National Aeronautics and
Space Administration

NASA Out-of-School Learning Network

Living and Working in Space

module

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Introduction

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NASA Out-of-School Learning Network

The NASA Out-of-School Learning (NOSL) Network is designed to offer inquiry-based science, technology, engineering, and mathematics (STEM) learning experiences that connect students with NASA scientists, engineers, and mission-content-related activities. The NASA engineering design challenge: *Why Pressure Suits?* has been paired with the Living and Working in Space Module and is located on the NOSL Web site. This engineering design challenge allows students the opportunity to work through the engineering design process used by NASA scientists.

The complete module is designed to provide the student with an

- Understanding of the dangers associated with space travel
- Understanding that our bodies work differently in space than on Earth
- Understanding of how robots can be used instead of humans to do tasks in hazardous places

Scope and Sequence

The Living and Working in Space module covers Next Generation Science Standards for Engineering Design, Life Science, and Physical Science.

Next Generation Science Standards

Middle School Engineering Design (MS–ET)

- MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Middle School Life Science (MS–LS)

- MS-LS1-3. Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.

Middle School Physical Science (MS–PS)

- MS-PS3-3. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.
- MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

Disciplinary Core Ideas

- Defining and delimiting engineering problems
- Developing possible solutions
- Optimizing the design solution
- Relationship between energy and forces
- Conservation of energy and energy transfer

Science and Engineering Practices

- Asking questions and defining problems
- Developing and using models
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations and designing solutions
- Obtaining, evaluating, and communicating information

Crosscutting Concepts

- Influence of science, engineering, and technology on society and the natural world
- Patterns
- Cause and effect
- Scale, proportion, and quantity
- Energy and matter

Connections to the Nature of Science

- Scientific knowledge assumes an order and consistency in natural systems
- Scientific knowledge is based on empirical evidence

Connections to Engineering, Technology, and the Applications of Science

- Interdependence of science, engineering, and technology

BACKGROUND INFORMATION FOR FACILITATORS

Addressing the Dangers of Living and Working in Space

Space is the name given to the void between stars, planets, and other objects. Although no exact line divides Earth’s atmosphere from outer space, scientists place it roughly 100 km (62 mi) above the Earth’s surface. At this point there is not enough air to breathe or to scatter light to create a blue sky; therefore, space appears to be black. Space is a vacuum: sound cannot travel from one place to another because molecules are not close enough to transmit sound between them.

As we live and work on Earth, our atmosphere provides air that we can breathe and pressure around our bodies. Gravity holds us to the Earth’s surface and provides resistance that helps our muscles and bones to stay healthy. Living and working in space is very different.

Because human bodies are adapted to the gravity levels on Earth, the reduced gravity in space can have many detrimental effects. When NASA sends humans into space, it must consider the many differences between the environment on Earth and the environment in space. The lack of an atmosphere, extreme temperatures, and objects that pass freely through space are but a few.

On Earth the atmosphere exerts pressure on our bodies in all directions. At sea level on Earth that pressure is 101 kPa, but in space, the pressure is nearly zero. In outer space, an unprotected human would die in a few brief, agonizing moments. With virtually no pressure from the outside, the air in the unprotected person’s lungs would immediately rush out into the vacuum of space. Gases dissolved in body fluids would expand, pushing solids and liquids apart. Consequently, skin would expand like an inflating balloon and bubbles would form in the bloodstream, making the blood unable to transport enough oxygen and nutrients to the body’s cells. Furthermore, the sudden absence of external pressure to balance the internal pressure of body fluids and gases would rupture fragile tissues like eardrums and capillaries. The net effect would be swelling, tissue damage, and oxygen starvation that would result in unconsciousness in less than 15 sec.

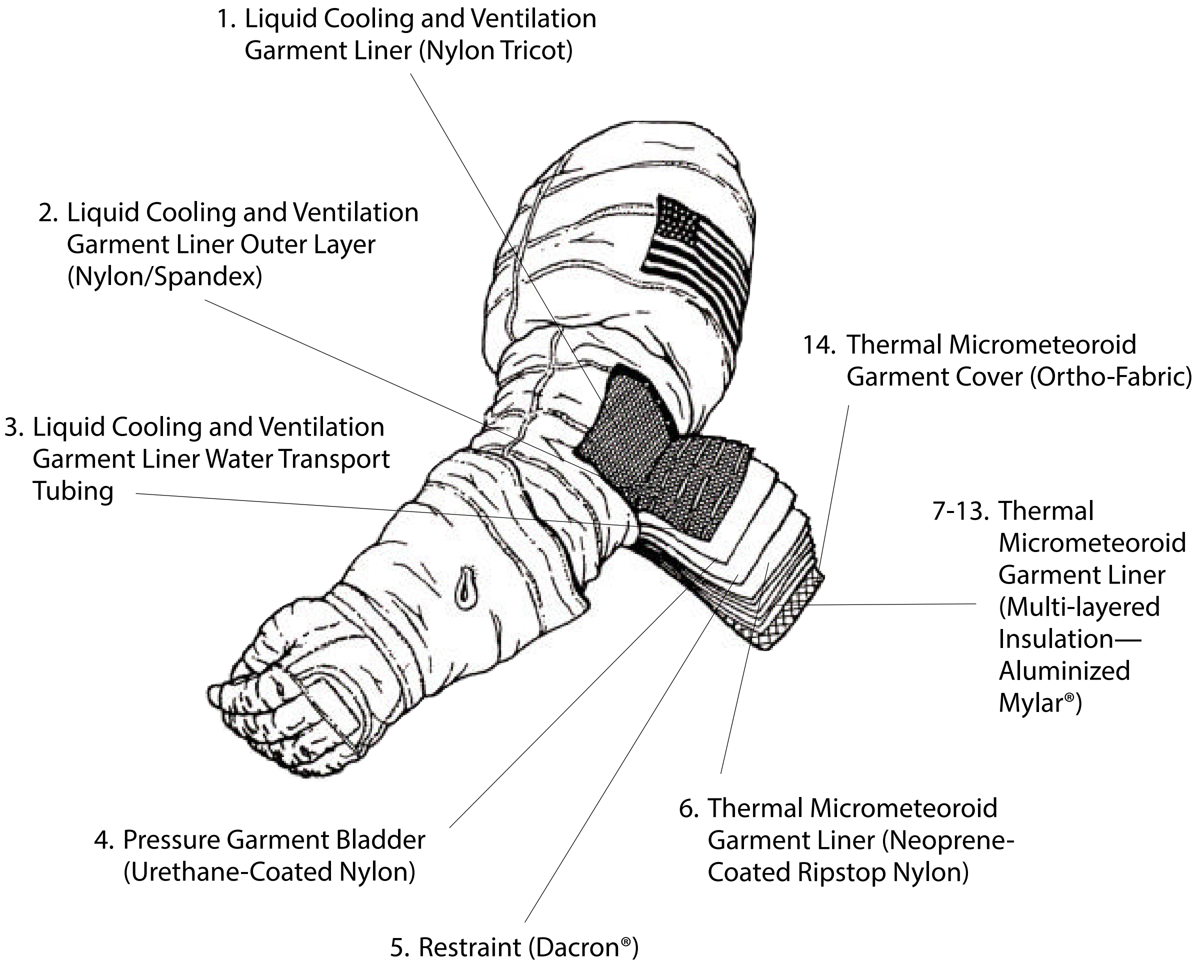
The extreme temperature range in outer space is a second major obstacle. In space at Earth's distance from the Sun, the temperature on the sunlit side of objects can climb to over 120 °C (248 °F) while temperatures on the shaded side can plummet to lower than –100 °C (–148 °F). Maintaining a comfortable temperature range becomes a significant problem.

In addition to these constant environmental challenges is the danger of meteoroids—pieces of rock and metal left over from the formation of the solar system and from the collisions of comets and asteroids. Although meteoroids are usually very small, even the tiniest micrometeoroids travel at very high velocities and can easily penetrate human skin and thin metal. Equally as dangerous is debris from previous space missions. A tiny paint chip traveling at thousands of kilometers per hour can do substantial damage.

Other environmental dangers in outer space include microgravity, the radiation of electrically charged particles ejected by the Sun, and ultraviolet radiation.

Extravehicular Mobility Unit for Working in Space

When an astronaut leaves the protective environment of a spacecraft, he or she must be protected from the environment of space within an Extravehicular Mobility Unit (EMU, or spacesuit). The EMUs that are used on the International Space Station (ISS) have 14 layers to protect astronauts during extravehicular activities (EVAs). The inner layers comprise the liquid-cooling and ventilation garment. The first layer is a liner of nylon tricot; over this is a layer of spandex fabric laced with plastic tubing. Next are a pressure bladder layer of urethane-coated nylon and a fabric layer of pressure-restraining Dacron®. Above the bladder and restraint layer is a liner of neoprene-coated ripstop nylon. This is followed by a seven-layer thermal micrometeoroid garment of aluminized Mylar® that is laminated with Dacron® scrim. The outer layer of the suit is made of Ortho-Fabric—a blend of GORE–TEX® fabric and Kevlar® and Nomex® materials.



Robots in Space

With the many hazards in space, NASA is developing robots that can perform many of the tasks that humans would normally do such as conducting EVAs and even exploring other planets.

Robonaut is a NASA robot that engineers designed to be humanoid, which means that it was built to look like a person. This makes it easier for Robonaut to do the same jobs as a person. Robonaut can help with anything from working on the ISS to exploring other worlds.

Robonaut 2 (R2), the newest version, is currently aboard the ISS. R2 is a state-of-the-art, highly dexterous anthropomorphic robot that can handle a wide range of EVA tools and interfaces. R2 can function in two ways. First, software allows R2 to “think” for itself. When the people who control R2 give it a simple task to do, R2 can figure out how to do it. R2’s controllers also can update R2’s software to enable it to do new tasks. Second, R2 can be operated by remote control. In this mode, an operator uses a headset to see what R2 sees through its cameras. The operator can then use controls to make R2 move. In either mode, human astronauts can stay safe inside a spacecraft while R2 works in the harsher environment outside.

Staying Strong in Space

Before astronauts go into space, they must do exercises to make them fit for travel and to help keep them fit in space. In space, astronauts’ bodies change. On Earth, our lower body and legs carry our weight. This helps to keep our bones and muscles strong. In space, astronauts float. They do not use their muscles much. Their lower backs and legs begin to lose strength, and their bones begin to get weak and thin. To lessen these negative effects, astronauts must exercise every day that they are in space.

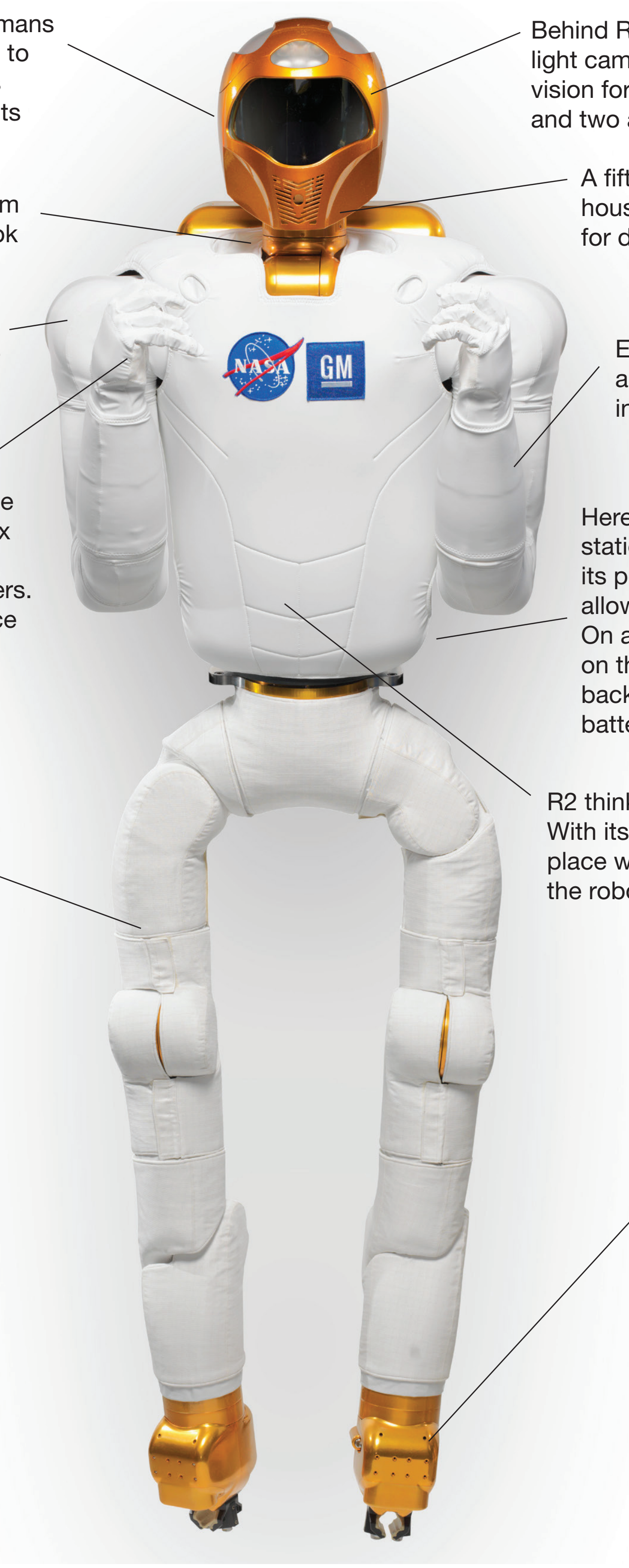
An astronaut walks on a treadmill to stay strong and healthy.

The heart and blood change in space too. When we stand up on Earth, blood goes to our legs. Our heart has to work very hard against gravity to move the blood all around our body. In space, without the pull of gravity, astronauts’ blood moves to their upper bodies and heads. The water in their bodies does the same thing, making the astronauts’ faces look puffy. When these fluids move from the bottom of the body to the top, the brain thinks that there are too many fluids. It tells the body to make less blood and other fluids. When astronauts come back to Earth, they do not have enough fluids in their systems. It takes their bodies a few days to make more blood and other fluids. If astronauts do not rest long enough when they return to Earth, they can feel very weak. They might even faint.

Specifications

Materials: Primarily aluminum with steel, and nonmetallics.
Weight with legs: 490 lb
Height: 8 ft (with legs fully stretched)
Average height while in motion: Approx. 5 ft 9 in.
Shoulder width: 2 ft 7 in.
Sensors: 500+, total
Processors: 3 Core-I7s, 36 Power PCs, 16 ARMs
Degrees of freedom: 58, total with legs
Limb speed: Up to 7 ft/sec

What Robonauts Are Made Of



A robot meant to work with humans and to use human tools begins to look humanlike. However, R2's head houses not its brain, but its vision equipment.

R2 has 3 degrees of freedom in its neck, allowing it to look left, right, up, or down.

Each arm is approximately 2 ft 8 in. long, giving the R2 a total armspan of 8 ft.

R2's hands have 12 degrees of freedom (DOF)—4 DOF in the thumb, 3 DOF each in the index and middle fingers, and 1 DOF each in the ring and pinky fingers. Each finger has a grasping force of 5 lb.

R2 now has legs with 7 DOF that are long enough to climb between modules. The double knees are not humanlike, but they provide flexibility to position the body as needed to perform tasks across ISS.

Behind R2's visor are four visible light cameras—two to provide stereo vision for the robot and its operators, and two auxiliary cameras.

A fifth infrared camera is housed in the mouth area for depth perception.

Each arm boasts 7 DOF and the strength to hold 20 lb in any pose in Earth's gravity.

Here on Earth and at the space station, R2's backpack holds its power conversion system, allowing it to simply be plugged in. On another planetary surface—or on the Moon or an asteroid—the backpack would hold the robot's batteries.

R2 thinks with its stomach—literally. With its head full of cameras, the only place with enough room for a brain is the robot's torso.

The end effectors (or feet) have grippers that can grasp the ISS handrails as well as engage the seat track, ensuring a stable attachment to the ISS at all times.

Building an Astronaut “Core”

Grades 6 to 8

INQUIRY-BASED ACTIVITY

activity

BUILDING AN ASTRONAUT “CORE”

Grades: 6 to 8 Prep Time: 0.5 hour Activity Time: 1 hour

About This Activity

In this activity, which was taken from the NASA “Train Like an Astronaut” site, students perform Commander Crunch and Pilot Plank exercises to improve the strength in their abdominal and back muscles.

Video Link

Building an Astronaut Core
https://www.youtube.com/watch?v=4ggTyC2e3uo

Materials

- Student handouts
- Pencil
- Watch or stopwatch

Next Generation Science Standards

MS-LS1-3. Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.

Learning Objective

Learners will

- Perform the Commander Crunch and Pilot Plank exercises to improve the strength of their abdominal and back muscles
- Record observations and analyze improvements in core muscle strength

Background

The human body is made up of cells. Cells work together to form tissues, tissues work together to form organs, organs work together to form organ systems, and organ systems work together to form an organism. Your core muscle strength depends on all of your organ systems being in good working condition.

Astronauts rely on their core strength. Did you know that astronauts begin training for missions as infants? An infant’s first motor control job is to stabilize his or her core. A strong upper body is needed for an infant to sit upright. It even requires strength for an infant to roll from his or her back onto his or her belly.

Astronauts are not the only ones who rely on their core strength every day. Dancers, athletes, and even people who are not involved in physical activities rely on core strength. Core strength is important because it powers all movement. For example, the abdomen and back muscles work together to support the spine when you sit, stand, bend over, pick things up, and exercise. As a child and as an adult, it is important to have strong core muscles.

Astronauts must have strong core muscles in order to move in the microgravity environment of space. Their core muscles allow them to move equipment and supplies around the ISS and perform extravehicular activities (EVAs, or spacewalks). During an EVA, astronauts work in their spacesuits for 6 or more hours. They must be able to move easily inside the suit as they twist, bend, and lift objects. EVAs are physically demanding, and having a strong core helps astronauts to complete EVAs successfully.

Astronauts on the ISS have a workout regimen that helps them to keep their core muscles strong and their bones healthy. This is critical because their bodies experience different conditions in space than on Earth. On Earth our muscles and bones support our bodies as we move against the force of gravity. In space’s microgravity environment, muscles and bones are not needed to support an astronaut’s body. Without use, an astronaut’s bones and muscles become weaker.

To avoid this problem, astronauts follow an exercise program to keep their muscles and bones physically fit during their stay in space. Exercise prevents the astronauts’ bodies from becoming weak. This is especially important when astronauts are in space for long-duration missions as well as when they return to Earth. Astronauts who travel to the ISS and stay for several months work out a minimum of 6 days per week for at least 2 hours per day. Crews on the ISS use specialized exercise equipment designed by NASA. The Advanced Resistive Exercise Device (ARED) and the Combined Operational Load-Bearing External Resistance Treadmill (COLBERT) are two examples of specialized exercise equipment on the ISS. For strength training, astronauts use ARED, which allows their muscles to experience effects similar to those experienced when someone uses weights on Earth. Each astronaut has a customized workout on ARED for exercising both the upper and lower body.

COLBERT, which works unused walking and running muscles, is a new-generation treadmill on the ISS. COLBERT is equipped with data collection devices that allow researchers and scientists to see how exercising on the treadmill can reduce the amount of bone and muscle lost in microgravity. Astronauts are lacing up their running shoes and getting some very important exercise time on COLBERT.

Procedure

Step 1

Find a suitable location. This physical activity should be conducted on a flat, dry surface free of rocks, dirt, or other obstacles.

Step 2

Group students in pairs and position all the students at least an arm's length from each other.

Step 3

Review safety: Remind students to continue breathing normally while conducting each part of the physical activity. Avoid obstacles, hazards, and uneven surfaces. Students must wear clothes and shoes that allow them to move freely and comfortably. Proper hydration is important before, during, and after any physical activity. Be aware of the signs of overheating. Everyone should warm up and stretch before exercise and cool down after exercise.

Step 4

Facilitate a conversation about why it is important to have strong core muscles.

Use the following open-ended questions before, during, and after practicing the physical activity to help students make observations about their own physical fitness level and their progress in this physical activity:

> How do you feel?
>
> What muscles do you feel that you are working?
> (Best answers: abdominal muscles, leg muscles, and/or back muscles)
>
> Which part of the physical activity seems to be the most difficult? Why?
>
> What are your abdominal and back muscles together commonly called?
> (Answer: core muscles)
>
> What happens to muscles in space? (Answer: muscles weaken)
>
> Why might astronauts need strong core muscles in space?
> (Best answers: to perform spacewalks, or EVAs; to move or maneuver through hatches or modules; to lift, bend, twist, turn, and/or carry things during EVAs or daily tasks in space flight)

Step 5

Demonstrate the two exercises that the students will be performing: Commander Crunches and the Pilot Plank.

Step 6

Explain to the students that they are going to do these exercises over a given number of weeks. (Give the students a length of time that is appropriate for your program. The table is designed for a 2-week program.) Students are to fill in the data in the table for each day over the assigned period of time. After the assignment period is over, the students will analyze their improvement or lack of improvement.

Exercise Directions

Commander Crunches

Step 1

Group the students in pairs. Then have all the students lie on their backs, knees bent, and feet flat on the floor. The students' chins should be pointed to the sky, and their arms should be crossed over their chests.

Step 2

Show the students how to use only their abdominal muscles to lift their upper bodies until their shoulder blades leave the ground. Have them put one hand on their abdomens to feel the muscles working as they raise their shoulders off the floor.

Step 3

Next have the students lower their shoulders while using only their abdominal muscles to complete one crunch.

Step 4

Have one partner in each pair continue to lie down to do crunches. Begin timing as you give the command to complete as many crunches as possible in 1 min. Have the other partner count the crunches performed. Then have the partners switch places before you give the command again.

Pilot Plank

Step 1

Keep the students in pairs and have them lie on their stomachs and rest on their forearms. They should make a fist with each hand and place their forearms on the floor shoulder-width apart.

Step 2

Show the students how to use only their arm muscles to push their bodies off the floor and support their weight on their forearms and toes. The students' bodies should be straight as a board from head to feet.

Step 3

Have one partner in each pair get into the plank position, tightening the muscles in their abdomens and backs to stabilize their bodies. Tell them to try to keep this position for at least 30 sec or as long as possible. Have the other partner do the timing.

Step 4

Have the partners switch places and follow the same procedure. Follow the directions at least 10 more times.

Step 5

Have the students record their observations before and after this physical experience in the table in the student handout.

Suggestions for Differentiation

Below are additional strategies to differentiate instruction based on student readiness.

Support:
Commander Crunches: Instead of having the students keep their legs straight, have them bend their knees and cross their legs, keeping their backs straight while performing the exercise.

Complexity:
Pilot Planks: Have the students extend one leg to the side and hold it out for 30 sec. Have the students alternate legs each 30 sec.

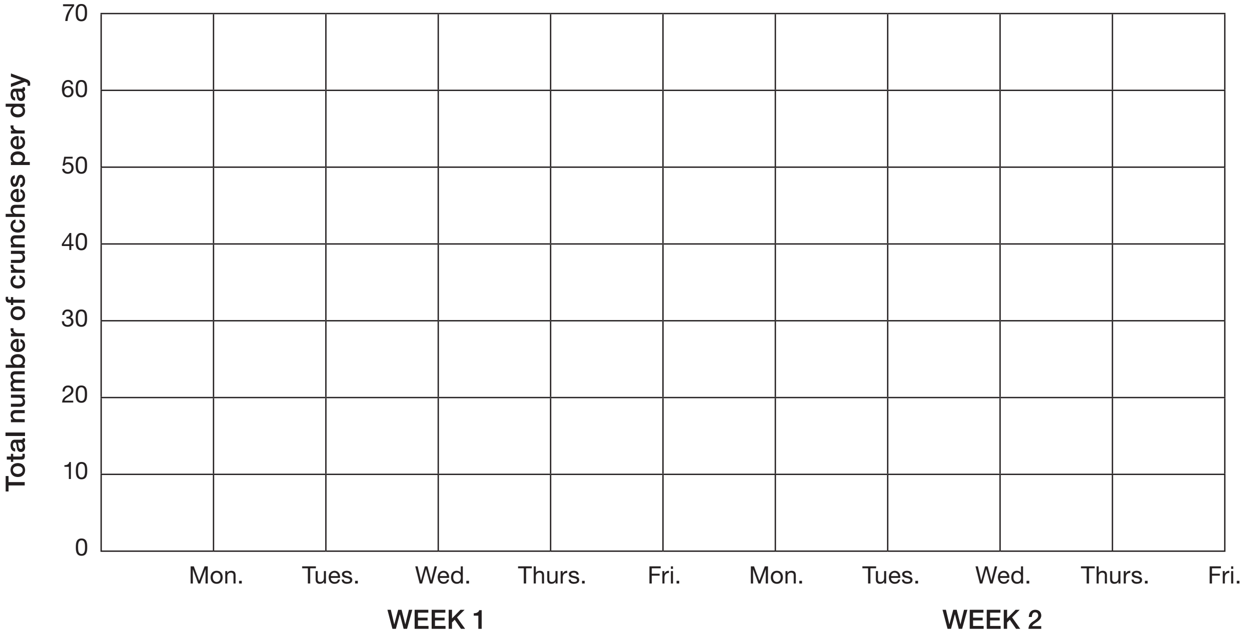
Name: ______________________________

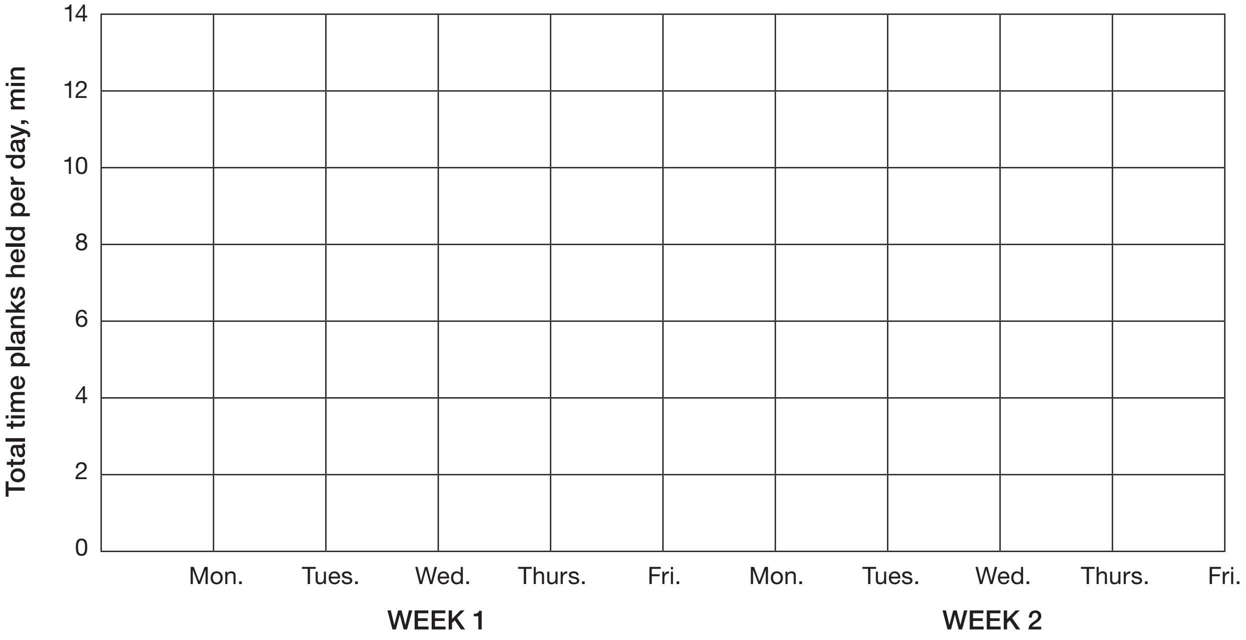
Directions

Each day perform Commander Crunches and Pilot Planks as demonstrated by your instructor. Record the information requested in the following table. At the end of the assigned period of time, graph your data on the graph provided and analyze your data.

	Commander Crunches		Pilot Planks	
	Total duration, min	Total number of crunches	Total duration, min	Total number of planks
WEEK 1				
Monday				
Tuesday				
Wednesday				
Thursday				
Friday				
WEEK 2				
Monday				
Tuesday				
Wednesday				
Thursday				
Friday				

Commander Crunches and Pilot Planks Results





Question

What have you discovered from analyzing your data?

Agility

Astro-Course Training

Grades 6 to 8

INQUIRY-BASED ACTIVITY

activity

AGILITY ASTRO-COURSE TRAINING

Grades: 6 to 8   Prep Time: 0.25 hour   Activity Time: 1 hour

About This Activity

In this activity, which was taken from the NASA "Train Like An Astronaut" site, students complete an agility course as quickly and as accurately as possible to improve agility, coordination, and speed.

Next Generation Science Standards

MS-LS1-3. Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.

Learning Objective

Learners will

- Complete an agility course as quickly and as accurately as possible to improve movement skills, coordination, and speed
- Record observations about improvement in agility

Video Link

Agility Astro-Course
https://www.youtube.com/watch?v=11N4AOHr1JE

Materials

- Eight marking cones or other small, steady objects
- Metric measuring tape or meter stick
- Paper and pencil
- Watch or stopwatch
- Student handout
- Pencil

Background

The human body is made up of cells, and these cells work together to form tissues. Tissues work together to form organs, organs work together to form organ systems, and organ systems work together to form an organism. Your agility depends on all your organ systems being in good working condition. Agility is defined as the ability to change direction rapidly without losing speed, balance, or body control. Therefore; agility training is part of an astronaut's endurance training to produce good working organ systems.

Astronauts are not the only people who need to be agile. Agility training reduces the risk of injury and helps build the endurance and flexibility that enable sports players to make it through a single game or an entire season. It enables your body to accept the challenges that come with any physical activity. Every day we come into situations where agility is needed to make us successful: riding a bike, skateboarding, playing videogames, rollerblading, or playing any type of sport. Practicing agility drills can improve your performance in any sport or physical activity.

Just like an athlete, it is necessary for an astronaut to do strength and agility training. The healthier and stronger the astronaut is, the better they will perform during a space mission and when they return to Earth. Astronauts go through vigorous fitness training before each mission to prepare their bodies for space flight, but they lose agility while spending time in space because they are in a microgravity environment for an extended period of time and do not have to change directions quickly. An overall strength, conditioning, and rehabilitation program is designed to enable the astronauts to meet the physical demands of space missions as well as to keep them healthy for their return to Earth's gravity.

Astronaut Strength, Conditioning and Rehabilitation (ASCR) specialists conduct annual fitness assessments on the astronauts, prescribe individualized exercise programs, and provide one-on-one preflight and postflight conditioning activities that increase strength and agility. Astronauts who stay in space for 4 to 6 months are assessed on their physical agility before and after a space mission. ASCR specialists focus on an astronaut's balance, coordination, and agility. Long periods of time in space can affect an astronaut's ability to react to normal situations on Earth in a timely manner. To help astronauts recover lost agility after a mission, ASCR specialists design an agility course that will test the astronaut's quickness, reaction time, hand-eye coordination, and speed. This test helps NASA understand how to help astronauts recover lost agility faster. Once the mission is over and the astronauts are back on Earth, they maintain their agility by staying active with a regular physical fitness routine.

Procedure

Step 1

Find a location that will suit this activity. Because the students will begin on the ground, this physical activity is best performed on a nonslip flat surface such as a gym floor, outside in dry grass, or on a five-lane athletic track.

Set up the course before the students arrive as described (and shown in Fig. 1). The length of the course is 10 m (33 ft), and the width (distance between the start and finish points) is 5 m (16.5 ft). Four cones are used to mark the starting point, finishing point, and the two turning points. An additional four cones are placed down the center of the course at an equal distance of 3.3 m (11 ft). The first cone along the center of the course is placed between the start and the finish cones, and the fourth cone along the center is placed between the two turning point cones (Fig. 1).

Agility Astro-Course

Adapted from the Illinois Agility Course

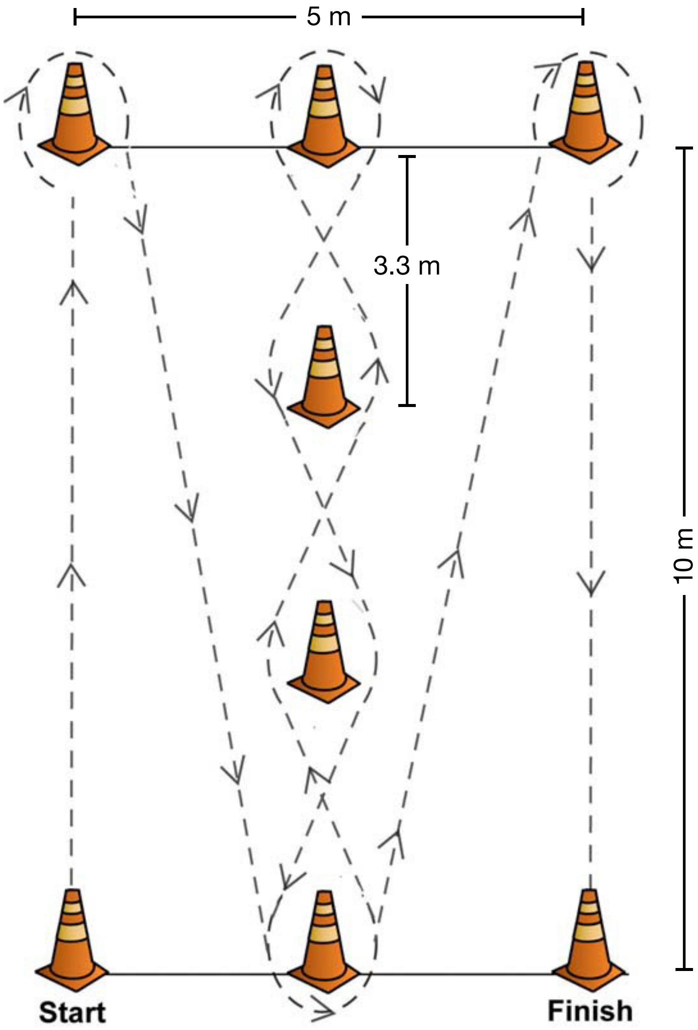


Figure 1

Step 2

Before students begin, discuss safety points:

- Avoid obstacles, hazards, and uneven surfaces.
- Wear clothes and shoes that allow students to move freely and comfortably.
- Hydrate properly before, during, and after any physical activity.
- Be aware of the signs of overheating.
- Warm up and stretch before exercise, and cool down after exercise.

Step 3

To facilitate a discussion, explain agility and why it is important. Explain that the human body is made up of cells and that these cells work together to form tissues, tissues work together to form organs, organs work together to form organ systems, and organ systems work together to form an organism. Agility depends on all your organ systems being in good working condition. Ask the students, “How can you perform a physical activity that will improve your agility, coordination, and speed?” Then discuss their ideas.

Step 4

Tell the students to think about the following questions as they go through the activity.

- How do you feel?
- Are you getting more tired each time you complete the course?
- Are you getting better each time you practice the course?
- How do you know you are getting better?

Step 5

Run the course to demonstrate for students the proper path to follow in the course.

Step 6

Have students form one line and complete the course one at a time as a trial run. Use a stopwatch or clock with a second hand, and time the students as they complete one lap through the course.

Step 7

When ready to actually begin the activity, have the first student lie face down (similar to starting a pushup) with his or her hands by his or her shoulders. (This is optional, students can start from a standing position.) Start the stopwatch when you say, “Go.” The student should get up quickly and run around the course in the directions indicated on Figure 1 without knocking the cones over. Time is stopped when the student crosses the finish line. Give the student their time and number of cones knocked over to record, and repeat with each student.

Step 8

Have students complete the course three times and record their times in the *Agility Training Log*.

Step 9

When all students have completed the course, ask the students the following questions:

> *Do you think that it would be more difficult for an astronaut to complete this course after a 14-day mission or after a 6-month mission? Why?*
>
> Answer:
> An astronaut working in space for 6 months will have a more difficult time completing the agility course when they return to Earth. During longer missions, an astronaut's body has been exposed to the microgravity environment for a longer period of time. Because of this, the body will take longer to adapt to the Earth environment. Astronauts must get as much exercise as they can in order to help their bodies prepare for the Earth environment.
>
> *Do you think an astronaut could successfully complete this course the day they landed from a 6-month mission? A week later? A month later?*
>
> Answer:
> An astronaut could complete the agility course after being in space for 6 months, but the astronaut's body will become better adapted to Earth's environment each day that he or she is back on Earth. The astronaut will begin to perform as well as he or she did before space flight and in some cases even better than before going into space. Being healthy and fit when returning to Earth helps astronauts to regain their strength and agility faster.

Suggestions for Differentiation

Below are additional strategies to differentiate instruction based on student readiness.

Support:
Use fewer cones and space the cones farther apart.

Complexity:
To increase agility, have students stand on one leg while waving their arms and moving their other leg about while maintaining their balance.

Name: ____

Directions

Step 1

Lie face down on the ground at the starting point. When you hear, “Go,” jump to your feet and run the course to the finish following these criteria.

- Complete the course as quickly as possible, following the pattern in the following figure.
- Try not to touch or knock over any cones. You will need to add a 2-sec penalty to your completed time for every cone that you touch or knock over.

Step 2

Record your time in the *Agility Training Log* for each run.

Step 3

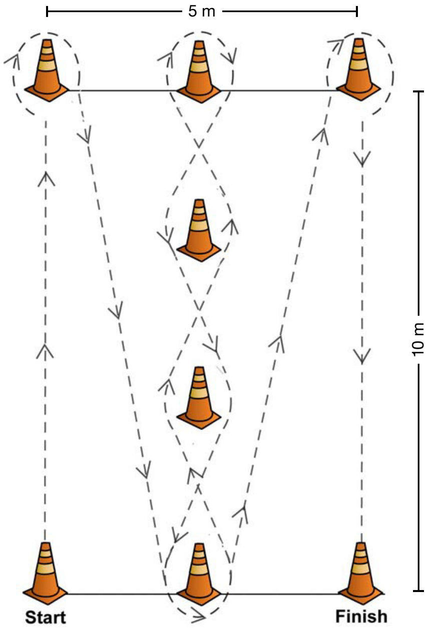
Rest at least 1 min between runs. Repeat the Agility Astro-Course at least three times. Continue to practice improving your movements, accuracy, and time.

Step 4

Average your times plus penalties: (total time for three runs + penalties) ÷ 3 runs = average time.

Agility Astro-Course

Adapted from the Illinois Agility Course



Agility Training Log

Day of the week	Run number						Average time + penalties (total for day ÷ 3), sec	Observations (e.g., easy, hard, somewhat hard)
	1	2	3	1	2	3		
	Running time, sec			Penalties, sec				
Monday								
Tuesday								
Wednesday								
Thursday								
Friday								

Get a Leg Up

Grades 6 to 8

INQUIRY-BASED ACTIVITY

activity

GET A LEG UP

Grades: 6 to 8   Prep Time: 0.25 hour   Activity Time: 1 hour

About This Activity

In this activity, taken from NASA KSNN 21st Century Explorers, “How Would Your Body Change in Space?” students mimic the fluid shift felt in space by staying in a reclined position for a certain amount of time.

Background

On Earth, gravity causes most of the body’s fluids to be distributed below the heart. In contrast, living in space with less gravity allows fluids in the body to spread equally throughout the body. When astronauts first travel into space, they feel as if they have a cold and their faces look puffy. Many astronauts talk about not feeling thirsty because of this fluid shift. The body records this shift as an increase in blood volume. The body takes care of this fluid shift by eliminating what it thinks are extra fluids as it would normally through the kidneys and urination. Once this “extra fluid” is flushed from the body, astronauts adjust to space and usually feel fine. Puffy faces and “chicken legs” are short-term changes that astronauts feel. Within 3 days of returning to Earth, the astronauts’ fluid levels return to normal and their bodies are “back to normal.”

Video Link

NASA KSNN 21st Century Explorers #3: How Would Your Body Change in Space?
https://archive.org/details/ksnn_21st_century_explorers_3

Materials

- Metric measuring tapes or string and metric rulers
- Washable markers or masking tape
- Stopwatch, watch, or clock
- Student handouts

Next Generation Science Standards

MS-LS1-3. Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.

Learning Objective

Learners will

- Gather data and use data to develop a conclusion to explain the changes observed
- Graph data collected

Procedure

Step 1 (Optional)

Show “How Would Your Body Change in Space?” to engage students and increase their knowledge about this topic.

Step 2

Discuss with students about the effects of reduced gravity on the human body. Have the students read the background section in the student handout and discuss in their groups. Encourage the students to discuss and make observations about this topic.

Step 3

Group students in pairs, and have them take their shoes off so that they do not scuff the wall. One person will be the test subject while the other person measures and records data. Identify the calf as one place to measure and allow the students to choose the other two places to measure on the leg.

Step 4

Have the students follow the step-by-step instructions in the student handout.

Step 5

The partner that has not been measured should stand during the 10 min that the other partner is “lying down” with their legs against the wall. The facilitator should lead the timing.

Suggested activities for the 10-min “lying down” period:

- Sing “Take Me Out to the Ball Game.” This takes about 20 sec. Tell the students that this is the same amount of time that it takes your heart to pump blood to every cell in your body.
- Read the next steps to the students.
- Have the students brainstorm songs that have the word “heart” in them.

Step 6

After 10 min, make sure that the test subjects remain lying down while their partners measure the test subjects’ legs again. Then have the students record the measurements on the *Leg Circumference Data Table*.

Suggestions for Differentiation

Below are additional strategies to differentiate instruction based on student readiness.

Support:
Demonstrate how to set up a bar graph and give students help putting their information in their graphs.

Complexity:
Have students turn in their observations and then ask students to compare gender results with a graphic organizer.

Directions

Step 1

Read the background material.

Step 2

Choose one partner to stand first and one partner to measure first. As one partner stands, trying to relax for 10 min, the other partner should do the following:

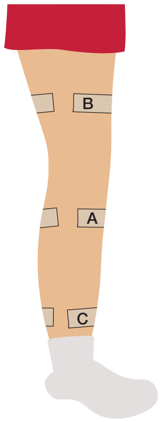


Figure 1

Label the places you will measure as A, B, and C.

a. Work with your standing partner to identify three places to measure on their bare leg. Make sure that one of the places is their calf.

b. Identify these locations on the *Leg Circumference Data Table*.

c. Use a washable marker or small pieces of masking tape to mark the places to be measured on the front and back of your partner's leg, labeling these A, B, and C (Fig. 1).

d. After your partner has been standing for 10 min, measure the distance around your partner's leg at each of the three places. This distance is the circumference. Note: Be sure to pull the tape measure or string firmly around your partner's leg, but not so tight that there are "dents" in the skin.

e. Record all data on the *Leg Circumference Data Table*. Double check your measurements.

Step 3

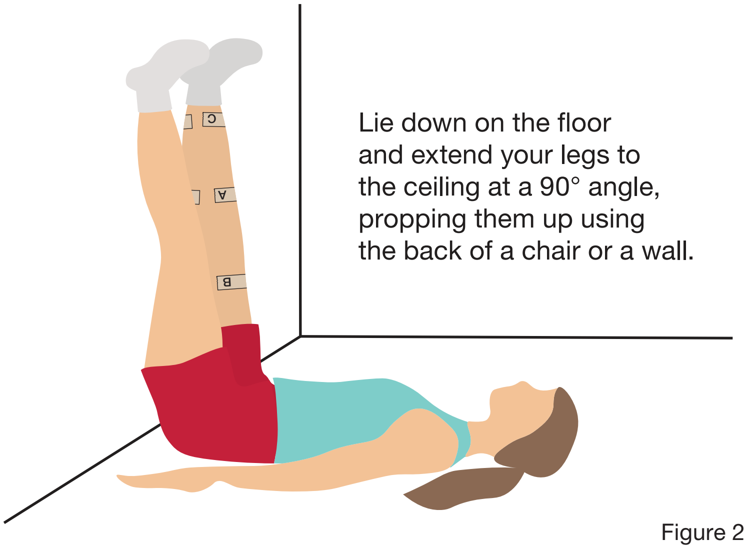
Predict what will happen to the circumference of your leg when you lie down for 10 min. Record your prediction on the *Leg Circumference Data Table*.

Step 4

The partner who has been standing for 10 min should do the following:

a. Lie down on the floor, placing your data sheet, measuring instrument, and pencil close to you.

b. Extend your legs against the wall or the back of a chair and toward the ceiling at a 90° angle (Fig. 2). Keep both of your legs raised for 10 min.



Lie down on the floor and extend your legs to the ceiling at a 90° angle, propping them up using the back of a chair or a wall.

Figure 2

Step 5

The partner who had been doing the measuring should do the following:

a. Remain standing for 10 min while your partner is lying down.

b. Identify three places on your leg to measure, as in Step 1.

c. If you need assistance marking your leg, ask someone else who is standing to mark three locations on your leg.

Step 6

The partner who is standing should do the following:

a. After 10 min, have your partner continue to lie down while you continue to stand.

b. Measure the circumference of all three places on your partner's leg again. Note: Be sure to pull the tape measure or string firmly around the leg, but not so tight that there are "dents" in the skin.

Step 7

The partner who is standing should record all data on the *Leg Circumference Data Table* and double check the measurements.

Step 8

The partner who was lying down should get up and repeat Steps 1(d) to 6 for his or her partner as he or she lies down.

Step 9

After taking all measurements, both partners should study and graph the data, and draw conclusions by answering the questions following the *Leg Circumference Data Table*.

Name: ______________________________

Background

On Earth, gravity causes most of our body's fluids to be distributed below our heart. In contrast, when astronauts are living in space, the reduced gravity allows fluids to spread equally throughout their bodies. When astronauts first travel into space, they feel like they have a cold and their faces look puffy. Many astronauts talk about not feeling thirsty because of this fluid shift. The body records this shift as an increase in blood volume and takes care of this fluid shift by eliminating what it thinks are extra fluids as it would normally—that is right, through the kidneys—resulting in visits to the restroom. Once this "extra fluid" is flushed from the body, astronauts adjust to space and usually feel fine. Puffy faces and "chicken legs" (skinny legs) are short-term changes that astronauts feel. Within 3 days after returning to Earth, astronauts' fluid levels return to normal and their bodies are "back to normal."

In this experiment, you will mimic the fluid shift that astronauts feel in space by staying in a reclined position for 10 min. Then you will record the effect that this position has on your body's fluid distribution.

Leg Circumference Data Table

Measurement conditions	Measurement location		
	A (calf)	B ( )	C ( )
	Leg circumference, cm		
After standing 10 min			
Measurement			
After lying with legs up 10 min			
Prediction			
Measurement			

Questions

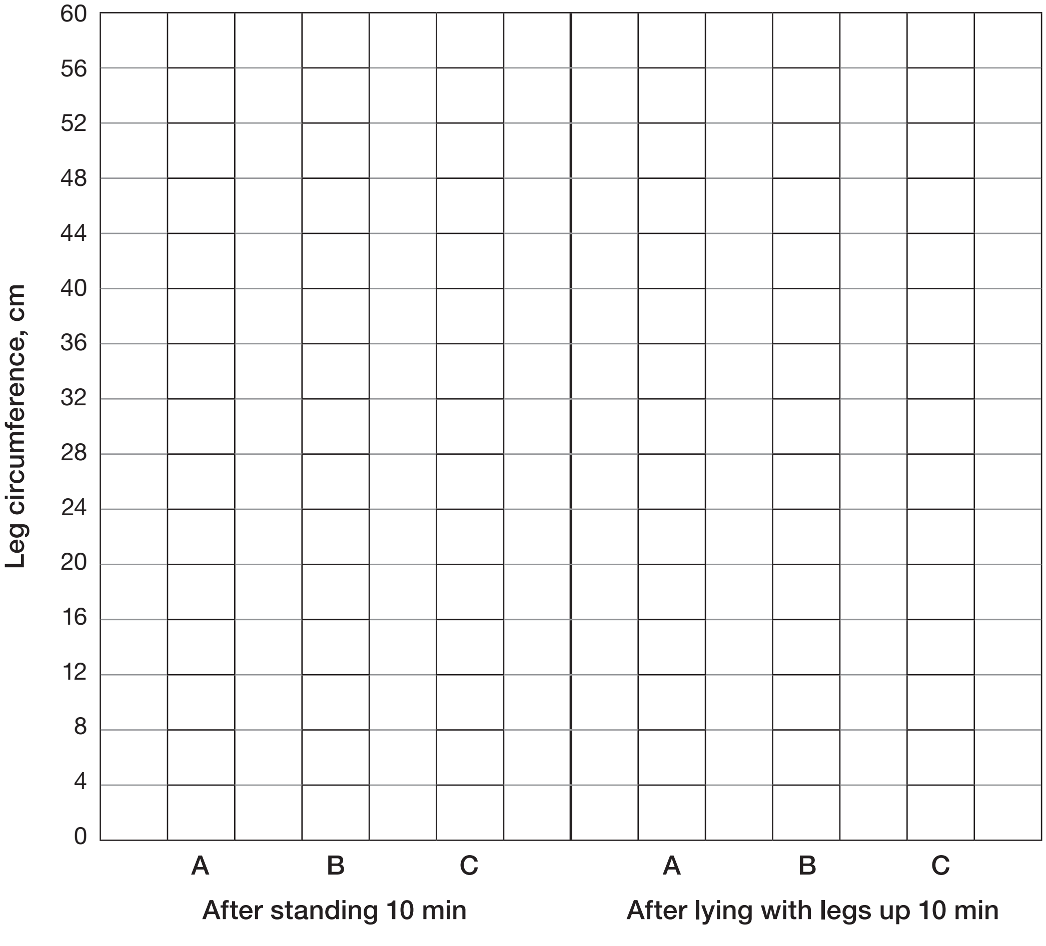
1. What happened to the circumference of your leg after it was raised for 10 minutes? Why do you think this happened?

2. Compare your results with what might happen to astronauts when they are in a reduced gravity environment.

3. Explain why we call what astronauts look like in space the puffy-face-and-chicken-leg syndrome. Did you get “chicken legs” during this activity?

4. How do you think the fluid shift you experienced might affect other parts of your body?

5. Use the following graph to create a bar graph to show the standing and reclining leg measurements.



Chill Out

Liquid-Cooled Astronaut Sleeve

Grades 6 to 8

INQUIRY-BASED ACTIVITY

activity

CHILL OUT—LIQUID-COOLED ASTRONAUT SLEEVE

Grades: 6 to 8 Prep Time: 0.25 hour Activity Time: 1.5 hours

About This Activity

In this activity, which was taken from the NASA Suited for Spacewalking guide, students demonstrate the principle behind the operation of the Extravehicular Mobility Unit (EMU, or spacesuit) liquid-cooling garment.

Next Generation Science Standards

MS-PS3-3. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.

Learning Objective

Learners will

- Investigate and experience how the water-cooling system in the International Space Station (ISS) EMU functions

Materials

- Two containers to hold at least 1.5 liters (1 per group)
- 105 cm (3 1/2 feet) of aquarium tubing (per student)
- 1 liter of ice water
- Kitchen-size plastic garbage bags (1 per student)
- Socks or tube-shaped fabric (1 per student)
- 60 ml/cc disposable syringes (1 per group)
- Thermometers
- Student handouts

Background

Astronauts not only need to be protected from the hazards of the space environment in which they are trying to work, they need to be protected from the conditions that are created by the spacesuit. One of the most important of these is temperature. Suit insulation technologies protect astronauts from the extreme high and low temperatures of the space environment. However, this same insulation technology also keeps the heat released by astronauts' bodies inside their suits.

To get an idea of what this is like, imagine walking around in summer wearing a plastic bag. For this reason, an active cooling system is used. In Extravehicular Mobility Units (EMUs) the cooling system consists of a network of small-diameter water circulation tubes that are held close to the body by a spandex body suit. Heat released by the astronaut's body movements is transferred to the water where it is carried to a refrigeration unit in the spacesuit's backpack. The water runs across a porous metal plate that is exposed to the vacuum of outer space on the other side. Small amounts of water pass through the pores where the water freezes on the outside of the plate. As additional heated water runs across the plate, the heat is absorbed by the aluminum and is conducted to the exposed side. There the ice begins to *sublimate*, "turn directly into water vapor," and disperse into space. Sublimation is a cooling process. Additional water passes through the pores and freezes as before. Consequently, the water flowing across the plate has been cooled again and is used to recirculate through the suit to absorb more heat.

Supplementing the EMU cooling system is an air-circulation system that draws perspiration-laden air from the suit into a water separator. The water is added to the cooling water reservoir, while the drier air is returned to the suit. Both the cooling system and the air-circulation system work together to contribute to a comfortable internal working environment for the astronaut. The wearer of the suit controls the operation rates of the system through controls on the Display and Control Module mounted on the chest of the EMU.

Procedure

Step 1

Gather and pass out all necessary materials and place the ice and water in one container. Place students in groups of two to four.

Step 2

Distribute one plastic garbage bag to each student.

Step 3

Ask all the students to place their bare arms inside their garbage bags and then gather the plastic so that it fits their arms closely along the entire length of their bags.

Step 4

Tell the students to repeatedly make a fist and/or wave their arm while it remains in the bag for about 2 min.

Step 5

After 2 min, have the students remove their arms from the bags and observe any sensations that they feel. Then discuss what the students felt. Make sure that the students understand that a spacesuit, like the plastic bag, retains body heat. Also discuss why the students' arms suddenly felt cooler when they were removed from the bags. (Warm air in the bag was released, and moisture from perspiration began evaporating.)

Step 6

Have the students cut small holes in their sock or tube-shaped fabric. (If using a sock, they will have to cut off the end of the toe, Fig. 1.)

Step 7

Have the students interlace the tubing in the holes of their cut fabric or sock (Fig. 2).

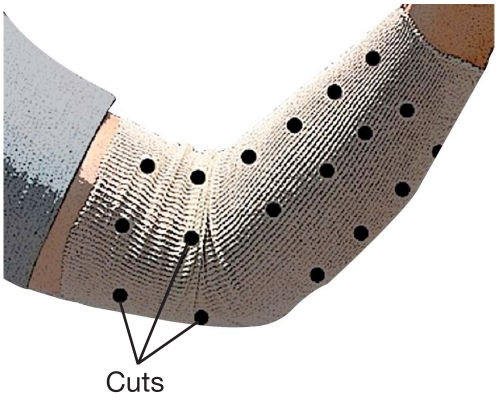


Figure 1

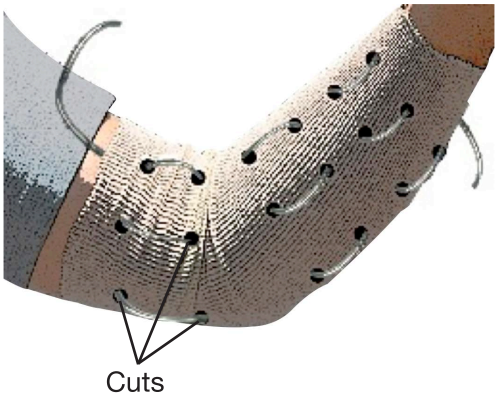


Figure 2

Step 8

Have the students place the tube or sock with tubing on their arms so that the tubing sticks out at both ends (near their wrists and above their elbows, Fig. 2).

Step 9

Have the students take the temperature of the water in the ice container and record the data.

Step 10

Have one student use the syringe to gather cold water from the container with ice water and force it through the tubing. Make sure that the second bucket is under the other end of the tubing to catch the water as it flows through the tubing.

Step 11

Have the students measure the temperature of the water in the second container (after it has passed through the tubing), and record the data. Be sure to empty the container each time.

Step 12

Steps 10 and 11 should be repeated until all students have had the opportunity to experience the cooling system.

Suggestions for Differentiation

Below are additional strategies to differentiate instruction depending on student readiness.

Support:
Skip the “plastic bag over the arm” activity.

Complexity:
Have students design a shirt or pants using the plastic tubing cooling system.

Names: ____

Directions

Step 1

Place your bare arm inside of a plastic bag and then gather the plastic so that it fits your arm closely along the entire length of the bag. Repeatedly make a fist and/or wave your arm while it remains in the bag for about 2 min. Remove the plastic bag.

What sensations do you feel, or what do you observe about your arm (e.g., temperature, perspiration, etc.)?

____

Step 2

Cut small holes in the sock or tube-shaped fabric provided. (If you are using a sock, cut off the end of the toe to open it up.) Put the fabric on your arm and then interlace the tubing in the holes with the tubing sticking out both ends (toward your wrist and above your elbow, Fig. 1).

Step 3

Take the temperature of the ice water, and add the information to the *Liquid-Cooled Astronaut Sleeve Data Table*.

Figure 1

Step 4

Have one of the group members use the syringe to gather cold water from the container of ice water and force it through the tubing. Make sure that the second container is under the other end of the tubing to catch the water as it flows through the tubing. Take the temperature of the water in the second container and record the data in the *Liquid-Cooled Astronaut Sleeve Data Table*. Repeat Steps 3 and 4 until all students in your group have participated. Make sure to fill out the *Liquid-Cooled Astronaut Sleeve Data Table*.

Liquid-Cooled Astronaut Sleeve Data Table

Student Name	Temperature of ice water (container 1), °C	Temperature of water after passing through tubing (container 2), °C	Temperature difference between water in container 1 and container 2, °C

Questions

1. Explain the sensation you felt as the water passed through the tubes.

2. Why do you think the temperature of the water changed as it passed through the tubing on your arm?

3. How might a device like this be beneficial to an astronaut while in space?

4. What professions on Earth might find liquid-cooled garments useful?

5. Think of how a liquid-cooled garment could be constructed that could operate continuously without using siphons and a container of ice water that would eventually run out. Write your ideas below.

Micrometeoroids, Space Debris, Meteors, and Meteorites

Grades 6 to 8

INQUIRY-BASED ACTIVITY

activity

MICROMETEOROIDS, SPACE DEBRIS, METEORS, AND METEORITES

Grades: 6 to 8   Prep Time: 1 hour   Activity Time: 1.5 hours

About This Activity

Parts 1 and 2 of this activity, taken from the NASA Suited for Spacewalking guide, demonstrate how the velocity of a projectile (not its mass) can determine its penetrating power. Part 3 of this activity, taken from Collecting Micrometeorites from the NASA Jet Propulsion Laboratory's Public Education Office, demonstrates how to find and identify micrometeorites.

Next Generation Science Standards

MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

Learning Objective

Learners will

- Demonstrate the penetrating power of a projectile with little mass but with high velocity
- Find and identify micrometeorites

Video Link

Micrometeoroids & Space Debris
https://www.nasa.gov/mov/329199main_Micrometeoroids.mov

Materials

- Tissue paper
- Cardboard frame (or box)
- Dried peas, popcorn, or other small items
- Tape
- Eye protection
- Raw potato
- Large-diameter plastic straws
- Hand-held microscopes
- Collected soil samples
- Strong magnets
- Plastic bags
- Toothpicks
- White paper
- Metric measuring tape or ruler
- Rubberbands (optional)
- Student handouts

Background

Micrometeoroids in Space

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

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

Spacecraft Debris

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

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

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

Meteoroids, Meteors, and Meteorites

Shooting stars are not, of course, really stars. They are meteors—small bits of rock and metal that collide with Earth's upper atmosphere and because of friction, burn up. On rare occasions, manmade satellites and spacecraft parts fall into the atmosphere and burn up the same way.

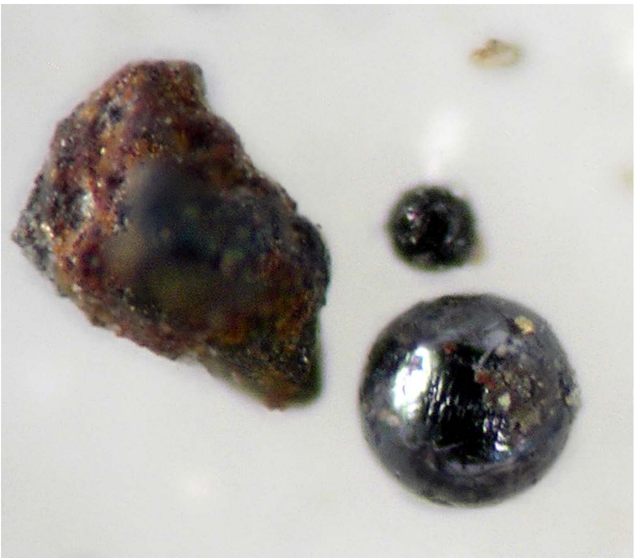
The bright streak of light from this incineration is correctly called a meteor. A meteor is formed when an object, usually the size of a marble or a piece of popcorn, hits the atmosphere at an altitude of 80 to 100 km (50 to 62 mi). The air at that height is very thin, but the objects are moving at tens of thousands of kilometers per hour. To get an idea of what friction does, place your hands together and rub them back and forth. Now rub faster. What is happening? That is what is happening to the particles in the upper atmosphere.

Larger objects do not burn up completely. Surviving fragments fall through the atmosphere and land on Earth. After one of these objects lands on Earth, it is called a meteorite. Most meteorites fall into Earth's oceans.

Meteorites can be either rock, metal (nickel and iron), or a mixture of both. Stony meteorites are difficult to identify because they do not glow or give off radioactivity. Stony meteorites outnumber metallic meteorites, but metallic meteorites are easier to find.

Even though chunks of metal are rarely found lying about, a metal detector can be used to search for metallic meteorites. Dry barren areas where there is little vegetation to cover up the ground and turn over the soil are the best. Dry lake beds are good places to search because wind can blow dust off of the surface, leaving the meteorites exposed. Many meteorites are found on the Antarctic ice sheet.

There is an easy way to collect meteorites, but we must be satisfied with finding tiny metal ones. They are actually microscopic and are known as micrometeorites. Tons of these fall on Earth each day.



Examples of micrometeorites

Micrometeorite on a magnet

Procedure

PART 1

Step 1

Make sure that all students are wearing eye protection. Then have the students cover the opening of a box with tissue paper, stretching the tissue tight.

Step 2

Have the students drop a pea or other pea-sized projectile onto the tissue paper from a distance of about 1 m (Fig. 1(a)). Does the pea penetrate?

Step 3

Tell the students that they are going to be blowing an object out of a straw and that they must be extremely careful to exhale, not inhale. Also tell them that they must not blow toward anyone. While the students are wearing eye protection, have them take turns standing a few meters from the box and blowing the pea through the straw toward the tissue paper. (With a little practice the pea should penetrate the tissue, Fig. 1(b).)

Step 4

Have the students tape two straws together end to end and repeat Step 3.

Step 5

Have the students test what happens when more than one layer of tissue paper is used to cover the box opening.

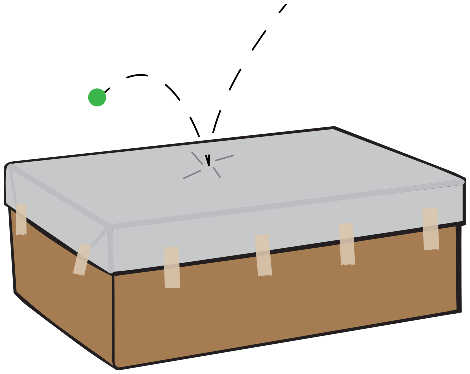


Figure 1(a)

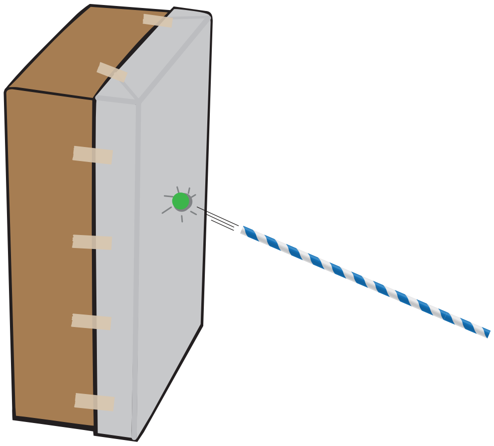


Figure 1(b)

PART 2

Step 1

Have the students hold a raw potato in one hand (Fig. 2). Explain that the potato represents an astronaut conducting an extravehicular activity (EVA) in space and that the straw represents a micrometeoroid. While grasping a straw with their other hands, have the students stab the potato with slow motion. Tell them to be careful not to strike their hands. Ask them to observe how deeply the straw penetrates the potato.

Step 2

Again have the students hold a potato, but this time have them stab the potato with a fast motion. Again ask them to observe how deeply the straw penetrates the potato. Have them compare their observations with the results of Step 1.

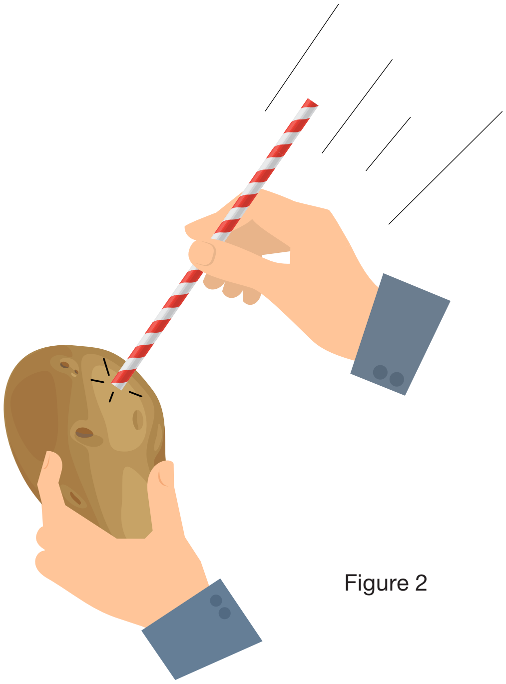


Figure 2

PART 3

Step 1

You will need to collect soil for students to look for micrometeorites. You need to find a place where they can become concentrated. The drains of a house or building work well because rainwater can wash particles off of an entire roof and collect them at the drain spout. (The older the structure, the more material will have collected at the end of the drain.) Tile roofs are best because they drain very well and do not produce many other sorts of particles or debris.

Step 2

Prepare a plastic bag of soil sample for each group of four students. Also hand out to each group two to four magnets, four white sheets of paper, two to four handheld microscopes, and four plastic bags.

Step 3

Have each group of students put one magnet into their plastic bag.

Step 4

Have the students carefully stir the magnet around in the soil sample while the magnet remains in the plastic bag.

Step 5

Have the students take the plastic bags to their white sheet of paper and pull out the magnet over the paper. This will allow the material that was sticking to the plastic bag to fall onto the white paper.

Step 6

Have the students use toothpicks to break up the material on the paper into tiny pieces. (Many times the magnet will pick up a large clump of dirt that contains some magnetic material.)

Step 7

Now have the students use the hand microscopes to examine the material more closely. Most of the particles will not be from space, but the micrometeorites will show signs of their fiery trip through the atmosphere. They will be rounded and may have small pits on their surfaces.

Step 8

Any material that students believe to be micrometeorites can be kept by lifting them off the paper with a strip of tape so that the students can take them home.

Suggestions for Differentiation

Below are additional strategies to differentiate instruction depending on student readiness.

Support:
Do parts 1 and 2 as demonstrations.

Complexity:
Have students design a method for protecting the potato astronaut from damage caused by the plastic straw when the straw is quickly stabbed into the potato.

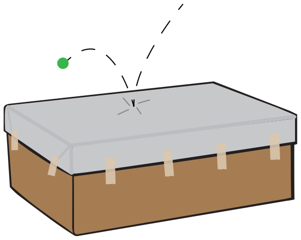
Name: ____

Directions

Put on eye protection and follow all the steps.

PART 1

Step 1



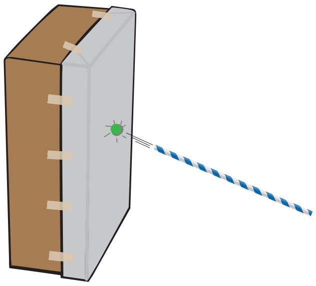
Cover the opening of a box with tissue paper. Stretch the paper tightly and tape or use a rubberband to hold it onto the box.

Step 2

Drop a pea or other projectile onto the tissue paper from a distance of approximately 1 m. Does the pea penetrate the tissue paper?

____

Step 3



Stand back a few meters from the box and blow a pea through the straw at the tissue paper. ***Caution: Do not inhale or blow toward anyone.***

What happened to the tissue paper this time?

____

Why do you think the results are different?

____

Step 4

Tape two straws end to end, and repeat Step 3. Did the speed of the projectile increase? How do you know?

____

Step 5

Add a second layer of tissue paper to the box and repeat. What effect did the second layer have on the penetration?

____

____

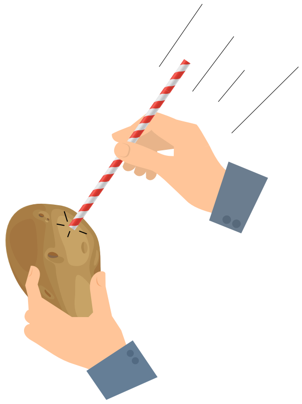
____

PART 2

Step 1

While holding a raw potato, grasp a plastic straw with the other hand, and stab the potato with a slow motion. The potato represents an astronaut in space, and the straw represents a micrometeoroid.

Observe how deeply the straw penetrates, and record your observation.



Step 2

Repeat, but this time stab the potato with a fast motion. This represents an astronaut being struck by a fast-moving micrometeoroid. Observe how deeply the straw penetrates the potato.

Compare your observation with the results of Step 1.

PART 3

Step 1

Place a magnet in a plastic bag.

Step 2

Carefully stir the magnet around in the soil sample provided, keeping the magnet in the plastic bag.

Step 3

Take the plastic bag to your sheet of white paper, and remove the magnet over the paper. This will allow the material that was sticking to the magnet to fall easily onto the white paper.

Step 4

Use toothpicks to break up the material into tiny pieces. (Many times the magnet will pick up a large clump of dirt that has some magnetic material inside of it.)

Step 5

Use a hand microscope to examine the material more closely. Most of the particles are industrial waste, not particles from space. The micrometeorites, however, will show signs of their fiery trip through the atmosphere. They will be rounded and may have small pits on their surfaces.

Step 6

Use a piece of tape to pick up any metallic micrometeorites that you would like to take home.

Step 7

Answer the following questions.

Did you find any micrometeorites?

If you found a micrometeorite, describe the shape. Why do you think it has that shape?

If your micrometeorite shows signs of small pits on the surface, how do you think they got there?

Grab On

With an End Effector

Grades 6 to 8

INQUIRY-BASED ACTIVITY

activity

GRAB ON—WITH AN END EFFECTOR

Grades: 6 to 8   Prep Time: 0.25 hour   Activity Time: 1 hour

About This Activity

In this activity, which was taken from the NASA International Space Station Basics, students follow a pattern to build a simple end effector and then use their experience to design and construct an end effector that can pick up more weight than the design that they were given.

Next Generation Science Standards

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Learning Objective

Learners will

- Construct, test, and design an end effector to pick up the most amount of weight

Materials

- Styrofoam cups
- 12-cm pieces of string
- Plastic serrated picnic knives
- Scale
- Variety of objects for the end effectors to pick up
- Variety of cup sizes and types
- Variety of string sizes and shapes
- Variety of types of tape
- Scissors
- Student handouts

Background

Space exploration today depends on humans and robots working together. Both bring important complementary capabilities to the exploration of space. This was demonstrated with the Space Shuttle Remote Manipulator System (RMS) robot arm (Fig. 1). The 15-m arm was mounted near the forward end of the port side of the orbiter's payload bay. It had 7 degrees of freedom (DOF). In robot terms, this means that the arm could bend and rotate in seven different directions to accomplish its tasks. Like a human arm, the RMS had a shoulder joint that could move in two directions (2 DOF); an elbow joint (1 DOF); a wrist joint that could roll, pitch, and yaw (3 DOF); and a gripping device (1 DOF). The gripping device was a type of end effector, which means that it was located at the end of the arm and it had an effect (such as grasping) on objects within its reach. The RMS's end effector was a snare device that closed around special posts, called grapple fixtures. The grapple fixtures were attached to the objects that the RMS wanted to capture.

On several occasions, the RMS was used to grasp the Hubble Space Telescope and bring it into the orbiter's payload bay. After Hubble was locked into position, the RMS helped spacewalking astronauts to repair the telescope and replace some of its instruments. During operations, the RMS was controlled by an astronaut inside the orbiter. The RMS actually became an extension of the operator's own arm. Television cameras spaced along the RMS enabled the operator to see what the arm was doing and to precisely target its end effector. At times, during the Hubble servicing, one of the spacewalkers hitched a ride on the end effector to gain access to parts of the telescope that were difficult to reach. The arm became a space version of a terrestrial cherry picker (or bucket truck).

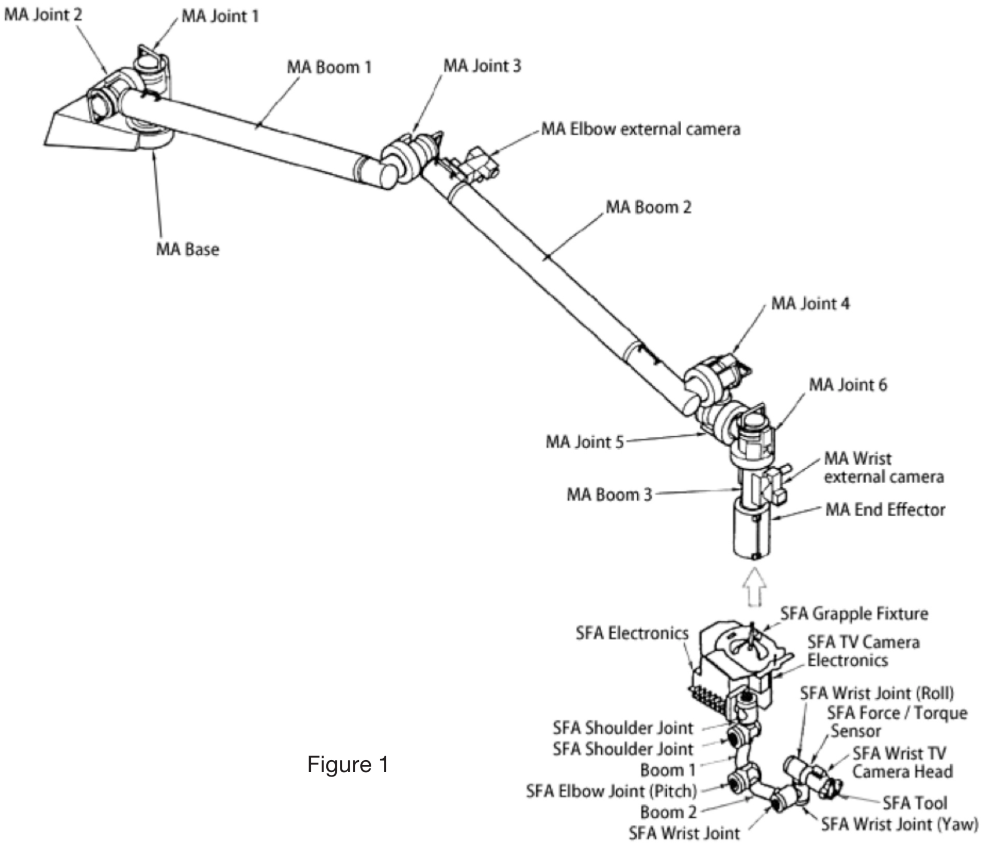


Figure 1

Procedure

Step 1

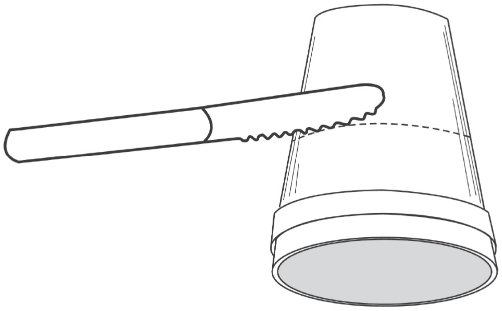


Figure 2. Saw through both cups.

Place students in groups of two or three and distribute the necessary materials. Have one student in each group nest two Styrofoam cups together and cut through both cups where indicated in Figure 2 by the dashed line. Smooth the cut edges by scraping them with the edge of the plastic knife.

Step 2

Have the students cut three pieces of string, each 12 cm long.

Step 3

They should tape the end of the first string to the inside of the inner Styrofoam cup just below the cut edge. Tape the other end of the string to the outside of the cup but do not press this piece of tape tightly yet (Fig. 3).

Step 4

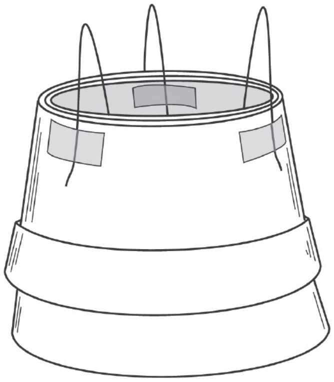


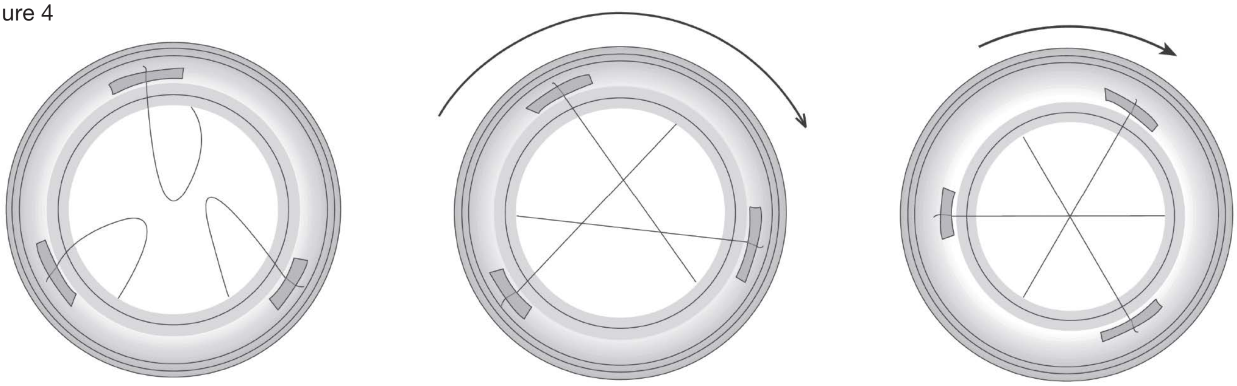
Figure 3. Tape string loop from outside to the inside.

Have the students repeat Step 3 two more times, spacing the strings about one-third of the way (120°) around the cup from each other.

Step 5

While they hold the rim of the inner cup, have the students rotate the outer cup until the three strings cross each other. The strings will have some slack. The students should pull the end of the strings on the outside until they are straight and intersect exactly in the middle of the opening (Fig. 4). Then have the students press the tape on the outside firmly to hold the strings.

Figure 4



Open position

Rotate outer cup

Continue rotating to close snares

Step 6

Next have the students use the end effector to pick up an object. Tell them to do the following:

a. Weigh one of the lighter objects and record the weight in the *End Effector Data Table*.

b. Open the end effector so that the strings are not crossing each other.

c. Slip the string end of the end effector over the object so that the object extends through the center and not through any of the loops.

d. Rotate the outer cup until the strings grasp the object; then lift the object up with the end effector (Fig. 5).

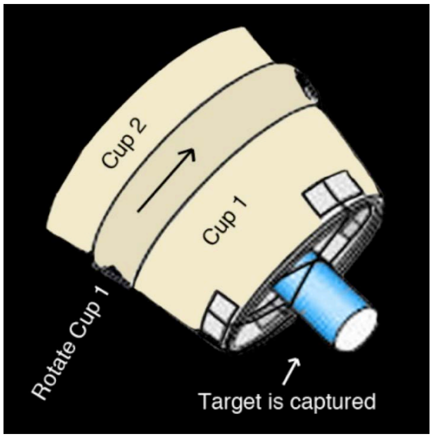


Figure 5

Step 7

After the students have constructed and used their simple end effector, have them work in their groups to design a better end effector. Have them sketch out their designs and decide what materials they want to use (from the additional materials provided). Give students a variety of materials to choose from for construction, such as different types of cups, string, tape, and so forth.

Step 8

Have students pick out the materials that they will need to use and begin construction.

Step 9

After they have finished, have the students test their new device and record the data in the *End Effector Data Table*.

Step 10

Have the students design a third end effector and test and record the data in the *End Effector Data Table*.

Step 11

After all the students have completed at least three designs and have tested them, have each group report their results to all the students. Have all the students discuss which designs worked the best and picked up the most amount of weight and why.

Suggestions for Differentiation

Below are additional strategies to differentiate instruction based on student readiness.

Support:
Have students only make the simple end effector.

Complexity:
Have the students search robot sites on the Internet and review different end effector designs. How does the design of an end effector enable it to pick up and manipulate various objects?

Names: ____

Directions

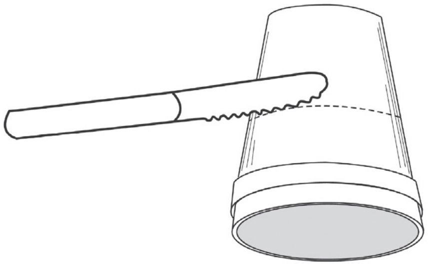


Figure 1

Step 1

Nest two cups together and cut through both cups where indicated in Figure 1 by the dashed line. Smooth the cut edges by scraping them with the picnic knife edge.

Step 2

Cut three pieces of string 12 centimeters long each.

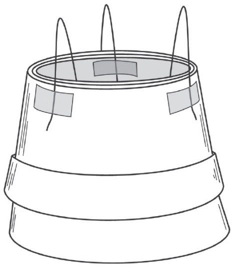


Figure 2

Step 3

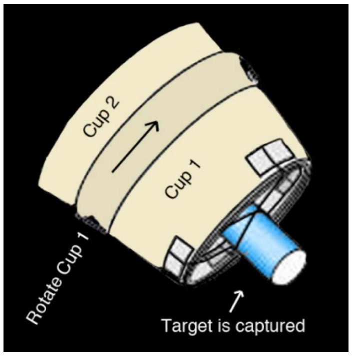
Tape the end of the first string to the inside of the inner cup just below the cut edge. Tape the other end of the string to the outside of the cup (Fig. 2). Do not press this piece of tape tightly yet.

Step 4

Repeat Step 3 two more times, placing the strings about one-third of the way around the cup from the first string.

Step 5

Hold the rim of the inner cup and rotate the outer cup until the three strings cross each other. The strings will have some slack. Pull the end of the strings on the outside until they are straight and intersect exactly in the middle of the opening. Press the tape on the outside to hold the strings.



Step 6

Record the weight of an object in the data table. Open your end effector so that the strings are not crossing each other. Slip the end effector over the object so that the object extends down the center and not through any of the loops. Rotate the outer cup until the strings grasp the object and then lift the object up with the end effector. Record the information in the *End Effector Data Table*.

Step 7

You will now design a better end effector. Sketch out a design and decide what materials you will need from the additional materials provided.

Step 8

Test your new device and record the data in the *End Effector Data Table*.

Step 9

Redesign and record the data in the *End Effector Data Table*. You will need to do this three times.

End Effector Data Table

End effector	Sketch of design	Objects tested (describe objects below)			
		1. ________________		2. ________________	
		Weight, g	Did it lift? (yes or no)	Weight, g	Did it lift? (yes or no)
Simple design provided					
First new design					
Second new design					
Third new design					

I Want To Hold Your Robotic Hand

Grades 6 to 8

INQUIRY-BASED ACTIVITY

activity

I WANT TO HOLD YOUR ROBOTIC HAND

Grades: 6 to 8   Prep Time: 0.5 hour   Activity Time: 2 hours

About This Activity

In this activity, which was adapted from NASA SciFiles, students will design an end effector to replicate the human hand.

Next Generation Science Standards

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Learning Objective

Learners will

- Create an end effector designed to replicate the human hand

Video Links

Robonaut 2—NASA's Humanoid Robot
https://www.youtube.com/watch?v=g3u48T4Vx7k

Materials

- Scissors
- Variety of cord
- Metric ruler
- Pen
- Variety of rubberbands
- Variety of drinking straws or small tubes
- Variety of construction material: cardboard, construction paper, plastic foam core, Styrofoam food tray
- Duct tape, electrical tape or other type of heavy-duty tape
- Utility cutters (depending on age of students)
- Student handouts

Background

A robot is a machine that collects information from its surroundings. It uses that information to follow instructions and complete tasks. Today's robots have multiple sensors and can make their own decisions based on given information. Robots come in all shapes and sizes. The jobs they do are also varied. Some robots are used in factories. Others are experimental robots that use artificial intelligence. Artificial intelligence allows robots to behave more like human beings and to act independently in a changing environment.

The gripping device at the end of a robotic arm is called an end effector. Robonaut 2 (R2) is a state-of-the-art highly dexterous anthropomorphic (humanlike) robot. It can handle a wide range of extravehicular activity (EVA) tools and interfaces. R2's dexterous hand will make it a very important tool for keeping astronauts safely inside spacecraft on future missions.

Procedure

Step 1

Discuss with students that space is a dangerous place and it is important to keep astronauts from being exposed to space as much as possible. This is why astronauts use robots like R2, which has dexterous hand movement, to do many of the tasks they would otherwise have to do.

Step 2

Explain that they will be designing and constructing their own robotic hands that must be able to lift and move an object. Set up an area where students will test their hands once completed.

Step 3

Demonstrate one method that can be used to make one of the fingers of the robotic hand in front of the students. Make sure students are watching your demonstrations. This will be helpful when they start their designs. Leave your example in a place that students can refer to if needed.

Step 4

Pass out the student handouts.

Suggestions for Differentiation

Below are additional strategies to differentiate instruction based on student readiness.

Support:
Have students only make finger with two joints or only make one finger.

Complexity:
Have students attach their robotic hand to a robotic arm.

Directions

Step 1

Make a palm for the robotic hand by cutting a piece of cardboard 10 by 10 cm.

Step 2

To make a finger, cut one piece of cardboard 2 by 9 cm.

Step 3

Cut the cardboard finger piece into three equal pieces (Fig. 1).

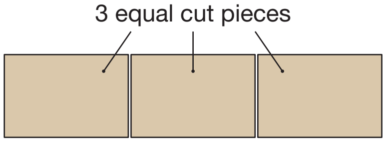


Figure 1

Step 4

Place the three equal finger pieces back together and use tape to reconnect them. Label one side of the taped finger "inside" (Fig. 2). Make sure that the three pieces are able to move freely.

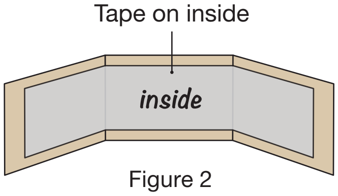


Figure 2

Step 5

Cut a rubberband 5 cm long.

Step 6

Turn the segmented finger over so the word "inside" is face down.

Step 7

Put the rubberband across the middle of the first joint (Fig. 3).

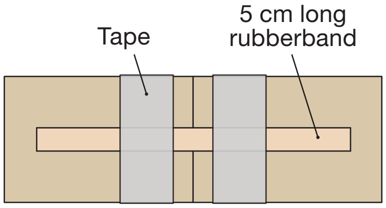


Figure 3

Step 8

Tape the rubberband on both sides of the joint, making sure to leave the ends of the rubberband not taped.

Step 9

Fold the ends of the rubberband so that they rest on top of the tape and tape them firmly in place (Fig. 4). Taping prevents the rubberbands from slipping.

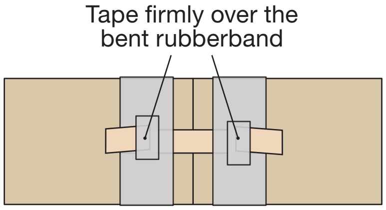


Figure 4

Step 10

Repeat steps 5 through 9 for the second joint.

Step 11

Tape the finger onto the palm with "inside" facing up (Fig. 5).

Step 12

Turn the hand over.

Step 13

Cut a rubberband 5 cm long.

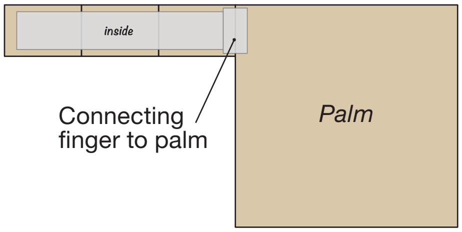


Figure 5

Step 14

Put the rubberband across the last joint (touching the palm).

Step 15

Repeat steps 8 and 9 for the last joint, connecting the finger to the palm.

Step 16

Turn the hand over with "inside" facing up, then cut a piece of nylon cord 35 cm long.

Step 17

Tape one end of the nylon cord over the end of the finger (Fig. 6).

Step 18

Cut four pieces of straw 2 cm each.

Step 19

Thread the pieces of straw onto the nylon cord.

Step 20

Tape a piece of straw in the middle of each finger section.

Step 21

Tape the last straw to the palm.

Step 22

Operate the finger by pulling the nylon cord.

Step 23

Follow Steps 2 to 21 two more times to add two other fingers (Fig. 7).

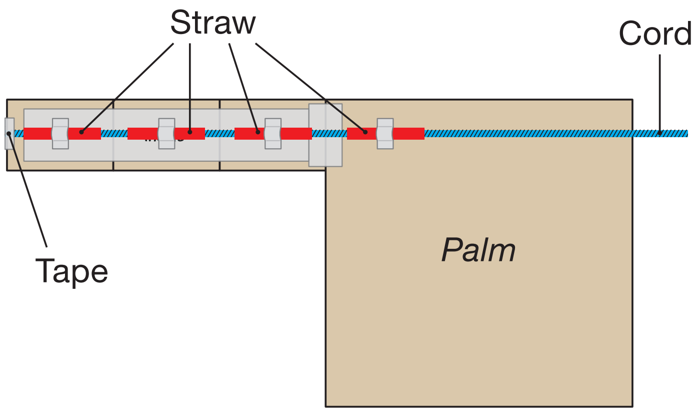


Figure 6

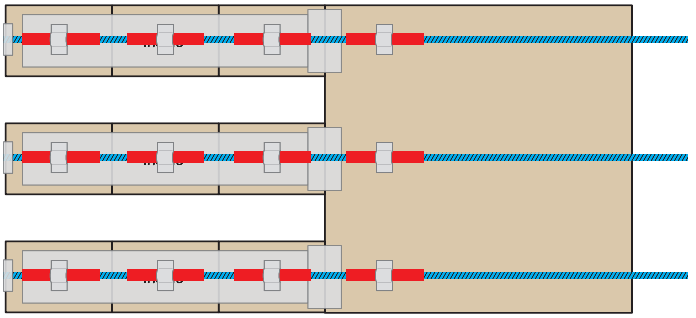


Figure 7

Name: ____

Directions

1. Design your robotic hand below.

Robotic Hand Design

2. Gather your materials and construct your robotic hand.
3. Take your robotic hand to the designated area for testing. Use your robotic hand to grab, lift and move the object and answer the questions below. If your hand does not work on the first attempt, go back and redesign the hand and test again.
4. Was your hand able to lift the object and move it? ____________

   If not, what modifications did you make in order to test your hand again?

   ____

5. What items can you pick up with your robotic hand?

   ____

6. How do you think adding additional fingers would affect your robotic hand?

   ____

7. Did you have a thumb? ____________

   If yes, how do you think this helped your hand? If not, would adding a thumb help your design?

   ____

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