a real spacecraft with their parachute and cushioning system design?

### Extras

- Ask students the following questions: *Now that you have designed and tested a new parachute for the Orion spacecraft, what things might you apply your new knowledge about parachutes and your skills in making them? Can you think of other uses for your parachute?*
- Talk about spinoff technology with your students. Spinoff is the term NASA uses to identify technologies in the marketplace that had their origin in the exploration of the atmosphere and of space. The research leading to hardware and other systems needed for flight often have applications elsewhere. When a commercial product spins off from aeronautics and space research, it is called a spinoff.
- Hold a discussion about the parachutes students made for the Orion capsule. What other uses can they think for it. You may have to stimulate their ideas by offering a couple of possibilities:
    - Rescue system for light aircraft that experience power failures
    - Escape system for people in skyscrapers when there is a fire
    - Rapid stopping system to prevent car crashes

  Note: NASA has actually helped develop a parachute system for light aircraft. The system has saved the lives of more than 200 people who were riding in airplanes that would have crashed without the parachute. You can learn about this system at:
  http://www.nasa.gov/offices/oct/partnership/hallmarks-videogallery.html?media_id=36980671

**About the NASA Spinoff Home Page**

Access the NASA Spinoff Home Page at the following address:

http://spinoff.nasa.gov/

Click on the "View Feature" button for NASA@Home and City. The button should be located in the upper right corner of the page. You can also access NASA@Home and City directly at this address:

http://www.nasa.gov/externalflash/nasacity/index2.htm

Two floating hemispheres will appear. One will show a home and yard. The other will show a city. Clicking on one picture or the other will bring up a more detailed version of the picture with many clickable features. Arrows permit rotating the hemisphere to see the other side. Each side features different parts of home or city living. Selecting any of these parts (E.G., City – Air Travel) will provide more buttons that each relate to a particular spinoff technology that has affected our lives. Selecting any of these technologies opens a brief summary video explaining the technology and links to detailed explanations of the science and technology involved.

- Have students explore the NASA Spinoff Home Page.
- Ask students, how might life be different with out some specific spinoffs? Sample: Braces

# Orion Spacecraft Parachute Challenge

**Your mission is to design a parachute recovery system for an Orion spacecraft to permit safe ocean landings. Working as a team you will:**

a. Construct a model Orion spacecraft.
b. Design and construct a parachute landing system (1 or more parachutes) to safely land the model capsule.
c. Test and consider the parachute design, adjust and/or redesign as needed.
d. Add the "Dummy Astronaut" and retest your design.

**Materials**

Plastic cup
Styrofoam disk
masking tape
small sealable plastic bag
egg
cotton or paper towels

Steps:

**Building the Space Capsule**

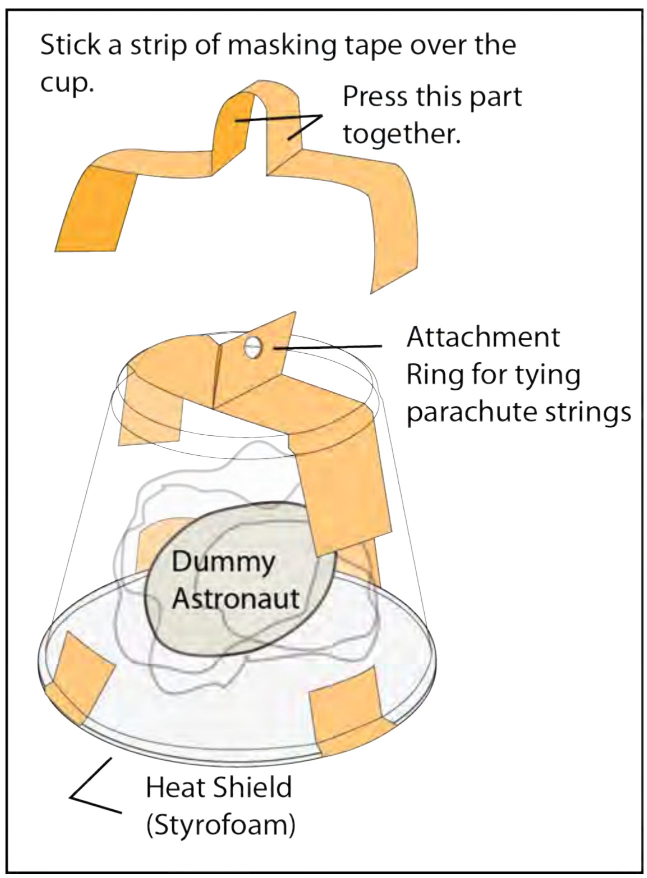
1. Turn the cup upside down and trace the rim on a flat piece of Styrofoam
2. Cut the circle out of the Styrofoam.
3. Fill the cup with padding material.
4. Using short pieces of tape, tape the Styrofoam circle to the capsule.
5. Make a parachute attachment ring at the top of the capsule from masking tape. First stretch a piece of tape across the top and double it in the middle to make an upright tab. Then punch a hole through the tab with a hole punch and use this hole to tie parachute lines.

**Designing and Making the Parachutes**

1. Decide on the size, shape and number of parachutes you think the capsule will need to land safely.
2. Draw and label your design in your journal and explain why you think it will work.
3. Use the plastic bags to make your parachute/s. Cut out your chosen shapes.
4. Use tape to attach the strings to your parachute/s and then fasten the parachute/s to the capsule. In your journal explain you "string" choices, including location, number, length and size.
5. The Orion space capsule is ready for a trial run.
6. Wait for instructions from your teacher.

**Redesign or Adjust?**

1. Consider how your parachute/s functioned. Do you need any redesign or adjustments before re-launching considering the addition of the payload (egg) to the capsule? Ask, Do you think the parachutes will perform as before. Discuss possibilities.
2. Complete any redesigns to the parachutes.
3. Place the egg in a sealed plastic bag. Then place it in the capsule tape securely closed.
4. Again, wait for instruction from your teacher.



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# 5D) Working in Space

## *Glove Box*

### Time Needed
2 Sessions

### You Need This Stuff
<u>*Per Group*</u>

- Copy machine paper box with lid and hand holes pre-cut (see instructions)
- Razor knife for cutting holes
- Pair of long kitchen plastic gloves
- 4 Plastic cups, 18-ounce
- Masking tape
- Aluminum foil
- Plastic kitchen wrap
- Clear plastic tape
- 2 large #64 rubber bands
- 1 Alka Seltzer tablet
- 16 ounce plastic bottle with lid
- Graduated cylinder or beaker
- funnel
- 250 ml cooking oil
- 125 ml water
- small bottle food coloring
- foil pie pan or another container to catch any spillover
- copy of "How Dense Is It?"
- flashlight (optional)

### What It's About

The microgravity environment of the International Space Station (ISS) is a unique place to conduct scientific research. The absence of gravity's effects permits scientists to conduct experiments into the fundamental nature of matter. On Earth, gravity tends to mask subtle processes. For example, proteins have very complex crystalline structures. When crystals are grown on Earth, they are subject to the effects of gravity, such as convection currents that can distort the structure. In the microgravity environment of space, convection currents, do not exist. Scientists are able to grow large protein crystals undistorted by gravity. Back on Earth, the scientists study the crystals and use the information gained to create new medicines.

Even though it provides new opportunities, the ISS offers scientists new challenges to typical labs and research methods. Objects behave differently in microgravity than they do on Earth. Imagine transferring a liquid from one beaker to another. Gravity makes the transfer easy. On the ISS, liquids don't pour. Chemicals don't automatically mix when combined. Laboratory apparatus doesn't stay put when set down. Small particles can get into eyes and are easily inhaled. Spills go everywhere in three dimensions!

Scientists have to make accommodations to their research techniques and equipment when doing their research in microgravity. One important accommodation in space is a glove box. While glove boxes can be very complicated, their basic design is relatively simple. Experiments are placed inside the glove box and the researcher looks at them through windows. The researcher places his or her hands through two holes in the side of the glove box and directly into rubber gloves. Once the experiment is inside the box, it is completely sealed from the ISS. The researcher handles the experiment equipment without making any direct contact with it. Any mishaps are easily contained by the box.

Astronaut Kenneth D. Bowersox using the portable glove box on the International Space Station

ISS006E07275

### What's The Question

How do astronauts do scientific experiments in the microgravity environment of the International Space Station?

### Before You Start

Make sure students understand the concept of microgravity. Do the Making Microgravity activity prior to this activity.



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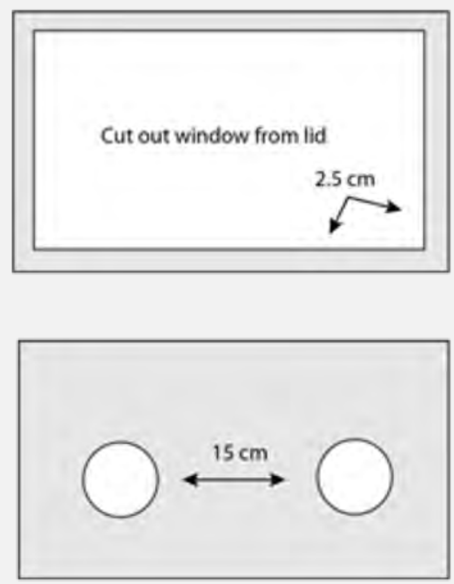
Prepare the boxes by cutting the holes. It is important for the hand holes to be the right size. Larger or smaller and the gloves will not fit.

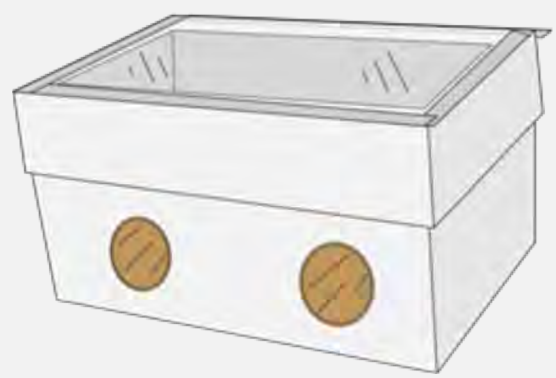
**Glovebox Teacher Preparation**

Using a razor blade utility knife, cut two hand holes in the side of the boxes. The holes should be just smaller than the rim diameter of the plastic cups. If cut the correct size, the cups will fit through the hole but the rim will stop them from going all the way through. Cut one of the cups four centimeters below the rim to use for tracing. Trace inside the rim for each hand hole. The holes should be about 15 centimeters apart. Cut a rectangular window in the box lid. Measure 2.5 centimeters in from the four edges to outline the window for cutting.

Glovebox Cutting Instructions




Assembled Glovebox



## What To Do

Part 1

1. Organize your students into research teams of three. Explain to the teams the value of microgravity based research and some of the limitations. Tell them that they will be creating a glove box and conducting a scientific investigation of their own design inside the box just as astronauts do in space.
2. Have teams assemble their own gloves and install them into the prepared glove boxes, using the assembly diagram. Have teams cover the lid window with clear plastic wrap and tape. Also have them line the inside of their glove boxes with aluminum foil and tape to protect against liquid spills. This should be done prior to installing the gloves.

Part 2 - States of Matter Investigation

Description: Astronauts on the International Space Station (ISS) will combine various liquids and solids in an investigation on the states of matter. How will these states behave in the microgravity environment on the ISS? Prior to flight, researchers will conduct this investigation in a glovebox. Their purpose is to collect data on the interactions that occur in the investigation in a one-gravity environment and predict what may happen in space and to identify techniques for making the flight investigation successful.

Note: Eye protection not needed because the glovebox will serve this purpose.

1. To begin the second session, Ask, What do you know about density of different substances? Given oil and water which will sink and which will float? Discuss. Explain that they will be investigating the behavior of these two liquids when a third substance, Alka Seltzer, is added. Alka Seltzer is an effervescent antacid used to neutralize stomach acid. It is a combination of sodium bicarbonate, potassium bicarbonate, and anhydrous citric acid. Ask, how will the Alka Seltzer behave in the oil and water. Have students record their predictions. They can draw before and after pictures.
2. Explain that they will be performing the investigation in the glovebox to simulate working in space. Ask, *What might be the differences in working with liquids on Earth and in space?* Discuss how liquids in microgravity float around and can be difficult to contain.
3. Have students gather materials from a central location.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4. Give students directions for performing the experiment. Place all materials in the glovebox.

Ronald M. Sega uses a glove box on Space Shuttle Mission STS-76.

   1) Use funnel to pour 250 ml cooking oil into the soda bottle.
   2) Next, add 125 ml water, observe. What happens to the water?
   3) Place 10 drops of food coloring into the bottle. Observe how the substances mix.
   4) Break the Alka-Seltzer tablet into 4 pieces.
   5) Drop one of the pieces of Alka-Seltzer into the oil and water mixture. Observe. Continue to add pieces as you observe.
   6) Place your bottle on a flashlight and turn the room lights off.
   7) When you have used up all the Alka-Seltzer, and the reaction has ended, Place the lid on the soda bottle. You may want to make other observations as you shake the sealed bottle.
   8) Remove all materials from the glove box and return to a central location.

5. After all the groups have completed the investigation, have them share what happened. What did each team learn about the experiment? Could they invent better ways of doing things? How could the experiment be done in microgravity?

   Use the following questions as a guide to their discussion.

   - What happened when the tablet encountered the colored water?
   - Where did the bubbles come from?
   - How did the bubbles look?
   - Were there any other motions in the liquids?
   - What states of matter did you observe interacting?
   - Will the same equipment work in the microgravity environment on the ISS?
   - If no, how would you change it?
   - Do you think the oil and water will separate in microgravity like they did on Earth? Do you think the tablet will sink in microgravity?
   - Will the bubbles rise?
   - How can you keep the liquids from escaping the cylinder in microgravity?
   - Based on your investigation, how would you do the same experiment in space?
   - Explain your plans. Draw pictures.

   Science Note: Under normal conditions, molecules of water do not mix with molecules of oil. When you pour the water and oil into the bottle the water sinks to the bottom and the oil floats to the top, just like an oil spill from a ship on the ocean. This behavior is due to differences in polarity of oil and water molecules and differences in their density. If you shake the bottle, the oil breaks up into small drops dispersed through the water, but it does not actually mix with the water. Shortly, all the oil drops will rise to the top of the water to form a floating layer. Food coloring is mostly water and it easily mixes with other water to dye it but it does not mix with or dye the oil. Alka Seltzer is an effervescent antacid used to neutralize stomach acid. It is a combination of sodium bicarbonate, potassium bicarbonate, and anhydrous citric acid. Drop the Alka-Seltzer tablet into oil and the oil will coat it but not dissolve it. Drop the tablet into water and it dissolves in a chemical reaction that produces tiny



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bubbles of carbon dioxide gas that attach themselves to small balls of colored water. This causes them to quickly float up to the surface. The bubbles resemble the globs of wax that rise in lava lamps. When the bubbles pop, the colored water sinks back to the bottom of the bottle.

6. Ask students, how might this investigation be different in space? Would the substance mix? How might they behave?

Adapted from http://www.stevespanglerscience.com/experiments

### Wrapping Up

Hold a group debriefing session with the teams. Have each team describe the investigation they performed inside their glove box. Make sure students understand that glove boxes are an essential too for space research as matter of convenience and safety. Show pictures of astronauts using glove boxes on the International Space Station.

### Extras

- Construct a larger glove box with two sets of gloves opposite each other. Have students work together with a project inside the glove box.
- After all investigations have been conducted, challenge the teams with a competition. Using LEGOs, K'Nex, or other assembly toys, challenge each team to assemble a structure. Prepare sets of the same pieces for each team and reserve one set for the example. Assemble a small structure consisting of 5 pieces. Place it inside an open box or behind a partition. Have each team designate one student to work in the glove box. Designate a second student to be the communicator and a third student as the observer.

  Start the competition by inviting the observer students to look at the structure you assembled. The observers can look as long as they like. They then go to a corner of the room, away from the glove boxes and describe the structure to their team's communicator. The communicator then goes to glove box team member and instructs him or her how to build the structure. The communicator relays questions back to the observer and carries new instructions.

  Switch roles and repeat the competition with a new structure using two additional pieces. Do the competition once more so that all students get to do each job.

European astronaut Pedro Duque (Spain) works with equipment in a large glove box on the International Space Station.

ISS007E17880



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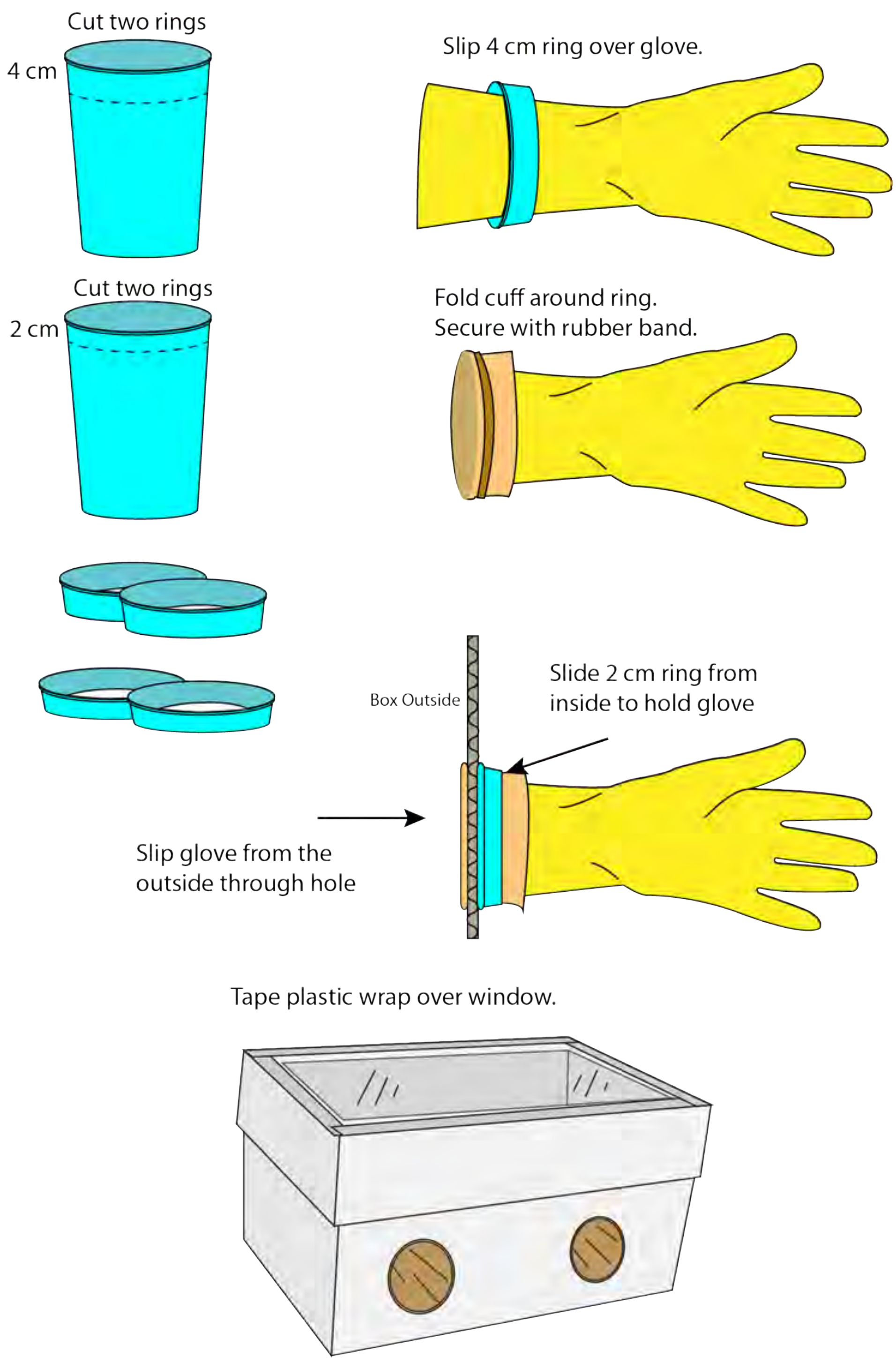
# Glovebox Assembly Diagram





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## How Dense Is It?

**Directions for investigation in the Glovebox:**

1. Gather materials and place in glovebox.
2. Use funnel to pour 250 ml cooking oil into the soda bottle.
3. Next, add 125 ml water, observe. What happens to the water?
4. Place 10 drops of food coloring into the bottle. Observe how the substances mix.
5. Break the Alka-Seltzer tablet into 4 or more pieces.
6. Drop one of the pieces of Alka-Seltzer into the oil and water mixture. Observe. Continue to add pieces as you observe.
7. Place your bottle on a flashlight and turn the room lights off. (optional)
    - Does it remind you of anything?
8. When you have used up all the Alka-Seltzer, and the reaction has ended, Place the lid on the soda bottle. You may wan to make other observations as you shake the sealed bottle
9. Remove all materials from the glove box and return to a central location.

Use this box to record observations or draw what was observed.

| Use this box to record observations or draw what was observed. |
|---|
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# 5E) Interplanetary Travel

## *Mars or Bust*

### Time Needed
1 – 2 Sessions

### You Need This Stuff
<u>*Per Class*</u>
- string (about 40 meters total)
- Meter stick
- Black marker pen
- Basketball or beach ball
- Small bell (optional)

### What It's About

In the 1930s, farm families escaping the drought in Oklahoma often wrote signs on the side of their trucks proclaiming "California or Bust." It wasn't the first time such signs were used. Miners and other pioneers on their way to California in the 1800s put the signs on their covered wagons. More recently, the crew of the Gemini 5 mission sought a new space record of 8 days in space. The mission, taking place in 1965, had the motto "Eight Days or Bust." A similar motto may someday be used for the first manned missions to Mars - "Mars or Bust." Certainly, traveling to Mars will be far more difficult that any of the travels of the past. At their very closest points in their orbits (the same side of the Sun), Mars is 54 million kilometers from Earth. Since both planets have independent orbits, most of the time they are considerably farther away. At their farthest points (on opposite sides of the Sun) they are 102 million kilometers apart. Clearly, a manned mission to Mars is a big deal.

Unlike travelers to California, who could stop along the way to get food and fuel (if driving), everything needed by future Martian explorers will have to be packed on board at the start. That means food, water, oxygen, toilet paper, clothing, medical supplies, fuel, etc. go along with the crew and no more resources can be obtained until Mars is reached (Mars doesn't have stores but it does have raw materials that can be processed into things that are needed).

How many supplies to be taken on a Mars mission depends upon two factors. First, how may crew members are going. More crew needs more food, etc. Second, how long will it take to get there? Shorter trips, fewer supplies needed. Unfortunately, basic physics sets some rules of what can be done.

Rule 1: Earth and Mars travel around the Sun in elliptical orbits at different speeds and distances. You don't aim for Mars where it is today. You aim for where Mars will be when you get there.

Rule 2: While still on Earth, and thanks to Earth's motion around the Sun, you are actually traveling about 110,000 kilometers per hour just standing still. You have to factor that motion into the course you set for Mars.

Rule 3: The Sun's gravity will cause your spaceship to travel in a curved line. You cannot just launch straight out toward Mars. (Try this: Try walking in a straight line while someone is pushing on your right shoulder.)

Rule 4: To take advantage of Earth's orbital velocity, launches to Mars must take place in the same direction Earth is moving. The extra velocity produced by the rocket will gradually send the spacecraft further and further from the Sun in a spiraling path until the orbit of Mars is reached.

Rule 5: The fastest rockets to date can achieve a velocity of about 60,000 kilometers per hour. However, the spacecraft they carry are very small. A spacecraft large enough to carry people to Mars at that speed has to be more powerful than any rocket available today. Current rockets for a Mars mission will be much slower.

In this activity, a model of the orbits of Earth and Mars will be set up and students will take on the roles of Earth and a spacecraft and Mars and try to successfully arrange a rendezvous of the spacecraft with Mars.

### What's The Question

What is the best course for traveling to Mars?

### Before You Start

Make two circles and mark them to represent the orbits of Earth and Mars. Cut one piece of string 15.6 meters long and join it end-to-end to make a circle. Cut the second piece 23 meters long and join it end-to-end. The smaller circle represents the orbit of Earth. Use a black marker or masking tape to place 12 equally spaced marks on the line. The distance between the marks should be 1.3 meters. Each mark represents one month of Earth's orbit. Using the larger circle, place 23 marks each 1 meter apart. These marks represents the months in Mars's orbit.

### What To Do

1. Find an open space and place the basketball or beach ball in the middle to represent the Sun. Stretch the Earth orbit rope circle around the Sun and then the larger Mars orbit rope circle around the Earth orbit. Explain to your students that the marks on each orbit rope represent the movement of Earth and Mars in 1 month Earth months intervals. Earth travels at a speed of about 110,000 kilometers per hour around the Sun. Mars is a bit slower, 86,870 kilometers per hour. Therefore, the spacing between month marks for Mars is smaller than the spacing for Earth.
2. Pick two students to represent Earth and Mars. Have the Earth student straddle the Earth orbit rope at one of the marks. Have the Mars student straddle the Mars orbit rope at one of the marks. Have the students step to the next marks on their ropes when they hear the bell or click. The bell or click will mean that one month has passed and both planets have moved to new places. Have them step in a counterclockwise direction.
3. Every 3 seconds, ring the bell or clap to advance the planets around the Sun. Continue the ringing or clapping for about 2 minutes. Earth will make just over 3 complete orbits of the Sun. Mars will make about 2 complete orbits. Repeat with two other students to permit the original Earth and Mars students a chance to observe the action.
4. As the two new students representing the planets orbit the Sun, tell the student representing Earth that he or she is now a spacecraft for a Mars mission. It will be up to him or her to decide when and step outside Earth's orbit in a spiral path to rendezvous with Mars. The student should take one step for every bell ring or clap. The step should be the same length that was taken during orbiting. The spacecraft should follow the same general direction as the orbit of Earth but move outward a little bit for each step. No right angle turns!
5. Hold a class discussion. Have students share their observations in particular about the changing positions of Earth and Mars. A spacecraft to Mars will be launched from Earth in the same direction Earth is traveling around the Sun to take advantage of Earth's orbital speed. Would it be best to launch when Mars and Earth are closest to each other? (No - the model will show them why.) What positions would be best? (When Mars is ahead of Earth.)



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6. Continue the discussion but ask students where Mars and Earth should be for the return trip. (The orbital speed of Mars is less than Earth's orbital speed. Mars should be ahead of Earth in its orbit for the return launch. As the spacecraft heads inward toward Earth's orbit, Earth will catch up.)

### Wrapping Up

- Ask students if they would volunteer for a trip to Mars. Point out that a Mars trip is two-way. The trip out might take 6 months and the trip back might take 6 months. Then, there is the time spent exploring the surface of Mars. That could take another year. Ask again if students would like to go.

  Ask them what might be done to make the trip shorter

  - More powerful rockets would speed up the transit time.
  - Send robot spacecraft to Mars ahead of the manned mission. Lots of supplies, fuel, and oxygen could be waiting the crew when they arrive. The crew spacecraft could then be smaller and travel faster.


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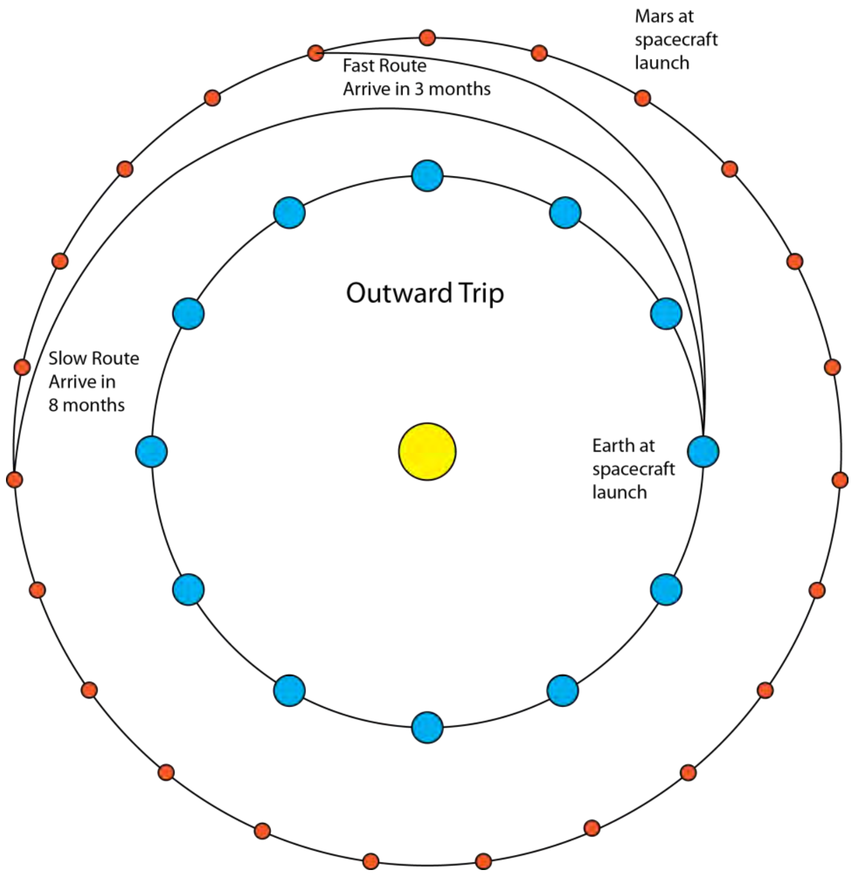


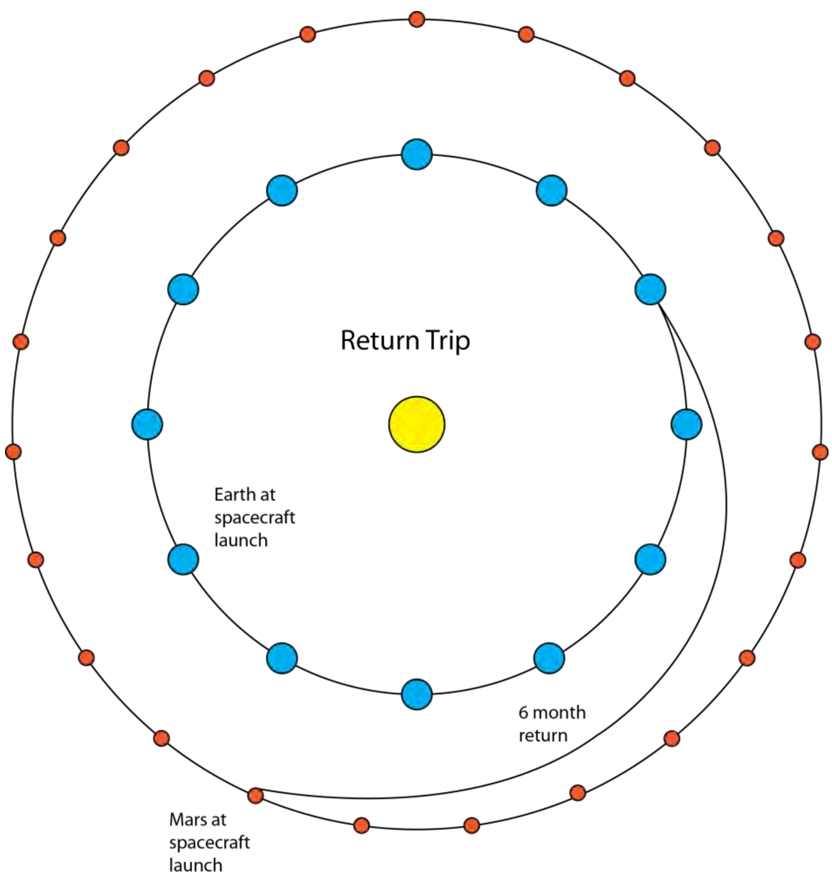




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# 5F) Glider Design

## *Wings over Mars*

### Time Needed

1 Session

### You Need This Stuff

*Per Class*

- Tape measure

*Per Student Pair*

- 2 unused styrofoam food trays (about 15 by 8 inches)
- Scissors
- 3 3/8ths inch metal washers (measurement refers to hole size)
- 2 sheets of copy machine paper for each student
- Marker pens
- (Optional) Low-temperature glue guns and glue
- Medium grade sandpaper squares (3"x3") - 1 per team
- Mars Airplane Design page

### What It's About

One of the first people to set foot on the planet Mars may be sitting in your classroom today. The National Aeronautics and Space Administration is building new rockets that will carry astronauts out into the solar system. The Moon will be one of NASA's possible destinations but so will asteroids, the tiny moons of Mars, and Mars itself. These missions will offer many challenges. One of the most important is supplying astronauts with the basics of life on missions that could last several years. A mission to Mars could take three years. With an astronaut crew of six, for example, providing enough water and food will be difficult. It would be to the astronauts' advantage to know where reliable supplies of water are located on Mars. The way to do that is to send robot spacecraft to Mars to locate its resources before the astronauts arrive.

Many different kinds of robot spacecraft have been sent to Mars. Some have landed on the surface and remained in place, reaching out with sample arms to collect soil and rock. Others had wheels that enabled them to rove about the Martian surface. Still others orbited the planet, gathering data with cameras. A new kind of Mars robot spacecraft has been proposed - a Mars airplane. Skimming the Martian surface from different altitudes, the plane would be able to cover large areas of the planet. Sensors would look for magnetic fields, variations in gravity, sample the atmosphere, and take pictures to search for water.

Because the Martian atmosphere is very thin, long wings will be needed to obtain enough lift to keep airborne. Long wings are used on Earth for soaring airplanes, enabling them to stay aloft for long periods of time. The proposed aircraft will have small rocket engines that will fire from time to time to accelerate the airplane and keep it flying. Between rocket bursts, the airplane will glide.

### What's The Question

What should a Mars airplane look like?

### Before You Start

Make a paper airplane to use as an example.

### What To Do

1. Have students pick partners to work with on a design and construction of a Mars airplane.

2. Discuss the mission to Mars. Tell them that NASA is looking at transporting an airplane to Mars to explore the planet's surface



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and look for signs of water that can be used by future Mars astronauts. Ask each team to design and flight test a proposed Mars aircraft. The aircraft they build will be a unpowered glider but future upgrades could include a propulsion system such as small propellers. Explain that teams must first draw a design of what their aircraft should look like. Discuss the parts of an airplane and what the parts do. Refer to the diagram on the next page for information on aircraft control. Have students make paper airplanes and see how controls work as they fly their paper airplanes with different control configurations. Look for the directions that follow on the next pages.

3. Have teams begin the design and construction process of their Mars aircraft. Have them make sketches of their ideas and construct a prototype flyer out of paper to test. When teams are satisfied with their designs, give each team two styrofoam food trays and three washers. Make scissors, tape, marker pens, and sandpaper squares (for shaping and smoothing the styrofoam) available to teams when needed. The metal washers will be used for balancing the Mars gliders the teams construct. Refer to the diagram that follows for instructions on how to balance the gliders. If providing low-temperature glue guns for students to use, set up a gluing station where teams will bring the pieces needing gluing. Also, set up a dish of ice water nearby. If a student gets glue on the skin, immersing the skin in ice water immediately will stop the discomfort.
4. Set up a test area where teams can flight test their glider designs. Pick an open area, such as a hallway, for the tests. Use masking tape to mark the floor so that teams can determine the distances their planes flew. Encourage teams to adjust their designs to try to improve flight performance.
5. When all teams have constructed their Mars airplanes, hold a flight competition to see which team's airplanes fly the farthest. Give teams at least two flight opportunities and average their results.

**Wrapping Up**

- Give awards to teams whose planes flew the farthest and the straightest.
- Ask your students how they will get their airplanes to Mars. How will they make it fit into a space capsule? After hearing their ideas, show them pictures of the ARES Mars airplane NASA is considering. ARES will be folded inside a capsule for the journey to Mars. Upon descending into the atmosphere, parachutes will pop out and the capsule will open. The airplane will unfold and begin flying.


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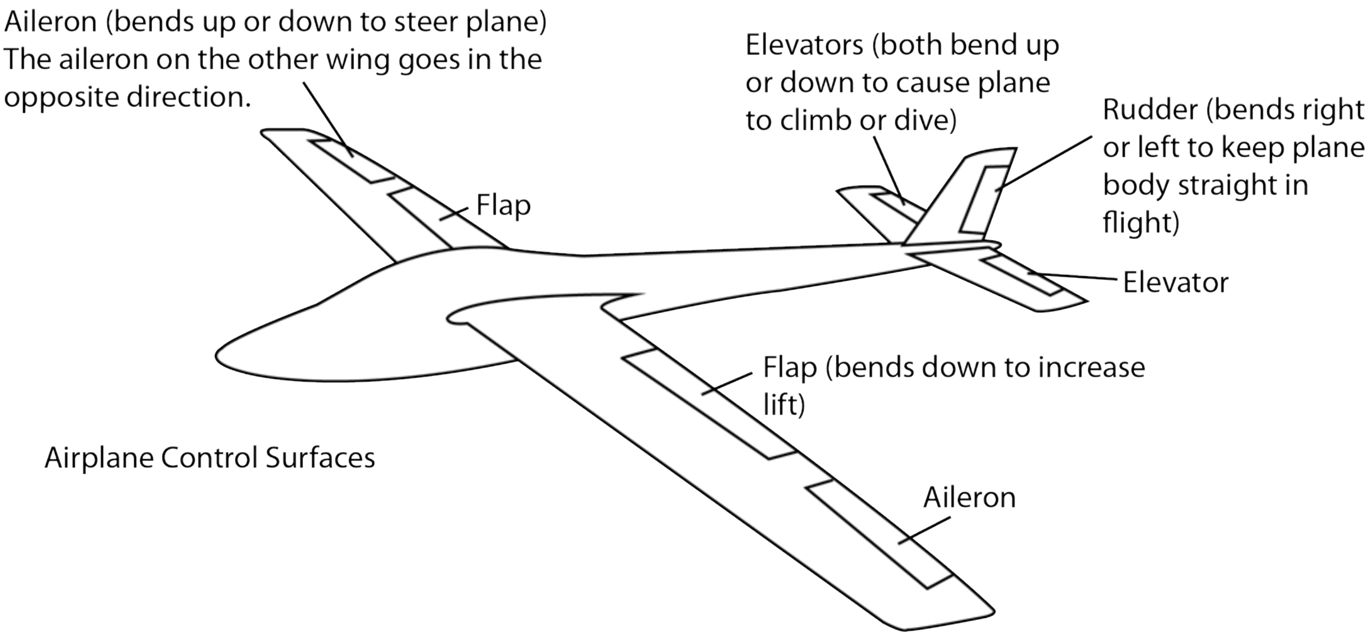
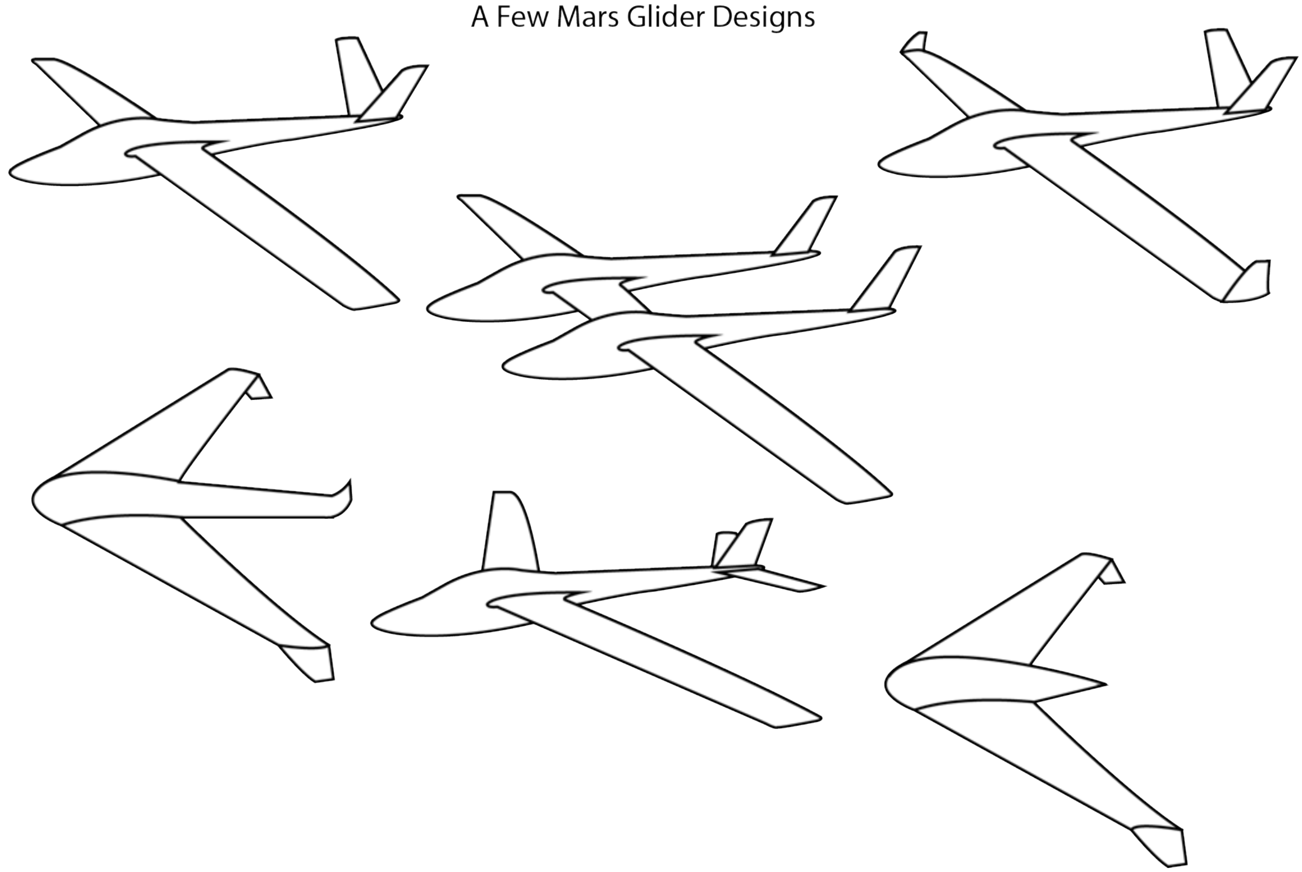



Airplane Control Surfaces

A Few Mars Glider Designs





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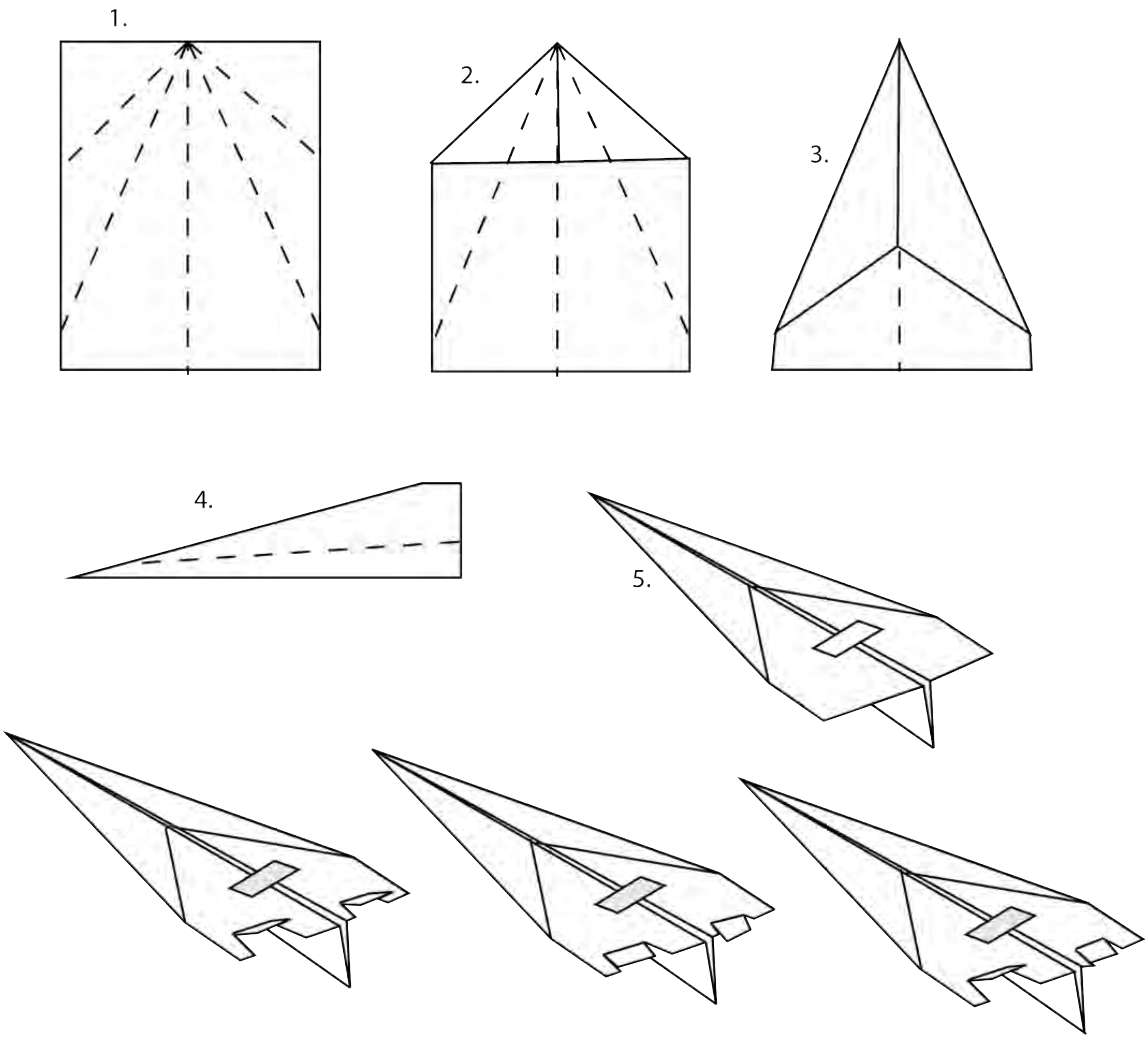


Learn how airplanes are controlled by making a paper airplane. Follow the folds and hold the plane together with a piece of tape.

Test fly the plane. Then, cut two flaps into the back edges of the wings. Bend them both up and fly the plane. Bend them both down and try again. Bend one up and the other down. For the last flight, bend the flaps the other way. With both flaps up, the plane climbs. With both down, it dives. With one up and the other down, it starts turning to the side and then rolls in that direction.


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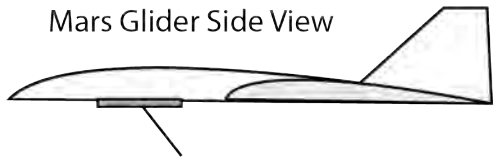


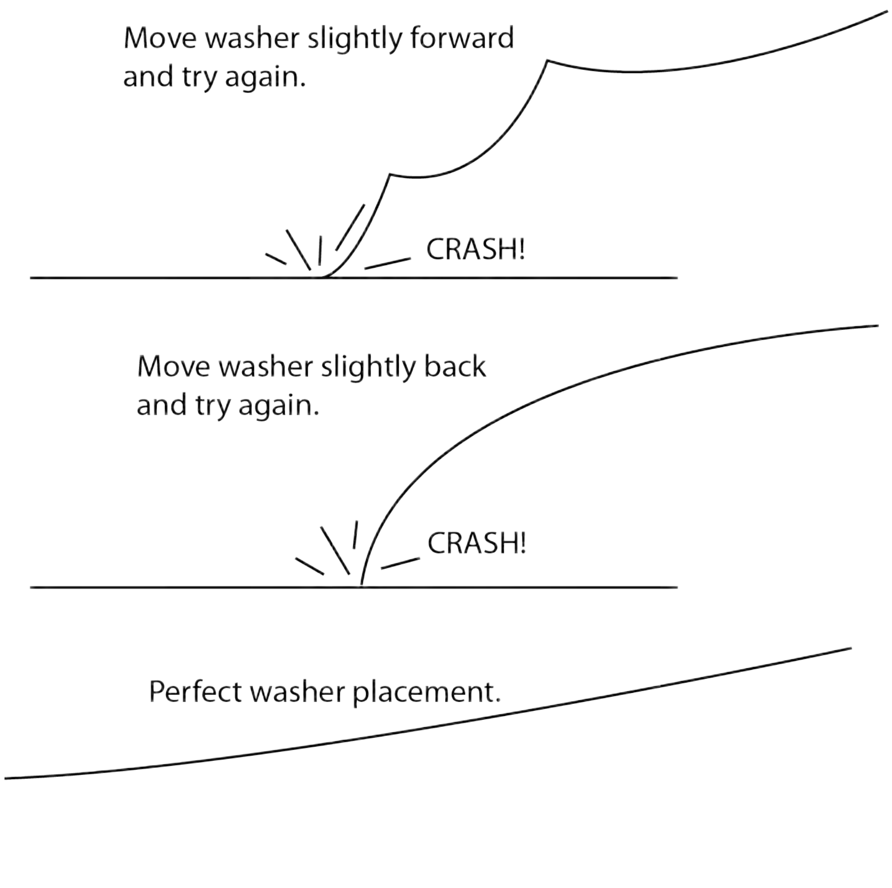



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## Mars Airplane Design Page

**Company Name:** ______________________________________________

**Name of Airplane:** ______________________________________________

**Team Member Names:** ______________________________

______________________________

**Draw your airplane design here.**



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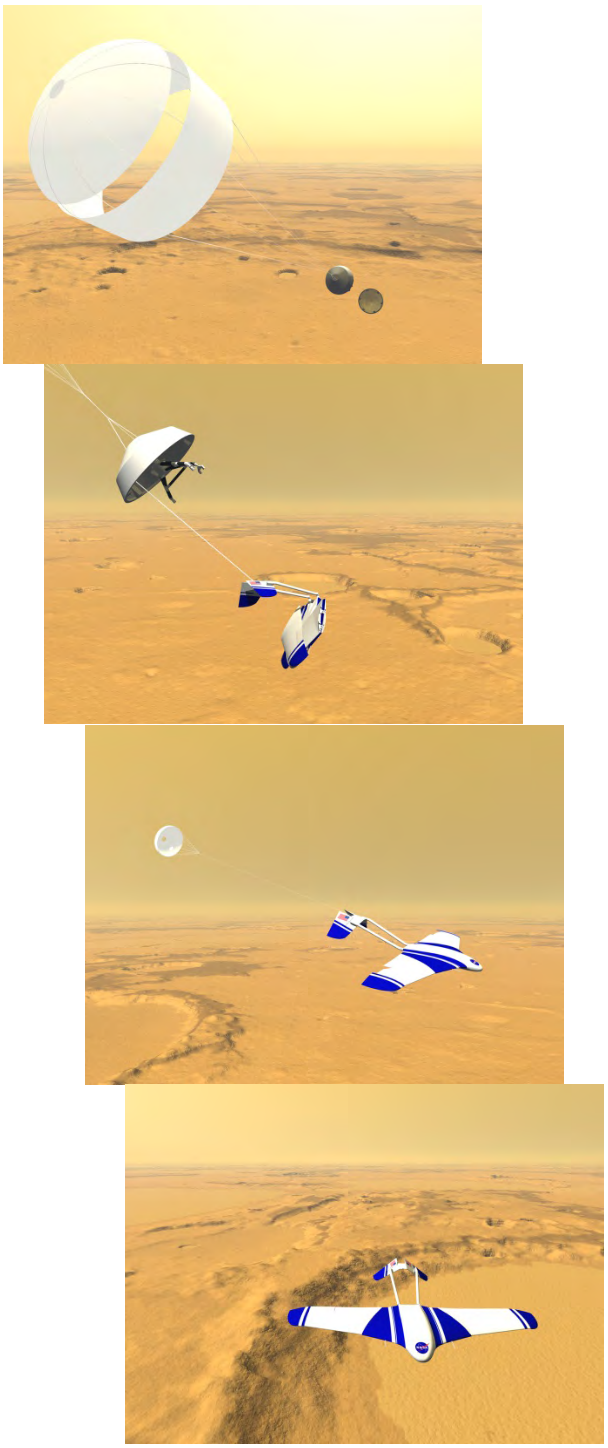
## ARES

NASA is working on a Mars aircraft called ARES (Aerial Regional-scale Environmental Survey of Mars). ARES will be folded up inside a capsule that will enter the Martian atmosphere. Parachutes will slow the capsule and the capsule bottom will drop off. ARES will unfold and begin gliding over Mars. Occasional thrust from small rockets will give it a push and keep it airborne.



Top, front, and side views of ARES



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# 6) Astronaut Issues / Living in Space

## 6A) Space Suit Safety: *Best Dressed Spacewalkers*

Students explore requirements for space suits and the dangers of space.

## 6B) Fluid Shift in Microgravity: *Heads Down*

Students examine fluid shift on Earth as a model for the experience in space.

## 6C) Gravity and Muscles: *Balancing Bodies*

Students learn about center of gravity and how the body adjusts to the force of gravity to remain balanced.

## 6D) Space Flight Fitness: *Staying Fit in Space*

Students are challenged to design exercise equipment for microgravity.

## 6E) Building Strength: *Good Stress*

Students learn that muscles and bones need to work to stay strong.

## 6F) Eating in Space: *Spaced out Foods*

Students investigate BMR, make a calorimeter, and examine food storage.

## 6G) Food for Life: *Essential Building Blocks*

Students will learn about the nutritional needs of healthy bones and muscles, and how to make good food choices, especially in terms of getting enough calcium.


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# 6A) Space Suit Safety

## *Best Dressed Spacewalker*

### Time Needed

3 – 4 Sessions

### You Need This Stuff

*Per Class*

- Paper mache paste (see recipe)
- White paper or newsprint (if using newsprint you may want to add white tempera paint to cover the newspaper inks.)
- Spacesuit design PowerPoint
- 2-4 sets of calipers and field of vision devices (see notes about construction)
- Additional materials such as: marker pens, colored tape, pencils, cardboard, pipe cleaners, etc.

*Per Student*

- twelve-inch round balloons
- sheet of white paper (such as white butcher paper) that is slightly longer than the student is tall
- scissors
- empty 2-liter soft drink bottles (straight-sided, not bumpy)
- 2 brads (brass paper fasteners)
- Styrofoam soup bowl

### What It's About

Spaced out? That's not a good idea. Outer space is unlike any place you have ever been. If you were in space, dressed as you are, your life expectancy would be reduced to about 20 or 30 seconds.

Space is the void that lies beyond the uppermost reaches of Earth's atmosphere and between all objects in the universe. Although a void, outer space is an environment. It has properties that make it very different from Earth.

The principal environmental characteristic of space is the vacuum, or nearly total absence of gas molecules. The gravitational attraction of large bodies in space, such Earth and the other planets and stars, pulls gas molecules close to their surfaces. Gravity leaves the space between virtually empty. Some stray gas molecules are still present in space, but are few and far between. On Earth, the atmosphere exerts pressure in all directions. At sea level, that pressure is 101 kilopascals (14.7 psi). In space, the pressure is nearly zero. Air inside an unprotected astronaut's lungs would immediately rush out and suffocation would ensue. It gets worse. Dissolved gases in body fluids expand, pushing solids and liquids apart. The skin enlarges much like an inflating balloon. Bubbles form in the blood-stream and render blood ineffective as a transporter of oxygen to the body's cells. The right side of the heart fills with froth and is no longer able to provide pumping pressure to the circulatory system.

Without air, the absence of external pressure, balancing the internal pressure of body fluids and gases, will cause fragile tissues, such as eardrums and capillaries, to rupture. The net effect on the body would be swelling, tissue damage, and a deprivation of oxygen to the brain that would result in unconsciousness in less than 15 seconds.

The temperature range found in outer space provides a second major obstacle. The sunlit side of objects in space, at Earth's distance from the Sun, can climb to over 120° Celsius (248 Fahrenheit) while the shaded side can plummet to lower than minus 100° Celsius (-148 Fahrenheit). Maintaining a comfortable temperature range becomes a significant problem.

Other environmental factors encountered in outer space include: microgravity, radiation of electrically charged particles from the Sun, ultraviolet radiation, and meteoroids. Meteoroids are very small bits of rock left over from the formation of the solar system and from the collisions of comets and asteroids. Though usually small in mass, these particles travel at very high velocities and can easily penetrate human skin. Equally dangerous is debris from previous space missions. A tiny paint chip traveling at



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thousands of kilometers per hour can do substantial damage.

For an unprotected human, the environmental conditions of outer space means a quick and painful death. Fortunately, there are ways of preventing that from happening. Space suits are like a shell that isolate astronauts from the dangers of outer space. They contain an atmosphere, air pressure, protection against heat and cold, and protection from high speed particle impacts. Capping the space suit is a helmet with sun visors, lights, and a TV camera. The front of a space suit has a control module for adjusting the temperature and oxygen flow inside the suit and the switches for a radio communication set. Supplies of oxygen and cooling water and a radio are carried in a backpack. Space suits have to be flexible. Joints are built into the arms, hands, waist, and knees. The full space suit weighs close to 200 pounds on Earth.

### What's The Question

How can astronauts be protected so that they can work safely in outer space?

### Before You Start

Gather the needed materials. Prepare the paper mache paste. See recipe.

### What To Do

1. Ask students what astronauts wear while space walking. (Space suits or extravehicular mobility units - EMUs - in NASA terms.) Why do they wear them? Collect student ideas. Have students describe what a space suit looks like. Summarize the reasons for wearing a space suit.

    No air in space - can't breathe

    No air pressure - skin expands, ear drums burst, bubbles form in the blood, blood flow becomes blocked

    Hot in sunlight - cooks the skin

    Cold in shade - freezes skin

    Radiation - damages cells and could cause cancer years later

    Meteoroids and space debris - can punch holes in skin or worse

    *Death in 20 to 30 seconds.*

    Show students the website below and have them choose a spacesuit to explore further.
    http://www.nasa.gov/externalflash/nasa_spacesuit/

2. Cut student-sized piece of white butcher paper for each student. Have students work in pairs - boy/boy and girl/girl. Start with one student laying down on the paper and assuming a pose. Have the second student use a pencil, held straight up and down, to trace a line around the posed student. Switch positions so that each student has their own tracing of themselves. Using markers, colored tape, and other art supplies, have them do a self portrait as an astronaut wearing a space suit and helmet. Have them illustrate the suit with important features of their design such as controls, pockets, connections, etc.

3. Display the space suit art around the room and discuss student designs. Look for similarities between suits. Ask students where they will get their air supply. How will they talk with other spacewalkers and with mission control on Earth? How will their suits protect them from heat, cold, and meteoroids and space debris?



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**Paper Mache Recipes**

There are many different recipes for paper mache paste. Most involve flour and water.

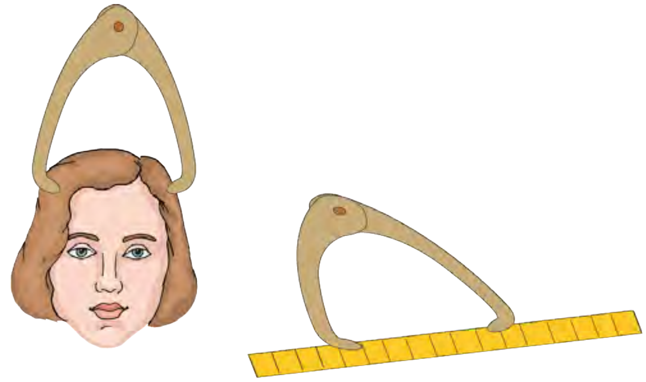
<u>No-Cook Recipe</u>

Stir 1 part flour with 2 parts water. Adjust amounts to achieve thick but runny glue. Add a little salt if you are in a humid area to reduce mildew.

<u>Cook Recipe</u>

Heat until boiling 1 part flour with 5 parts water. Stir to paste consistency

Pre-mixed wallpaper paste works but is more expensive.



4. Tell students that they will be constructing a personal space helmet. It will take several sessions to make the helmet. The first step will be to take measurements of everybody's heads to make sure helmets are large enough. Construct calipers from cardboard using the provided pattern. Each calipers needs two identical pieces that are held together with brass paper fasteners (brads). Have students make the calipers or make them in advance. They will also need rulers and flexible tape measures. Students should make five measurements.

    Head width (left to right)

    Head depth (front to back)

    Head height (top to chin)

    Circumference (around forehead)

    Field of view

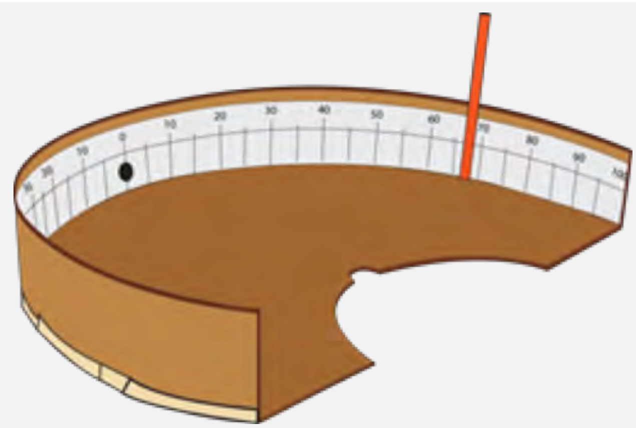
   Have students record their head measurements on the Space Helmet Design Page.

5. Discuss student helmet designs and begin the construction process.

   Have students blow up and tie the large balloons. The balloons should be larger in diameter than their heads. Have students tear strips of newspaper, coat with paper mache paste, and apply to the balloons. Students should apply one complete layer of paper to the balloon and let it dry completely. Use the soup bowls as stands while covering the balloons and to support the balloons while drying. Occasionally, turn the balloon to avoid sticking to the bowls.

   Tip: Place a sheet of newsprint below the helmets while they are drying to catch drips.

6. Over the next several sessions, apply another three layers of paper. Use white paper towels for the last layer.



**How to Measure Field of View**

One student holds the viewer to his or her face so that the bridge of the nose fits into the smaller half circle. That student stares at the black dot in the center. A second student hold a colorful straw or pencil and moves it along the degree scale starting from the back towards the dot. The student being measures will say stop when the straw comes into view. The test is repeated for the other eye. Adding the degrees from the left and right sides gives the field of view. Eg.g 67 degrees and 65 degrees = 132 degrees field of view.



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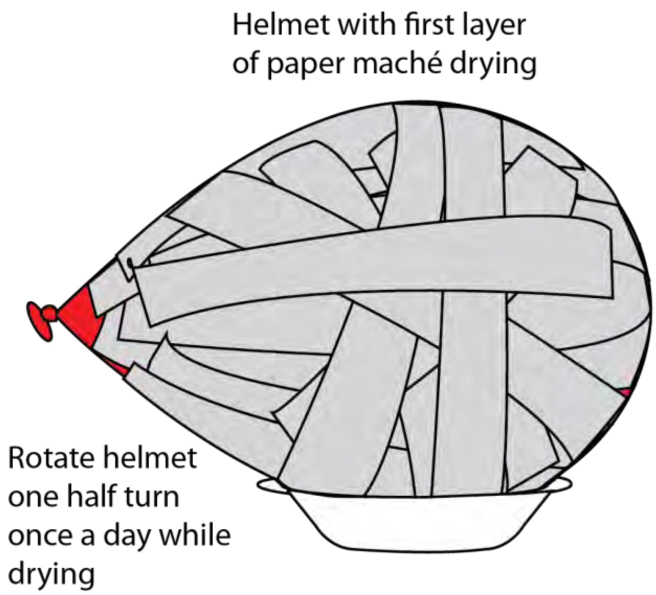


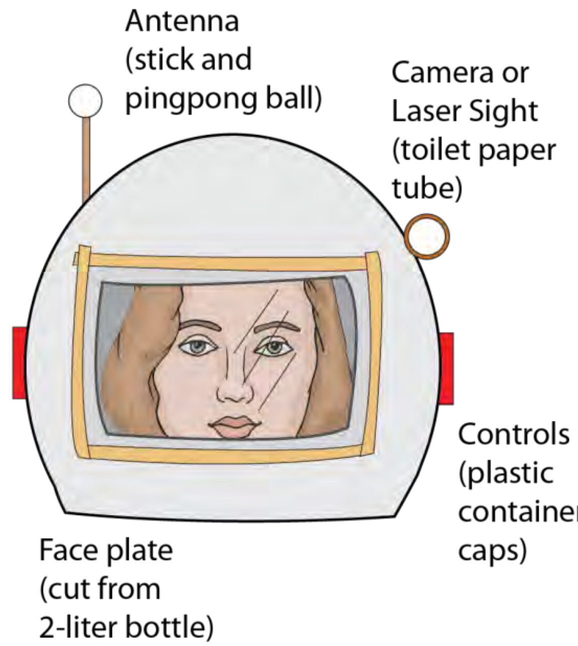


7. When the paper mache is completely dry, Puncture the balloons and cut a hole large enough in the helmet to pass over student's heads.
8. Using their designs and the field of view measurement as a guide, have students cut out the face hole in the helmet.

Tip: Reinforce the cut edges with masking or colored tape to prevent paper layers from separating.

9. Cut the mid section of a 2-liter soft drink bottle to make a transparent visor. Shape the visor to fit the face hole and tape it in place. Add decorations to the helmet as desired. When helmets are completed, have a space helmet fashion show. Don't forget a camera.

**<u>Optional Space Suit Demonstrations</u>**

**Liquid Cooling**

Space suits have to form a complete seal around the astronaut. Otherwise, the atmosphere inside the suit leaks out. Not only do space suits hold in air, they also hold in body heat and astronauts could become cooked in no time.

**What to Do**

Pick a volunteer wearing a short sleeve shirt or have the volunteer roll up the sleeve. Wrap a length of aquarium tubing around the bare arm with several coils about 3 cm apart. Place the upper end of the tube into a bucket of ice water. Place another bucket on the floor. Suck out air from the tube to start a siphon and aim the water stream into the bucket on the floor. Watch the reaction of the volunteer! Repeat with other students.

Astronauts wear a long underwear-like suit of Spandex under the space suit. The Spandex has plastic tubing zigzagging around the astronaut. Cold water runs through the tubes to keep the astronaut cool during spacewalks.


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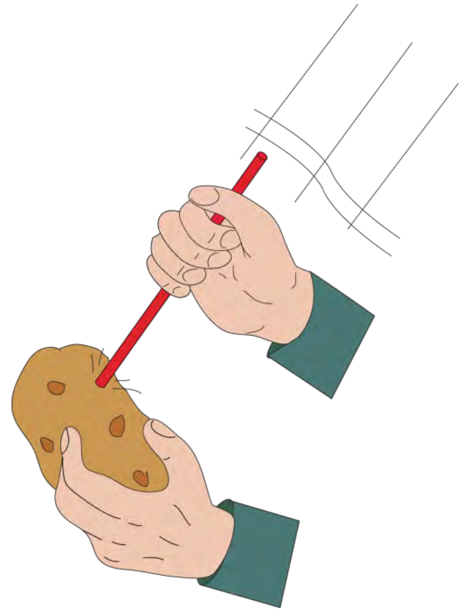
**<u>Protecting Against Impacts</u>**

**What to Do**

Demonstrate how high-speed particles in space can penetrate skin with a potato and a plastic straw. Hold the potato as shown slowly press the straw on the potato. The straw will collapse before it causes much damage. Repeat (with another straw) and rapidly stab the potato. The straw will penetrate deeply into the potato and may go all the way through. (Be careful to keep your hand holding the potato off to the side so that it doesn't get struck. Try the demonstration one more time but wrap the potato in a piece of notebook paper. The paper forms a shield, like the layers of a space suit. The fibers of the paper distribute the force of the impact over a larger area, preventing penetration.



The space environment surrounding Earth is crisscrossed with tiny meteoroids and space debris particles traveling at speeds of 10 or more kilometers (6 miles) per second. Astronauts are protected from impacts by these particles by the tough fabrics used to make space suit and the materials that make up helmets. The materials were adapted from those used on Earth to protect police and soldiers. They work just as well protecting astronauts in space.

## Wrapping Up

- Have students model their space helmets and describe their features.
- Hold a discussion about the jobs astronauts might perform on space walks. Would they need special tools?
- Talk about space careers. Astronauts wear space suits but engineers design and build them. Much testing goes into space suit design and suit engineers and constantly improving suits to make them lighter and easier to wear and use.

## Extras

- NASA has a website devoted to space suits.
  http://www.nasa.gov/audience/foreducators/spacesuits/home/index.html



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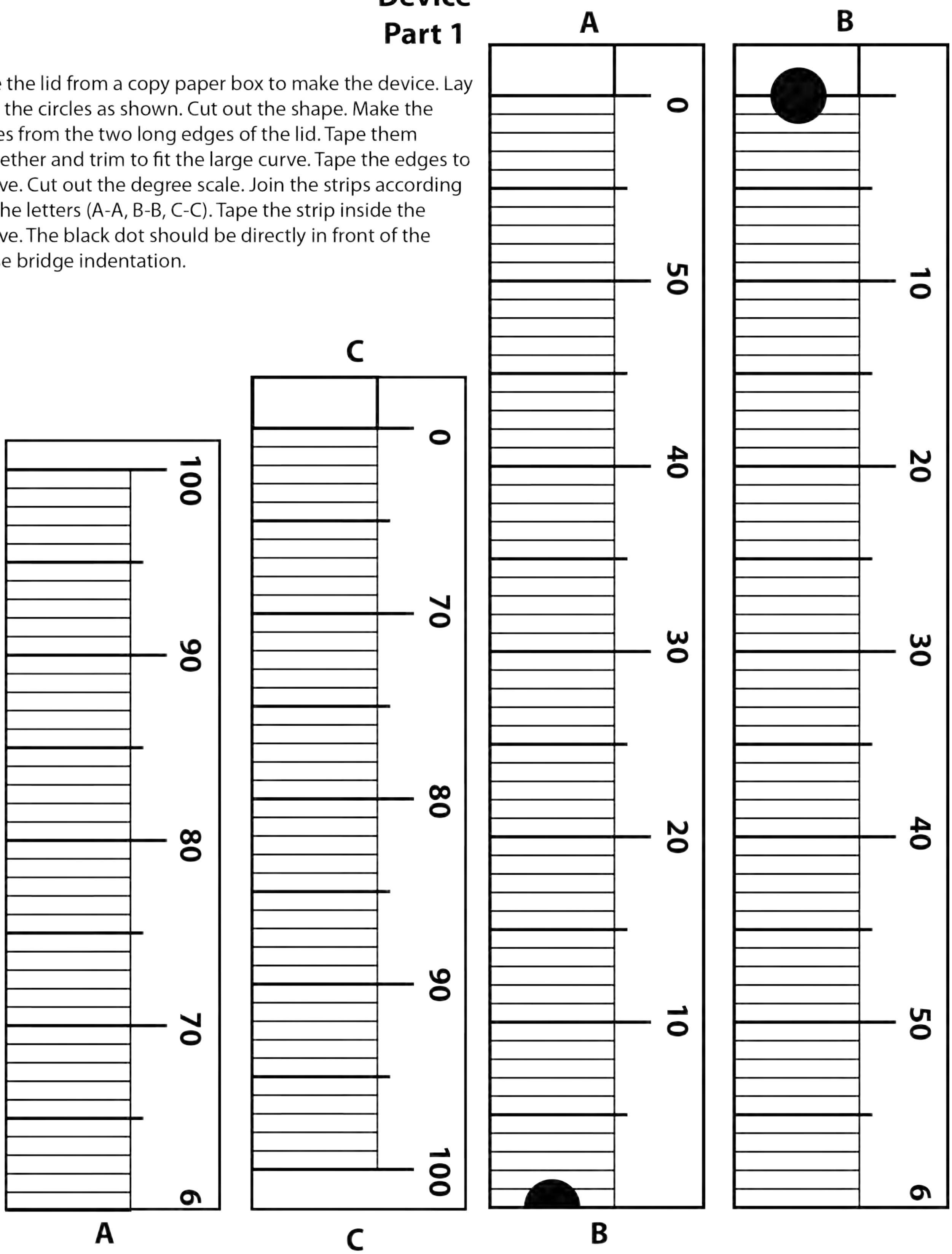
## How to make the Field of Vision Measurement Device Part 1

Use the lid from a copy paper box to make the device. Lay out the circles as shown. Cut out the shape. Make the sides from the two long edges of the lid. Tape them together and trim to fit the large curve. Tape the edges to curve. Cut out the degree scale. Join the strips according to the letters (A-A, B-B, C-C). Tape the strip inside the curve. The black dot should be directly in front of the nose bridge indentation.



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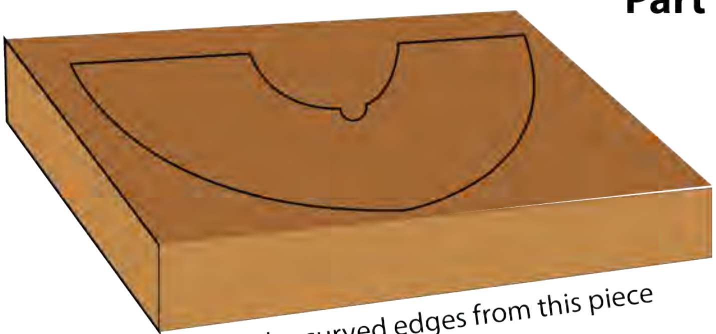
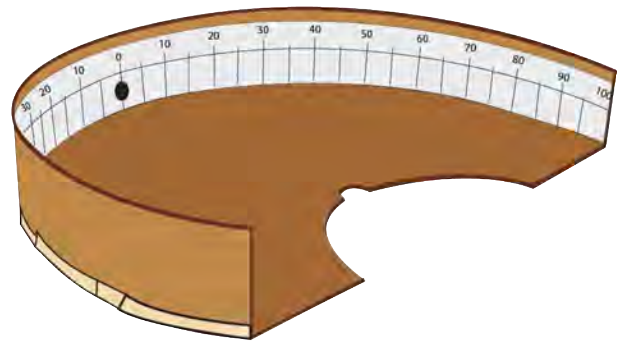
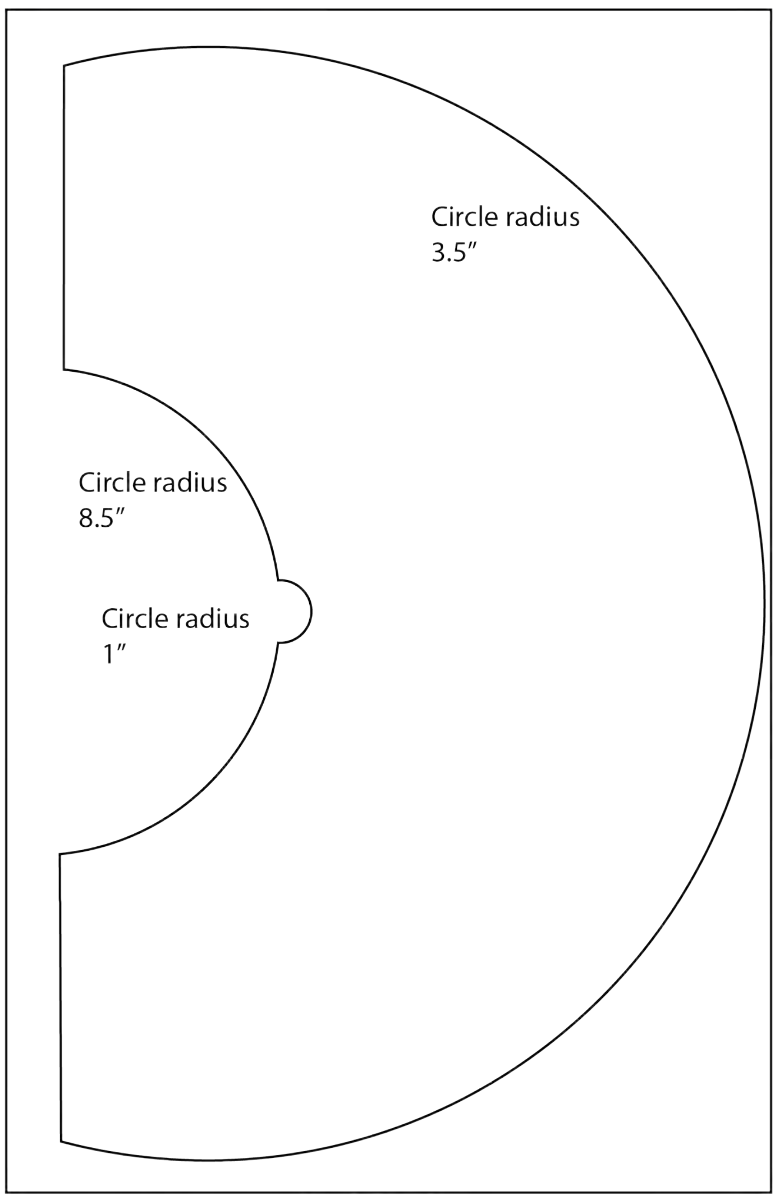
# How to make the Field of Vision Measurement Device
# Part 2

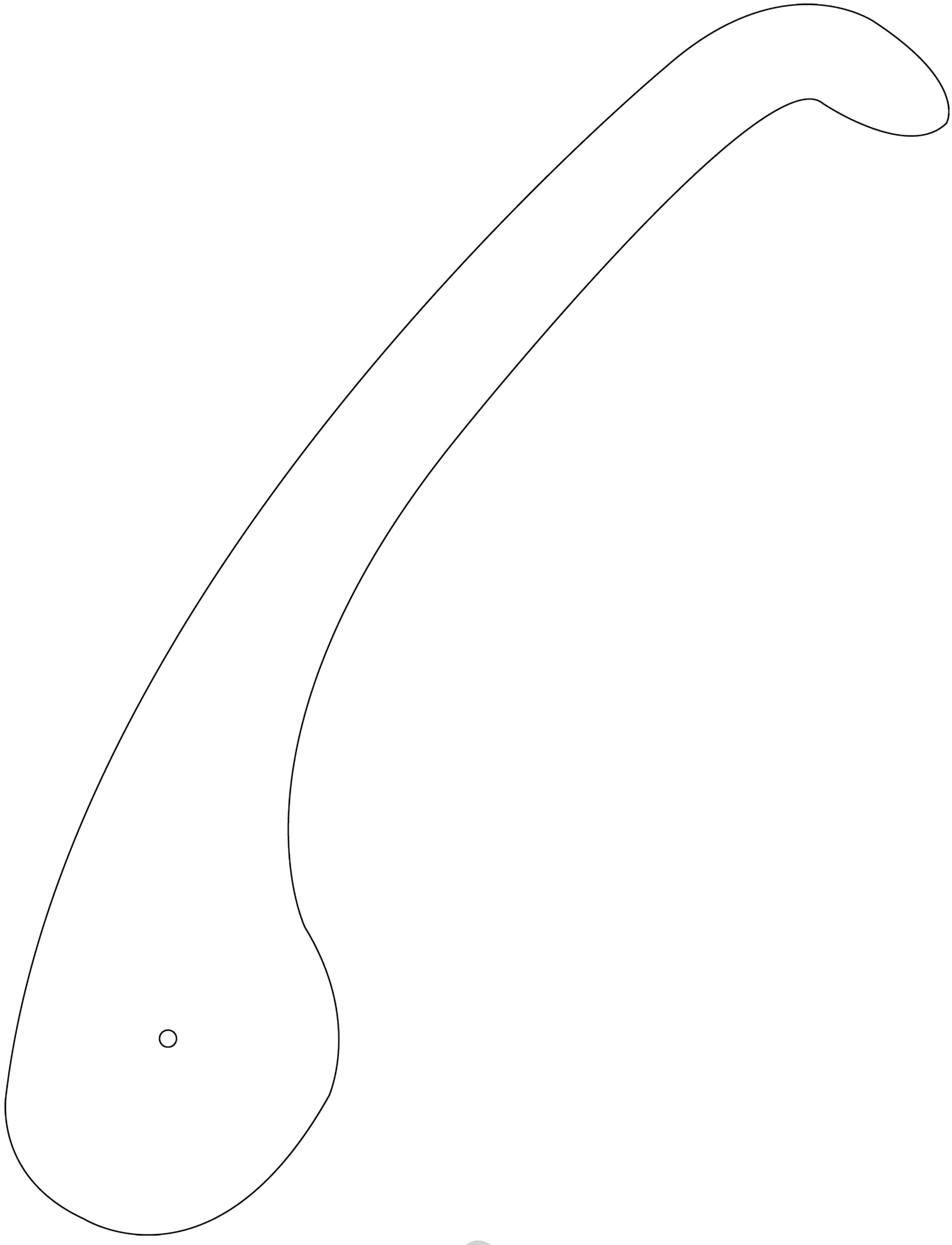


Cut the curved edges from this piece joined with the opposite one.






Box lid outline





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# Space Helmet Design Page

**Astronaut Name:**________________________________

**Head Dimensions:**

**Head width (left to right):** ________ **cm** **Head depth (front to back):**__________**cm**

**Head height (top to chin):** ________ **cm** **Circumference :** __________**cm** **(around forehead)**

**Field of view (right eye):** __________**degrees** **(left eye):** ___________**degrees**

**Draw a Diagram of your proposed space helmet.**

**Refer to head dimension measurements to make sure the helmet fits.**

**Include labels of the helmet parts.**

**Add dimensions to your diagram**



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# 6B) Fluid Shift in Microgravity

*Heads Down*

### Time Needed

1 – 2 Sessions

### You Need This Stuff

<u>*Per Class*</u>

- Digital camera with card reader or other way of downloading the images to a computer
- Computer
- (Optional) LCD projector and screen or Smart Board
- Meter or yardstick
- 4 or 5-inch-diameter balloon
- (Optional) Aquarium - 10 gallon
- Water
- (Optional) 8-foot folding banquet table (legs folded) and box or some other support to hold up one end at about a 6 to 10 degree angle
- Cloth tape measure
- Marker pen

### What It's About

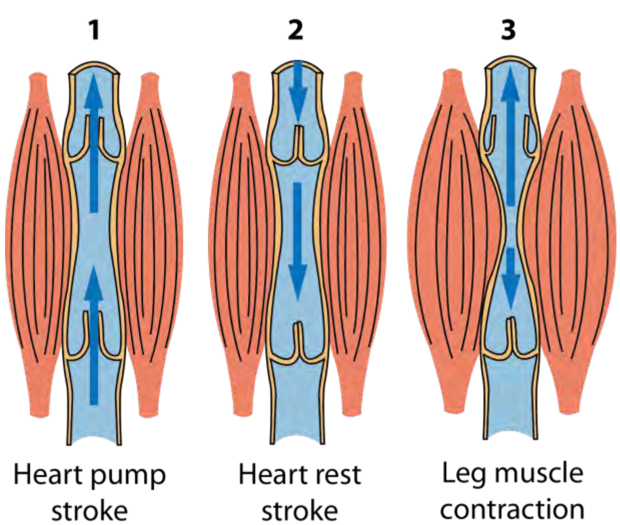
The International Space Station is an amazing science laboratory. Orbiting above Earth, scientists can study materials, forces, and processes without the effects of Earth's gravity. NASA calls the environment of the ISS microgravity.

Microgravity doesn't mean zero gravity. It means an environment in which gravity's effects are greatly reduced. Many students believe gravity goes away in space. It doesn't. It holds the ISS in orbit. Otherwise, the ISS would spin off into deep space. Microgravity is created by free fall. The ISS is falling toward Earth but its horizontal speed is so great that its falling path is shaped into a circle. In other words, it is falling but it continually misses the ground. Falling makes it seem like gravity is gone because the ISS and everything inside are falling together.

A video tour of the International Space Station shows Sunita Williams maneuvering through the space station in microgravity. The entire station and all its contents are in free fall, so there is no clear "up" or "down.

http://www.youtube.com/watch?v=doN4t5NKW-k

Microgravity changes the astronauts. For example, astronauts grow taller in space. The growth is not real. Their bodies just stretch out a bit because their spinal columns are not compressed by gravity. The disks between the vertebrae, that act like shock absorbers, expand in microgravity because of lack of pressure on them. They push the vertebrae apart slightly, lengthening the back. This is the same thing that happens when you sleep at night. Your spine lengthens a bit and in the morning you are slightly taller than when you went to bed.




NASA uses bed rest to study the effects of microgravity on the human body. Volunteers are asked to remain in bed for several months at a time. The beds are tilted head down at a 6 degree angle to simulate continuous microgravity. Doctors monitor the volunteers to learn what changes take place. Changes include reduced muscle mass and skeletal strength (use it or loose it). Another change is a shift in body fluids and a decreased total blood volume. Bed rest can produce the same changes in the volunteers.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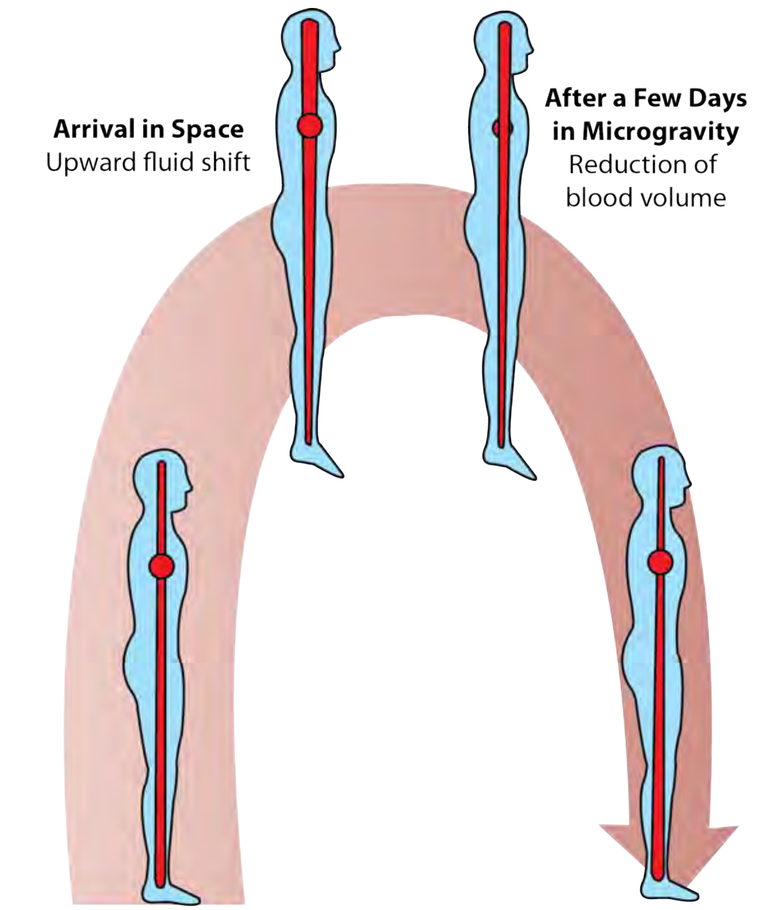
One of the interesting effects of microgravity and bed rest is a change in the astronaut's / volunteer's appearance. Their faces get puffy and their legs get thinner. These change occur very quickly. The changes are caused by a small head-ward body fluid shift, in particular, blood.

We all know that the heart pumps blood through the body. It beats about 104,000 times a day and propels blood through a network of 96,500 km (60,000 miles) of blood vessels. There is a secondary pumping system as well. One-way valves in the large veins of the legs keep blood from settling and pooling in the feet during the resting strokes of the heart. Without the one-way valves gravity would make it harder for the heart to work.

In microgravity, the one-way valves continue to function and the lack of gravity's effects make them more efficient in moving blood back to the heart. This causes an increase the amount of blood in the upper part of the body and a decrease it in the lower part. As a result, legs get thinner. Astronauts call the effect "chicken legs." Extra blood in the upper part of the body causes the face and veins of the neck to get puffy.




Chicken legs and puffy face are not harmful but do lead to a reduced blood volume. Sensors in the body interpret the extra blood in the upper body as too much blood overall. The body breaks down some of the blood and expels extra fluid through the kidneys.

When returning to Earth, astronauts are slightly anemic. Shortly before landing, they drink extra fluids which reduces the tendency to be light headed or faint.

In this activity, students will perform a photographic investigation on how microgravity affects the appearance of astronauts during their first days in space and learn about some of the underlying physiologic changes that occur. Volunteer students will be photographed with a digital camera while standing up and again while laying on a slightly tilted surface with their heads down. NASA uses inclined beds to simulate the effects of microgravity. The images will be compared for differences.

### What's the Question?

How does microgravity affect body fluid?

### Before You Start

Clear a 2 meter wide area of the room next to a wall.

### What To Do: Part One – Puffy Face

1. Discuss space flight with your students. Relate some of the changes that occur to astronaut bodies when in microgravity.



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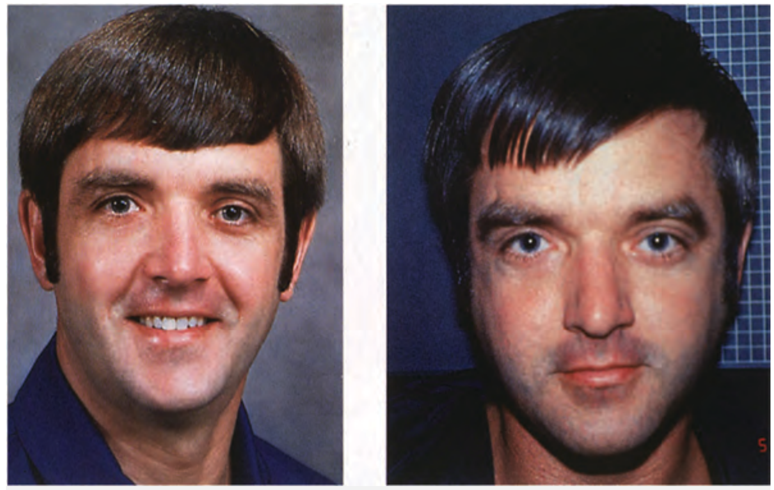
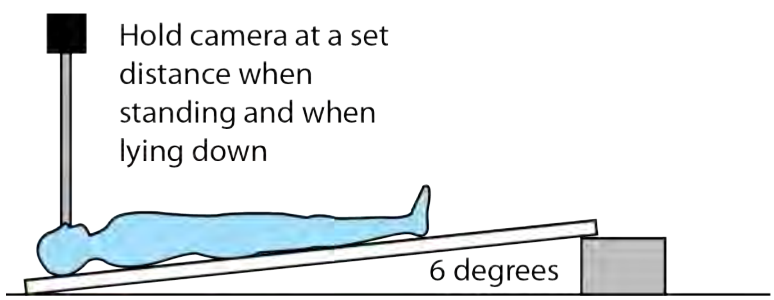
2. Ask for volunteers for an experiment. Pick one or more students to be photographers and others to serve as test subjects.
3. Have the photographers take pictures of the heads and shoulders of the subjects. They should stand straight and look straight into the camera with no facial expressions. It is important that pictures be taken from the same distance every time. Use a meter or yardstick as a guide.



Portrait of Astronaut Daniel C. Brandenstein on Earth (left) and a portrait of Brandenstein on the Space Shuttle (right) shortly after arriving in orbit. Compare the facial appearance on Earth to that in microgravity. Although the camera distances are different, the difference can be clearly seen.

4. Set up a tilt table by placing one end of a wide 8-foot-long board or 8-foot-long banquet table (with legs retracted) on a box or some other object that will raise it about 10 inches off the floor. The other end of the board or table should be on the floor.

   Note: As an alternative to a tilted table, students can lay on their backs perpendicular to the wall and raise their legs up and brace them with the wall.
5. Have each subject in turn lay on the tilt table with their heads at the lower end. Measure the position of the camera. The subjects should look straight into the camera and have a straight facial expression as before. Wait two minutes and take the picture.




6. Load the pictures on a computer and arrange picture pairs for each subject for the class to examine. Look for differences between the one gravity (standing) picture and the simulated microgravity picture.
7. Discuss what has happened. (The head down position has shifted some of the blood supply in the subject's bodies so that their faces become puffy. If the subjects remained in a head down position for several days, their bodies would begin making adjustments as bodies do in space.
8. Do a demonstration on what is happening. Fill a balloon with water and tie it off. Hold up the balloon by its nozzle. Have students describe its shape. The weight of the water (the attraction of Earth's gravity on the water) causes the balloon to sag. Toss the balloon straight up into the air and catch it several times. Have students describe the shape of the balloon in flight. The balloon will be rounder because the balloon is in free fall and gravity's effects on the water in the balloon are greatly reduced. The rubber of the balloon returns the balloon to a more rounded shape. Compare the balloon in the air to the microgravity environment of the ISS. How does the shape of the balloon relate to what happens to astronauts in microgravity?

As an alternative to tossing the water balloon in the air, immerse it in an aquarium. NASA uses underwater tanks for training astronauts. The water tanks simulate the effects of microgravity.

**What To Do: Part Two – Chicken Legs**

Note: This activity works better if students are wearing short pants or pants with loose legs that can be rolled up above the knee.

1. While having volunteer students standing, put a couple of small marker pen marks on their legs (Thigh - about 15 to 20 cm above the knee. Calf - mid-calf.
2. Using a cloth tape measure, measure the circumference at the marked points with the volunteer students standing. Have boys measure boys and girls measure girls. Record the measurements.
3. With students laying down on the tilt table or on the floor with their legs raised, measure the leg circumference again. It is very important to position the measuring tape exactly in the same place and aligned exactly the same way. Record and compare the measurements.

## Wrapping Up

Have students write their observations and explanations in their lab journals. What happened to the volunteer subject's faces and legs when they experienced simulated microgravity? Why did it happen? What did it feel like? Have them speculate on the effects of microgravity on astronauts traveling to Mars. (The International Space Station is an analog for long-duration space flights. A trip to Mars might take six months which is a typical tour of duty on the ISS.)



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# 6C) Gravity and Muscles

## *Balancing Bodies*

### Time Needed

1 – 2 Sessions

### You Need This Stuff

*Per Group*

- light-weight chair
- copies of "Balancing You!" sheet

*Per Student Pair*

- copy of "Balancing Act" student sheet
- meter stick
- standard weight items such as heavy coins, washers, etc.
- masking tape
- copy of "Balancing Act" student sheet

### What It's About

Gravity places a heavy load on the human body. Only through coordinated muscle movement is the body able to counteract the downward pull of gravity and remain upright. Muscles in the back, legs, ankles and feet are used most. The nervous system tells these muscles which changes to make to help the body maintain posture and balance during movement.

To balance itself, the body makes tiny adjustments to maintain its center of gravity over the feet. The center of gravity is an imaginary point within the body at which there is balance and from where the weight on all sides is equal. Fortunately, the minor muscle adjustments necessary to maintain balance and posture are made automatically.

### What's The Question

What is balance? How does the body respond to gravity?

### Before You Start

Place meter sticks, weights and masking tape in a central location. Have students work in pairs.

### What To Do

Part 1. Balance, Weight and Stability

1. Ask students, Do you usually fall over when you are walking, riding a bicycle or standing on a bus? Why? Encourage students to think about how the body coordinates balance. Ask, Do you need muscles to keep your balance? Would your skeletal system alone be able to keep you upright in a moving vehicle? Explain to students that they will be investigating balance and stability using different amounts of weight and meter sticks (Part One) and that they will be learning how living things use muscles and body position to maintain balance (Part Two).

2. Tell each Materials Manager to collect weights, masking tape and a meter stick for her/his group.

3. Instruct one student in each group to hold the meter stick horizontally by supporting it with one index finger at each end. Have the student move his/her fingers slowly toward each other, keeping the stick balanced until the fingers meet. Explain that the point where the fingers meet is the balance point for the stick. In other words, the balance point is the place where the weight on each side is equal and the object is balanced. Have the students in each team record the balance point for their meter stick.

4. Next have students tape one weight on the 30-cm mark



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of the meter stick. Ask students to predict where the new balance point will be and to record their predictions. Have them determine the new balance point of the meter stick as before and record it.

5. Have students add another weight to the one already on the meter stick and repeat the process. They should repeat the experiment one more time with three weights on the meter stick.

6. Direct students' attention to their data sheets and ask, What happened to the balance point of the meter stick as more weight was added? [the balance point moved toward the added weight]. What would have happened if you had not moved your finger to find a new balance point? [meter stick would have fallen]. Help students understand that, in order to stay balanced, the weight of each end of the meter stick had to be equal. The only way to achieve this when more weight is added is to move the balance point.

Part 2. Maintaining Balance

1. Ask students to think about whether maintaining their own balance is as simple as moving their fingers on the meter stick. Follow by asking them to think about whether their center of gravity ever changes. Ask, What do you do to keep yourself from falling when you trip over something? How about when you are standing in a moving train or bus? Tell students that they will be exploring their own centers of gravity in two different ways.

2. First, have students in each group take turns standing up from a seated position in a chair. They should record the results on their data sheets. Ask, How easy was it to stand up? (very easy).

3. Follow by having students try again to stand up from a seated position in a chair. This time, however, have them do so without leaning their back and shoulders forward. Have them record their results.

4. Next, instruct one student to stand with feet shoulder-width apart. Have the second student place a lightweight chair 15 cm in front of the feet of the first student. Instruct the first student to try to pick up the chair and to record his/her results. Then have the other student in each group try it and record his/her results.

5. Tell students to move to the periphery of the room and take turns repeating the process again, but this time with their heels, hips, back and shoulders against the wall and with feet flat on the floor. Again, have them record their results.

6. Discuss the students' results. Ask them to identify the differences between the two trials of each experiment. Ask, Why do you think it was not possible to stand up when you didn't move your shoulders? Why was it impossible to pick up the chair when you stood against the wall? Help students understand that in both cases, their body movement was limited.

### Wrapping Up

- Discuss gravity again. Ask, Does gravity affect people? Do people have a center of gravity? The meter stick center of gravity changed as students added more weight. Ask, Have you been able to observe whether a person's center of gravity changes? Have students think about where their centers of gravity are when they are sitting in chairs and how their centers shift when they begin to stand up. Their weight shifts from their seats to their feet; thus, their centers of gravity must change also. Have students think about where their centers of gravity are when they lift a chair. The chair adds extra weight to the body, so the body must compensate for that weight by moving the center of gravity. The body changes the center of gravity and achieves balance by moving the hips backward. This is why students were not able to pick up the chairs with their backs against a wall. Have students try these two experiments again, and this time have them watch their partners' body movements.

### Extras

- The body constantly makes adjustments to compensate for the pull of gravity. Some of these adjustments are large, as when we pick up a chair, but many of the adjustments are very subtle. The muscles make minor adjustments constantly to maintain balance and posture. Have students work in pairs and observe the movements made by their partners as they perform certain tasks. The tasks can be: moving from standing on two feet to standing on one foot, walking heel-to-toe, squatting or standing on tip toes.

- To keep from toppling over, an object's center of gravity must stay above the area outlined by the object's base. This is why you will fall over if you lean too far forward. Once your center of gravity is beyond the limits of the base defined by your feet, you lose your balance and stability. This is why people will stand with their feet farther apart (and thus widen their "base") to keep their balance in a moving bus or train.

- **Free Fall**

  Objects falling with an acceleration equal to that caused by gravity alone experience "free fall," or weightlessness. The acceleration required to achieve free fall is 9.8 meters per second squared or 1 g at the Earth's surface. Free fall is the lightness that you feel on some amusement park rides. Astro-nauts orbiting the Earth also experience weightlessness for  the same reason.

  Under these conditions, many movements can be accomplished with minimal effort. However, after long space flights, astronauts may demonstrate changes in their posture upon return to Earth. These changes are believed to be related to adaptation by the body to microgravity conditions.

- **Muscle Control!** The brain and nervous system coordinate muscle movements necessary to maintain balance.

- NASA scientists find it crucial to have a weightless environment for some of their experiments. They use tall towers, long tubs, rockets and airplanes, as well as spacecraft, to create artificial weightless environments.

  

  Astronaut Mary Ellen Weber, STS-101 mission specialist, is shown onboard KC-135 during a brief period of weightlessness afforded by one of the parabola patterns flown repeatedly by NASA aircraft. Weber is testing a device for stabilizing herself when she operates the robotic arm aboard the Space Shuttle Atlantis

(Photo courtesy of NASA)



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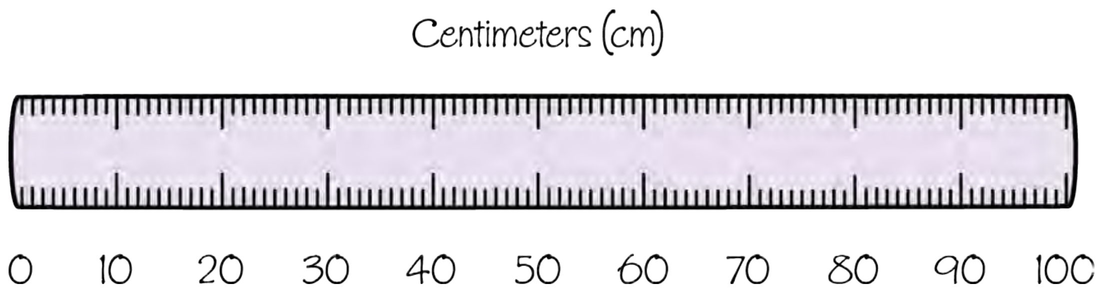
# Balancing Act

You will need:
- meter stick
- 3 weights (coins, washers, etc.)
- tape

1. Hold out your hands with only index fingers extended.
2. Have your partner lay the meter stick across your outstretched fingers.
3. Starting with you fingers at opposite ends of the meter stick, slowly move your fingers together, keeping the meter stick balanced at all times. The point where your fingers meet is the balance point. Note that position on the meter stick and record it on the picture of a meter stick below.




4. Tape one weight to the meter stick at the 30-cm mark.
5. Find the balance point of the meter stick with the weight on it and record your result below.
6. Tape another weight on top of the first one at the 30-cm mark.
7. Determine the balance point and record your result.
8. Tape the third weight on top of the others at the 30-cm mark.
9. Determine the balance point of the meter stick and record your result.

| | No Weights | 1 Weight | 2 Weights | 3 Weights |
|---|---|---|---|---|
| Balance Point | | | | |

10. What happened to the balance point as you added more weight?

_______________________________________________

_______________________________________________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# Balancing You!

You will need:
- Light-weight chair
- Metric ruler

**Experiment 1: From a sitting position**

1. Sit in a chair and try to rise to a standing position. Switch places so your partner can try. Record your results below.
2. Again, sit in a chair and try to rise to a standing position, but this time, do not let your shoulders move forward. Switch places with your partner so he or she can try. Record your results below.

| Experiment 1 | Results |
|---|---|
| A. Standing up from a seated position | |
| B. Standing up from a seated position without shoulder movement | |

**Experiment 2: From a standing position**

3. While you are standing, have your partner place the chair 15 cm in front of you. Try to pick up the chair. Switch places so your partner can try, and then record your results.
4. Repeat Step 3, but this time, stand with your heels, hips, back and shoulders flat against a wall. Now let your partner try it. Record your results below.

| Experiment 2 | Results |
|---|---|
| A. While standing, pick up a chair | |
| B. While standing with heels, hips, back and shoulders flat against the wall, pick up a chair. | |

5. What happened during part B of each test?

______________________________________________

______________________________________________

6. Did you expect this result? Why or why not?

______________________________________________

______________________________________________



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# 6D) Space Flight Fitness

*Staying Fit in Space*

### Time Needed

2 Sessions

### You Need This Stuff

<u>*Per Class*</u>

- sample exercise gear
- internet access

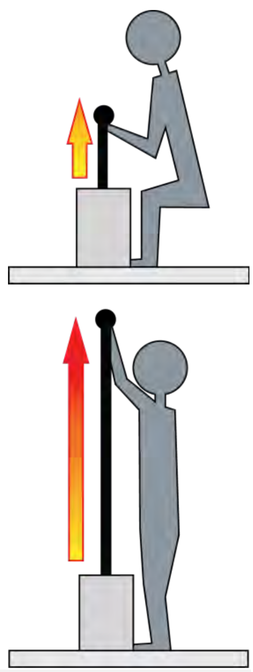
<u>*Per Student Pair*</u>

- miscellaneous materials determined by student teams, such as weights, elastic bands, springs, etc.
- design sheets for the teams

### What It's About

Needless to say, astronauts have to be fit to fly in space. Strength and endurance are essential in spite of the microgravity environment they work in. For example, doing a space walk takes a lot of upper body strength. Space suits have to be pressurized so that the astronaut doesn't get injured. Without a spacesuit the extreme low pressure of space will quickly lead to excruciating pain and death. Pressurizing space suits protects astronauts but makes them stiff. Bending in them during a long space walk is exhausting.

There is another reason to be fit for space flight. Muscles and bones are both affected by microgravity. During a two-week space flight, up to 5 pounds of total body muscle mass is lost. After about 6 months on the International Space Station, the volume of calf muscles are reduced by an average of 13 percent. Weight bearing bones, such as femurs and the spine, loose about 1 percent of their mass every month in space. The heel bone actually looses about 2 percent. The reason for the loss is lack of physical stress (the body's weight pressing down on weight bearing muscles and bones). Consequently, astronaut muscle and skeletal strength on long space missions can diminish to the level comparable to that of an elderly person.

Cosmonaut Oleg V. Kotov works out on the Interim Resistance Exercise Device on the International Space Station. Mechanisms in the two adjustable mechanisms in the cylinders to Kotov's right and left provide lift resistance to the bar.

On Earth, standing, walking, and even sitting produces physical stress on the body. Muscles are needed to maintain an erect posture and to walk or lift something. The old saying "Use it or loose it!" is very true when it comes to muscles. If you have ever broken a leg or an arm and needed a cast for several weeks, you will have had first hand experience with muscle loss. When the cast was removed, the muscles surrounding the injury were noticeably smaller. Weeks or months of rehabilitation will be needed to rebuild the muscle mass.

The skeletal system also weakens in microgravity. The bones in your body are continually being remodeled (old bone matter replaced with new bone matter). Osteoclast cells break up bone tissue by removing its mineral content in a process called bone resorption. The work of osteoclasts is balanced by another cell type, called osteoblasts, that form new bone matter. Without the stress imposed by gravity, the osteoblasts do not form as much replacement bone matter as they would on Earth. They rebuild bones to be as strong as they need to be for the



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environment. Bones literally become weaker in microgravity. Essentially, microgravity accelerates the condition called osteoporosis where the sponge-like interior of long bones become more porous, reducing bone strength and making them brittle.

To keep astronauts in space as strong as possible and to slow the loss of muscle and bone mass, vigorous exercise is called for. Taking turns using exercise gear, astronauts put in at least 2 hours of exercise a day, combining both endurance and strength building.

Microgravity does more than deconditioning astronauts. It also makes it difficult for them to exercise. Imagine being on the International Space Station and try to exercise by lifting weights. Hold a hand weight or a barbell and lift. Seems simple but microgravity is an environment in which gravity's effects are greatly reduced. In other words the weights you are lifting feel like they have no weight at all. Lifting a 100 kg (220 lbs) barbell is not much more difficult than lifting a 10 kg (22 lbs) hand weight.

How about a treadmill? A 30 minute jog on a treadmill on Earth makes quite a workout. In space, the first running step on a treadmill ricochets you to the ceiling (Newton's Third Law - Action and reaction). In space, gravity provides no assistance in exercise.

Space flight exercise equipment may look like exercise equipment on Earth but it has to be modified to provide resistance. For example, lifting a barbell is great for strengthening hands, arms, back, and legs. Gravity provides resistance. To lift the barbell, a force greater than the weight of the barbell has to be exerted in a direction opposite to the pull of gravity. In microgravity, some sort of resistance device, such as bungees or a mechanism, is needed to create the same benefits of a barbell on Earth. The ends of the barbell are anchored to the floor. The mechanism provides resistance as the astronaut lifts the bar. At the same time, the resistance keeps the astronaut's feet on the floor.

The exercise machines on the International Space Station are continually being revised to improve their conditioning benefits of the astronaut crew. Redesigning the machines has other goals as well. If the machines can be made smaller, they would take up less space in the ISS. Space that can be used for other purposes such as science experiments. Isolating the machines from the station is another goal. Running on the treadmill sets up vibrations that can be felt throughout the entire station. Vibrations can interfere with sensitive science investigations and be irritating to other crew. Engineers, designing future exercise machines for the ISS, have to include some sort of isolation system to prevent the transmission of vibrations.

Astronauts Sunita L. Williams (running on a treadmill) and James S. Voss (catching up on reading on the cycle ergometer) on the ISS. Williams is held to the treadmill by a bungee cord harness. Voss is firmly attached to the cycle ergometer by a harness and belt.

### What's The Question

Can we design and build the perfect exercise machine for the astronauts on the International Space Station?

### Before You Start

Collect some fitness gear such as stretchy bands and tubes, hand weights, grip strength trainers, or kettle bells. If possible also obtain some exercise machines such as a stationary bike or treadmill.

**What To Do**

1. Ask students if they like to exercise. What exercises do they do? How often do they exercise? Why is exercise important? Collect their ideas on the board. Ask them if they think Astronauts need to exercise in space. Why or why not? Discuss the importance of astronaut exercise for maintaining muscle and skeleton fitness.
2. Lead the discussion into the topic of exercise equipment. What kinds of equipment are there? Make a list of their ideas. How do they work?

    Hand weights, kettle bells

    Wrist and ankle weight

    Barbells

    Stretch bands and tubes

    Treadmills

    Stationary bikes

    etc.

3. Ask your students if any of these exercise machines and weights would be useful in space. Why or why not?
4. Challenge your students to design an exercise device for use by the astronauts on a mission to Mars. The device will have to be light in weight because launching materials and astronauts to Mars will be very expensive. The device will have to be easy to set up and not interfere with other parts of the spacecraft. A good device should be useful for exercising more than one part of the body. Organize students into design teams. Permit them to investigate the exercise equipment you brought in. Invite students to bring materials from home to make prototype devices. Also permit teams to investigate exercise equipment on the Internet. Limit their search to sports stores and manufacturers of equipment.

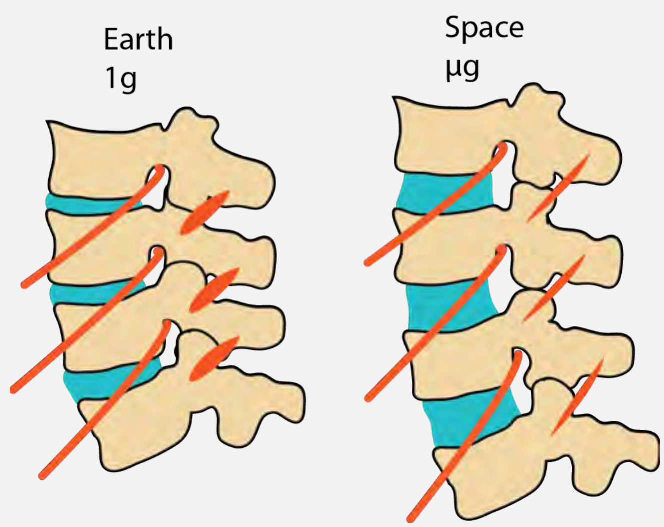
    As an alternative to constructing a prototype for an exercise device to be used in microgravity, have students design and test a ground-based exercise program for helping astronauts improve their fitness before their mission in space. Have students describe their program and its fitness goals.

5. Hold an exercise fair with your student. Have teams set up a small table display or poster explaining their ideas for exercises or exercise equipment. Invite guests to come and learn about their ideas. Teams should explain what the exercise does and why it is important to astronauts on long space voyages. If they propose using a device of their design, they should have an exercise plan that uses the device they created. Challenge teams to test their programs for a week and report their results.

Going to Space Makes You Taller

Another of the effects of microgravity is stature. When astronauts travel to space, they add 6 to 8 centimeters to their morning height on Earth. Morning height means how tall you are when you get up. It is different from when you go to bed. The reason is due to the way our spines are constructed. Spines are made up of many bones called vertebrae. Each are separated by spongy disks that act as shock absorbers. At the end of the day, the disks are slightly compressed, shortening our bodies. By morning, the disks expand to their normal size, stretching us out again. In space, the pressure on the spine is gone and the disks expand even more. Muscles become stretched, which leads to lower back pain for many astronauts. "Growth" in space is only temporary. Back on Earth, gravity takes over and astronauts return to their normal heights.

Lumbar Vertebrae on Earth and in Microgravity




Challenge Activity

Challenge students to measure their height at home just before they go to bed. Have them measure again just after they get up. Is there a difference? For accuracy, its best if someone assists your students measure their height.



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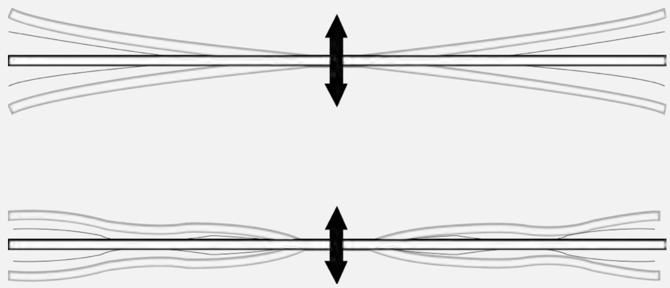
### Wrapping Up

- Hold a post fair briefing with the teams and discuss the importance of exercise on Earth. What will each of them do to make themselves fit for flight?

### Extras

- When astronauts return from space, their bodies will be much weaker than when they left Earth. Have teams design a rehabilitation program to help returning astronauts regain their strength and fitness. Include dietary recommendations. What kinds of food will help them rebuild muscle and bone strength? Use the Internet to research different kinds of diets and exercise programs.



Mechanical Resonance Demonstration

The ISS exercise treadmill features an isolation mount that prevents vibrations or mechanical resonance from its use from affecting the ISS.

Mechanical resonance can be demonstrated with a flexible rod like a long piece of 1/2 PVC pipe, fishing pole (without the grip), long thin dowel, etc. Grip the rod in its middle and hold it horizontally. Shake the rod up and down while gradually increasing the frequency (up-down speed). When the correct frequency is reached, the rod will absorb energy and its ends will oscillate with wide swings. This is called mechanical resonance. If the resonance frequency is not matched, movement of the rod ends will be chaotic.

The concern for the International Space Station is that the treadmill's vibrations will match the resonance frequency of parts of the station and cause them to vibrate, possibly producing damage.

Compare small energy inputs from the ISS treadmill too small pushes on a child on a swing. Match the frequency of the swings and the child swings higher and higher.



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# 6E) Building Strength

## *Good Stress*

### Time Needed
1 – 2 Sessions

### You Need This Stuff
*Per Class*
- overhead projector and screen
- clock with second hand or timer

*Per Group*
- 2 transparent plastic knives

*Per Student*
- spring-hinge clothespin
- copy of "Stress This!" student sheet

### What It's About

Generally, when we think of stress, we think of being overworked, mentally tired or overwhelmed by our daily lives. While too much stress can be detrimental to the body, too little of some kinds of stress can be harmful. Activities like walking, carrying packages and mopping the floor are physical stresses. Activities like doing crossword puzzles, balancing the check-book and reading are mental stresses. There also are emotional stresses, like receiving a bad grade on a test or walking into a surprise birthday party. Our bodies, including muscles and bones, require some physical and mental stresses to be healthy and grow.

Physical stress is created when bones and muscles are made to work against a force. It occurs when we pick up something heavy, like a 20-pound bag of cat litter. Gravity pulls down on the bag and we have to work to overcome that force to lift the bag. Swimming also causes stress because muscles and bones have to work against the resistance of the water to move the body. Gravity pulls on our bodies and our muscles and bones constantly work to counteract that force and keep us balanced.

Stress from physical activity is necessary for bone growth and maintenance. The body builds bone based on its needs. The need for any particular bone is dictated by the amount of stress placed on it. During the years a person's bones are growing (birth to about age 25), physical stress on bones causes builder cells to work more, which makes bones grow. Builder cells produce collagen fibers that form the framework of bones. The framework is then filled in with minerals, producing a strong, thick bone (see Activity 4). Even after they stop growing, bones still need physical stress to maintain thickness and strength.

Muscles also rebuild and grow as a result of physical stress. Stress can lead to change in either muscle strength or muscle stamina (the ability to perform an activity for a long time without becoming tired). High-intensity, short-duration exercises (or stresses), like weight lifting, cause muscles to increase in strength. Low-intensity, long-duration activities, such as running and swimming, cause muscles to increase in stamina.

### What's The Question?

Can physical stress be good for the body?

### Before You Start

Place the materials for each session in a central area for Materials Managers to collect for their groups.

Part 1. Divide students into groups of 2–4 and give each group two plastic knives. Set up the overhead projector.



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Part 2. Give every student one clothes pin and a copy of "Stress This!"

### What To Do

<u>Part 1. Stress observations</u>

1. Introduce the topic of stress by asking questions such as, What is stress? How can stress be a good thing? What are some good stresses? Explain that there are "good" stresses and "bad" stresses and that the body needs good stresses, like exercise, to be healthy.
2. Tell students that they are going to investigate how physical stress can affect bone—a hard material.
3. Have students compare the two knives to determine if they are the same or different.
4. Instruct students to mark one knife and bend it back and forth several times without breaking it.
5. Again, have the students compare the two knives. Ask them if anything is different between them. Request a volunteer to bring up his/her group's knives and place them on an overhead projector. Have students observe the knives and ask again if there is anything different between them. The students will be able to observe that very thin opaque lines have developed only in the knife that was bent. Often, the lines are observable even without using an overhead projector. However, the projector will make the lines easier to see.
6. Discuss students' observations. Explain that when they bent the knives or plastic strips, they applied physical stress and changed the appearance of the objects. Ask, If we wanted to break this knife, would it be easier to do so where we bent it before, or at another point? Why do you think it would be easier to break where we've already bent it? The changes in the knives may look minor, but they are important to the objects' structure. This concept is true for bones, too. Gravity and movement cause invisible stress patterns in bones. These patterns are very small. If we could see them, they would look very unimportant, but they tell the "bone construction crews" where to work to make bone thicker and stronger.

<u>Part 2. Stress and muscles</u>

1. Explain to students that they will be exploring the effects of stress on the muscles in their hands.
2. The first trial will test each student's initial muscle strength and stamina. Explain the exercise to students. Ask students to predict how many times they will be able to click a clothespin with their right (or dominant) hand during each of three, one-minute trials, and to record their predictions on their "Stress This!" student sheets. Have each student count the actual number of times he/she can click a clothespin in one minute using his/her right (or dominant) hand, and record his/her results. Have students rest for one minute and then repeat the trials two more times. If students are working in pairs, have one student complete the trial while the other measures the time. Then have students switch roles. After students have completed all trials, ask, Did you feel your hand muscles burn? Were you more tired after each minute of clicking? Why do you think that happened?
3. Every other day for the next two weeks, have students repeat the exercise described above. This is the conditioning period. The stress induced by the clothespin on the muscles of the hand will cause the muscles to become stronger and gain stamina. Students should predict and report their results each day.
4. The test of how well the stress conditioning worked comes on the last day of the two-week period. Again, have each student predict how many times he/she will be able to click the clothes-pin during the timed periods and record his/her prediction. Have each student repeat the clicking-resting experiment again exactly as it is described in Step 2 and record the results.
5. Instruct students to write a paragraph (on a separate sheet of paper) about the results of their experiment. They should explain what happened and why they think things turned out the way they did.



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6. Discuss results from the initial and final experiments. Students will discover that they were able to click the clothespin more times (and with less muscle soreness) in the first one-minute period after the conditioning period. This shows that their muscles have grown stronger. Students also will discover that they are able to click more times in the second and third one-minute periods after the conditioning has taken place. This shows that the muscles have increased in stamina. Ask students, Were you able to click more times in the third trial after two weeks than at the beginning of the experiment? Why do you think that happened? How did your results compare with your predictions?

### Wrapping Up

- Have students graph their results to produce a visual representation of changes that occurred in the three bi-daily trials over the course of two weeks. They should create separate graphs for each one-minute period and record how the number of clothespin clicks changed over time. This will help students to understand how their strength and endurance increased.

### Extras

- None of your bones are as old as you are. Each year, about 10% of your bone is eaten away and replaced by special cells.
- Muscle soreness the day after physical activity is the result of a temporary mild inflammation in the muscle. The "burn" felt immediately after vigorous exercise is a result of the accumulation of waste (in the form of lactic acid) in hard-working muscle tissue.
- Lack of stress is bad! Stress dictates the amount of bone that is built at a particular site—depending on need.

  Muscles need stress, too. With regular practice, your body will become better at performing almost anything because your muscles will change in response to the stress caused by the new activity. It may be difficult to run a mile or to do 20 push-ups at first, but if you practice, it may become easier after 1–2 weeks.
- Exercise has been shown to be effective in improving muscle strength and performance, even in elderly persons. Exercise also helps maintain bone density and may reduce the calcium loss from bones (osteoporosis).
- **Stress Fractures:** Bone construction crew workers, osteo-blasts and osteoclasts, repair cracks before they get too large so that bone strength is maintained and fractures are prevented. If an area of bone is repeatedly stressed, the con-struction crew may not have sufficient time to repair cracks, and fractures (broken bones) may occur. This happens in some athletes who suffer breaks known as "stress fractures."



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## Stress This!

You will need:
- clothespin
- timer, watch or clock

21. Predict the number of times you will be able to click the clothespin between your thumb and index finger in your right (or dominant) hand for a one-minute period. Record your prediction in the table.
22. Hold the clothespin in your right (or dominant) hand between your thumb and index finger. While your partner is watching the timer, count the number of times you are able to click the clothespin in a one-minute period. Record the result.
23. Rest for one minute, then predict again and repeat Step 2. Rest for another minute. Repeat prediction and Step 2 again for a third trial. Be sure to hold the clothespin the same way during every time trial.
24. Switch roles with your partner and have him or her conduct the same experiment, Steps 1–3, with his or her right (or dominant) hand and record the results.
25. After completing the trials, write a paragraph on a separate sheet describing whether any of your numbers changed from Trial 1 to Trial 3. If they did, describe what changed.
26. On the same sheet of paper, describe what happened to your muscles during this experiment.
27. Repeat steps 1–4 every other day for two weeks, for a total of seven days. Record your predictions and results in the table below.
28. After two weeks, write another paragraph about the results of your experiments. Tell what happened and explain why you think things turned out as they did.

| Date | Trial 1 | | Trial 2 | | Trial 3 | |
|---|---|---|---|---|---|---|
| | Prediction | Actual | Prediction | Actual | Prediction | Actual |
| | | | | | | |
| | | | | | | |
| | | | | | | |
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# 6F) Eating in Space and on Earth

## *Spaced Out Foods*

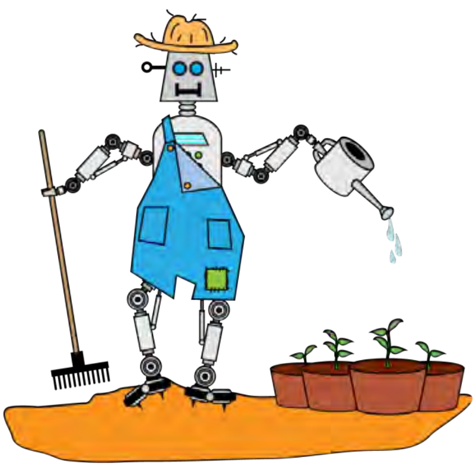
**Time Needed**
2 – 3 Sessions

**You Need This Stuff**

*Per Class*
- bathroom scale
- metric ruler or metric tape measure
- 1 butane lighter – long (for teacher to use)
- Can opener
- Needle nose pliers
- Scissors

*Per Teams of 3 students*
- 2 small aluminum pot pie pans
- 2 small binder clips
- Solid copper wire (about 15 cm) or large paper clip
- Empty soft drink can
- 50 ml of water for each calorimeter test (use graduated cylinder for measuring)
- Safety goggles
- Thermometers
- Cheerios® breakfast cereal (four pieces)
- ¼ of a pecan half

*Optional*
- Ziploc vacuum bags and vacuum pump
- Assorted snack food and mixes



**What It's About**

Going to space is a bit like going on a camping trip. Before you leave, you have to gather everything you are going to need. Clothing, shelter, cook gear, and food all have to be thought out very carefully. When you get to your destination, you will either have what you need or go without.

Astronaut Kent Rominger prepares a snack.

Recipe: Peanut butter, chocolate bar, on tortilla. Warm in an oven.

It's the same for space flight. Fortunately, astronauts don't have to take everything with them when they visit the International Space Station. The station provides shelter from the dangers of space and most of the tools astronauts will need were brought up on previous space missions. They do have to bring food. Everything they will eat for their stay in space has to be planned in advance. In space, you can't send out for a pizza.

Food is energy. Astronauts need lots of energy to perform their work in space. When planning the food for a space mission, many things have to be taken in consideration. One of the most important things is the energy value of foods. Does the food chosen for space flight provide enough energy to sustain the astronauts on during their mission? Along with energy are other important considerations. Does the food provide essential nutrients? Is it healthy? Does it taste good so that astronauts will actually want to eat it in space?

Before every space mission, astronauts sit down with dieticians to plan their menus. Samples of food are taste tested. Breakfast, lunch, dinner and snacks are planned out for weeks at a time. This is the food the astronauts will eat in space. Anything forgotten? Missing items can be brought up on supply ships but it will take a month or more to get them. Careful planning is really important.

There is much more to space food than just picking things to eat. There is microgravity to consider. On Earth, you cook a pot of noodles for spaghetti. You fill a pot with water and heat it up and then add the noodles. When cooked, you strain the noodles and add sauce. Sounds easy. In space, it would be a nightmare. First, microgravity makes it feel like gravity has gone away. It hasn't but the free fall orbit of the ISS greatly reduces gravity's effects



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like buoyancy. If you boil a pot of water, the bubbles remain at the bottom of the pot nearest the heat because they don't rise to the top as they do on Earth. Instead, the pot bottom fills with bubbles and pushes the hot water out of the pot. If you could cook the noodles, separating them from the water would be a challenge without gravity's effects. The water and noodles won't pour from the pot and if you get the water and noodles into a strainer, the water won't drip out. Then, there is the sauce. We don't even want to talk about that!

ISS crew members Peggy Whitson and Valerly Korzun prepare to eat hamburgers.

The solution to a spaghetti meal in space is packaging. Pre-cooked noodles and sauce are packaged in a foil pouch. Cooking it in space is simply a matter of heating the pouch, cutting it open with a scissors, and dipping in with a fork. Packaging is really the secret of space foods. Everything goes into a package. The food can be pre-cooked, freeze-dried, or natural form like dried apricots. If the food is freeze-dried, hot or cold water is added to it to make it ready to be eaten. A convection oven is available for extra heating.

The one food astronauts don't get enough of is fresh foods. Each time a supply ship arrives, a small quantity of fresh items like fruit are brought up. Because the astronauts don't have a refrigerator, the fresh foods have to be eaten over the next couple of days or the station will begin to smell like spoiled fruit - yuck.

One of the most uprising things about space food is its ordinariness. Except for the packaging, it's just like the food we eat on Earth. Many of the items come straight from the supermarket and are repacked for flight. Some things, like candy bars, come just as they are.

Preparing three healthy meals plus snacks for the crew of the International Space Station is quite a chore. Imagine what preparing the food for a mission to Mars, that would last about 2 years, would be like. For one thing, no supply ships. It has been suggested that an unmanned spacecraft could be sent to Mars before the human crew. Robots could start processing the Martian surface for oxygen, water, and even rocket fuel for the return. Other robots, could start growing food.

### What's The Question

What foods would you like to take on a space voyage?

### Before You Start

Prepare calorimeters for teams of 3 students. See instructions.

### What To Do

<u>Part 1: BMR and Daily Calorie Needs</u>

1. Begin a discussion about food by asking questions such as why do we need to eat, what is a diet, how many calories do we need a day, etc. Food is an essential part of life. We all have to eat to provide energy for living. What we eat and how much we eat is called our diet. (Dieting, on the other hand, refers to changing one's diet to accomplish some goal such as loosing weight. improving health, or fitting into tight jeans.)  Ask students What did you eat in the last 24 hours? Have them write out a list of foods they ate. Ask them to list what they think astronauts would eat. When we think about food, it is mostly about what we are going to have for dinner or what we need to buy from the store. It is a different matter for astronauts in space. There aren't any stores or fast food restaurants where



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they can pop in for a snack. All the food needed for a space mission has to be planned in advance. Imagine what it would be like to plan meals for a space mission to Mars. Six astronauts together for 690 days (Earth to Mars and back). Everything you are going to eat has to be taken with you. You don't want to run out.

2. Ask your students how much food they need every day. Make sure they understand that they are not being asked how much food they want every day. Instead, how much do they need? When they know how much food for a day, they can calculate how much food they would need for a long space voyage. The calculation involves several steps.
    1. Calculate individual basal metabolic rate.
    2. Determine kilocalorie needs based on activity level.
    3. Examine the kilocalorie content for potential space foods.
    4. Create balanced menus.

> What is a kilocalorie?
>
> When you look at nutritional information on a food package, one of the first things listed are calories. By definition, a calorie is the amount of energy needed to raise one gram of water one degree Celsius. Even though packages use the term calories, they are actually referring to kilocalories (1,000 calories). It is less frightening to see that a 1/2 cup serving of ice cream is 400 "calories" (kcal) than to see to the actual amount - 400,000 calories!

3. Begin the calculations by giving every student a copy of the BMR for Male (or Female) Astronaut page. Place the bathroom scale in a corner of the room and put a measuring scale (in centimeters) against a blank wall. The scale can be made from two meter sticks taped to the wall, one on top of the other.

   Tip: If students are shy about their weight, they can make up an imaginary astronaut with made-up weight, height, and age and use that for their calculations.

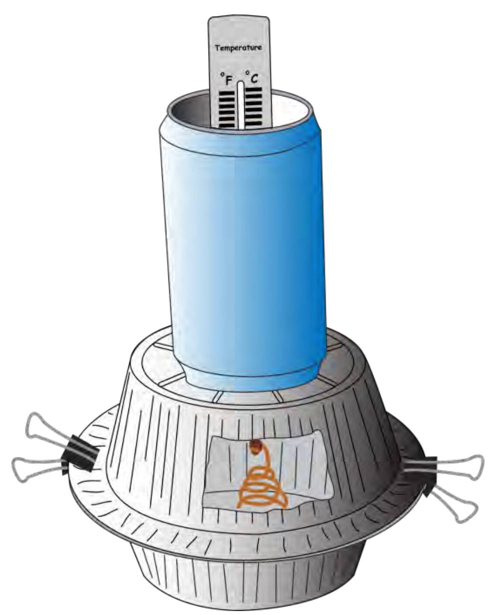
   BMR or basal metabolic rate is an estimate of how much energy is produced by your body from the food you eat, the action of your muscles, and the normal functions of your internal organs. Students will need to know their mass in kilograms, height in centimeters, and their age. The calculations are different for males and females. Once the BMR is determined, students will multiply their BMR times a number based on their activity level to get the total amount of kilocalories they need every day.

   When students have determined their BMR and daily kcal needs, have them multiply their daily kcal needs by 690 to find out how much food energy they will need for a Mars mission.

Part 2: Measuring Calories

Making a Calorimeter (To be done by teacher or teacher aide)

- Cut a side window and a bottom hole in an aluminum pot pie pan for each calorimeter.
- Bend a copper wire or large paper clip to make a stand for the foods that will be tested.
- Cut the tops off the soft drink cans with a can opener.




How to Use the Calorimeter

- Place a food item to be tested on the wire stand.
- Place the stand in the bottom of an (uncut) aluminum pot pie pan.
- Invert the cut pan and place it over the top of the first pan. Hold the two pans together with the binder clips.
- Place 50 ml of water in the soft drink can. Measure its initial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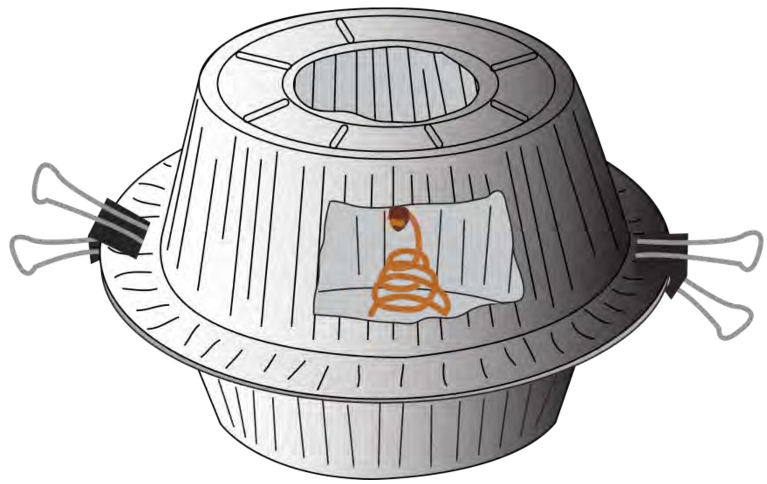
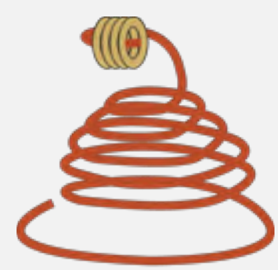
temperature. Put on eye protection.

- Light the food on fire (teacher does this). Immediately place the can with the water over the hole.
- When the fire goes out, measure the final temperature of the water.
- To determine how many calories (actual calories) the food item contained, multiply the temperature change in degrees times 50 (the quantity of water).



1. Hold up a package of Cheerios® and a package of pecan nuts. Ask students, which food would be better to take on a trip to Mars? List their ideas on the board. What are the advantages and disadvantages of each food? Which one provides the most food energy?
2. Tell students that the energy in foods can be measured with a calorimeter. Show them a calorimeter setup. Tell them that food samples are placed inside the calorimeter and burned. The heat released by the burning can be measured with this device.
3. Demonstrate how the calorimeter is set up. The food sample to be burned is placed inside. A can with water is placed on top of the calorimeter. The food sample to be burned is placed inside. Heat from the burning food raises the water temperature. Multiplying the temperature change times the number of milliliters of water, determines the calories the food contained. See more details on the next page.
4. Have teams of three students set up their calorimeters as described on the student page.
5. Provide each team with 4 Cheerios pieces and 1/4th of a pecan nut half. (4 Cheerios® and 1/4 of a pecan half have approximately the same mass. If you have a sensitive scale, have students compare the two and make adjustments to the quantities if necessary.) Have students place one of the foods on the wire stand. When teams are ready, use the lighter and light the food item. Immediately, upon ignition, place the can on top of the calorimeter and let it stay there until the food is fully consumed. Repeat with the other food item.

Wire Stand



Paper Clip Stand

Important Tips

- Both food items should have the same mass. If you have a sensitive beam balance or electronic scale, have students measure the two foods. Small amounts of the nut can be broken off to make it weigh the same as the Cheerios. Otherwise, about 4 Cheerios equals 1/4th of a pecan nut half.
- Have teams change out the water for each test. Warn them not to touch the blackened bottom of the can. Carbon black makes a mess of clothing.
- Remind students not to touch the calorimeter when food inside is burning. Give the wire stand a few minutes to cool before touching it.



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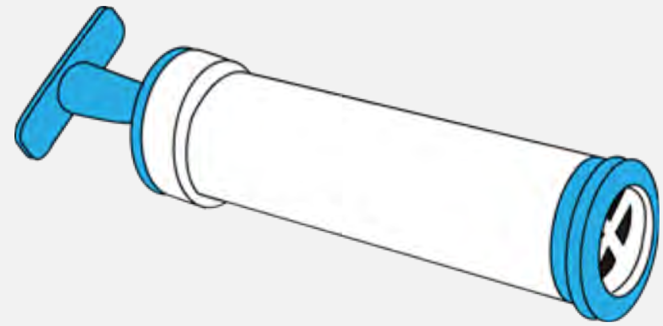
## Optional Extension: Make a Space Snack

Invite students to make their own space foods. The recipes below provide instruction for making trail mix, a beverage, or a pudding desert.



Vacuum bags (quart and gallon size) are available from supermarkets along with an inexpensive pump. Ziploc® brand.

1. Talk about space food packaging. Ask if they have seen what happens to food, like bread, potato chips, or fruit, when left out too long. What happened to the food? How did it look? How did it smell? Compare their observations to the same kinds of food in stores. Why does that food last longer on the shelf? Point out that food packaging reduces spoilage because it limits food exposure to oxygen, humidity, and microbes such as bacteria and mold. One of the best ways to preserve food is vacuum packaging. Air is pumped out of the package before sealing. Many space foods are vacuum packed for just that reason and it makes the packages smaller for easier storage.
2. Set up a simple investigation on bread shelf life. Place a slice of white bread in a zip locking bag and a second slice in a bag that can be vacuum sealed. Pump out the air in the second bag. Observe the condition of the bread samples over the next couple of weeks. (Do not open them!)
3. Have students make a space food pack from the recipes on the next page. The beverage and pudding recipes require checking store packages for quantities needed. Show students how to vacuum seal their packages. Have students create a label for their space food packs.
4. Collect the packs. Double check the packages to make sure students sealed them properly. Save the packs for a field trip, field day, or special classroom event.

<u>Comparison of Storage Methods</u>

The chart below shows why vacuum storage is superior to regular or freezer storage.  Vacuum-stored food has a longer shelf or freezer life, which makes it suitable for long-duration space flight to Mars. Food, grown on Mars, will be vacuum packed for the return trip.

| Food Stored in Cupboards | Regular Storage | Vacuum Storage |
|---|---|---|
| Bread/Rolls | 2-3 days | 7-8 days |
| Pastry | 120 days | 300 days |
| Crackers/Potato Chips | 5-10 days | 20-30 days |
| Raw rice/pasta | 180 days | 365 days |

| Food Stored in Freezer | Regular Storage | Vacuum Storage |
|---|---|---|
| Fresh meat/poultry | 6 months | 18 months |
| Ground meat | 4 months | 12 months |
| Cold meats | 2 months | 4-6 months |
| Bread/rolls | 6-12 months | 18-36 months |

All comparisons are approximate.

## Wrapping Up

- Discuss what is recommended for a healthy diet by the United States Department of Agriculture. Go to the following site for details.

    http://www.choosemyplate.gov/



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The USDA diet:

Emphasizes fruits, vegetables, whole grains, and fat-free or low-fat milk and milk products;

Includes lean meats, poultry, fish, beans, eggs, and nuts; and

Is low in saturated fats, trans fats, cholesterol, salt (sodium), and added sugars

- Have students plan a 1 day menu for a mission to Mars. Have students make their choices from the current International Space Station food list. Use the menu planner. Ask students "Why a scissors? (Astronauts need to be able to open the food packages.) Have students share their menus. Check to see if all food groups are included.
- Have students plan a 1 day menu for themselves. Have them use http://www.choosemyplate.gov for information on the five food groups, sample daily food plans, and healthy eating tips.

**Extras**

- Obtain packages of Astronaut Ice Cream as a treat for the students. Astronaut ice cream was flown only once on the Apollo 9 mission in 1969. Obtain the treat from museum gift shops or from the following sources:

  http://Amazon.com

  http://www.thespacestore.com/asicecream.html


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# BMR for Female Astronaut (and you)
## and
# Daily Energy Needs

**Instructions:**
You are planning a mission to Mars. The Mission will take 690 days from launch to landing on Mars to a return to Earth. You will need to determine how much food energy (kilocalories) you will need for the entire mission. Doing so is a three-step process.
1. Determine your BMR or basil metabolic rate. This is an estimate of how much energy is produced by your body from the food you eat, the action of your muscles, and the normal functions of your internal organs.
2 Determine the number of kilocalories of food energy you will need each day to maintain body mass and fitness.
3. Multiply your answer for number 2 times 690 for the total number of kilocalories you will need for the entire mission. Your other crew members will do the same.

---

What is your weight in kilograms?
(divide your weight in pounds by 2.2) [ kg ]

What is your height in centimeters? [ cm ]

---

**1**
## BMR Calculation

A: Your mass times 9.5663 = ___________

B: Your height times 1.85 = __________

C: Your age times 4.76 = ____________

Add A + B + 655.1 = _______________

Subtract C from your total = ______________

**This is your BMR**

**2**
## Daily Energy Needs Based on Activity

**No exercise**
**(TV, computer games, sitting)**

_________________ times 1.2 = _____________kcal
**your BMR**

**Moderate exercise**
**(workouts, sports, 3-5 days a week)**

_________________ times 1.55 = _____________kcal
**your BMR**

**Very active**
**(hard exercise, heavy work)**

_________________ times 1.9 = _____________kcal
**your BMR**

---

**3**
## Your Energy Needs for 690 Day Mars Mission

**Pick the kcal for your daily energy needs that best represents your activity level.**

___________________ times 690 = ____________________kcal

**This is what you'll need for a 690 day mission to Mars.**


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# BMR for Male Astronaut (and you)
## and
# Daily Energy Needs

**Instructions:**

You are planning a mission to Mars. The Mission will take 690 days from launch to landing on Mars to a return to Earth. You will need to determine how much food energy (kilocalories) you will need for the entire mission. Doing so is a three-step process.

1. Determine your BMR or basil metabolic rate. This is an estimate of how much energy is produced by your body from the food you eat, the action of your muscles, and the normal functions of your internal organs.
2 Determine the number of kilocalories of food energy you will need each day to maintain body mass and fitness.
3. Multiply your answer for number 2 times 690 for the total number of kilocalories you will need for the entire mission. Your other crew members will do the same.

---

What is your weight in kilograms? (divide your weight in pounds by 2.2) [ ] kg

What is your height in centimeters? [ ] cm

---

**1**

## BMR Calculation

A: Your mass times 13.75 = ___________

B: Your height times 5.003 = __________

C: Your age times 6.775 = ____________

Add A + B + 66.5 = _______________

Subtract C from your total = ______________

**This is your BMR**

**2**

## Daily Energy Needs Based on Activity

**No exercise**
**(TV, computer games, sitting)**

_________________ times 1.2 = _____________kcal
**your BMR**

**Moderate exercise**
**(workouts, sports, 3-5 days a week)**

_________________ times 1.55 = _____________kcal
**your BMR**

**Very active**
**(hard exercise, heavy work)**

_________________ times 1.9 = _____________kcal
**your BMR**

---

**3**

## Your Energy Needs for 690 Day Mars Mission

**Pick the kcal for your daily energy needs that best represents your activity level.**

___________________ times 690 = ____________________kcal

**This is what you'll need for a 690 day mission to Mars.**



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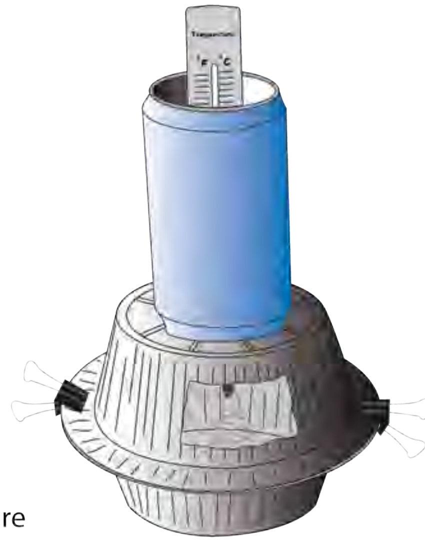
# Food For Mars Mission
# What to Take

**Student Names:** ____________________ ____________________ ____________________



1. Set up calorimeter as shown.
2. Remove the soft drink can temporarily.
3. Place 50 ml of water in the soft drink can. Measure and record the water's initial temperature.
4. Place the food to be tested at top of wire stand inside calorimeter.
5. Put on eye protection.
6. Call teacher over to light the Cheerios.
7. Immediately replace the can and wait until the flames go out.
8. Measure and record the new temperature of the water.

| Food Item | Initial Water Temperature | Final Water Temperature | Temperature Difference |
|---|---|---|---|
| 4 Cheerios® | | | |
| 1/4 Pecan Nut | | | |

How many calories did each item contain? Multiply temperature difference by 50.

| | Cheerios | Pecans |
|---|---|---|
| Number of Calories | | |

Of these two food items, which would be better to take to Mars?

Explain your choice.

Many potential food choices for space flight have been investigated and the calories they hold and the nutrients they contain are known. To learn out about many different foods, go to the following web site:

Nutrient Data Lab, US Department of Agriculture

http://ndb.nal.usda.gov/



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# Space Food Pack Instructions

Trail Mix

- Place 1/4 - 1/2 cup of trail mix (commercial or make your own - nuts, dried fruits, seeds, crackers, candies, etc.) in a quart vacuum bag.
- Pump out the air in the bag.
- Have each student make a label with their name on it and the words "Trail Mix."
- Save the snacks for the field trip.

Beverage

- Place a scoop of dry beverage crystals in a quart vacuum bag.

  (The exact amount of crystals depends upon the beverage chosen and its instructions. Plan for 8 ounce drinks.)
- Pump out the air in the bag.
- Have each student make a label with their name, beverage name, and instructions for preparation. (e.g., "Add 8 ounces of cold water.")
- Save the snacks for the field trip.

Pudding (typical proportions - confirm with package instructions)

- Place 1/4 package of instant pudding mix in a quart vacuum bag
- Place 1/6 cup dry milk in the bag.
- Seal and shake the bag to mix the dry pudding and milk.
- Pump out the air in the bag.
- Have each student make a label with their name, flavor of the pudding, and instructions for preparation. (e.g., Add 8 ounces of cold water. Squish the bag gently to mix the water. Wait 5 to 10 minutes.)


Assortment of International Space Station Vacuum Sealed Packages



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# Space Food List for the International Space Station

BEVERAGES

- Apple Cider
- Breakfast Drink, Chocolate
- Breakfast Drink, Strawberry
- Breakfast Drink, Vanilla
- Cherry Drink w/ A/S
- Chicken Consommé (B)
- Cocoa
- Coffee, Black
- Coffee w/ A/S
- Coffee w/ Cream
- Coffee w/ Cream & A/S
- Coffee w/ Cream & Sugar
- Coffee w/ Sugar
- Cranberry Peach Drink w/ A/S
- Decaf Coffee, Black
- Decaf Coffee w/ A/S
- Decaf Coffee w/ Cream
- Decaf Coffee w/ Cream & A/S
- Decaf Coffee w/ Cream & Sugar
- Decaf Coffee w/ Sugar
- Grape Drink
- Grape Drink w/ A/S
- Grapefruit Drink
- Green Tea
- Green Tea w/ Sugar
- Kona Coffee, Black
- Kona Coffee, w/ A/S
- Kona Coffee w/ Cream
- Kona Coffee w/ Cream & A/S
- Kona Coffee w/ Cream & Sugar
- Kona Coffee w/ Sugar
- Lemonade
- Lemonade w/ A/S
- Lemon-Lime Drink
- Mango-Peach Smoothie
- Orange Drink
- Orange Drink w/ A/S
- Orange-Grapefruit Drink
- Orange Juice
- Orange-Mango Drink
- Orange-Pineapple Drink
- Peach-Apricot Drink
- Pineapple Drink
- Strawberry Drink
- Tea, plain
- Tea w/ A/S
- Tea w/ Cream
- Tea w/ Cream & Sugar
- Tea w/ Lemon
- Tea w/ Lemon & A/S
- Tea w/ Lemon & Sugar
- Tea w/ Sugar
- Tropical Punch
- Tropical Punch w/ A/S

BREADS

- Chipotle Snack Bread (NF)
- Tortilla (NF)
- Waffle (NF)
- Wheat Flat Bread (NF)

CEREALS

- Bran Chex (R)
- Cheese Grits (T)
- Cornflakes (R)
- Granola (R)
- Granola w/ Blueberries (R)
- Granola w/ Raisins (R)
- Grits w/ Butter (R)
- Oatmeal w/ Brown Sugar (R)
- Oatmeal w/ Raisins (R)
- Rice Krispies (R)

ENTREES

- Baked Tofu (T) *
- Barbeque Beef Brisket (I)
- Beef Enchiladas (I)
- Beef Fajitas (I)
- Beef Ravioli (T)
- Beef Steak (I)
- Beef Stroganoff (R)
- Beef Tips w/ Mushrooms (I)
- Breakfast Sausage Links (I)
- Cheese Tortellini (T)
- Chicken Fajitas (T)
- Chicken-Pineapple Salad (R)
- Chicken Salad Spread (T)
- Chicken Strips in Salsa (T)
- Chicken Teriyaki (I)
- Chicken w/ Corn & Black Beans (T)
- Chicken w/ Peanut Sauce (T)
- Crawfish Etouffee (T)
- Curry Sauce w/ Vegetables (T) *
- Fiesta Chicken (T)
- Grilled Chicken (T)
- Grilled Pork Chop (T)
- Lasagna w/ Meat (T)
- Meatloaf (T)
- Mexican Scrambled Eggs (R)
- Pasta with Shrimp (R)
- Salmon (T)
- Sausage Pattie (R)
- Scrambled Eggs (R)
- Seafood Gumbo (T)
- Seasoned Scrambled Eggs (R)
- Shrimp Cocktail (R)
- Shrimp Fried Rice (R)
- Smoked Turkey (I)
- Spaghetti w/ Meat Sauce (R)
- Sweet & Sour Chicken (R)
- Sweet & Sour Pork (T)
- Teriyaki Beef Steak (I)
- Teriyaki Chicken (R)
- Tofu w/ Hoisin Sauce (T) *
- Tofu w/ Hot Mustard Sauce (T) *
- Tuna (T)

Tuna Noodle Casserole (T)
Tuna Salad Spread (T)
Turkey Tetrazzini (R)
Vegetable Quiche (R)
Vegetarian Chili (R) *

FRUITS

Applesauce (T)
Apples with Spice (T)
Berry Medley (R)
Citrus Fruit Salad (T)
Dried Apricots (IM)
Dried Peaches (IM)
Dried Pears (IM)
Fruit Cocktail (T)
Peach Ambrosia (R)
Peaches (T)
Pears (T)
Pineapple (T)
Rhubarb Applesauce (T)
Strawberries (R)
Tropical Fruit Salad (T)

SOUPS

Beef Stew (T)
Chicken Noodle (T)
Hot & Sour (T)
Minestrone (T) *
Mushroom (R)
Potato (T)
Tomato Basil (T)
Split Pea (T)
Vegetarian Vegetable (T) *

SNACKS & SWEETS

Almonds (NF)
Apricot Cobbler (T)
Banana Pudding (T)
Bread Pudding (T)
Brownie (NF)
Butter Cookies (NF)
Butterscotch Pudding (T)
Candy Coated Almonds (NF)
Candy Coated Chocolates (NF)
Candy Coated Peanuts (NF)
Cashews (NF)
Cheddar Cheese Spread (T)
Cherry Blueberry Cobbler (T)
Chocolate Pudding (T)
Chocolate Pudding Cake (T)
Cranapple Dessert (T)
Crackers (NF)
Dried Beef (IM)
Granola Bar (NF)
Macadamia Nuts (NF)
Nut & Fruit Granola Bar (NF)
Peanut Butter (T)
Peanuts (NF)
Rice Pudding (R)
Shortbread Cookies (NF)
Tapioca Pudding (T)
Trail Mix (IM)
Vanilla Pudding (T)
Yogurt Covered Granola Bar (NF)

STARCHES

Baked Beans (T)
Black Beans (T) *
Brown Rice (T)
Candied Yams (T)
Corn (R)
Cornbread Dressing (R)
Homestyle Potatoes (T)
Macaroni & Cheese (R)
Mashed Potatoes (R)
Noodles & Chicken (R)
Pasta w/ Pesto Sauce (T)
Potato Medley (T)
Potatoes au Gratin (R)
Red Beans & Rice (T) *
Rice & Chicken (R)
Rice Pilaf (R)
Southwestern Corn (T)

VEGETABLES

Asparagus (R)
Broccoli au Gratin (R)
Carrot Coins (T)
Cauliflower w/ Cheese (R)
Creamed Spinach (R)
Green Beans w/ Mushrooms (R)
Green Beans & Potatoes (T)
Italian Vegetables (R)
Mixed Vegetables (T)
Spicy Green Beans (R)
Sugar Snap Peas (T)
Teriyaki Vegetables (R) *
Tomatoes & Artichokes (R) *
Tomatoes & Eggplant (T)

YOGURT

Blueberry-Raspberry Yogurt (T)
Mocha Yogurt (T)

Abbreviations:
(A/S) Artificial Sweetener (B) Beverage
(FF) Fresh Food (IM) Intermediate Moisture
(I) Irradiated (NF) Natural Form
(R) Rehydratable (T) Thermostabilized (heat - canned food), (*) Vegan


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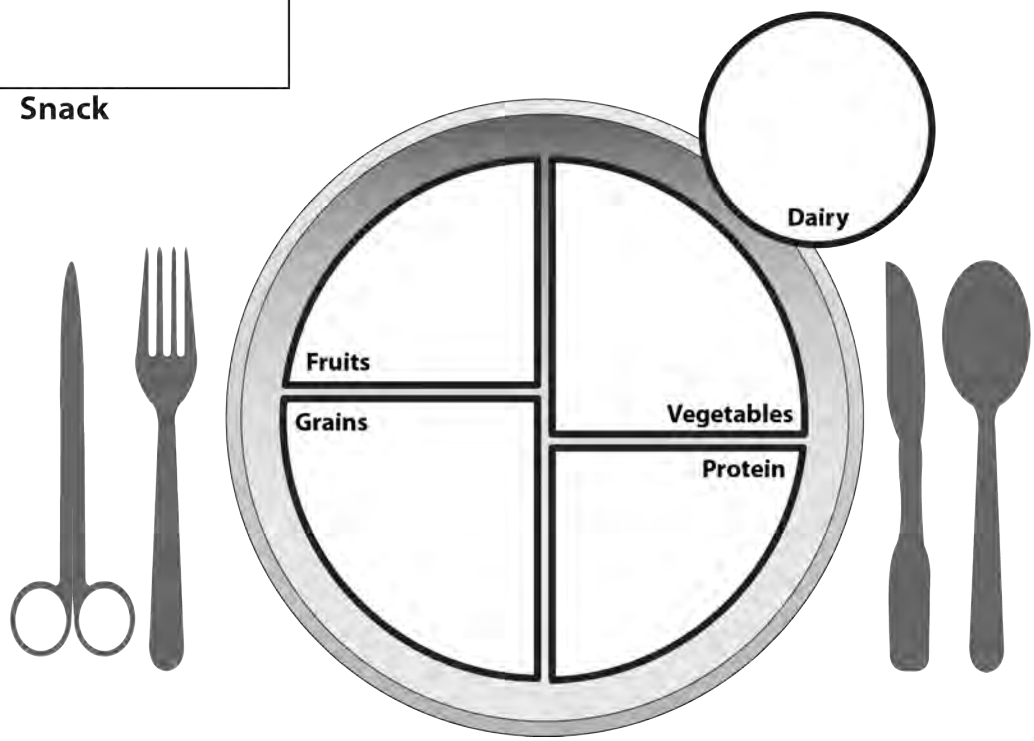
# One Day Menu for Mars Mission

**Name:**______________________

| Breakfast | Lunch | Dinner |
|---|---|---|
| | | |

**Snack**



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# 7) Out-of-this-World / Spacy Careers

## 7A) Careers in Space Exploration: *It Could be You!*

ACTIVITY DESCRIPTION



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# 7) How Can I Become an Astronaut?

*It Could be You!*

### Time Needed

1 Session

### You Need This Stuff

*Per Class*

- Item

*Per Student Pair*

- Astronaut cards for the NASA 20th Astronaut Group
- video camera
- simulated TV studio (chairs, backdrop, props, etc.)
- internet access

### What It's About

At one time or another, everybody wants to be an astronaut. From a particular point of view, we're already astronauts. We are traveling through space on a 12,000 kilometer (8,000 mile) wide "spacecraft" (planet Earth) at a speed of about 107,000 kilometers (67,000 miles) per hour. Our spacecraft's trajectory carries us around the Sun once a year. But wait, there's more! The Sun is not standing still. It is traveling in the general direction of the star Vega at a speed of about 70,000 kph (43,000 mph). The Sun's gravity drags us along with it. Then there is the rotation of the Milky Way Galaxy. The galaxy spins and at our distance from the its center, our rotation speed is about 792,0,00 kph (483,000 mph). Finally, our whole galaxy is moving through space at a speed of about 2,100,000 kph (1,300,000 mph). Put all the speeds together and our spacecraft is traveling at a whopping speed of 3.041,488 kph (1,893,000 mph)!

> *A note on the Mathematics: This is an approximation that combines all of the motions as though each motion is in the exact same direction so that they can be added. Instead, there variations in directions at different times. For example, Earth may be traveling now in the same direction as the Sun and speeds are added. But, six months later, Earth will on the Sun's far side and heading the other direction so that speeds have to be subtracted.*

Of course, when people say they want to be astronauts, they are thinking of donning some sort of flight suit and blasting off Earth's surface in a rocket. There are far fewer of those kinds of astronauts (Russia - cosmonauts, China - Taikonauts), less than 1,000 people who have flown in space. With the great activity in commercial space flight and space tourism, that number is set to get much larger. Still, most people who want to become an astronaut want to become a NASA astronaut. Many hundreds of people have become NASA astronauts and there will be many more in the future. How do they do that?

Before we answer that question, we should remind ourselves where space is. Space is beyond the bulk of Earth's atmosphere. According to the Fédération Aéronatique Internationale, outer space begins 100 km (62 miles) above sea level. The boundary is called the Kármán Line. If you go above that imaginary line, you are in space.

There are two main categories of NASA astronauts - pilot astronauts and mission specialists. As can be expected, pilot astronauts have to be pilots before becoming an astronaut. Usually, they do that by joining one of the branches of the U.S. military and becoming jet pilots. Many go on to become test pilots before applying to the astronaut corps. Mission specialists have their qualifications too. They have to have a science, medical, or engineering degree and experience working in some sort of scientific, medical, or technical field. NASA looks for people who have already demonstrated proficiency in their field. Because thousands of people apply for astronaut positions, many good candidates are turned down. Some astronauts had to apply several times before becoming selected.

When it comes to being a space tourist, all it takes is good health and lots of money to pay for the flight. Space tourist flights that carry the tourist just past the Kármán line cost over $100,000. Flights to Earth orbit cost many millions. As new space tourist rockets are developed, the cost will come down but it will be a long time before flying into space will be like buying a ticket on an airplane.

### What's The Question

What does it take to become an astronaut?

### Before You Start

Prepare the astronaut cards according to the instructions. Provide Internet access.

### What To Do – Part 1

1. Ask your students how many of them would like to be astronauts or wanted to be an astronaut at one point in their lives. Not all students may want to. Explain that being an astronaut is just one of the many jobs that make space exploration possible. Ask what other jobs may be connected to space exploration.
2. Tell students they will be learning about astronauts by looking up information about them on the Internet. They will gather information about one astronaut in particular and then conduct an imaginary interview. Divide students up into teams of two. One will play the role of the astronaut and the other will be a TV news person asking questions. Interviews should run no longer than 3 minutes. The students can decide which roles they will play. The teams will have to learn about the astronauts they are given and then present their interviews for the rest of the students to enjoy.
3. Before letting teams begin their research, ask students for ideas on what information they should collect about their astronauts. "What would you like to know?" Make a list of the things they want to know.
4. Place the astronaut cards in a box or a hat and have teams draw one card to determine which astronaut they will be learning about. If an all boy or all girl team draws a card with an astronaut of the opposite sex, let them draw again or trade cards with another team.
5. Give teams time to investigate their chosen astronauts. Encourage teams to look for more than one source of information. The following sites provide information about astronauts:

   http://astronauts.nasa.gov
   http://www.jsc.nasa.gov/Bios/astrobio.html
   http://www.wikipedia.orgWikipedia

   If an astronaut has retired from space flight, do a general search of the astronaut's name. The astronaut may have a website.
6. Create a small TV set (two chairs, backdrop, plants, etc.). Set up a camera to take videos of the teams as they do their interviews. Have student teams conduct their interviews in front of the group. Videotape each interview. Time the interviews and give a warning count when the time is almost up.

<u>Wrapping Up Part 1</u>

- At the conclusion of the interviews, ask again how many students would like to be astronauts. Is there a difference from before? Ask students to share the most interesting things they learned about being astronauts.



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**What To Do – Part 2**

1. Ask students if NASA just needs astronauts? Hopefully they will realize that it take a huge number of individuals to send a rocket into space. Discuss why other jobs might be necessary.
2. Next, give student the opportunity to read the ad and decide what career they might be interested in pursuing. If there is interest and time, have students research the positions on line and create a plan for pursuing the career.

**Extras**

- Check these sites for more information on becoming an astronaut:

  How to Become an Astronaut 101
  http://spaceflight.nasa.gov/outreach/jobsinfo/astronaut101.html

  Astronaut Selection and Training

  http://astronauts.nasa.gov/

  Frequently Asked Questions about Astronauts
  http://astronauts.nasa.gov/content/faq.htm

  Applying to be an Astronaut
  http://astronauts.nasa.gov/content/application.htm



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## Daniel M. Tani
**Mission Specialist**

B.S. Degree Mechanical Engineering
M.S. Degree Mechanical Engineering

"I enjoyed building things, figuring out how things work and inventing things. It led to a career in engineering and, fortunately, for me, it then led to something really exciting, like being in space."

Experience:
Space and Communications Design Engineer
Structures Engineer
Project Manager for unmanned rockets
Two space flights and six space walks

Interests:
Reading, hiking, camping, outdoor activities, and home renovation

## Kathleen Rubins (Ph.D.)
**Mission Specialist**

B.S. Degree Molecular Biology
Ph.D. Degree Cancer Biology

"I was inspired growing up by learning the constellations with my dad and going to local "star-gazing" parties and science museums."

"From as young as I can remember I wanted to be, in order, an astronaut, a geologist, and a biologist."

Experience:
Headed Laboratory studying viral diseases affecting Africa

Interests:
Scuba diving, triathlons, sky diving, flying

## John B. Herrington (CDR. USN, Ret.)
**Mission Specialist**

B.S. Degree Applied Mathematics
M.S. Degree AeronauticalEngineering

"What I share with kids is that you can have a dream, you can have struggles, but you can overcome those struggles through perseverance and the right mentors in your lives and (by) making good decisions."

Experience:
Aviator, United States Navy
Navy test pilot

Interests:
Rock climbing, snow skiing, running, cycling

## José Hernández
**Mission Specialist**

B.S. Degree Electrical Engineering
M.S. Degree Elecrical and Computer Engineering

"I (high school senior) was hoeing a row of sugar beets in a field ... I heard on my transistor radio that Franklin Chang-Diaz had been selected for the Astronaut Corps. "I was already interested in science and engineering, but that was the moment I said, 'I want to fly in space. And that's something I've been striving for each day since then."

Experience:
Worked at the Lawrence Livermore National Laboratory

Interests:
Scuba diving, private pilot


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**Michael S. Hopkins, LTC USAF**
**Pilot Astronaut**

B.S. Degree Physics
M.S. Degree Aerospace Engineering
Doctor Degree Aerospace Engineering

"(I) ...tried to do the best job I could throughout my career, and applied, applied, applied.

(Wanted to become astronaut)
In high school during my junior year.

Experience:
Air Force Space Systems Technologies
USAF Test Pilot
USAF Project engineer and program manager

Interests:
Reading, hiking, camping, outdoor activities, and home renovation

**Jack. D. Fischer, Major USAF**
**Pilot Astronaut**

B.S. Degree Aeronautical Engineering
M.S. Degree Aeronautics/Astronautics

"I've done my best along the way to always take advantage of the opportunities I was given, to put the team first, and to do my absolute best at whatever my job was... ."

When I was 6 years old - pretty much as long as I can remember.
(Wanted to become an astronaut.)

Experience:
Air Force fighter pilot with combat experience
Air Force Test Pilot

Interests:
Time with family, flying, camping, traveling and construction

**Jeanette J. Epps (Ph.D.)**
**Mission Specialist**

B.S. Degree Physics
M.S. Degree Aerospace Engineering
Doctor Degree Aerospace Engineering

"The NASA mission has always inspired me because I have a great desire to help further our understanding of the world we live in and the universe."

"My life has been geared toward it (being an astronaut) indirectly with the hope of becoming a viable candidate."

Experience:
2 years Technical Specialist, Ford Motor company
7 years Technical Intelligence Officer, Central Intelligence Agency

Interests:
Teaching kids about science
Traveling, reading, trying new things

**Serena M. Auñón (M.D.)**
**Mission Specialist**

B.S. Degree Electrical Engineering
Doctor of Medicine Degree
Master of Public Health Degree

"Most important is that the decisions I made in my professional career were not toward a specific goal but because I loved what I was doing at the time."

"I wanted to be an astronaut since I saw my first space shuttle launch in elementary school."

Experience:
3 year residency in internal medicine
1 year chief resident internal medicine
Aerospace medicine residency
NASA flight surgeon

Interests:
Basketball, softball, and cricket
Hiking and jet skiing


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**Catherine Coleman (Ph.D., Col. USAF, RET)**
**Mission Specialist**

B.S. Chemistry
Doctor Degree Polymer Science and Engineering

"Being an astronaut wasn't really a common occupation when I was a kid. I didn't think about it until I was in college, and Sally Ride came to speak at MIT. Listening to her, I thought wow, I want that job! I wanted adventure in my life."

Experience:
Research chemist at the USAF
Special Assistant to NASA Johnson Space Center Director
Logged more than 4,000 hours in space on the Space Shuttle and the International Space Station

Interests:
Flying, scuba diving, sports, music

**Michael L. Coats**
**Pilot Astronaut**

B.S. Degree U.S. Naval Academy
M.S. Degree Administration of Science and Technology
M.S. Degree Aeronautical Engineering

(About being selectes as an astronaut) "I thought wow, being an astronaut would certainly be a cool thing to do, but working with a group of people that really enjoyed their jobs would be especially special. Then, I really wanted to be selected. I was in the first group interviewed (by NASA) and had to wait about five months before we heard anything. I was in graduate school at the time. January 16th, my birthday, 1978, they made the announcement."

Experience:
U.S. Naval Aviator and Test Pilot
Three Space Shuttle flights
Director, NASA Johnson Space Center

Interests:
Reading, racketball, jogging

**Bernard A. Harris (M.D.)**
**Mission Specialist**

B.S. Degree Biology
Doctor of Medicine Degree
M.S Degree Biomedical Science

"It's not just a straight path to outer space, there are a lot of peaks and valleys… a lot of challenges. It doesn't matter how you persevere through those challenges, but how you use them as stepping stones to reach higher."

"I watched the sun go down at night, the stars appear in the heavens and wondered what it would be like to travel among those stars."

Experience:
Joined the NASA as a scientist and flight surgeon and clinical scientist.
First African American space walker.

Interests:
Flying, sailing, skiing, scuba diving running, art, music

**Peggy A. Whitson (Ph.D.)**
**Mission Specialist**

B.S. Degree Biology/Chemistry
Doctor Degree Biochemistry

"Well, I was inspired by the men who walked on the moon… as a kid of 9 years old… I thought what a cool job! It didn't become… a goal until I graduated from high school, which was coincidentally the same year they picked the first set of female astronauts. I think that was when I decided I wanted to become an astronaut."

Experience:
Biochemistry research.
Adjunct Assistant Professor
Two tours on the International Space Station and six space walks.

Interests:
Weight lifting, biking, basketball, water skiing



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*** * * * * * * * Want A NASA Job? * * * * * * * ***

Want to be an astronaut? How about being an aerospace engineer, a space suit designer, robot builder, aircraft builder, parachute designer, or launch controller? Do you like to work with your hands? Do you like math and computers? NASA has thousands of jobs that require people with the sense of adventure, people who want to explore the atmosphere and space.

To find out what NASA jobs are available and what the qualifications for those jobs are, go to the NASA Jobs site. While you are still in school, checking the jobs NASA has open can give you an idea of what you need to do to get ready to apply. For example, you may want to work on spacecraft destined to go to other planets. Science and mathematics would be good subjects to concentrate on. You want to train astronauts to fly spacecraft. Engineering is a good field to study. You want to manage space missions. Try business classes. If you want to fly in space, learn how to fly on Earth.

The NASA Jobs site can start you on an adventure of a lifetime.

**http://nasajobs.nasa.gov**

*** * * * * * * * Want A NASA Job? * * * * * * * ***

Want to be an astronaut? How about being an aerospace engineer, a space suit designer, robot builder, aircraft builder, parachute designer, or launch controller? Do you like to work with your hands? Do you like math and computers? NASA has thousands of jobs that require people with the sense of adventure, people who want to explore the atmosphere and space.

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The NASA Jobs site can start you on an adventure of a lifetime.

**http://nasajobs.nasa.gov**