Grades 3–5, 6–8

10–60 minutes

TOUCH DOWN

DESIGN CHALLENGE

Design and build a shock-absorbing system for a spacecraft to protect two marshmallow astronauts when they land. The astronauts should not fall out when the craft is dropped from a height of 1 foot.

SUPPLIES AND EQUIPMENT

Per whole group

- ☐ Scissors
- ☐ 100 index cards
- ☐ 100 rubber bands
- ☐ 100 straws
- ☐ Sponge or foam pieces

Per team

- ☐ 1 piece of cardboard, 4" x 5"
- ☐ 1 paper cup
- ☐ 1 roll transparent or masking tape
- ☐ 2 marshmallows

GETTING READY

Cut the cardboard into pieces approximately 4" wide by 5" long.

INTRODUCTION

How do you protect an astronaut from being crushed by the forces of lift-off?

NASA spacecraft require shock-absorbing devices. Rockets shake violently as they launch and landers touch down on places like the Moon or Mars with a great deal of force. Without shock absorbers, these extreme vibrations on launch would shake the astronauts with a force 5–6 times stronger than Earth's gravity or destroy the delicate equipment in the landers when they reached these places in the solar system.

INSTRUCTIONS

Introduce the design challenge by explaining that groups of 3–4 participants will design, build, and test shock absorbers for a spacecraft lander. The lander will consist of a platform (the cardboard) with shock absorbers underneath and a crew cockpit (paper cup) on top. Guidelines regarding materials for this activity:

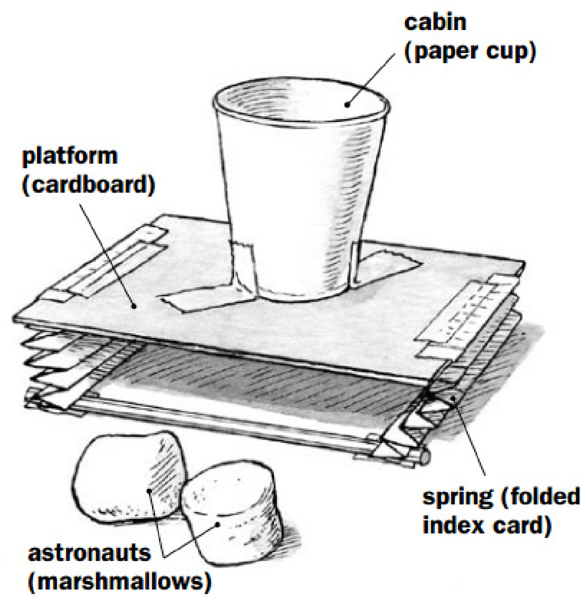
- Participants can use any of the materials provided, and you may decide to limit the quantity of materials each person or group uses.
- You may wish to distribute materials to each group instead of allowing participants to take large amounts. This can reduce waste and ensure that there are enough materials for everybody. It also helps to illustrate the concept of constraints in the engineering design process.
- Caution: For safety, be sure to inform participants not to taste or eat any of the materials during this activity.

Provide guidance to participants if necessary:

Think about how you can use the materials provided to make springs or cushions. Build the shock absorbers on the bottom of the platform, and then attach a paper cup to the top of the platform. Test your design by placing two marshmallow astronauts, uncovered, in the cup and dropping it from a height of 1 foot. Adjust your design as needed.

Evaluate the success of each design.

- ☐ Did the spacecraft land on the shock absorbers?
- ☐ How well did the shock absorbers soften the impact of landing?
- ☐ Did the marshmallow astronauts remain in the cup?



One possible shock-absorbing system. Credit: Hannah Bonner for WGBH Educational Foundation

ACTIVITY VARIATIONS

Design landers that will protect marshmallow astronauts from higher and higher drops.

Up the stakes by using an egg instead of marshmallows. Test prototypes with weights before dropping the egg.

Vary the materials provided.

TROUBLESHOOTING

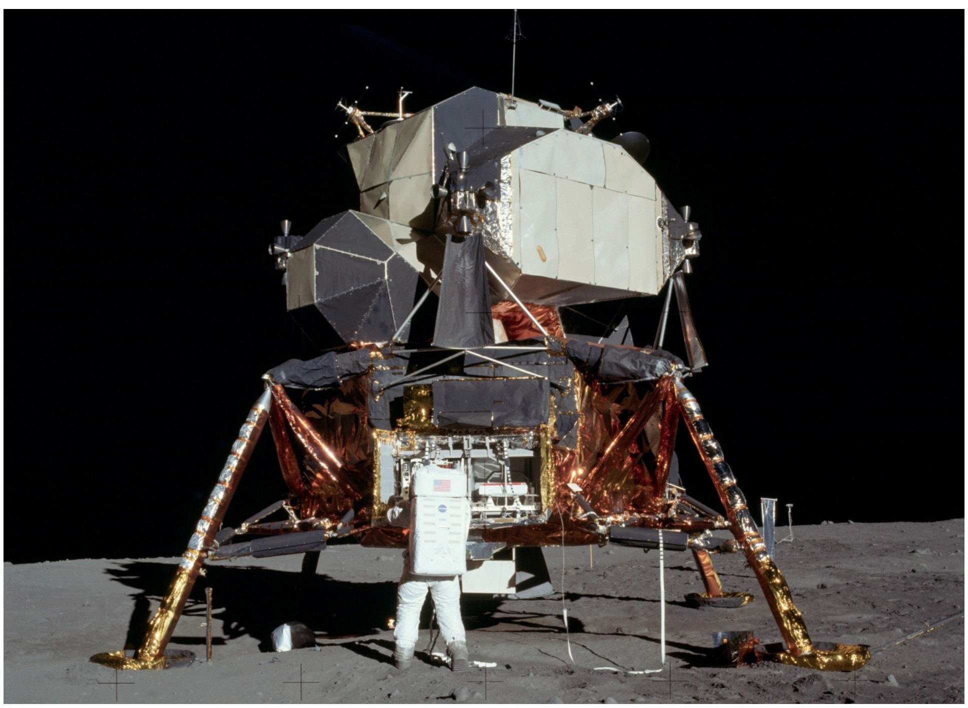
If the device lands on its side, make sure it is being dropped straight. You may need to add a tail (like on a kite) to direct the fall so that it lands in the proper orientation.

If the lander bounces, try adjusting the springiness of the shock absorbers.

RELEVANT TERMINOLOGY

Shock absorber: A device used to dampen or lesson sudden, rapid motion.

Kinetic energy: Energy of motion. The cup of marshmallow astronauts is demonstrating kinetic energy when it drops.



Engineers working on the Apollo mission didn't know whether the surface of the moon was hard or soft, so they had to prepare for both. Shock absorbers were built into the struts on the lander. Credit: NASA.

GUIDANCE FOR YOUNGER CHILDREN

QUESTIONS TO ASK AFTER THE ACTIVITY

- Did you succeed in designing a set of shock absorbers that protected your astronauts?
- What material(s) did you use to create your shock absorbers? Why did you choose them?
- If your astronauts fell out of the cockpit when you first dropped them, what changes did you make to improve on the next test?
- What things, other than shock absorbers, did you use to protect your astronauts?
- If your spacecraft bounced or landed on its side, how did you modify your design to prevent this from happening?

ENGINEERING CONNECTIONS

Without shock absorbers, riding in a car would be both uncomfortable and dangerous! Not only do the shock absorbers create a comfortable ride by smoothing out bumps, but they also keep the tires on the road at all times. But shock absorbers aren't used only in cars. They also protect buildings from earthquakes and make landing gear safer for airplanes and spacecraft.

The first astronauts to land on the moon in the Apollo 11 spacecraft had no idea what landing there would feel like, since no one had ever done it before. This is a challenge engineers face: designing devices to do something that has never been done before, such as shock absorbers to protect a spacecraft that is landing on a new planet. The engineers for Apollo 11 had to understand math and science well enough to make a device that would protect the astronauts the first time it was used. Fortunately, everything went perfectly on the first moon landing!

SCIENCE CONNECTIONS

The science of shock absorption becomes easier to understand if you think about eggs. If you were to drop an egg, what would be the best material to use as a shock absorber to keep it from breaking: wood, or Jell-O? The answer is clearly Jell-O. Jell-O has two advantages that make it a better choice. First, Jell-O has a high density (meaning it is thick and heavy), which allows it to slow the egg down quickly without getting pushed out of the way of the falling egg (like, say, a pile of feathers would). However, the second advantage is that its shape will change when the egg hits it. This means that the Jell-O pushes back against the falling egg. It slows it down over a longer period of time than it would if the egg hit a piece of wood. Since the Jell-O slows the egg down over more time (in other words, more gradually) than the wood does, the Jell-O makes it much less likely that the egg will break on impact.

GUIDANCE FOR OLDER YOUTH AND ADULTS

QUESTIONS TO ASK AFTER THE ACTIVITY

- What kind of materials might absorb the shock of an impact or crash landing?
- How did you arrange the shock absorbers so that they would absorb the impact most effectively?
- What other supports did you include to protect your astronauts? Why?
- How did you decide on the cabin placement when designing your spacecraft?
- If you could use any materials you wanted for this activity, what would you use?

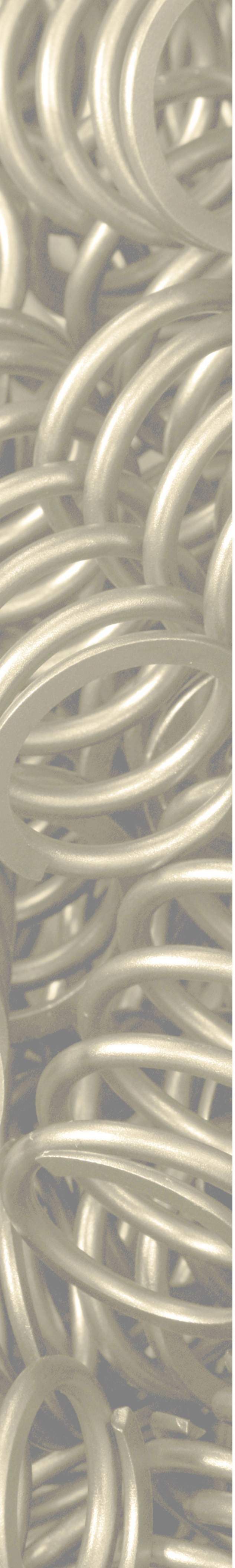
ENGINEERING CONNECTIONS

In addition to using shock absorbers in cars, engineers have begun to use them in earthquake-resistant buildings. These are referred to as dampening systems. One dampening system found in earthquake-resistant buildings places dampers on each level of the building. The dampers are connected to a column. The dampers have a giant piston head inside of a cylinder filled with silicone oil. When the building begins to shake, the pistons push against and compress the oil, effectively converting the mechanical energy into heat energy, which eventually dissipates into the surrounding environment. After the 1989 Loma Prieta earthquake in San Francisco, engineers lifted City Hall from its foundation and rested it on 530 such dampers. If another earthquake hits, San Francisco City Hall can sway horizontally up to 26 inches before suffering any catastrophic damage to its structure.

SCIENCE CONNECTIONS

According to the Law of Conservation of Energy, energy cannot be created or destroyed, only transformed from one type to another. Therefore, the only way to reduce the effects of kinetic energy, or energy of motion, is to transform that energy into another type of energy.

Shock absorbers are mechanical hydraulic devices. This means that they use pressurized liquids to transfer energy from one type to another. Shock absorbers dampen the effects of shock waves by converting the kinetic energy of the waves into heat energy that can be transferred into the hydraulic fluid. They are usually made of a cylinder containing a piston and springs that move up and down as a result of the vibrations caused by the shock. As the piston moves up and down, the hydraulic fluid is compressed and reduced, thereby transforming the "shocking" kinetic energy into thermal energy, which can be easily dissipated into the surrounding environment.



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