Egg Drop

Build a device to keep an "egg-stronaut" safe and sound as it lands! See how great a height each creation can be dropped from before the egg breaks.

Suggested grade level: 3-4

Activity length: 30-40 minutes

Required materials: Flexible

Relevant topics: Energy, forces, aerodynamics

Purdue Space Day, an educational outreach program of Purdue University's Department of Aeronautical and Astronautical Engineering, organizes the largest free STEM advocacy children's event in the Midwest, as well as myriad year-round outreach events throughout the surrounding metropolitan area. These activity write-ups are provided free of charge as an extension of Purdue Space Day's STEM programming.

PURDUE SPACE DAY

Questions? Comments? Contact Purdue Space Day via email at psd@purdue.edu. We'd love to hear your feedback to help us improve our activities and write-ups.

Activity Summary

Students simulate landing a vehicle on another planet by building a device to protect an egg falling from a building.

Key Concepts: Energy, Forces, Aerodynamics

NGSS Summary: The key concepts of this activity align with NGSS Disciplinary Core Ideas for third and fourth grade science education. Specifically, they meet the following Physical and Life Sciences standards:

- 3-PS2.A – Forces and Motion
- 3-PS2.B – Types of Interactions
- 4-PS3.A – Definitions of Energy
- 4-PS3.B – Conservation of Energy and Energy Transfer
- 4-PS3.C – Relationship Between Energy and Forces

This activity also connects to the following standards for Engineering, Technology, and Applications of Science:

- ETS1.A – Defining and Delimiting an Engineering Problem
- ETS1.B – Developing Possible Solutions
- ETS1.C – Optimizing the Design Solution

Learning Objectives

Students will be able to understand the relationship between forces and acceleration, the different forms in which energy can exist, and the ways in which these concepts relate to spacecraft landing on other planets.

Scientific Background

When we think of space travel, we often picture big rockets launching both crewed and robotic vehicles into the heavens. Yet what many people fail to appreciate is the intense difficulty we face in doing the opposite – bringing spacecraft back to Earth, or to the surfaces of other bodies in the solar system. Space travel requires vehicles to travel at thousands of miles per hour – but to make a safe landing, these vehicles must be decelerated to a standstill in safe and controlled manner. This is true both for space capsules and shuttles bringing astronauts back to Earth and for robotic explorers landing on other planets in the solar system – sometimes, one of the biggest challenges is figuring out how to stop.

Over the years, different spacecraft have landed in a variety of different ways. Some early robots landed on the Moon and on Mars with the help of air bags – big gas-filled balloons which helped absorb the impact of landing. Manned missions to the Moon landed with the help of powerful rocket engines which slowed the descent of the spacecraft and allowed the astronauts to make smooth touchdowns. Many manned spacecraft returning to Earth use big parachutes to slow down before landing in the water, or on the land with the help of air bags. The Mars rover Curiosity actually landed on Mars with the help of a giant rocket-powered “sky crane” which slowly lowered it to the surface with a cable. In short, there are a lot of ways to slow down a spacecraft and to protect it from impact.

What actually goes on when a spacecraft slows down for a landing? There are two convenient ways to think about the science involved – forces and energy. Forces are a very intuitive explanation as we interact with them every day in a very physical, obvious way. A force is really just a push or a pull on something – so pushing someone on a swing or pulling open a door, is exerting a force. Forces have a very useful property – they are capable of changing objects’ speeds. If you exert a force on something, its speed will change (assuming that there are no other forces acting on that object). Think of pushing someone a swing. As you push, you can feel the force in your hands, and you will see the person on the swing start to move away from you. Note that this example only really works if you are pushing someone from the lowest point at the swing (when they would normally be at rest) or downwards towards this point – you can exert a force on someone without changing his or her velocity if he or she is past the lowest point and “up” the other side because then the force of gravity is cancelling out the force you are exerting. However, if you push someone who is at rest at the bottom of the swing or swinging downward, you will notice a chance in velocity, otherwise known as acceleration.

This fundamental relationship between force and acceleration (velocity change) is the subject of Isaac Newton’s second law of motion, which states that the acceleration of an object is equal to the total force acting on it divided by its mass. To go back to the example of a spacecraft, we want to cause a very fast-moving spacecraft to decrease its velocity by decelerating. To do so, we must apply a force which opposes the spacecraft’s direction of motion – using rockets, parachutes, landing bags, etc. In accordance with Newton’s second law, this will cause a change in velocity – since the force and the object’s motion are in opposite directions, the velocity will decrease - the spacecraft will slow, allowing it to land safely.

The other convenient explanation for the process of landing a spacecraft is energy. Energy is harder to conceptualize than force, but it is most easily described as a fundamental property of all objects which describes how much capacity that object has to “do something”. This is a vague definition, because there are many different kinds of energy – thermal energy, electrical energy, kinetic energy, gravitational energy, etc. The useful thing about energy is that it can often be converted from one form to another. For example, the energy stored in a pile of logs can be transformed into heat and light energy by setting those logs on fire. A fire has a lot of energy because it can do a lot of things – it can heat things up and create light. Once that fire has burned out, however, it will have much less energy, because it is no longer capable of producing heat or light. In addition to changing energy into different forms, we can dissipate energy by applying forces - most commonly, we dissipate energy through friction.

When it comes to landing spacecraft, there is one kind of energy that we care about the most – the energy of motion (called kinetic energy). Objects have kinetic energy when they are moving. Think of a ball flying through the air – it has a lot of capacity to “do something” – it could break a window, or make a dent in something, or give someone a bruise. As a spacecraft falls towards a planet, it has a lot of kinetic energy because it is moving so quickly. To land safely, it needs to get rid of this excess energy so that it has very little kinetic energy left when it reaches the ground. Many spacecraft get rid of some of their energy as heat – they plunge through the atmosphere at high speed, heating up the spacecraft and the atmosphere with their energy. Parachutes allow spacecraft to dissipate energy by creating more drag (a kind of friction with the air). Landing bags help to dissipate energy when the spacecraft touches down, because the gas in the bags absorbs even more energy. Many spacecraft are even built with springs to absorb the last bits of energy at touchdown.

The principles for safely landing an egg from a tall building are no different than the principles of landing a spacecraft from orbit. Obviously we can’t easily slow our egg down with rocket engines, but we can use parachutes to dissipate energy to the atmosphere and install cushioning devices to absorb impact energy when the egg reaches the ground. Designing a system to successfully bring an egg to Earth follows exactly the same ideas as designing a system to decelerate and land a spacecraft.

Suggested Activity Practices

- Explain how spacecraft need to decelerate from extraordinarily high velocities to rest.
- Explain the concept of energy and how energy can be transferred from one form to another or absorbed by an environment.
- Challenge students to explain how different spacecraft landing components – parachutes, landing bags, etc. – use energy.

Assessment Techniques

Students can be observed for the following signs of comprehension or learning. The level to which a student understands the fundamentals of the activity is often clear from observing their rocket construction or asking basic questions about the scientific principles of it.

- Students indicate an understanding of aerodynamic braking by building vehicles which employ parachutes, streamers, or other aerodynamic devices.
- Students demonstrate an understanding of impact absorption by including cushioning/padding systems in their designs.
- Students show an understanding of energy by providing examples of objects with lots of energy.
- Students are able to explain how different parts of their egg landers absorb, transfer, or dissipate energy.

Participant learning can also be assessed using the following pre-activity and post-activity questionnaires.

Pre-Activity Questionnaire

How do spacecraft land on other planets?

What is energy?

What does a parachute do?

Post-Activity Questionnaire

Draw and label the parts of your spacecraft that will allow it to land safely.

What is energy?

How do parachutes work?

Construction Directions

Note: There are no real instructions for this activity as it is intended as a creative, free-form exercise. Students should be encouraged to design and build their own landing vehicles according to what they have learned about landing systems and energy transfer processes. Students should work in small groups to construct landers which can be dropped from stairwells or out of high windows. This provides an effective way to embrace collaborative problem solving and the engineering design process by applying the concepts they have learned.

Suggested Materials:

- Plastic shopping bags
- Cardboard
- Construction paper
- Tape
- String
- Tissue paper or newspaper
- Empty plastic containers (jars, bottles, etc.)
- Cotton balls
- Popsicle sticks
- Drinking straws
- Zip-loc bags (to contain eggs)