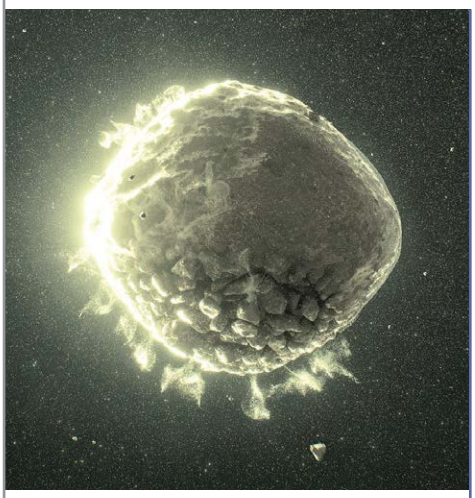


ABOUT ASTEROID HUNTERS

Asteroid Hunters is a spectacular new IMAX experience film that travels into orbit from the asteroid belt and back, showing us how remnants from the formation of the Solar System hold the keys to both our past and our future. Scientists believe that an asteroid impact is one of the greatest dangers facing Earth, but as we see in the film, they have embarked on incredible efforts to protect against such an event.

Target Audience:
These activities are designed for students in grades 6-8, as a supplement to environmental, Earth, and physics science curricula.

Objectives:
- *To introduce the space environment as part of the history of Earth*
- *To explore the opportunities and risks posed by asteroids orbiting near Earth*
- *To highlight some of the programs NASA and its partner agencies are conducting to study asteroids*
- *To teach standards-based lessons in physics and Earth science, and engage students in age-appropriate discourse and research*

Program Components:
- *This two-page teacher's guide*
- *Three reproducible activity sheets (two pages each)*
- *A standards alignment chart on page 19*
- *An online feedback form available at* **ymiclassroom.com/feedback-asteroid**

How to Use These Activities:
Make copies of the activity sheets for students. Review the material and web resources before scheduling the activities. Each lesson should take approximately 20-40 minutes. While students do not have to see ***Asteroid Hunters*** *to complete the activities, the activities are designed to enhance your students' viewing experience. Students can also complete the activities before viewing the film.*

National Standards:
These activities align with Next Generation Science Standards and Social Studies standards for grades 6-8. For standards correlation, see page 19.

WHAT ARE ASTEROIDS?
Instructions for Educator

Begin the program with a general discussion to assess what students already know about asteroids, meteors, and the Solar System. Ask if they have seen movies on these topics, and if those images were realistic or not. Then provide some time for students to complete the quiz. As you discuss the answers, guide students in an understanding of how our Solar System formed and how it has changed over 4.6 billion years, and what asteroids can tell us about that history.

Answers:

1) **A.** 4.6 billion years ago

2) **B.** Shooting stars (small objects are called shooting stars, large objects are called meteors)

3) **A.** Between Mars and Jupiter. Asteroids orbit the Sun just like planets. Scientists believe that Jupiter's gravity prevented the asteroids from combining into a planet.

4) **C.** Water. Asteroids contain a variety of metals and other chemical compounds that tell us about how they formed.

5) **B.** Arizona. Vesta is approximately 326 miles in diameter. Asteroids can range in size, from hundreds of miles across to smaller than gravel.

6) **B.** Binary pairs

7) **A.** 200

8) **C.** Less than the mass of the Moon

9) **B.** Near-Earth Objects (NEOs). As of January 2020, more than 20,000 NEOs have been discovered.

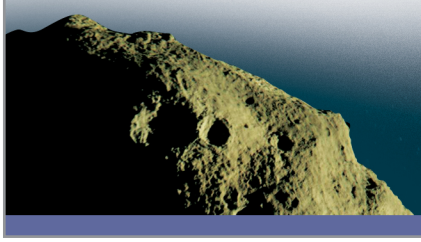
10) **B.** 2,000

Extension:
Add an arts component to this lesson by having students make their own asteroids using clay and an assortment of pebbles, chalk fragments, beads, etc. An example can be found here: **jpl.nasa.gov/edu/teach/activity/modeling-an-asteroid**

MAKING A SPLASH
Instructions for Educator

Explain to students that when an asteroid enters Earth's atmosphere, it compresses the air in front of it, which generates heat and causes the asteroid to burn and create a flash of light called a *meteor* (also known as a shooting star). A meteor that survives the trip through the atmosphere and hits the ground is called a *meteorite*. At impact, a meteorite has a lot of kinetic energy, which is transferred into the ground when it crashes. The top layers of Earth are compressed, causing shockwaves, and are displaced in a spray of dirt and rocks called *ejecta*, which leaves a crater. The greater the energy, the larger the crater and the wider the ejecta pattern.

Materials Needed:
1. Pans or containers, at least several inches deep
2. A variety of powdery filler materials of different colors and densities, such as flour, cocoa powder, sand, potting soil, baking sprinkles, etc.



3. Small objects of various sizes and masses to use as meteors: rocks, marbles, magnets, beads, etc.
4. Safety equipment, including goggles

Instructions:

1. Divide the class into 3-4 groups and provide materials and activity sheets to each group.
2. Instruct students to layer the filler materials, one at a time, in their containers. The bottom layer should be the deepest, and the total should be 2"-3" deep.
3. Ask students to observe the differences in each object before beginning to drop them, and talk about how those differences might affect the impacts.
4. Provide time for the class to conduct the experiment and record the results.
5. Discuss the results of the experiment and the question answers.

Answers:

1) When you let go of the object, gravity caused it to fall; and the force of the filler materials and the container pushing up against the object caused it to stop.
2) The object's speed and kinetic energy would be much greater; therefore, the impact force would be much greater.
3) Earth doesn't change orbit because its mass is so much greater. Since F=ma, speed and kinetic energy is almost negligible when mass is so high. Diagrams should show that the force comes down from the asteroid at the same angle it was falling and fans out into the crater as a counterforce pushes up from Earth towards the asteroid.

Bonus Question:

During an impact event, kinetic and thermal energy are transferred via shockwaves into the earth. Prior to collision or explosion, the asteroid is moving very fast and has many forces acting upon it, so the amount of energy is enormous. This energy, in the form of soundwaves, causes windows to break—it's the same transfer of energy that causes the impact crater.

Extension:

In a real asteroid event, there would be additional forces to consider, such as air resistance from Earth's atmosphere, and velocity and mass would be much higher. Depending on your students' level of understanding, you can use this activity as a jumping off point for more complex lessons in energy and waves, such as a discussion of why asteroids burn up and even explode as they fall through our atmosphere.

WORKING TOGETHER

Instructions for Educator

Explain to students that scientists are working on developing solutions for mitigating asteroid disasters. The first step is in knowing as much about the dangers out there as possible. Discuss the projects described in Part 1, adding that there are many other explorations underway through private groups as well as NASA and its counterparts around the globe.

After students have completed Part 1, explain that technologies to deflect an asteroid are still being developed and tested. Many of them are still theoretical.

Answers:

Part 1: Answers will vary.

Part 2: Exact wording will vary; general definitions:

- *Nuclear Probe*: Uses a nuclear explosive to evaporate the outer layers of an asteroid to change its trajectory or increase its potential for missing Earth.
- *Gravity Tractor*: Uses the gravitational pull between objects in space to shift an asteroid's orbit by positioning a spacecraft near the asteroid, but not touching it.
- *Kinetic Impactor*: Shifts an asteroid's orbit by crashing a spacecraft into it to deflect it.
- *Solar Sail*: Uses the Sun's energy, through reflectors, to push the asteroid out of its trajectory.
- Additional ideas may include electrostatic pushing or using lasers to redirect asteroids.

Extension:

Some of the biggest and most impactful efforts towards asteroid detection and mitigation are international collaborations amongst multiple government agencies, university research departments, and/or private companies in different countries. Have students write or explain why they think it's important to take an international, collaborative approach to these efforts.

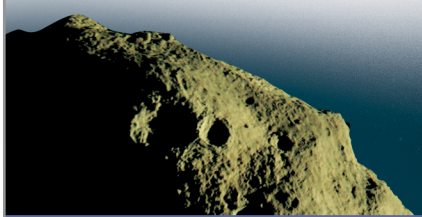
STEAM FOCUS

Add an arts component to this program:

- Before they view the film, ask students what they think it would sound and feel like to be orbiting in the asteroid belt or riding an NEO (Near-Earth Object) as it enters Earth's atmosphere and during an asteroid collision. Borrow instruments from the school's music department, or have students gather materials to make their own; then create a space soundtrack of this experience in the classroom. After students have seen the film, ask them how the soundtrack enhanced the dramatization.
- Have students illustrate the asteroid belt, Solar System, or an asteroid impact using charcoal pencils or collage.

RESOURCES

- Terrestrial Impact Craters **lpi.usra.edu/publications/slidesets/craters/crater_index.shtml**
- How NASA Studies and Tracks Asteroids Near and Far **jpl.nasa.gov/edu/news/2017/4/18/how-nasa-studies-and-tracks-asteroids-near-and-far/**
- Planetary Defense: Near-Earth Object Observations Program **nasa.gov/planetarydefense/neoo**
- Center for Near-Earth Object Studies: Planetary Defense **cneos.jpl.nasa.gov/pd/**



WHAT ARE ASTEROIDS?

In a spectacular new IMAX experience, ***Asteroid Hunters***, space will feel closer than you've ever imagined. You'll travel to the outer reaches of the Solar System and back to discover the origins of our planets and some dangers that may lurk ahead for our world.

There are hundreds of thousands of asteroids in our Solar System, and ***Asteroid Hunters*** will show you how scientists are studying them and why they matter. In the film, international scientists and engineers track the fictional asteroid Ficta A3D as it barrels towards Earth—watch and find out if it can be stopped.

HOW MUCH DO YOU ALREADY KNOW ABOUT ASTEROIDS?

Take this quiz to test your knowledge.

1. Asteroids are remnants left over from the early formation of our Solar System about:

   ☐ A. 4.6 billion years ago ☐ C. 4.6 million years ago

   ☐ B. 460 million years ago ☐ D. Don't know

2. When asteroids fall through Earth's atmosphere, air resistance causes them to burn up, creating a tail and flash of light. These are sometimes known as:

   ☐ A. Comets ☐ C. Meteorites

   ☐ B. Shooting stars ☐ D. Don't know

3. Most asteroids orbit the Sun within the main asteroid belt, which is located:

   ☐ A. Between Mars and Jupiter ☐ C. Between Earth and Venus

   ☐ B. Between Jupiter and Saturn ☐ D. Don't know

4. Asteroids are usually made of rock with bits of clay and metals like iron and nickel, but some asteroids contain:

   ☐ A. Petroleum ☐ C. Water

   ☐ B. Diamonds ☐ D. Don't know

5. The smallest asteroid that scientists have studied is 2015 TC25, a space rock only about 6 feet wide. The largest is Vesta, which is nearly as wide as:

   ☐ A. Rhode Island ☐ C. Texas

   ☐ B. Arizona ☐ D. Don't know

WHAT ARE ASTEROIDS?

6. Some asteroids have tiny moons that orbit around them, while others orbit together with a similarly sized partner; these are known as:

☐ A. Bola pairs ☐ C. Balanced pairs

☐ B. Binary pairs ☐ D. Don't know

7. Most asteroid impact craters on Earth have been worn away by erosion, but with new technology, scientists have now located about _____ craters on Earth.

☐ A. 200 ☐ C. 1,000

☐ B. 500 ☐ D. Don't know

8. Scientists believe that there are about a billion asteroids in the Solar System and that the total mass of all the asteroids combined is:

☐ A. More than the mass of the Sun ☐ C. Less than the mass of the Moon

☐ B. Equal to the mass of Earth ☐ D. Don't know

9. Asteroids that orbit within 18.6 million miles of Earth's orbit are classified as:

☐ A. Extraterrestrial Objects (ETOs) ☐ C. Deep Space Objects (DSOs)

☐ B. Near-Earth Objects (NEOs) ☐ D. Don't know

10. Asteroids that orbit within 4.65 million miles of Earth and are large enough to survive a fall through our atmosphere are classified as Potentially Hazardous Asteroids (PHAs). So far, scientists have identified about _____ PHAs.

☐ A. 20,000 ☐ C. 200

☐ B. 2,000 ☐ D. Don't know

FRONT ROW SEATS! Reading about asteroids on paper is no comparison to experiencing ***Asteroid Hunters*** in IMAX. If you get the chance to see the movie, write two new questions based on asteroid facts and technologies you learn and quiz a friend.

1) _____

_____

2) _____

_____

MAKING A SPLASH

In ***Asteroid Hunters***, we see that the Moon is covered in surface craters from asteroid impacts. Earth has craters, too, but because our planet's surface has changed so much over millions of years, they're much harder to see. Find out how craters form with a simple experiment.

1. Your teacher will provide you with a deep container and several filler materials like flour or cocoa powder. Layer these materials, one at time, into your pan to create a model of Earth's surface.
2. Gather a series of small objects such as pebbles, marbles, and magnets. These will be your asteroids.
3. Working with your group, take turns dropping the objects from different heights into the pan, and measure the craters that form. Since asteroids can come from many different directions, drop your objects from a variety of angles. Watch how the layers of "dirt" spray out from the center in different patterns called *ejecta*. Be sure to wear safety goggles for the experiment.

Hypothesis: Before you begin, how do you think the size and speed of the falling object (or asteroid) will affect the size of the crater and the ejecta pattern?

Data: Record your findings in the chart below and use the back of this page to make notes and draw pictures. Follow the example listed.

ASTEROID	DIRECTION OF IMPACT	CRATER DEPTH	CRATER WIDTH	EJECTA PATTERN
Small Pebble	Straight down			
Small Pebble	45° angle			

MAKING A SPLASH

Conclusion: Once you've conducted your experiment several times using a variety of objects, discuss the results with the class. Write a statement summarizing how the size of the object and the distance from which it fell affected the dimensions of the crater. Explain what the size of the crater and the ejecta pattern tell us about the amount of kinetic energy that was transferred.

Evaluate: On the back of this sheet or a separate paper, answer each of the questions below.

1. Newton's first law tells us that an object will continue moving at the same speed unless force is exerted on it. What force(s) caused the asteroids in your experiment to fall? What force(s) caused them to stop?
2. Newton's second law tells us that force is equal to the mass of an object times its acceleration (F=ma). How would the force of impact be different if the asteroid was shot from a machine instead of dropped?
3. Newton's third law tells us that whenever there is an interaction between two objects, equal force is exerted on both objects. If equal force is exerted onto the Earth during a collision, why doesn't Earth itself change its orbit? On the back of this page, draw a diagram depicting the forces on the asteroid and Earth at the point of impact.

Bonus Question: In the film's footage from a 2013 meteorite crash in Chelyabinsk, Russia, we see windows breaking. How does the transfer of energy that causes an impact crater also cause windows to break? Draw a diagram to illustrate this.

WORKING TOGETHER

In ***Asteroid Hunters***, we watch with anticipation as the fictional asteroid Ficta A3D appears on a crash course towards Earth. We stand with dozens of scientists and engineers, wondering as they try to deflect its path with a nuclear probe. Will they succeed?

Most asteroids that enter our atmosphere burn up before they ever come close to the ground, but scientists know that the real question is not IF an asteroid will hit Earth again but WHEN. That's why space-faring agencies around the globe are working to track, study, and measure asteroids that pose a threat to Earth's safety, and to devise and test systems that will protect us.

PART 1 TRACKING AND STUDYING

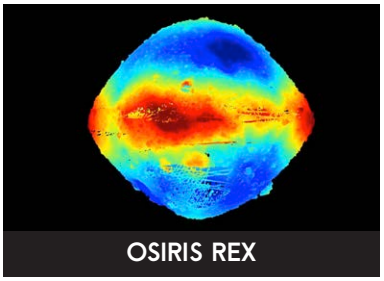
First, scientists need to know where the asteroids are and what they're made of. These profiles describe just a few of the programs NASA and partner agencies have launched to track asteroids and study their trajectories. Conduct research on Near-Earth Objects (NEOs) and planetary defense to learn more. Start with NASA's planetary defense website, **nasa.gov/planetarydefense/neoo**. On the back of this sheet, write three facts you find interesting and share them with the class.

NEOWISE

NEOWISE is part of a telescope that orbits Earth and uses infrared cameras to capture images of even very dark objects usually hidden by atmospheric haze. NEOWISE has scanned the skies 12 times, collecting information on the size and properties of asteroids, and offering a view into how NEOs orbit over time.

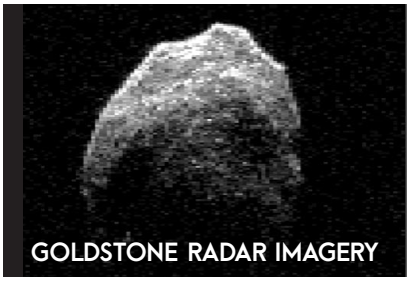
PAN-STARRS TELESCOPE

NASA can find bright asteroids from the ground using powerful telescopes, like Pan-STARRS1 in Hawaii, that capture and scan images taken every several minutes. An object that changes position in each image, relative to the stars around it, will be identified as an asteroid.



OSIRIS REX

This spacecraft has been tasked with gathering data about Bennu, an asteroid that scientists believe could pose a great threat to Earth in the next century. It will take samples of the rock for study and use laser rays to map the surface.



GOLDSTONE RADAR IMAGERY

In the film, Marina Brozović from NASA's Jet Propulsion Laboratory explains that her team bounces radar signals off space objects, and uses the transmissions to model images of them.

Image Sources: Pan STARRS - https://panstarrs.stsci.edu | NEOWISE - https://www.jpl.nasa.gov/missions/neowise/
OSIRIS REx - https://www.nasa.gov/image-feature/goddard/2019/osiris-rex-captures-laser-3d-view-of-bennu
Goldstone - https://www.jpl.nasa.gov/spaceimages/details.php?id=PIA20043

ASTEROID HUNTERS
AN IMAX ORIGINAL FILM

WORKING TOGETHER

PART 2 DEFLECTING

The more we learn about asteroids, the better prepared we can be. But just what can we do to stop them? The Asteroid Impact and Deflection Assessment (AIDA) mission is a program of NASA and the European Space Agency that is testing how kinetic energy can be used to change an asteroid's trajectory using a probe, similar to what we see in ***Asteroid Hunters***. Below are some other suggested asteroid defense technologies. Research and describe each one, and explain what you think are the pros and cons of each method. Here is a link to get you started: **neoshield.eu/mitigation-measures-kinetic-impactor-gravity/**.

NUCLEAR PROBE:

Description: _____

Pros: _____

Cons: _____

GRAVITY TRACTOR:

Description: _____

Pros: _____

Cons: _____

KINETIC IMPACTOR:

Description: _____

Pros: _____

Cons: _____

SOLAR SAIL:

Description: _____

Pros: _____

Cons: _____

PART 3 CREATING A PLAN

Using what you've learned about existing ideas for studying and, if necessary, deflecting asteroids, come up with your own idea for protecting Earth from an asteroid collision. Keep in mind general science principles of gravity, energy, and motion, like Newton's laws. On the back of this sheet, write a brief description of your technology, and illustrate, collage, or construct a model of how you think it would work.