The NASA SCI Files™

The Case of the Great Space Exploration

# Segment 3

Bianca continues her training at Space Camp while Catherine visits Mr. Mark Weyland at NASA Johnson Space Center in Houston, Texas. Mr. Weyland explains that there are two basic types of radiation and that it is one of the top biological concerns facing our astronauts during long-term space travel. He also tells Catherine about new technology that NASA is exploring to overcome the effects of space radiation. This new technology will enable the next generation of explorers to travel safely to the Moon, Mars, and beyond. Next, the tree house detectives dial up Ms. Dana Novak at the University of California at Santa Barbara to learn how mussels and bloodworms are helping scientists invent new self-healing materials for spacecraft. Bianca takes a break from her training to go over and talk with Mr. Steve Cook at NASA Marshall Space Center in Huntsville, Alabama to learn about future propulsion systems for space travel. Finally, Dr. D goes to Space Camp and meets with Bianca to learn about gravity, G forces, and the feeling of weightlessness on a ride that is "out-of-this-world."

# Objectives

Students will

- demonstrate the power of solar radiation.
- investigate the effect of solar radiation on an object.
- analyze the effectiveness of different Sun Protection Factors (SPF).
- understand how technology can be inspired by nature.
- demonstrate the symmetrical shape of nanotubes.
- explain nanotube technology.
- simulate the properties of self-healing materials.
- demonstrate self-assembly characteristics of materials.
- investigate alternative sources of energy.
- understand that weight is a result of gravity.
- simulate microgravity.

# Vocabulary

**bio-inspired** — designed to copy patterns in nature

**biology** — the science or study of life and living things

**composite** – made up of more than one material

**electromagnetic spectrum** — forms of electromagnetic radiation that include radio waves, microwaves, infrared radiation, visible light, ultraviolet rays, X-rays, and gamma rays.

**g** — a unit of force equal to the force exerted by gravity on a body at rest; used to indicate the force to which a body is subjected when accelerated

**nanotechnology** — applying technical knowledge or tools to build things on a microscopic level by controlling how the atoms are arranged

**photon** — a tiny packet or bundle of energy belonging to a particular wavelength that is released when an electron loses its extra energy. Light is made up of a stream of photons.

**propulsion system** — the source of energy that moves an object forward

**radiation** — the emission or putting off of energy, especially light and heat, in waves or particles

**ray** — a straight line that represents the motion of light in one direction

**self-healing** — able to repair itself by sealing small cracks or holes

**solar array** — panels used to collect and store energy from the Sun

**visible spectrum** — the only part of the electromagnetic spectrum that we can see, including the colors of the rainbow: red, orange, yellow, green, blue, and violet

**wavelength** — distance between any two corresponding points on successive waves, usually crest to crest or trough to trough

# Video Component

## Implementation Strategy

The NASA SCI Files™ is designed to enhance and enrich existing curriculum. Two to three days of class time are suggested for each segment to fully use video, resources, activities, and web site.

## Before Viewing

1. Prior to viewing Segment 3 of *The Case of the Great Space Exploration*, discuss the previous segment to review the problem and assess what the tree house detectives have learned thus far. Download a copy of the **Problem Board** from the NASA SCI Files™ web site, select **Educators**, and click on **Tools**. The **Problem Board** can also be found in the **Problem-Solving Tools** section of the latest online investigation. Have students use this section of the web site to sort the information learned so far.
2. Review the list of questions and issues that the students created prior to viewing Segment 2 and determine which, if any, were answered in the video or in the students' own research.
3. Revise and correct any misconceptions that may have been dispelled during previous segments. Use tools located on the Web, as was previously mentioned in Segment 1.
4. Review the list of ideas and additional questions that were created after viewing Segment 2.
5. Read the overview for Segment 3 and have students add any questions to their list that will help them better understand the problem.
6. **Focus Questions**—Print the questions from the **Educators** area of the web site ahead of time for students to copy into their science journals. Encourage students to take notes during the program so they will be able to answer the questions. An icon will appear when the answer is near.
7. **"What's Up?" Questions**—These questions at the end of the segment help students predict what actions the

## Careers

biologist
biomedical researcher
communications expert
chemical engineer
chemist
electrical engineer
mechanical engineer
nanotechnologist
radiologist
spacecraft design engineer
Health Physicists
Nuclear Engineer

tree house detectives should take next in the investigation process and how the information learned will affect the case. Teachers can print them from the Educators area of the web site ahead of time for students to copy into their science journals.

## View Segment 3 of the Video

For optimal educational benefit, view *The Case of the Great Space Exploration* in 15-minute segments and not in its entirety. If you are viewing a taped copy of the program, you may want to stop the video when the Focus Question icon appears to allow students time to answer the question.

## After Viewing

1. Have students reflect on the "What's Up?" Questions asked at the end of the segment.
2. Discuss the Focus Questions.
3. Have students work in small groups or as a class to discuss and list what new information they have learned about space flight and its effects on human beings, the importance of good nutrition and exercise, and how astronauts train for missions. Organize the information, place it on the **Problem Board**, and determine whether any of the students' questions from the previous segments were answered.
4. Decide what additional information is needed for the tree house detectives to determine what else astronauts need to deal with radiation, weightlessness, and the harsh environment of space. Have students conduct independent research or provide students with information as needed. Visit the NASA SCI Files™ web site for an additional list of resources for both students and educators.
5. Choose activities from the Educator Guide and web site to reinforce concepts discussed in the segment. Pinpoint areas in your curriculum that may need to be reinforced and use activities to aid student understanding in those areas.
6. For related activities from previous programs, download the **Educator Guide**. On the NASA SCI Files ™ home page, select **Educators**. Click on **Episodes** in the menu bar at the top. Scroll down to the 2001–2002 Season and click on *The Case of the Inhabitable Habitat*. In the green box, click on **Download the Educator Guide.**

a. In the **Educator Guide** you will find

1. **Segment 3** – *Vomit Comet*

Close the PDF window to return to the **Educator Guide** page. Using the yellow back arrow on the NASA SCI Files™ page (do NOT use the back button on your browser), return to the Episode description page. In the green box, click on **Activities/Worksheets**.

b. On the web site in the **Activities/Worksheets** section you will find

1. *Creating Microgravity*

Close the PDF window and return to the **Educator Guide** page. Click on **Episodes** in the menu bar at the top. Scroll down to the 2001–2002 Season and click on *The Case of the Mysterious Red Light*. In the green box, click on **Download the Educator Guide**.

a. In the **Educator Guide** you will find

1. **Segment 1** – *Natural or Artificial*
2. **Segment 1**—*Traveling the Straight and Narrow*
3. **Segment 1** – *Roping the Wave*
4. **Segment 1** – *Wave Upon Wave*
5. **Segment 1** – *Roll out the Frequency*
6. **Segment 3**—*Spinning White Light*
7. **Segment 3**—*Primary Colors of Light*
8. **Segment 3**—*Rainbow of Knowledge*

Close the PDF window to return to the **Educator Guide** page. Using the yellow back arrow on the NASA SCI Files™ page (do NOT use the back button on your browser), return to the Episode description page. In the green box, click on **Activities/Worksheets**.

b. On the web site in the **Activities/Worksheets** section, you will find

1. *Pouring a Little Light on the Subject*
2. *Incredible Edible Wave*
3. *The Edible Spectrum*

Close the PDF window and return to the **Educator Guide** page. Click on **Episodes** in the menu bar at the top. Scroll down to the 2001–2002 Season and click on *The Case of the Galactic Vacation*. In the green box, click on **Download the Educator Guide**.

a. In the **Educator Guide** you will find

1. **Segment 3** – *There's a Micro in my Gravity*
2. **Segment 3** – *All Aboard for Destinations Unknown*
3. **Segment 3** – *Rocket Go Round*
4. **Segment 3** – *Rocket Racer*
5. **Segment 3** – *There's an Ant in Your Acid*

Close the PDF window to return to the **Educator Guide** page. Using the yellow back arrow on the NASA SCI Files™ page (do NOT use the back button on your browser), return to the Episode description page. In the green box, click on **Activities/Worksheets**.

b. On the web site in the Activities/Worksheet section, you will find

1. *3-2-1 Launch!*
2. *Newton's Car*

7. If time did not permit you to begin the web activity at the conclusion of Segments 1 or 2, refer to number 6 under After Viewing on page 15 and begin the PBL activity on the NASA SCI Files™ web site. If the web activity was begun, monitor students as they research within their selected roles, review criteria as needed, and encourage the use of the following portions of the online, PBL activity:

   **Research Rack** – books, Internet sites, and research tools

   **Problem-Solving Tools** – tools and strategies to help guide the problem-solving process

   **Dr. D's Lab** – interactive activities and simulations

   **Media Zone** – interviews with experts from this segment

   **Expert's Corner** – listing of Ask-an-Expert sites and biographies of experts featured in the broadcast

8. Have students write in their journals what they have learned from this segment and from their own experimentation and research. If needed, give students specific questions to reflect upon as suggested on the **PBL Facilitator Prompting Questions** instructional tool found by selecting **Educators** on the web site.

9. Continue to assess the students' learning, as appropriate, by using their journal writings, problem logs, scientific investigation logs, and other tools that can be found on the web site. Visit the **Research Rack** in the **Tree House** and find the online PBL investigation main menu section, **Problem-Solving Tools**, and the **Tools** section of the **Educators** area for more assessment ideas and tools.

# Resources *(additional resources located on web site)*

## Books

Gherman, Beverly: *Mysterious Rays of Dr. Roentgen.* Simon and Schuster, 1994, ISBN: 0689318391.

Goodman, Susan E.: *Ultimate Field Trip: Blasting off to Space Academy.* Simon and Schuster Children's, 2002, ISBN: 0689848633.

Hillerman, Astrid and Hillerman, Anne: *Done in the Sun: Solar Projects for Children.* Sunstone Press, 1990, ISBN: 0865340188.

Petersen, Christine: *Alternative Energy.* Scholastic Library, 2004, ISBN: 0516228048.

Petty, Kate: *You Can Jump Higher on the Moon and Other Amazing Facts About Space Exploration.* Millbrook Press, 1997, ISBN: 0761305920.

Riley, Peter D.: *Energy.* Heinemann Library, 1998, ISBN: 1575726173.

Snedden, Robert: *Energy.* Heinemann Library, 1999, ISBN: 1575728796.

Stewart, Melissa: *Life Without Light.* Scholastic Library, 1999, ISBN: 0531115291.

Walisiewicz, Marek: *Essential Science: Alternative Energy.* DK Publishing, Inc., 2002. ISBN: 0789489198.

## Video

Interactions Real Math – *Real Careers: Building a Rover*
Grades 7–adult

Scholastic: *Magic School Bus: The Space Adventures*
Grades K–5

TMW Media Group: *Cool Space Stuff: Delivering Destiny*
Grades 6–adult

## Web Sites

**NASA: Space Radiation Health Project**
Visit this web site to learn what NASA is doing to overcome the effects of radiation during long-term space travel.
*http://srhp.jsc.nasa.gov/*

**Space Radiation Shielding**
The Space Radiation Shielding Program is part of Space Radiation Health Research, a new research initiative sponsored by the Office of Biological and Physical Research to help understand the effects of longer duration radiation exposure to astronauts.
*http://www.radiationshielding.nasa.gov/about.html*

**NASA: Radiation Belts**
An in-depth look at Earth's radiation belts.
*http://www-istp.gsfc.nasa.gov/Education/Iradbelt.html*

**NASA: Electromagnetic Spectrum**
Take a closer look at the electromagnetic spectrum and learn about wavelength, frequency, and more.
*http://imagers.gsfc.nasa.gov/ems/ems.html*

**Radiation and Long-Term Space Flight**
Visit this web site to learn more about space radiation, methods used to measure radiation, the effect of radiation on human beings, and NASA's plans to deal with space radiation.
*http://www.nsbri.org/Radiation/*

**NASA Aerospace Scholars: Radiation**
A great resource for educators to learn about radiation and its effects on the human body in space.
*http://aerospacescholars.jsc.nasa.gov/HAS/cirr/em/11/5.cfm*

**Radiation for Kids**
This web site has a wealth of information related to radiation, with many links to other sites that contain information about radiation, including a site to calculate your annual radiation exposure.
*http://www.philrutherford.com/radiation_kids.html*

**NASA Marshall Space Flight Center**
Find out more about the missions, organizations, history, and projects of NASA Marshall Space Flight Center in Huntsville, Alabama.
*http://www.msfc.nasa.gov/*

**NASA Advanced Space Transportation**
Visit this web site to learn about future transportation systems.
*http://www.spacetransportation.com/ast/index.html*

**How Stuff Works: Solar Sails**
Learn how solar sails will use photons from the Sun to propel spacecraft across the solar system.
*http://science.howstuffworks.com/solarsail1.htm*

**In-Space Propulsion Innovations**
NASA's Office of Space Science has issued a research announcement asking academic and industry researchers to propose in-space propulsion technology innovations—ideas that could revolutionize exploration and scientific study of the solar system.
*http://www.msfc.nasa.gov/NEWSROOM/news/releases/2002/02-269.html*

**Exploring the Nanoworld With LEGO® Bricks**
This web site shows how various physical and chemical principles relate to nanoscale science and technology and can be demonstrated with LEGO® models. Three-dimensional models are excellent tools for grasping structure-function relationships.
*http://www.mrsec.wisc.edu/edetc/LEGO/index.html*

**What is a Nanotechnologist?**
Interested in becoming a nanotechnologist? Visit this web site to learn what a nanotechnologist does.
*http://www.mrsec.wisc.edu/edetc/technologist/index.html*

**The Next Big Thing (Only Smaller)**
Watch a video about nanotechnology.
*http://www.mrsec.wisc.edu/edetc/cineplex/nanotech.html*

**Microgravity**
This educator guide contains excellent background information accompanied by classroom activities that enable students to experiment with the forces and processes microgravity scientists are investigating today.
*http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Microgravity/*

**Your Weight on Other Worlds**
Ever wonder what you might weigh on Mars or the Moon? Here's your chance to find out.
*http://www.exploratorium.edu/ronh/weight/*

# Activities and Worksheets

## In the Guide



## On the Web

**Cooking with Radiation—S'Mores Anyone?**
Use solar radiation to cook a real treat.

**No Assembly Line Needed**
A few blocks and some water is all you need to demonstrate the self-assembly characteristics of materials.

**You Said I Weigh How Much?**
Find out how much you weigh on other planets, the Sun, and the Moon.

# Somewhere Over the Rainbow

Segment

**Purpose**

To discover the colors and order of the visible spectrum

**Procedure**

1. Place the mirror in the plastic shoebox and lean it against one end.
2. Slowly pour water into the box until the mirror is covered halfway.
3. Hold the poster board above the box at the opposite end of the mirror where the air, mirror, and water touch.
4. Shine the flashlight on the water just in front of the mirror.
5. Adjust the mirror's angle until a rainbow's reflection appears on the poster board.
6. On your art paper, draw the rainbow, making sure to place the colors in the correct order.

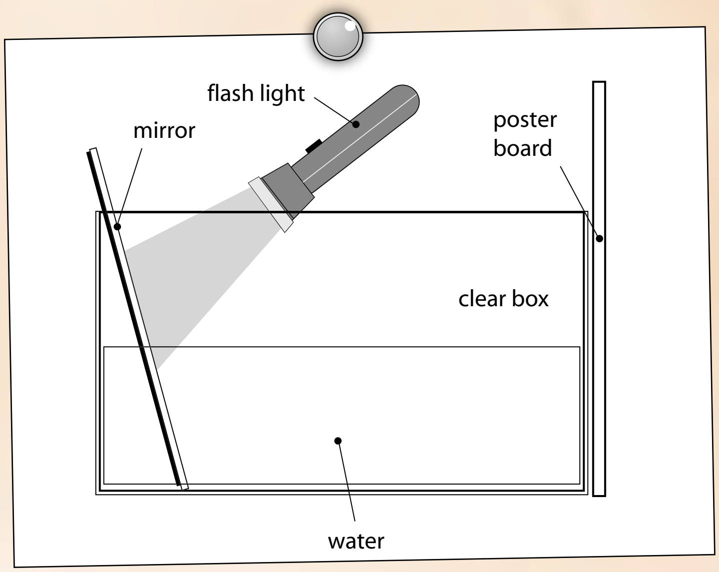
## Materials

clear plastic shoebox or glass baking pan
9-in. x 12-in. white poster board
small mirror
ruler
white art paper
marker or crayons
water
flashlight

**Conclusion**

1. What are the colors of the rainbow? ________________________________________________
________________________________________________________________________
2. How did the light, water, and mirror make a rainbow? ________________________________
________________________________________________________________________
3. Where have you seen other "rainbows?" ____________________________________________
________________________________________________________________________

**Misconception:** *The visible spectrum has six colors: red, orange, yellow, green, blue, and violet. Scientists originally thought that the color indigo was between blue and violet. However, with more modern equipment, they now know there are only six colors. Therefore, Mr. ROY G BIV became Mr. ROY G BV.*



# Photons and More Photons

Segment 3

## Purpose

To simulate photons in light

*Note: A teacher or parent should guide this activity. Prior to conducting this activity, students should have a basic understanding of the electromagnetic spectrum, visible light, and wavelength. Find activities in the Educator Guide for The Case of the Mysterious Red Light. Download a copy of the guide (2001–2002 Season) at http://scifiles.larc.nasa.gov/educators/index.html?p=episodes/guides*

### Materials

large open area such as a playground or field
chalk or duct tape to outline areas
15–20 meters (m) of thick rope knotted on each end and sectioned off in 1-m increments (Use marker or tape.)

## Background for Educator

When we look at a source of light, whether it be a candle or a star, our eyes respond to a particular range of energy that makes up what we call visible light. Visible light, however, is only a small portion of the electromagnetic spectrum, the whole range of radiant energies from radio waves to gamma rays.

One of the biggest hazards involved in interplanetary spaceflight is exposure to radiation. During interplanetary spaceflight, outside of the protection of Earth's magnetic field, crews will be exposed to radiation from the Sun (from solar flares) and from cosmic radiation (from the rest of the universe). Space radiation, often considered the primary hazard associated with space flight, is also important to study because it can have a great impact on human health. In space, crewmembers are subjected to greater amounts of natural radiation than they receive on Earth, exposing them to possible immediate and long-term risks.

There are three major sources of radiation in space. The first, trapped belt-radiation, occurs from particles found in the Earth's magnetic field. A second type, called galactic cosmic rays (GCRs), consists of particles that originate outside the solar system. The third type results from a solar particle event (SPE), which sometimes accompanies solar flares and may be the most potent space radiation hazard to lightly shielded spacecraft. Regardless of the source, large amounts of radiation exposure can lead to radiation sickness and have the potential to damage the body's chromosomes.

## Procedure

1. Prior to the simulation, outline an area on the ground approximately 3 m by 3 m to represent the Earth.
2. To represent the Sun, outline another area as a large circle approximately 5–8 m in diameter and 15–20 m from the Earth.
3. Discuss with the class the definition of a simulation.
4. Explain that a photon is the smallest amount of visible light or other form of electromagnetic radiation that demonstrates both particle and wave properties. Light is made up of a stream of photons.
5. Place students in the center of the Sun.
6. Have one student stand on the edge of the circle facing the Earth and grasp one end of the rope. He/she will be the first photon.

# Photons and More Photons

Segment 3

7. Stretch the rope in a straight path toward the Earth.
8. Explain that the students in the Sun represent emerging photons.
9. To begin the simulation, choose one of the photons to leave the Sun and tag the first photon at the edge of the circle.
10. Never letting go of the rope, the "tagged" photon will then move up the rope to the next mark.
11. Meanwhile, other photons should leave the Sun in an orderly fashion, tagging the last photon on the edge of the circle and repeating the previous steps to create a "chain reaction" that simulates a flow of photons (light) from the Sun.
12. Continue until all photons have left the Sun.
13. Discuss the simulation with the students.
14. Use activities from *The Case of the Mysterious Red Light* to discuss reflection, refraction, and scattering.
15. Afterwards, repeat this simulation to enhance student understanding of what happens to light as it enters the atmosphere and strikes the Earth. Use objects, such as a chair or box, to "reflect, absorb, refract, or scatter" the photons as they enter the Earth's atmosphere.
16. Discuss why Earth does not receive as much radiation as objects in space.

### Discussion Questions

1. How do the photons represent a beam of light?
2. What would happen if the photons stopped coming from the Sun?
3. What happens to the photons as they enter the Earth's atmosphere?
4. Explain why radiation is dangerous to astronauts in space.
5. Have students draw a diagram that represents the simulation.

### Extension

1. Place a single sheet of newspaper or other thin paper on top of a grassy area. With adult supervision, gather several small pebbles to represent radiation and throw the pebbles at the newspaper. Note how the pebbles tear the paper. Discuss how radiation affects the human body on a cellular level.

# Solar Radiation and SPF Levels

Segment 3

**Purpose**

To investigate the effects of solar UV radiation on an object and to analyze the effectiveness of different Sun Protection Factors (SPF)

## Materials

**(per group)**

dark construction paper (blue, purple, or red are best)
scissors
permanent marker
sunscreen of 5 different SPFs (same brand)
gingerbread man template p. 63
science journal

**Background**

The Sun's radiation is very powerful and can be dangerous to human beings. In space, astronauts are exposed to more UV radiation than they are here on Earth and must be particularly careful to protect themselves by wearing face shields as part of their helmets. On Earth, we have the ozone layer and lower atmosphere to help absorb and/or scatter some of the harmful ultraviolet (UV) rays of the Sun; however, there is still enough to harm us. Have you ever been sunburned? Exposing your skin to too much solar radiation causes sunburn. People protect their skin from harmful solar UV radiation by using sunscreen.

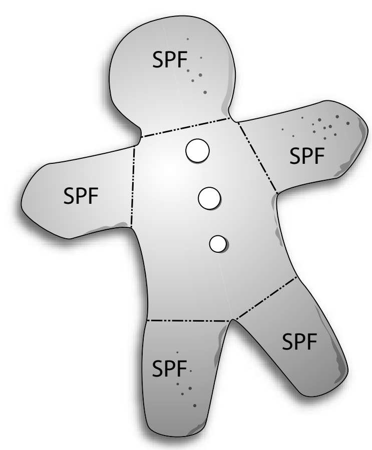
Sunscreen blocks or absorbs some of the UV light. Sunscreens offer various levels of protection and have a Sun Protection Factor (SPF), a number on the sunscreen. This number, multiplied by 10, gives you the number of minutes you can be exposed to the sun without getting burned. For example, an SPF 10 provides you with 100 minutes of protection from the Sun's harmful rays. Recent studies have shown that there is little difference between the protection power of SPF 30 and any of the higher SPFs.

On a sunny day, your shadow can be a great help in determining the amount of UV exposure to your skin. When the Sun is low in the sky, more of the UV light is absorbed, leaving less to harm you. As the Sun gets higher above the horizon, the atmosphere stops less of the UV light, allowing more of the harmful rays to burn you. To avoid being sunburned, you need to think about the **position** of the Sun in the sky. As a rule of thumb, when your shadow is longer than your height, your skin is getting less UV exposure. As your shadow shortens, more of the Sun's UV light can reach you and sunscreen is a must. One note of caution – even on cloudy days, when you can't see your shadow – UV rays are still there and can burn you.

**Note:** *Be sure to do this activity on a sunny day.*

**Procedure**

1. Use the template to cut one large gingerbread man from the dark construction paper.
2. Using the pen, divide the gingerbread man into sections: head, arms, and legs. See diagram.
3. Label each section with a different SPF number.
4. Coat the sections with the corresponding SPF sunscreen. Note: To control as many variables as possible, use the same brand of sunscreen for all samples.
5. Do not put sunscreen in the middle of the gingerbread man.
6. In your science journal, predict what will happen when you place the gingerbread man outside in the Sun.
7. Place your gingerbread man outside in a very sunny location.
8. Every 30–60 minutes check on your gingerbread man and record your observations in your science journal.
9. After a few hours, bring the gingerbread man inside.
10. Observe and record the appearance of the gingerbread man. Be sure to observe the other side of the gingerbread man.
11. Record your observations in your science journal.



***Diagram***

# Solar Radiation and SPF Levels

Segment 3

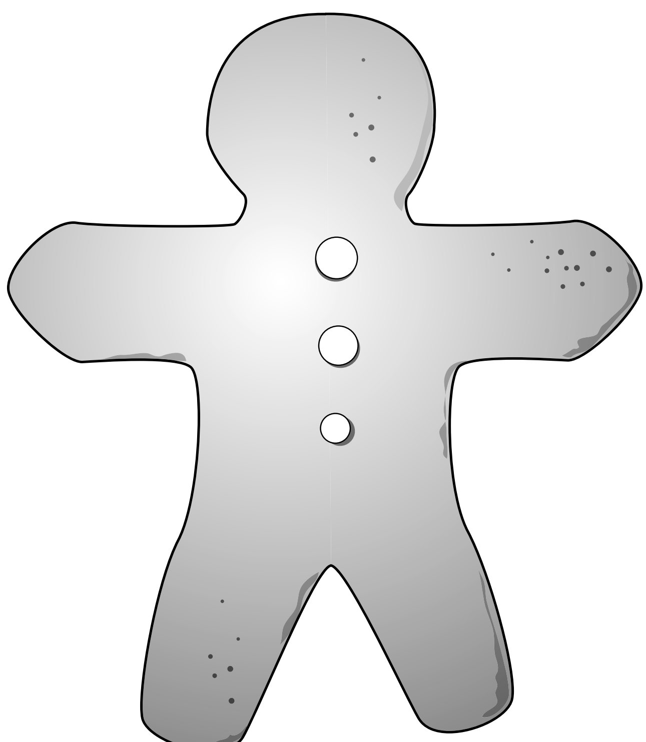
### Conclusion

1. What happened to the gingerbread man when he was exposed to the Sun?
2. What happened to the unprotected part of the gingerbread man?
3. Which SPF gave the most protection? How can you tell?
4. Why is sunscreen important?
5. What conditions may change the amount of sunscreen needed?

### Extension With UV Beads

**Note:** *UV beads change from white to various colors when exposed to UV light.*

1. Tie a UV bead to a string and take it, along with a ruler and a pail of water, outside. Lower the bead 2 centimeters (cm) into water and watch for a color change. Record your observations. Repeat by lowering the bead 2 more cm each time until no color change is observed. How far down does sunlight penetrate water?
2. Take a pair of sunglasses and place them in front of the UV bead, shading the bead from the Sun. Do the sunglasses protect the bead from UV light?
3. Observe UV beads indoors. What happens when the beads are indoors? Place the beads in a windowsill. Does UV light penetrate glass?
4. Take the beads outside on a cloudy day. Is there UV light on a cloudy day?
5. Try creating other experiments on your own with the UV beads.



***Template***

# Let's Go Propelling

Segment 3

## Purpose

To evaluate the effectiveness of a material

## Background

Launching an object into space can be costly. NASA scientists are currently researching new methods to launch vehicles into space. They want to improve the fuel used for launch, to create new designs, new propulsion techniques, and new launch vehicles. Some new launch methods include orbital space planes, microwaves, and single-stage tethers. Because being in space is not at all like being on Earth, scientists must carefully test all materials for the new systems before they are actually used. In space there will be little gravity, no air, significant radiation, and extreme temperatures. The materials that are chosen must be effective in the space environment.

**CAUTION: Adult supervision needed!**

## Materials

empty aluminum soft drink can
medium size balloon
thick rubber band
60 mL very hot water
large bowl
ice cubes (optional)
tongs
scissors
science journal

## Procedure

1. Twist the pop tab off the empty soda can.
2. Being careful, stretch the balloon over the top of the can.
3. Fasten the rubber band around the rim of the can so the balloon will not pop off or leak air. See diagram 1.
4. With an adult's help, carefully pour the hot water into the bowl.
5. Using tongs, place the soda can in the bowl and hold it there for a couple of minutes. See diagram 2.
6. Observe the balloon and have your partner record the observations in your science journal.
7. Continue holding the can in the hot water and making observations every two minutes until the can cools completely.
8. Optional: If ice is available, empty the water from the bowl and refill it with ice.
9. Repeat steps 5–6, holding the soda can in the bowl for about 6–9 minutes.
10. Observe and record your observations.

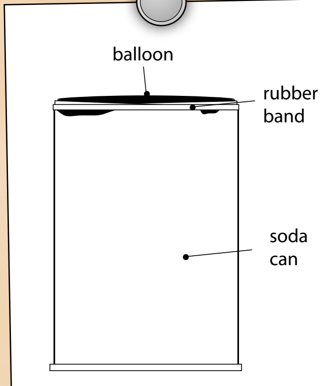


*Diagram 1*

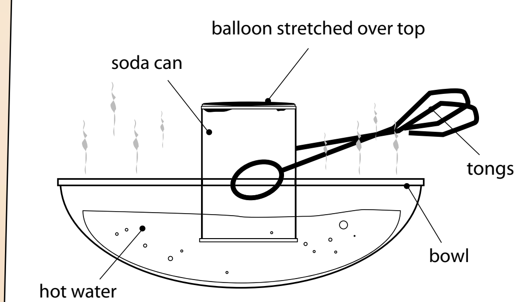


*Diagram 2*

## Conclusion

1. What happened to the balloon when it was exposed to the hot water? Why?
2. What happened to the balloon as the water cooled? Why?
3. What happened to the balloon when the soda can was placed in the ice?
4. Would this material be appropriate for making a fuel tank on a spacecraft that was going to Jupiter? Why or why not?
5. Why is it important for scientists to carefully test new products?

## Extensions

1. Scientists must also determine whether or not the cost of the new material is worth the expense. Go to the NASAexplores web site at *http://www.nasaexplorers.com/search_nav_5_8.php?id=03-033&gl=58* Read the article, *"Catch a Microwave."* Click on the link for the activity, *"What Are You Worth in Launch Bucks?"* Complete the activity. Decide which of the launch systems is the most cost effective. Should the least expensive choice always be used? Why or why not?
2. Research the NASA web site *http://www.nasa.gov* to find other types of propulsion systems NASA scientists are considering for future space flights. Make a poster explaining some of the the new propulsion systems.

# Hooks and Loops

Segment 3

### Materials

two matching pieces of hook and loop tape (such as Velcro®)
magnifying lens
white sock
drawing paper
pencil
area with tall grass
science journal

**Purpose**

To understand how nature can inspire technology

**Background**

In 1948, a Swiss mountaineer named George de Mestral began to look closely at the burrs that had clung to his clothes during a walk through the woods. After examining the burrs under a microscope, he saw the small hooks on the seed-bearing burrs that allowed them to cling so tightly to the tiny loops in the fabric of his pants. De Mestral realized that it might be possible to use this principle to make a fastener that would compete with zippers. With the help of a weaver from France, de Mestral perfected his hook and loop fastener. He patented the design in 1955 and founded Velcro® Industries to manufacture his invention. Today the multimillion dollar company produces millions of yards of hook and fastener tape, the product inspired by nature.

**Procedure**

1. Put the white sock on over the top of your shoe.
2. With adult supervision, go for a short walk in an area that has tall grass.
3. Return and carefully remove the sock.
4. Peel off any burrs that are stuck to the sock.
5. Observe the burrs with a magnifying lens.
6. In your science journal, draw a picture of your observations.
7. With a magnifying lens, observe each piece of the hook and fastener tape.
8. Put the two pieces together so that they stick.
9. Try to pull the pieces apart.
10. Change the direction of one of the pieces. Do they still stick?
11. Try to attach the pieces of hook and fastener tape together from the back side.
12. In your science journal, make a series of drawings to show how hook and fastener tape works.
13. Compare your drawings of the burrs to the drawings of the hook and fastener tape.

**Conclusion**

1. What makes the hook and fastener tape work?
2. What are some common uses for hook and fastener tape?
3. What is the advantage of hook and fastener tape over other kinds of fasteners?
4. What does bio-inspired mean?
5. What similarities to nature do you see in common, everyday tools and inventions?

**Extension**

1. Scientists look at animals to help discover new technology designs. Make a list of animals, other than birds, that might help scientists design new aircraft. Explain why you chose each animal.
2. What animals did the tree house detectives learn are inspiring stronger materials for future spacecraft. What other animals should scientists look at? Conduct research on biomemetics. Present your findings to the class.
3. Find out about other unique inventions. Where did the inventor get the inspiration for his/her invention? Make a poster advertising this "new" invention.

# Nano, Nano, Nanotubes

Segment 3

### Materials

3 brands of paper towels
water
measuring cup
large pan
pennies
magnifying lens
calculator

**Purpose**

To explain nanotube technology and to demonstrate the symmetrical shape of nanotubes

**Background**

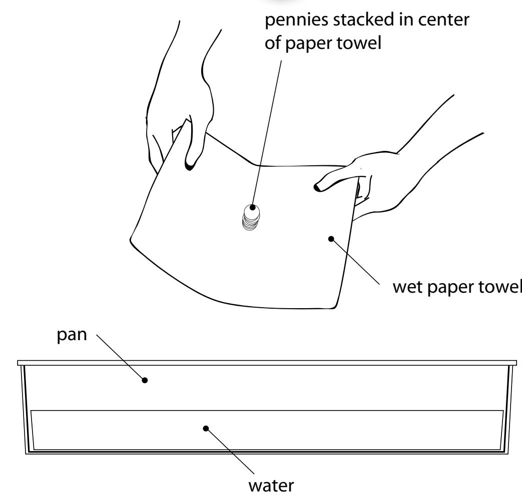
For more than a decade, scientists have dreamed of using carbon cylinders with walls just one atom thick as the building blocks for a new generation of sensors, transistors, and other tiny devices. Graphite is formed when carbon atoms are arranged in a honeycomb, or hexagonal, pattern. These honeycomb patterns are layered one above the other to create a single sheet of graphite that is stable, strong, and flexible. However, it does not bond well with other sheets of graphite. To bind graphite sheets together, a strong epoxy is used to form a composite that is often used for aircraft materials, tennis rackets, and racing bicycles. There is another way of arranging graphite sheets that makes them even stronger. Graphite sheets can be rolled to form carbon nanotubes. These microscopic nanotubes have superior mechanical and electrical properties. Scientists have been able to grow nanotubes in the lab that are several hundred meters long and the width of a human hair. When the tubes are spun into composite fibers, the fibers are tougher than steel, Kevlar, or spider silk.

Imagine what would happen if you cut off the ends of the nanotube and folded them into a top and a bottom. You would have another very stable, symmetrical form of carbon known as a buckyball. A buckyball contains sixty carbon atoms and is shaped like a soccer ball. Buckyballs can actually be produced under certain conditions. Meteorites frequently contain buckyballs because the vacuum of space is an ideal place for their formation. Buckyballs have also been produced in laboratories. They are being researched for their potential as propellants, superconductors, lubricants, and optical equipment.

Scientists must test the strength of new composite materials that are formed. To simulate testing of new composite materials, you will conduct an experiment to test the strength of several different brands of paper towels.

**Procedure 1**

1. Obtain three brands of paper towels.
2. Tear off three sheets from each roll and label each sheet with the brand name.
3. Using a magnifying lens, examine each set of paper towels.
4. In your science journal, record your observations about the shape and texture of each brand of paper towel.
5. Hold one sheet of the first brand of paper towel over a large pan and carefully pour 30 mL of water in the center.
6. While you hold the edges of the paper towel, ask your partner to carefully place pennies on the wet portion of the towel one penny at a time. See diagram.
7. Continue adding pennies until the towel breaks apart or tears.
8. In the chart, record the number of pennies the wet towel held.
9. Repeat steps 5–8 with the other two sheets from the same brand of paper towels.
10. Add the number of pennies for all three sheets and enter the results in the chart on page 67.



# Nano, Nano, Nanotubes

Segment 3

11. Find the average number of pennies the paper towels would hold by dividing the total by 3. Record your average in the chart.
12. Repeat steps 5–11 with the second and third brands of paper towels.
13. Compare the results for each brand of paper towel.
14. Discuss and determine which paper towel is the strongest. Explain your reasoning.

***Chart***

| **Number of Pennies** | ***Brand 1*** | ***Brand 2*** | ***Brand 3*** |
|---|---|---|---|
| Sheet 1 | | | |
| Sheet 2 | | | |
| Sheet 3 | | | |
| ***Total Pennies*** *(sheets 1+2+3=total)* | | | |
| Average (total ÷ 3) | | | |

# Nano, Nano, Nanotubes

Segment 3

## Procedure 2

*Scientists are trying to form new and stronger materials by making nanotubes. In nanotubes, the arrangement of the molecules is changed to make the original material better, but the material itself, in this case carbon, is still carbon.*

1. Place two books on the table 16–20 cm apart.
2. Lay a piece of plain paper on top of the books.
3. Begin gently adding pennies to the center of the paper not supported by the books.
4. Continue to add pennies until the paper falls. In your science journal, record the number of pennies the paper held before falling.
5. Now fold the piece of paper back and forth like an accordion.
6. Replace the folded paper on the books.
7. Gently add pennies to the paper until it falls and record your observations.
8. Did the folded paper hold more or fewer pennies than the flat paper?
9. Trace the hexagon template onto various types of materials, such as cloth, construction paper, or foil.
10. Cut out the shape and roll it into a tube.
11. Use either tape or glue to secure the sides of the tube.
12. With your partner, design a test to assess the strength of the various nanotubes.
13. Use what you learned from Procedure 2 and repeat Procedure 1 with the weakest brand of paper towel. How many pennies did it hold?

### Materials

hexagon template p. 69
scissors
assortment of paper, fabric, foil
glue or tape
metric ruler
2 books

## Conclusion

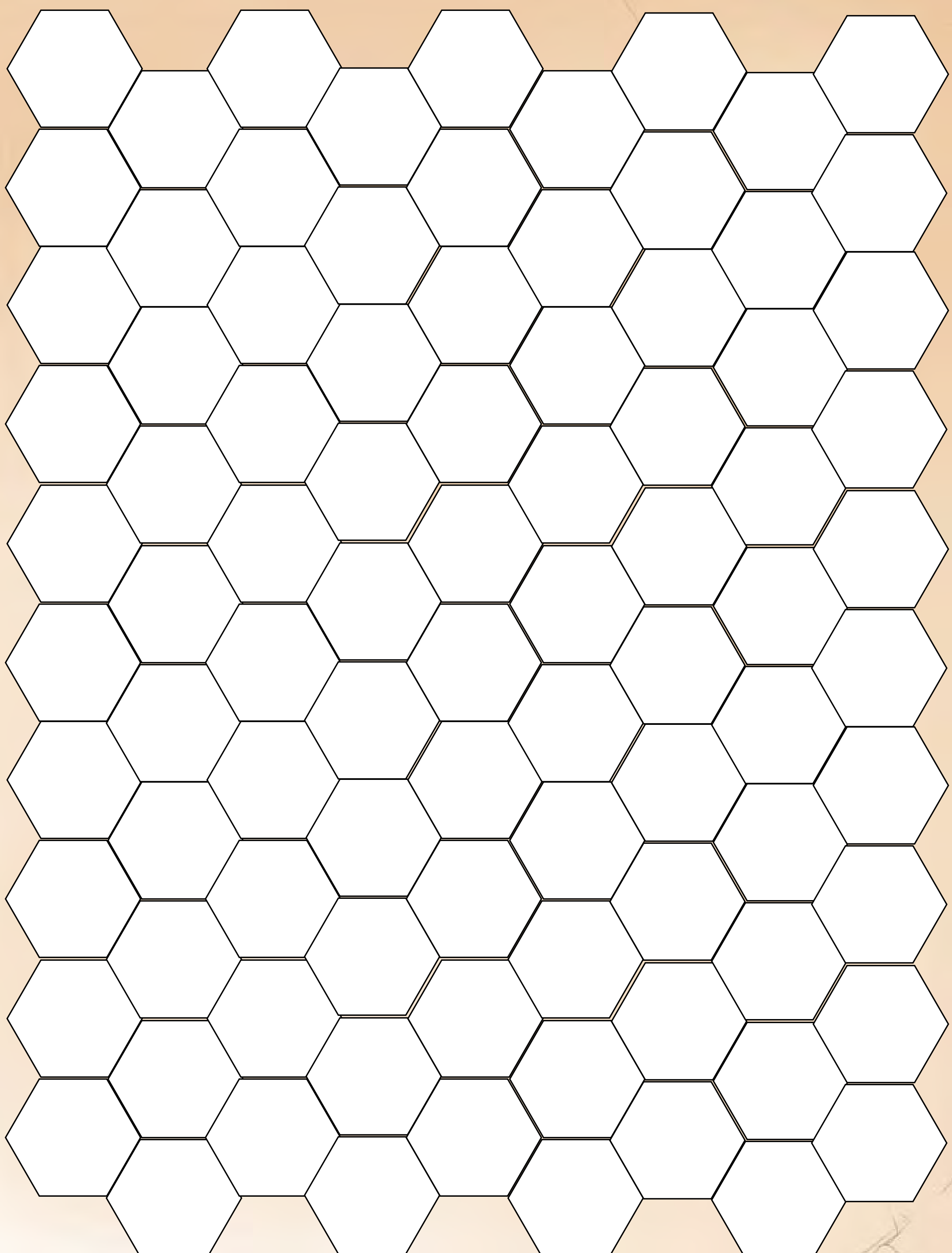
1. Which of your paper towels was the strongest?
2. What did you notice about the design of this paper towel compared to the others?
3. What changes in the material occur when nanotubes are made?
4. How is the folded paper model similar to the process used by scientists to form nanotubes?
5. How did you test the strength of the nanotube you designed?
6. Why are scientists concerned with making nanotubes?

## Extension

1. Tessellations are patterns that cover a plane or flat surface by repeating the same shape over and over. Most tessellations are made of triangles, squares, and hexagons. The carbon nanotube contains a hexagon tessellation pattern. The artist, M. Escher, used tessellations to make unusual pictures and sculptures. Learn more about Escher's art. Find samples of his pictures on the Internet. Using these repeated patterns, try to design your own tessellations.
2. A Hoberman sphere is an interesting science toy that is based on the principles of the buckyball. The shape and size of the sphere can be changed by rearranging the interlocking pieces that form the sphere. Architectural structures, such as the Iris Dome at the Museum of Modern Art in New York or the Hoberman Arch that was built for the 2002 Olympic games in Salt Lake City, Utah, have been inspired by these mathematical and scientific discoveries. Using gumdrops, toothpicks, straws, or other common materials, build your own geodesic design. Be sure to use repeating patterns.
3. Collect the 6-pack rings from soft drinks and roll the rings into tubes. Connect the tubes together with string to form long nanotube models. Hang your nanotubes from the ceiling. Note: Plastic 6-pack rings are photodegradable. When exposed to UV light for an extended period of time, they will begin to break down. Do not hang heavy objects from the rings.

# Nano, Nano, Nanotubes

## Hexagon Template



# Self-Healing Materials

Segment 3

## Materials

454 grams (g) (one 16-oz box) cornstarch
400 mL (approximately 1 2/3 cups) water
food coloring (optional)
disposable pie pans
heavy wooden or metal spoon
bowl
science journal

### Purpose

To simulate the properties of self-healing materials

### Background

As human beings travel farther into space, NASA will need new, advanced materials to design and build the spacecraft that will take them there. As we journey millions of miles from Earth, we won't find parts stores or repair shops along the way; therefore, a spacecraft must be made of strong material that can repair itself. A weakness of current composite material is that it tends to form tiny hairline cracks that cause major damage over time. Scientists observing the human body noticed that the body has an amazing ability to heal itself. When you get a cut, the body works to heal the skin around the cut. A scar is evidence of the body's self-healing power. Scientists are now developing a new type of composite material that will give those same self-healing qualities to spacecraft. This new synthetic material will heal itself when cracks form.

Oobleck is a unique substance that appears to be both a solid and a liquid. It is, in fact, a non-Neutonian fluid, which means that when a small amount of force is used on the substance, it acts like a liquid. Hold some Oobleck in the palm of your hand and watch it puddle like thick syrup. When more force is applied, Oobleck behaves like a solid. Make a fist and the Oobleck will form a hard ball from the pressure of your fist. Release your fist and the ball will simply "melt" into a liquid again. In a container, pressure may be used on the Oobleck to form cracks, but as soon as the pressure is removed, the Oobleck flows together, "healing" the cracks and forming a smooth perfect surface again, much like the synthetic self-healing materials scientists are now developing.

### Procedure

1. Pour the cornstarch into a large mixing bowl.
2. Add a few drops of food coloring to the water.
3. Slowly add water to the cornstarch, stirring carefully. (The mixture will be very hard to stir.)
4. Continue stirring until no more powder is visible.
5. Pour the mixture into pie plates.
6. Use your senses of touch, sight, and smell to describe this substance.
7. In your science journal, record your observations.
8. Poke your finger quickly into the mixture. Describe what happens.
9. Now set your finger on the surface of the mixture. Describe your observations.
10. Pick up some of the mixture. Hold it in the palm of your hand. Describe your observations.
11. Now make a fist with the mixture. Describe what happens when force is added.
12. Set a spoon on the surface of the mixture. What happens?
13. Try stirring the mixture. What happens?
14. Push on the mixture in the pie pan until a crack or crevice forms.
15. Observe what happens as soon as you stop pushing on the mixture.
16. Record your observations.

# Self-Healing Materials

Segment 3

**Conclusion**

1. What are the characteristics of a solid?
2. What are the characteristics of a liquid?
3. Is Oobleck more like a solid or a liquid? Why?
4. What happens when the pressure is removed after making a crack in the surface of the Oobleck?
5. What can the tree house detectives learn about self-healing materials from doing this experiment?
6. In your own words, explain why self-healing materials are necessary for space exploration.

**Extension**

Obtain a piece of memory metal wire from a science supply store. Many science stores, such as TeacherSource (www.teachersource.com) carry nitinol or some other smart metal alloy. Make a shape out of the wire. Place the wire in hot water to watch it return to its original shape. Find out more about memory (smart) metals. Why were they developed? How are they used? Record your findings in your science journal.

# Weightless Clothespin

Segment 3

## Purpose

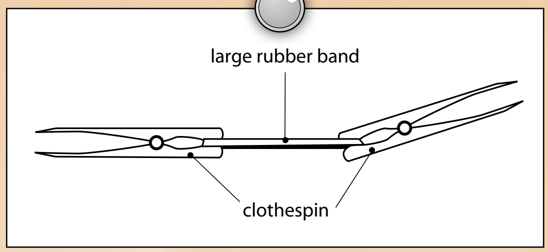
To learn about microgravity

## Background

Fortunately, on Earth we have gravity to keep us grounded so that we don't float away, but in space there is very little gravity, so astronauts are "weightless." NASA has special equipment to simulate a microgravity environment on Earth, such as the NASA Neutral Buoyancy Laboratory (NBL), a modified KC-135 jet aircraft nicknamed, "The Vomit Comet," and the NASA Weightless Environment Training Facility. However, there is a simple experiment you can do to learn more about microgravity and its effects.

### Materials
**(per group)**
2 clothespins
1 big, thick, rubber band
science journal

## Procedure




1. Observe the shape of the rubber band.
2. In your science journal, record the shape of the rubber band.
3. Clip one clothespin to one end of the rubber band.
4. Clip the other clothespin to the opposite end of the rubber band.
5. Hold up one of the clothespins.
6. Notice how the bottom clothespin pulls down on the rubber band, causing it to stretch.
7. In your science journal, record the shape of the rubber band with one clothespin hanging down.
8. Let go of the clothespin.
9. Observe the shape of the rubber band as it falls to the ground and record what happens.
10. Repeat the experiment several times.

## Conclusion

1. Why did the rubber band stretch when you attached the clothespin to it?
2. Why did the clothespins and rubber band fall to the ground?
3. What shape did the rubber band take as it fell? Why?
4. Why do astronauts float while they are in space?

## Extension

1. Visit the NASAexplores web site at *http://www.nasaexplorers.com/show_k4_teacher_st.php?id=030108124259*. Read the article *"Microgravity: Always a Bad Hair Day"* and complete the activity called *"Gravity at Work."* You will learn more about how gravity works.
2. Create a hat to demonstrate weightlessness. Securely attach 5–10 ribbons (approximately 10–15 cm each) to the center top of a baseball hat. Attach a clothespin to each ribbon. Place the hat on your head and make sure that the clothespins are not near your eyes. Cut ribbons if needed and reattach clothespins. Wearing the hat, bounce up and down (pogo sticks and trampolines work great) and have a partner observe what happens. Switch places with your partner.

# Answer Key

Segment 3

**Somewhere Over the Rainbow**

1. Red, orange, yellow, green, blue, and violet (purple).
2. The light hit the wedge of the water between the mirror and the water's surface, causing the light to bend (refract). Because each wavelength of light bends at a different angle, the colors are refracted in slightly different directions, and the colors are spread out or split, creating a rainbow.
3. Answers will vary but may include that rainbows have been seen in the sky, on bubbles, CDs, dish soap, and many other places.

**Photons and More Photons**

1. The photons travel in a straight line just as a beam of light travels. Light is made up of a stream of photons.
2. If there were no photons, there would be no light.
3. As the photons enter the Earth's atmosphere, some are blocked by the ozone layer and absorbed, reflected, and/or refracted by the clouds and particles in the lower atmosphere.
4. In space there is no atmosphere to help protect the astronauts from radiation.
5. Drawings will vary.

**Solar Radiation and SPF Levels**

1. As the Sun shines on the construction paper, it fades at different rates, depending on the protection level of the sunscreen applied.
2. The unprotected sections should fade the most.
3. Answers will vary, but the higher SFP levels should provide the most protection.
4. Sunscreen protects our skin from harmful UV radiation.
5. Answers will vary, but may include the season, time of the day, location, and activity.

**Let's Go Propelling**

1. The balloon began to expand. The hot water in the bowl heated the can, which in turn heated the air inside the can. As the air inside the can was heated, it began to expand and rise, filling the balloon with warm air.
2. As the water cooled, the air inside the can also cooled. The air molecules began to compact (become denser) and sink toward the bottom of the can, thus deflating the balloon.
3. The ice cooled the air inside the can quickly and the balloon may have sunk into the opening of the can.
4. Answers will vary. Students may see a response to the environment as a positive adaptation; others will say that the flexibility of the material will make it unsuitable because you will not be able to compensate for size changes within the confines of the spacecraft.
5. Scientists must understand how materials will react in different situations, such as the high-pressure atmosphere on Jupiter or the extreme cold of Pluto.

**Hooks and Loops**

1. The "hook tape" has stiff little hooks on it, while the "loop tape" is soft and fuzzy. Together, they're called a "hook and loop fastener" or a "touch fastener."
2. Answers will vary, but may include these: hook and fastener tape can be used instead of shoelaces or buttons to hang pictures on walls or seal containers.
3. Hook and fastener tape is easier for young children or people with dexterity problems to use. The tape is stronger and holds longer than other types of tape.
4. "Bio-inspired" means to be patterned after something seen in the natural world.
5. Answers will vary, but students may talk about the shape of airplane wings that look like bird wings or shark fins, and/or the computer, which uses electrical impulses patterned after brain waves.

**Nano, Nano, Nanotubes**

1. Answers will vary.
2. Answers will vary depending on results. However, the towels with quilting will usually be stronger.
3. The parent material remains the same; only the structure or organization of the atoms changes.
4. The structure of the paper is changed; in this case, it is folded, but the paper is still the same paper. When nanotubes are formed, the carbon is still carbon, but the atoms are rearranged.
5. Answers will vary.
6. Nanotube technology can be used to develop specific characteristics of a material, such as strength or flexibility.

**Self-Healing Materials**

1. A solid has a specific volume and maintains a specific shape.
2. A liquid has a specific volume but does not have a definite shape; it takes on the shape of its container.
3. Answers will vary.
4. The mixture becomes liquid and fills in the cracks, forming a smooth surface once again.
5. Answers will vary.
6. Answers will vary but should include that they will help avoid repairs during long-term space travel.

# Answer Key

Segment

**Weightless Clothespin**

1. The rubber band stretched because the force of gravity pulled the clothespin downward.
2. Gravity caused the clothespin and rubber band to fall. Gravity is the attraction between objects that causes objects on Earth to fall toward the surface of the Earth.
3. The shape becomes nearly round again (original shape) as it falls. Because the whole clothespin system is falling at the same speed, the bottom clothespin no longer pulls down; it appears weightless within the system.
4. The astronauts are actually falling in space; thus, they have no weight and float around.

## On the Web

**Cooking With Radiation—S'Mores Anyone?**

1. The temperature should rise during the experiment.
2. The temperature will rise more slowly and the inside of the pan will not get as warm.
3. Answers will vary, but students should discuss heat conductivity.
4. The S'Mores would burn, just as if they had been left in an oven too long.
5. Human skin also burns, not from the heat, but from the ultraviolet radiation of the Sun. We use sunscreen with SPF to protect our skin.
6. The astronauts are exposed to more significant levels of solar radiation in space because of a lack of atmosphere, particularly the ozone layer, to help absorb and scatter the ultraviolet light.

**No Assembly Line Needed**

1. Answers will vary depending on the number of blocks given to each person.
2. The blocks began to float on the water, moving toward each other to form a shape.
3. Scientists can use the arrangement of molecules to make certain characteristics of a material better.

**The Solar Wind in My Sails**

1. A solar sail is like a large mirror that reflects sunlight. As the photons of sunlight strike the sail and bounce off, they gently push the sail along by transferring momentum to the sail. Because there are so many photons from sunlight, and because they are constant, there is a constant pressure exerted on the sail, creating a constant acceleration of the spacecraft. The solar sail constantly accelerates over time and achieves a greater velocity than conventional chemical rockets, such as the Space Shuttle.
2. Answers will vary but might include that scientists are looking for alternative sources for propulsion systems. Solar sails will enable spacecraft to move through the solar system and between stars without bulky rockets and the need for great amounts of fuel.
3. Answers will vary.

**You Said I Weigh How Much?**

1. The planet you weigh the most on is Jupiter. However, on the Sun, you would weigh even more. You would weigh the least on Pluto.
2. You weigh almost the same on Earth as you do on Venus and Saturn.
3. The amount of gravity determines your "weight." Because the Sun, Moon, and each planet are various sizes and densities, they have different gravities.