National Aeronautics and
Space Administration

NASA Out-of-School Learning Network

Earth and Space Explorers

module

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NASA Out-of-School Learning Network

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

The complete module is designed to provide the student with an

- Understanding of the scale distance of the Solar System
- Understanding of the way planetary bodies are impacted by celestial objects
- Understanding that light is a term used to describe visible and invisible waves of electromagnetic energy

Scope and Sequence

The Earth and Space Explorers Module covers Next Generation Science Standards for Earth and Space Science and for Physical Science.

Next Generation Science Standards

Middle School Physical Science (MS–PS)

- MS–PS3–1. Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.
- MS–PS4–2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

Middle School Earth Science (MS–ES)

- MS–ESS1.3. Analyze and interpret data to determine scale properties of objects in the Solar System.
- MS–ESS2–2. Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.

Disciplinary Core Ideas

- Electromagnetic radiation
- Earth and the Solar System
- Earth's materials and systems

Science and Engineering Practices

- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Constructing explanations and designing solutions

Crosscutting Concepts

- Patterns
- Cause and effect
- Scale proportion and quantity
- Systems and system models
- Energy and matter
- Stability and change

Connections to the Nature of Science

- Scientific knowledge is open to revision in light of new evidence
- Scientific knowledge assumes an order and consistency in natural systems

Connections to Engineering, Technology, and the Applications of Science

- Interdependence of science, engineering, and technology

BACKGROUND INFORMATION FOR FACILITATORS

Introduction to Space and Objects in Space

The activities in this module examine some of the fundamental concepts relating to space and the Earth. The following information is meant to give background information for instructors as they conduct these activities.

There is not an exact line that divides the Earth's atmosphere from outer space. However, scientists say that it is roughly 100 km (62 mi) above the Earth's surface. At this point there is not enough air to scatter light to create a blue sky; therefore, space appears to be black.

Space (the name given to the void between objects) is a vacuum, meaning that sound cannot carry because molecules are not close enough to transmit sound between them. However, space is not empty. It contains plasma, gas (mainly hydrogen and helium), dust and other bits of matter, meteoroids, asteroids, comets, planets, stars, and galaxies.

No one knows exactly how vast space is. What we do know we've learned by using our telescopes to see light. Long distances in space are measured in *light-years* or *astronomical units* (AUs). A light-year represents the distance it takes for light to travel in a year, which is about 9.3 trillion km (about 5.8 trillion mi). Scientists also use AU to express distances in space, where 1 AU is the distance from the Earth to our Sun—about 150 million km (about 93 million mi).

Our Solar System is huge, and there is a lot of space between the planets. For example, *Voyager 1* (the human-made object that is farthest from Earth) had traveled 134 AU or 20,069,211,899 km from Earth by April 27, 2016. *Voyager 1* left Earth on September 5, 1977, and crossed into interstellar space in August 2012. Interstellar space is the region of space beyond the planets where gas and dust from other stars are found as well as the enormous *Oort Cloud*—a vast spherical shell of icy bodies surrounding our Solar System. It will be thousands of years before *Voyager 1* exits the Oort Cloud. Meanwhile, *Voyager 1* continues to transmit data back to the Earth by means of NASA's Deep Space Network.

A solar system consists of a star and all the objects that travel around it. Located in the Milky Way, which is a spiral galaxy, our Solar System formed 5 billion years ago with our Sun at its center and eight planets, as well as countless smaller objects, orbiting in its gravitational pull.

The four planets closest to our Sun—Mercury, Venus, Earth, and Mars—are referred to as the *"terrestrial planets"* because they have solid, rocky surfaces. The *gas giants*—Jupiter, Saturn, Uranus, and Neptune—are the four outer planets beyond the orbit of Mars. In 2006 the Astronomical Union declared that the former ninth planet, Pluto, does not fit the definition of a planet. The definition states that a planet must have cleaned its orbit (no longer have any other objects in its orbital path), must be large enough for gravity to pull it into a sphere, and must orbit a star (like the Sun). Pluto is now referred to as a *"dwarf planet."*

Our Solar System also includes debris left over from its formation, such as asteroids, meteoroids, ice, and gas. Most of the asteroids in our Solar System are found in the region between Mars and Jupiter, which is referred to as the *"asteroid belt."* Sometimes this leftover material still collides with objects in our Solar System, causing what we refer to as *"impact events."* These events can be catastrophic or can cause no damage at all. For example; 65 million years ago an asteroid hit the Earth, causing a mass extinction that wiped out many species, including the dinosaurs.

Asteroids are rocky, airless bodies that orbit our Sun but are too small to be called planets. Their diameters vary from only 530 km to 10 m across. Tens of thousands of these objects are gathered in the asteroid belt. Some asteroids even have their own moons, and at least one, *Chariklo*, has two dense, narrow rings.

Introduction to Spectroscopy

Many students ask how scientists can know so much about space and the objects in space when no one has actually visited those objects. Scientists use an instrument called a *spectrometer*, which breaks up electromagnetic radiation into spectral lines. For example, the spectrum of visible light consists of all the colors contained in white light (sunlight).

Spectroscopy is a scientific measurement technique. It measures the electromagnetic radiation that is emitted, absorbed, or scattered by materials and can be used to study, identify, and quantify those materials.

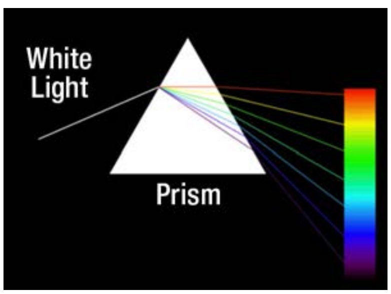

Figure 1

In physics, many scientists refer to all types of electromagnetic radiation as *"light."* In this sense, light includes much more than the spectrum of visible light that we can see (red, orange, yellow, green, blue, indigo, and violet (ROY G BIV)). In addition, there are gamma rays, x-rays, ultraviolet (UV) radiation, infrared (IR) radiation, microwaves, and radio waves. It is possible to take the light that a material reflects, absorbs, or emits, and separate it into its parts—just like a prism can break white light up into the visible light spectrum (ROY G BIV). If you break up a sample of light of all wavelengths, you get what's called a *continuous spectrum*. Figure 1 shows an example of a continuous spectrum for visible light.

You can do something similar across the full electromagnetic spectrum by using prisms made of different materials or by using a *diffraction grating* in a *spectrometer*, or a simpler version of this device called a *spectroscope*.

When light is absorbed or reflected by materials, not all of the light behaves in the same way. Only certain wavelengths of light get absorbed, others get reflected. This is why a red object looks red: all other colors are absorbed, only red is reflected back to your eye.

Some materials emit light without being hit by light first. Another energy source (for example, heat or electricity) is used to first excite the material; then, that energy is turned into light. For example, a common light bulb emits light when electricity is passed through it.

When you separate the light that is passing through a sample, or reflecting off a sample, an emission spectrum or absorption spectrum is produced instead of the continuous spectrum you would get if you broke up a source of all wavelengths of light.

An emission spectrum in the visible light range may look like Figure 2. Such a spectrum is created when material is given extra energy (by being heated, electrified, irradiated with light, etc.) and that extra energy is later emitted as light energy.

If that light is separated into its component parts, you can see the emission spectrum. In this case, only the wavelengths of light that are emitted come out in the spectrum (Fig. 3).

An absorption spectrum in the visible light range may look like Figure 4. Such a spectrum is created when light is passed through a gas or a liquid or when it strikes a solid. Certain wavelengths of light are absorbed by the material and later emitted in random directions. Most of the wavelengths, however, pass through the gas or liquid (or are reflected off the solid) without being absorbed.

If the light that passes through (or reflects off) is then separated into its component parts, you can see the absorption spectrum. In this case, the wavelengths of light absorbed by the material are absent in the spectrum, leaving blank spaces behind (Fig. 5).

The emission or absorption spectrum of a substance is as unique to that substance as a fingerprint is to a human being. Therefore, scientists are able to use the spectral information to determine what the chemical makeup the object being observed is made up of. For example, if we see spectral lines like those in Figure 6, we know that hydrogen and helium are present.

Figure 2

Figure 3

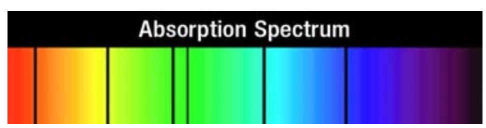

Figure 4

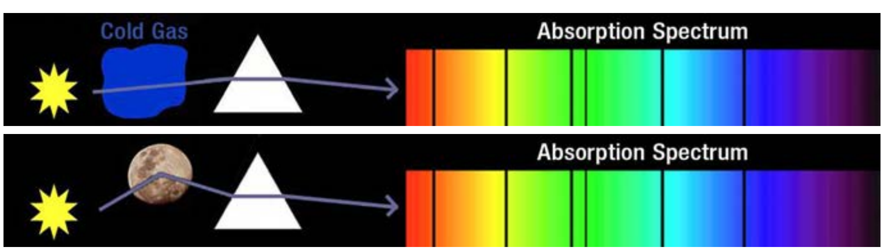

Figure 5

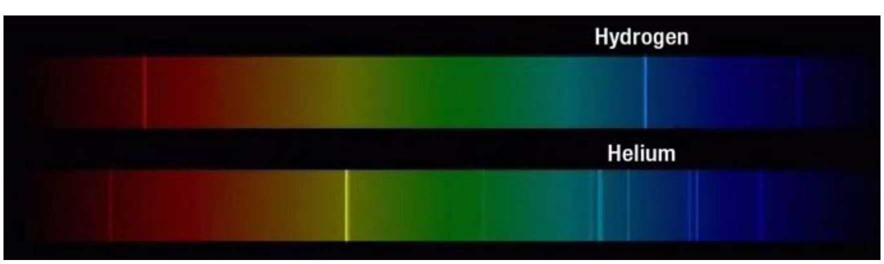

Figure 6

Scale Model

of the Sun and Earth

Grades 6 to 8

INQUIRY-BASED ACTIVITY

activity

SCALE MODEL OF THE SUN AND EARTH

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

About This Activity

This activity, which was taken from the NASA Sun-Earth Day Program, explores the relative sizes of the Sun and Earth and the distances between them.

Background

A scale model is a representation of something that is larger or smaller than the actual size of the thing being represented. You can make a scale model that is larger than the actual size to visualize something very small, like the different parts of a human cell. You also can make a scale model that is smaller than the actual size to visualize something very large, like our Solar System.

The Sun image in this activity was taken by a telescope that is mounted on a satellite in space as part of NASA's Transition Region and Coronal Explorer (TRACE) mission. This telescope looks at extreme ultraviolet (EUV) light. By looking at a different part of the *electromagnetic spectrum*, scientists are able to "see" features that cannot be detected with visible light alone.

To measure the vast distances within our Solar System, scientists use a scale named the *"astronomical unit* (AU)." One astronomical unit is the distance between the Sun and the Earth: about 150 million km (93 million mi).

The Earth is very small in comparison to the Sun: it would take 1.3 million Earths to fill up the volume of the Sun. The Sun makes up 99.86 percent of the mass of our Solar System.

Materials

- Sun and Earth scale model images
- Scissors
- Measuring tape or ruler
- An open space longer than 20 m (65 ft) in which to make the measurements
- Student handout

Next Generation Science Standards

MS–ESS1.3. Analyze and interpret data to determine scale properties of objects in the solar system.

Learning Objective

Learners will

- Create a scale model of the distance between the Sun and Earth

Procedure

Step 1

Show the students the image of the Sun. This is a good opportunity to point out what the Sun's surface looks like and to discuss that the Sun is not as featureless and uniformly bright as students might think. Have the students guess how big the Earth would be if the Sun were only the size of this image. Allow them time to make guesses, but do not give them the answer.

Step 2

Divide students into groups of two or three. Provide each group with a copy of the Sun and Earth images without the directions printed on them, scissors, and a measuring tape or ruler. Provide a student handout to each group.

Step 3

Have the students cut out the scale model images of the Earth and Sun from the handouts. Then have them predict how far apart their models should be and record their answers on the student handouts.

Step 4

Take the students to a long hallway, large room, or outdoor space. Have one student in each group hold up the image of the Sun and the other group member(s) measure the distance that they predicted and hold up the image of the Earth.

Step 5

Give each group of students a copy of the images of the Sun and Earth with the directions printed on them and have them cut out the images. In each group, have one student hold up the image of the Sun as before. Have the other student(s) in the group measure 20 m from the image of the Sun and hold up the image of the Earth. Point out that the size that the image of the Sun appears to be from the position where the image of the Earth is should be about the same size that the actual Sun appears to us in the sky. Have the student holding up the Sun switch positions with the student holding up the Earth so that all the students can observe this effect. (NOTE: It is always a good idea to remind students not to look directly at the Sun.)

Suggestions for Differentiation

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

Support:
Premark the correct distances for the images of the Earth and Sun.

Complexity:
Have students determine where the Moon would be in this scale model.

Name: ____

Directions

Step 1

Cut out the scale model images of the Sun and Earth from the paper you were given. Predict how far the scale model of the Earth should be from the model of the Sun (in meters), and write your guess in blank 1. Measure out your prediction, and mark the location of the Earth and Sun with the images.

1. Write your prediction in meters as to how far the model Earth should be from the model Sun.

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____

____

Step 2

Cut out the second set of scale model images of the Sun and Earth from the paper you were given and follow the directions on the image page. Take turns holding up the model of the Sun. Then answer the following questions.

2. Subtract your predicted distance (on blank 1) from the actual distance of 20 m. How close were you to the correct distance?

____

____

____

3. Did you notice anything interesting about the size of the model of the Sun when you were standing at the model of the Earth 20 m away?

____

____

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4. What surprised you in this activity?

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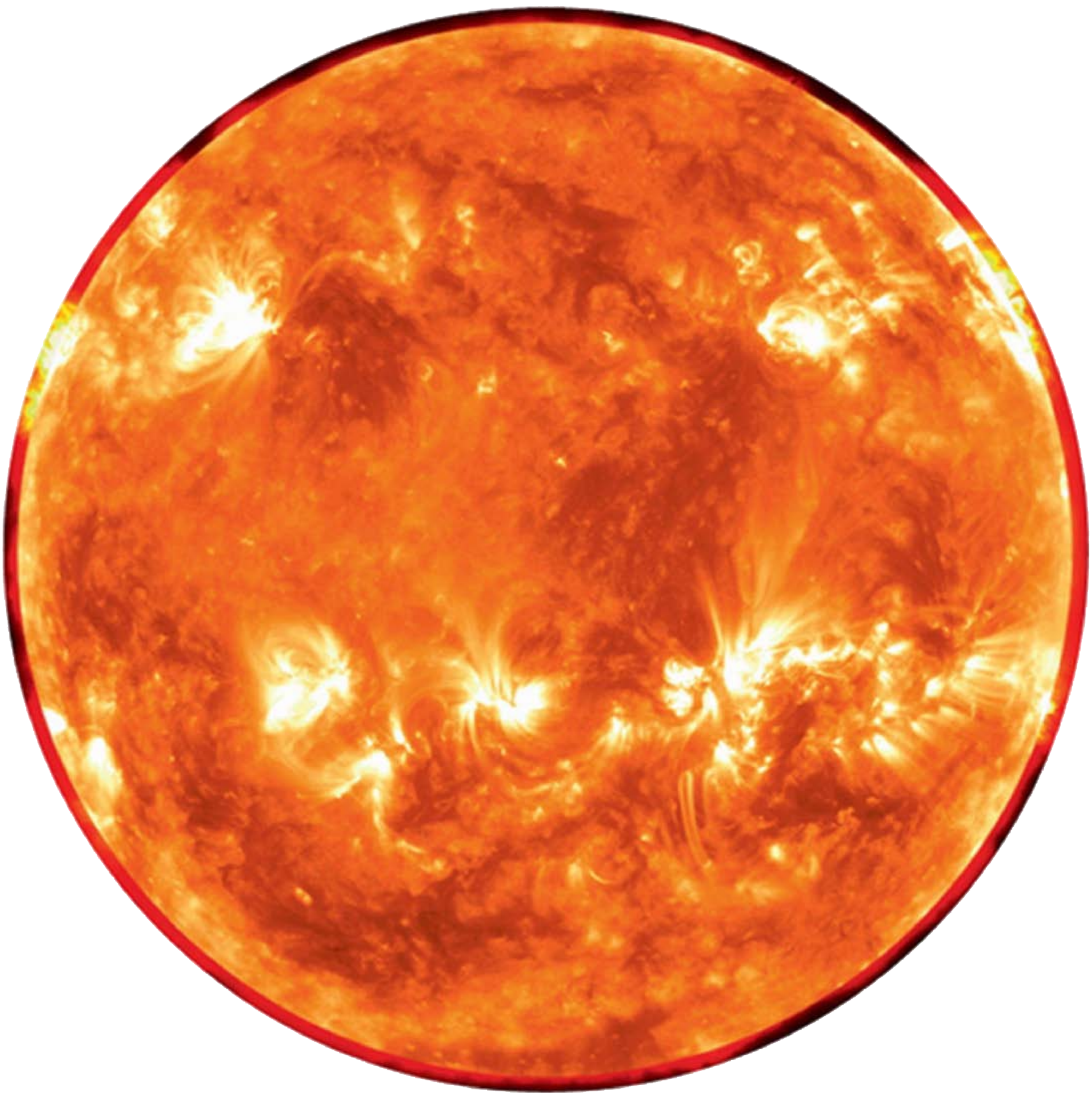
SCALE MODEL OF THE SUN AND EARTH

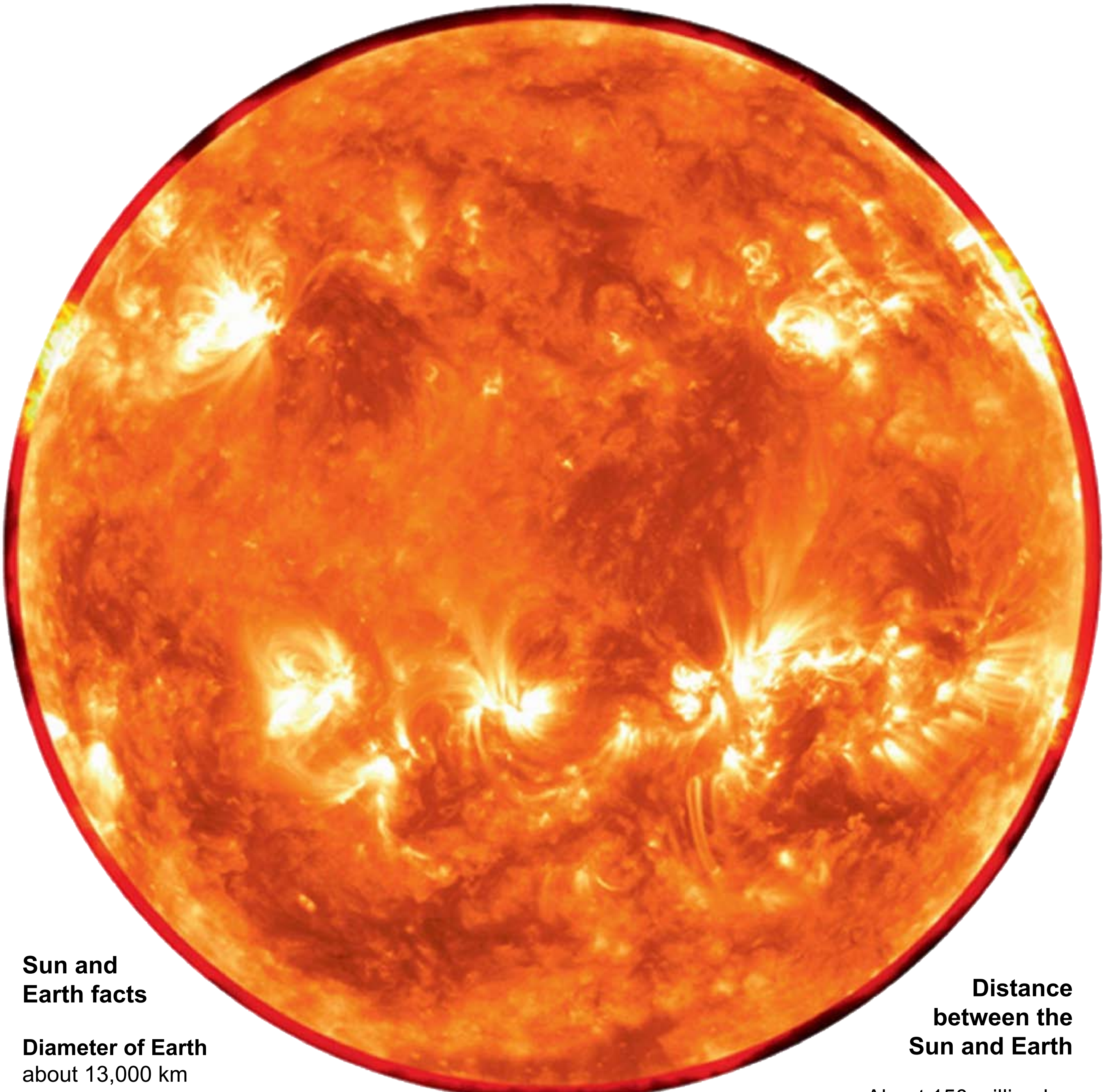
This image of Earth is scaled to the proper size in relation to the image of the Sun below.



SCALE MODEL OF THE SUN AND EARTH

1. Cut out images of the Sun and the Earth.
2. To demonstrate the distance between Sun and Earth at this scale, separate the images about 20 m (65 ft) apart. This distance represents approximately 150 million km (93 million mi).

This image of Earth is scaled to the proper size in relation to the image of the Sun below.



Sun and Earth facts

Diameter of Earth
about 13,000 km
(about 8,000 mi)

Diameter of Sun
about 1.39 million km (about 863,000 mi)
You can fit 109 Earths across the Sun's diameter!

Distance between the Sun and Earth

About 150 million km
(93 million mi)
You would have to line up about 10,000 Earths side by side before you would reach the Sun.

Scale Model

of Our Solar System

Grades 6 to 8

INQUIRY-BASED ACTIVITY

activity

SCALE MODEL OF OUR SOLAR SYSTEM

Grades: 6 to 8   Prep Time: 0.5 hour   Activity Time: 1.5 hours

About This Activity

This activity was designed by the Solar Dynamics Observatory to give students a visual idea of how far apart the planets are in our Solar System.

Background

A scale model is a representation of something that is larger or smaller than the actual size of the thing being represented. You can make a scale model that is larger than the actual size to visualize something very small, like the different parts of a human cell. You also can make a scale model that is smaller than the actual size to visualize something very large, like our Solar System.

A solar system consists of planets and other objects and materials that orbit around a star located in the center. Our Solar System consists of our eight planets—Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune—the dwarf planet Pluto, other dwarf planets, asteroids, and meteoroids that orbit around the Sun.

Video Link

What Is a Planet?
https://www.youtube.com/watch?v=RQU2Q-CU6lY

Materials

- One of the following: a roll of toilet paper, adding machine tape, or a ribbon
- Two sets of planet images
- An open space longer than 13 m (42 ft) in which to conduct the activity
- Scissors
- Tape or glue
- Student handout
- Two objects to represent the Sun (e.g., paper plates)

Next Generation Science Standards

MS–ESS1.3. Analyze and interpret data to determine scale properties of objects in the Solar System.

Learning Objective

Learners will

- Develop a scale model of our Solar System
- Create a scale model of our Solar System using the data provided and compare the two models

Procedure

Step 1

Discuss with the students that models are representations of things that are either too large or too small to illustrate. The video "What is a Planet" can be shown in its entirety, or it can be started at time 4:45. At this point, the video describes a scale model of the Solar System based on how long it would take to travel to each planet if you were driving an automobile at 100 miles per hour. This is a speed that students can imagine, helping them to understand the immensity of our Solar System. This video is not necessary to do the activity.

Step 2

Separate the students into groups of four or five. Each group will need a set of planet images, a student handout, scissors, and tape or glue. Have the groups place an object that represents the Sun at one end of a long hallway, large room, or outdoor space. Then have the students walk in a straight line, placing the eight planets and the dwarf planet Pluto in the correct order and at the relative distances that they believe exist between the planets. Have groups leave their models in place.

Step 3

Each group will create a toilet paper scale model next to the scale model that the group created in Step 2. This will allow for easy comparison of the two scale models. Give each group the student handout, planet images, and a roll of toilet paper. Each group should unroll the toilet paper in a straight line parallel to their first scale model. The two "Suns" (any object can represent the Sun in both models) should be side by side. Have the groups use the chart on the student handout to know where to write the names of the planets and place the images along the rolled-out toilet paper. Make sure to remind the students that they should always begin counting sheets from the sheet located at the Sun.

Step 4

Discuss with all the students their answers to the questions on the student handout. Explain that this is only a model and does not provide actual distances or precise scale measurements.

Suggestions for Differentiation

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

Support:
Premark the locations for the planets in the scale model.

Complexity:
Instead of using the toilet paper, have students calculate the size of one sheet of toilet paper and measure out the distances in meters.

Name: ____

Directions

Each group will need to have planet cutouts, scissors, a roll of toilet paper, a pen or marker, and tape or glue. Using the chart below, start at the beginning of the roll of toilet paper and write “Sun” at the extreme edge. Place your toilet paper with the word “Sun” next to the object that represents the Sun in your first scale model. Starting from the edge of the first toilet paper sheet, count the number of sheets indicated in the following chart and mark the name of each planet and dwarf planet Pluto. Tape or glue each planet cutout on the positions that you have marked. Continue until you have all the planets and Pluto placed on your scale. Then answer the questions that follow the chart.

Planet or dwarf planet	Distance from model Sun, number of sheets of toilet paper
Mercury	1.0
Venus	1.8
Earth	2.5
Mars	3.8
Jupiter	13.2
Saturn	24.2
Uranus	48.6
Neptune	76.3
Pluto	100.0

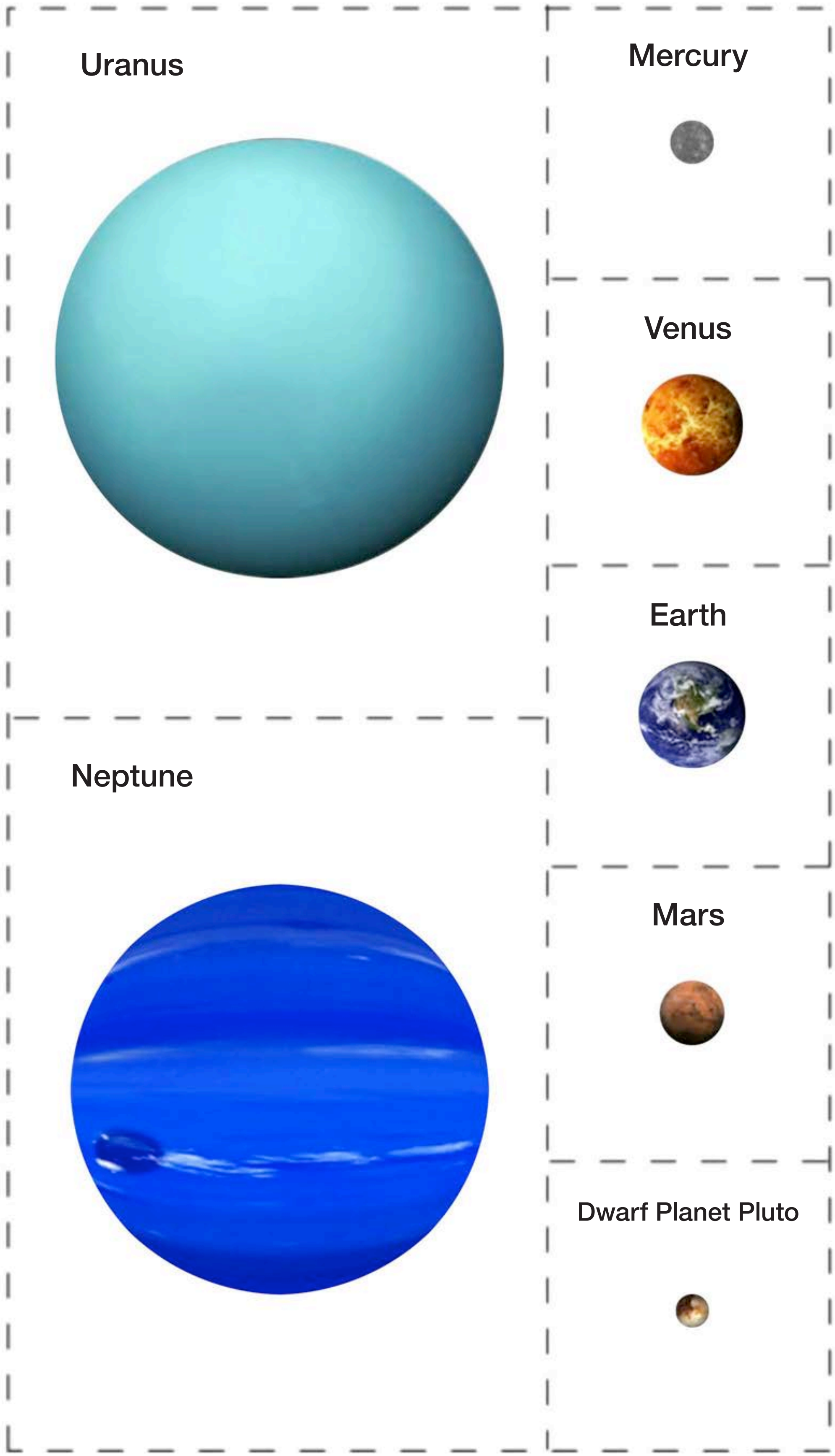
1. Compare and contrast your scale model to the scale model you created with the toilet paper.

____

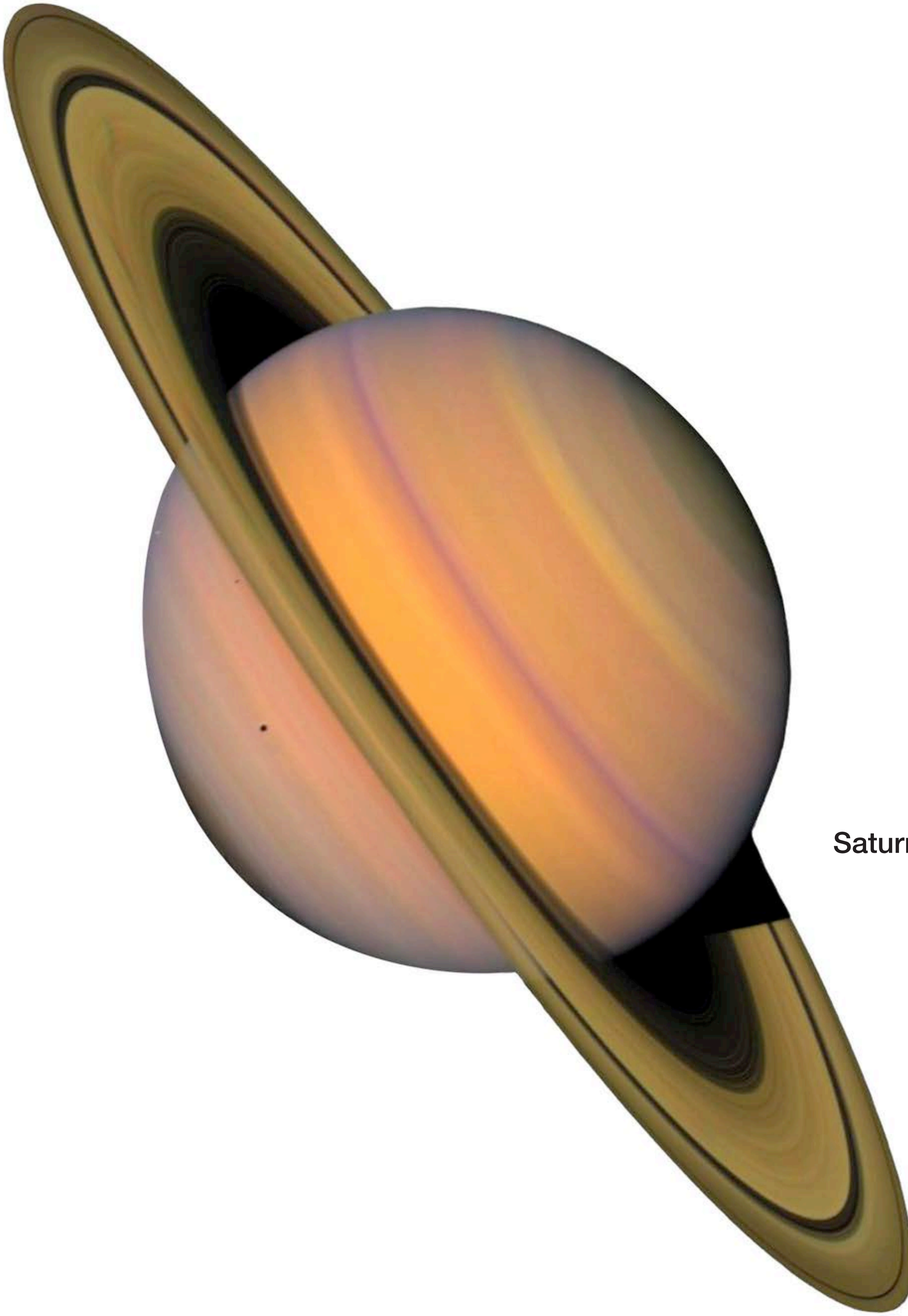
2. What did you discover that surprised you?

____

SCALE MODEL OF OUR SOLAR SYSTEM



Jupiter



Saturn

Impact Craters

Grades 6 to 8

INQUIRY-BASED ACTIVITY

activity

IMPACT CRATERS

Grades: 6 to 8 Prep Time: 0.5 hour Activity Time: 1.5 to 2 hours

About This Activity

In this activity, which was taken from NASA's Exploring the Moon Educator Guide, marbles or other spheres (steel shot, ball bearings, golf balls, wooden balls, etc.) are dropped as *impactors* from a series of heights onto a prepared "lunar surface." Dropping impactors with different masses from the same height allows students to study the relationship between the mass of the impactors and the size of the craters. Dropping impactors from different heights allows students to study the relationship between the velocity of the impactors and the size of the craters.

Next Generation Science Standards

MS–PS3–1. Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.

Learning Objective

Learners will

- Determine the factors affecting the appearance of impact craters and ejecta
- Understand how planetary bodies are impacted by celestial objects

Materials

- Pan (about 25 by 30 cm (10 by 12 in.))
- Dry tempera paint or powdered drink mix
- Balance or scale
- Meter stick
- Protractor
- Graph paper
- Goggles
- Lunar surface material (flour)
- Sieve or sifter
- Three impactors (marbles, ball bearings, etc.)
- Ruler
- Three data charts per group
- Student handout
- Newspaper (if the activity is not conducted outside)

Background

The circular features so obvious on the Moon's surface are impact craters that formed when impactors smashed into the lunar surface. The explosion and excavation of materials at the impacted site created piles of rock (called *ejecta*) around the circular hole as well as bright streaks of target material (called *rays*) thrown for great distances. If an impactor is larger than 40 km in diameter, a *central uplift* can form. This is a mountain that forms when there is a huge increase and then a rapid decrease in pressure during the impact event. Figure 1 shows two types of impact craters.

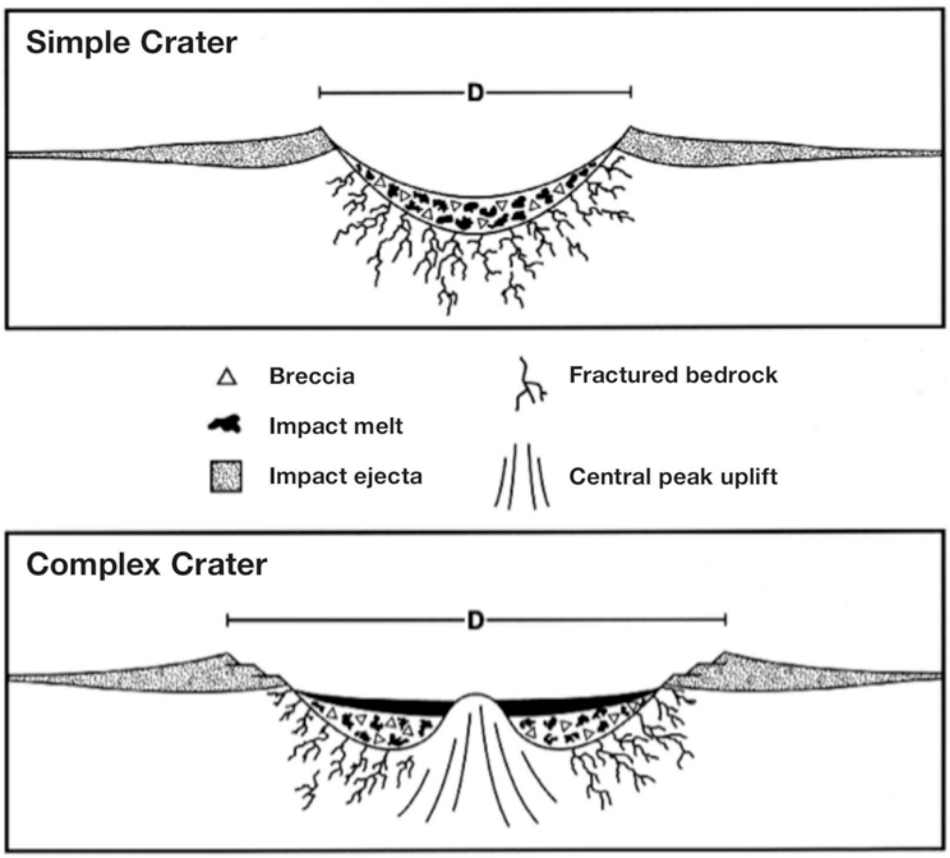


Figure 1. Simple and complex impact craters.

The two basic methods of forming craters in nature are (1) a projectile impacts a surface and (2) the top of a volcano collapses to create a crater termed a *caldera*. By studying all types of craters on Earth and by creating impact craters in experimental laboratories, geologists concluded that the Moon's craters resulted from impacts. The factors affecting the appearance of impact craters and ejecta are the size and velocity of the impactor and the geology of the target surface.

By recording the number, size, and extent of the erosion of craters, lunar geologists can determine the ages of different surface areas on the Moon and can piece together their geologic history. Impact craters are not unique to the Moon. They are found on all the terrestrial planets and on many of the moons of the outer planets. On Earth, impact craters are not as easily recognized because of weathering and erosion. Famous impact craters on Earth are Meteor Crater in Arizona, United States; Manicouagan in Quebec, Canada; Sudbury Basin in Ontario, Canada; Ries Crater in Germany; and Chicxulub on the Yucatan coast in Mexico. Chicxulub is considered by most scientists to be the source crater of the catastrophe that led to the extinction of the dinosaurs at the end of the Cretaceous period. An interesting fact about the Chicxulub crater is that you cannot see it. Its circular structure is nearly a kilometer below the surface and was originally identified from magnetic and gravity data.

Figure 2 shows the typical characteristics of a lunar impact.

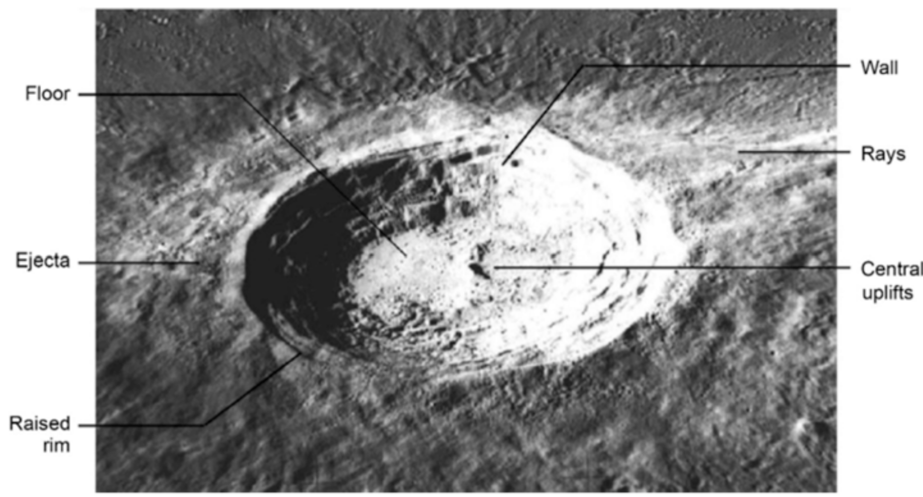


Figure 2. Aristarchus Crater on the Moon.

Procedure

Step 1

Gather all the necessary materials in a central location. Students will need pans (about 25.5 by 30.5 cm (10 by 12 in.)—the larger the better) that are either plastic, aluminum, or cardboard (no glass). They should be at least 7.5 cm (3 in.) deep. Students will need a base lunar surface material. Flour is suggested as the preferred medium, but baking soda, corn meal, or a 1:1 mixture of sand and corn starch can be used. Dry tempera paint, powered drink mix, or glitter should be sifted on the top of the base surface to create contrasting color. The student handout gives step-by-step instructions for completing this activity.

During this activity, the flour, baking soda, or dry paint may fall onto the floor and the baking soda may even be disbursed into the air. Spread newspapers under the pan(s) to catch spills, or consider doing the activity outside.

Have the students agree beforehand on the method they will use to "smooth" and resurface the material in the pan between impacts. The material need not be packed down. Shaking or tilting the pan back and forth produces a smooth surface. Reapply a fresh dusting of dry tempera paint or other material to the surface between impacts. Remind students that better experimental control is achieved with consistent handling of the materials. For example, results may vary if the material is packed down for some trials and not for others. Allow some practice time for dropping marbles and resurfacing the materials in the pan before actually recording data. Have the students use a different data sheet for each impactor.

Because the velocity of the marbles will be much lower than those of impactors in space, the experimental impact craters may not have raised rims, central uplifts, or terraced walls.

The higher the drop height, the greater the velocity of the marble. Therefore, a larger crater will be made, and the ejecta will spread out farther.

Step 2

Begin by looking at the photographs of lunar craters provided (Figs. 3 and 4). Ask the students for their ideas about how the craters formed.

Step 3

Show the students Figure 5 (the handout of the impact crater features on the Aristarchus Crater at the end of this section) and explain the features and how they were formed.

Step 4

Explain that they are going to simulate lunar impacts. Then pass out the student handout, the *Impact Craters Data Chart*, and the graphs worksheet to begin the activity.

Suggestions for Differentiation

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

Support:
Prepare the lunar surface in advance.

Assist students with measuring their impact craters.

Complexity:
Ask the following questions. After they have given answers, have the students try their suggestions and write about their results.

- What would happen if you changed the angle of impact?
- How could this be tested?

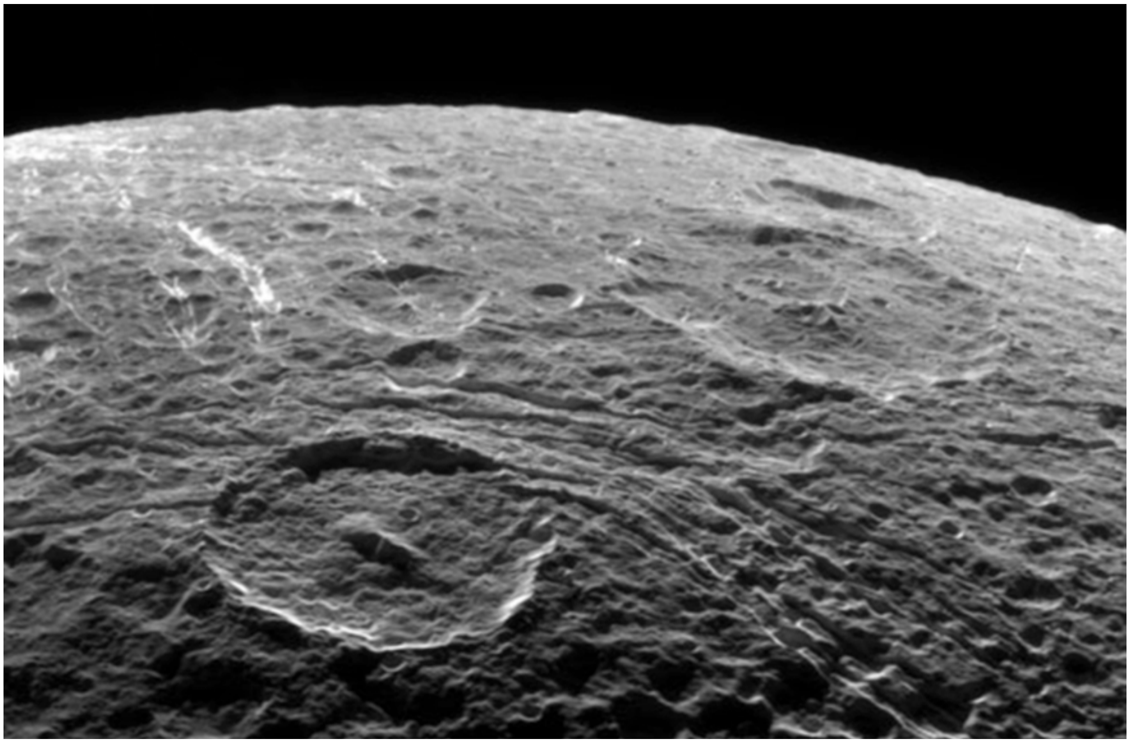


Figure 3. Photograph of impact craters on the Moon.

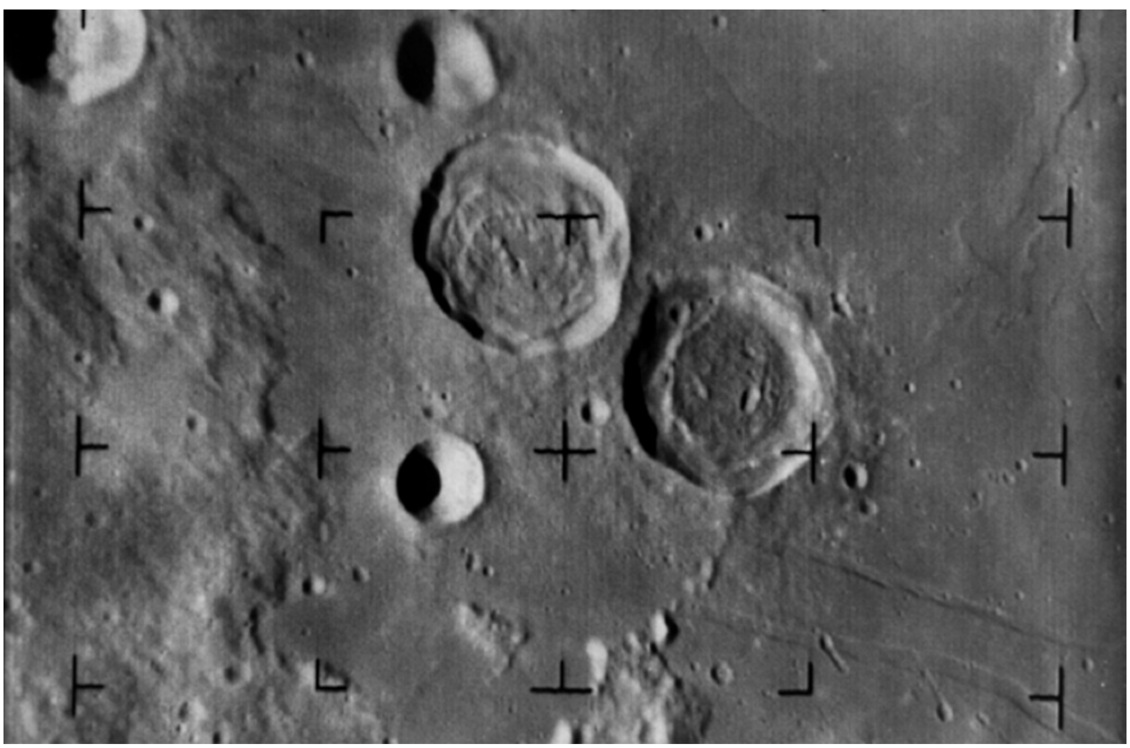


Figure 4. Photograph of impact craters on the Moon.

Impact Crater Features

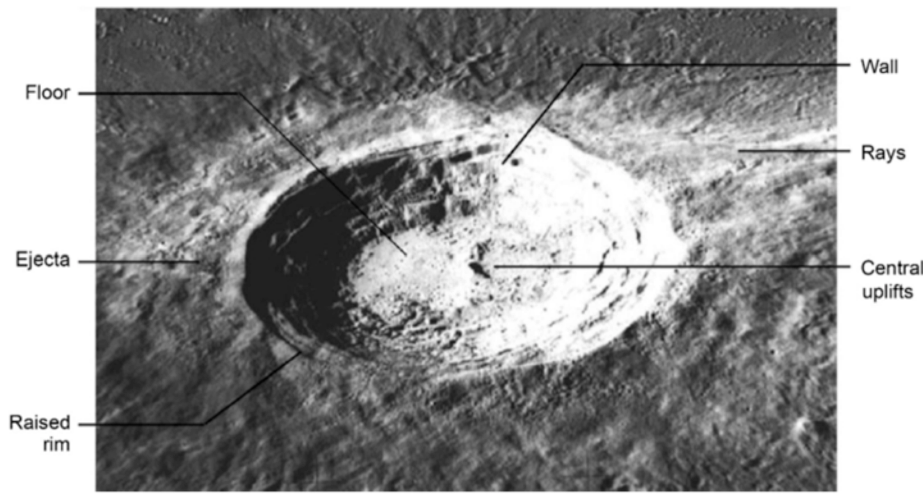


Figure 5. Impact crater features on the Aristarchus Crater.

Floor The floor is bowl-shaped or flat. It is characteristically below the surrounding ground level.

Ejecta Material surrounding the crater that was excavated during the impact event. Ejecta become thinner farther away from the crater.

Raised rim During the explosion and excavation of an impact event, rocks are thrown out of the crater and deposited as a ring-shaped pile of debris at the crater's edge.

Wall Walls are characteristically steep and may have giant stairs called terraces.

Rays Bright streaks of ejecta that start at a crater and extend away for great distances.

Central uplifts Mountains are formed because of the huge increase and rapid decrease in pressure during the impact event. They occur only in the center of craters that are larger than 40 km in diameter.

Name: ____

Directions

Make a Prediction

Step 1

Answer questions 1 and 2:

1. Look at the photographs of the Moon's craters; then describe how you think the craters were formed.

____

____

2. What factors would affect the appearance and size of craters and ejecta?

____

____

Preparing a "Lunar" Test Surface

Step 2

Put on goggles to prevent eye injury, and keep them on for this entire activity. Fill a pan with surface material to a depth of about 2.5 cm. Smooth the surface, then tap the pan to make the materials settle evenly.

Step 3

Sprinkle a fine layer of dry tempera paint, or other provided material, to create a contrast layer, evenly and completely, over the surface. Use a sieve or sifter for more uniform layering.

3. What does this "lunar" surface look like before testing?

____

____

Forming the Craters

Step 4

Use the balance to measure the mass of each impactor. Record each mass on the *Impact Craters Data Chart* for that impactor.

Step 5

Drop impactor 1 from a height of 30 cm onto the prepared surface. Measure the diameter and depth of the resulting crater, and record it on the *Impact Craters Data Chart*.

Step 6

Note the presence of ejecta (rays). Count the rays, measure the lengths of the rays, determine the average length of all the rays, and record the average on the *Impact Craters Data Chart*. (To get the average, add all lengths together and divide by the number of lengths that you measured. The result is the average.)

Step 7

Compute the average values for crater diameter, depth, and rays, and record them on the *Impact Craters Data Chart*.

Step 8

Repeat steps 2 through 7 for impactor 1, increasing the drop heights to 60 cm, 90 cm, and 2 m (you might need to stand on steps for this drop). Finish the Data Chart for this impactor. Note that the higher the drop height, the faster the impactor hits the surface.

Step 9

Repeat steps 1 through 8 for two more impactors. Use a **separate** *Impact Craters Data Chart* for each impactor.

Graphing Your Results

Step 10

Create two graphs:

- Graph 1: Average crater diameter versus impactor height and velocity
- Graph 2: Average ejecta (ray) length versus impactor height and velocity
- Use different symbols (e.g., dot, triangle, plus, etc.) for different impactors

Step 11

4. Was your prediction in Step 1 about what affects the appearance and size of craters supported by the test data? Explain why or why not.

____

____

5. What do the data reveal about the relationship between crater size and the velocity of the impactor?

____

____

6. What do the data reveal about the relationship between the ejecta (ray) length and the velocity of the impactor?

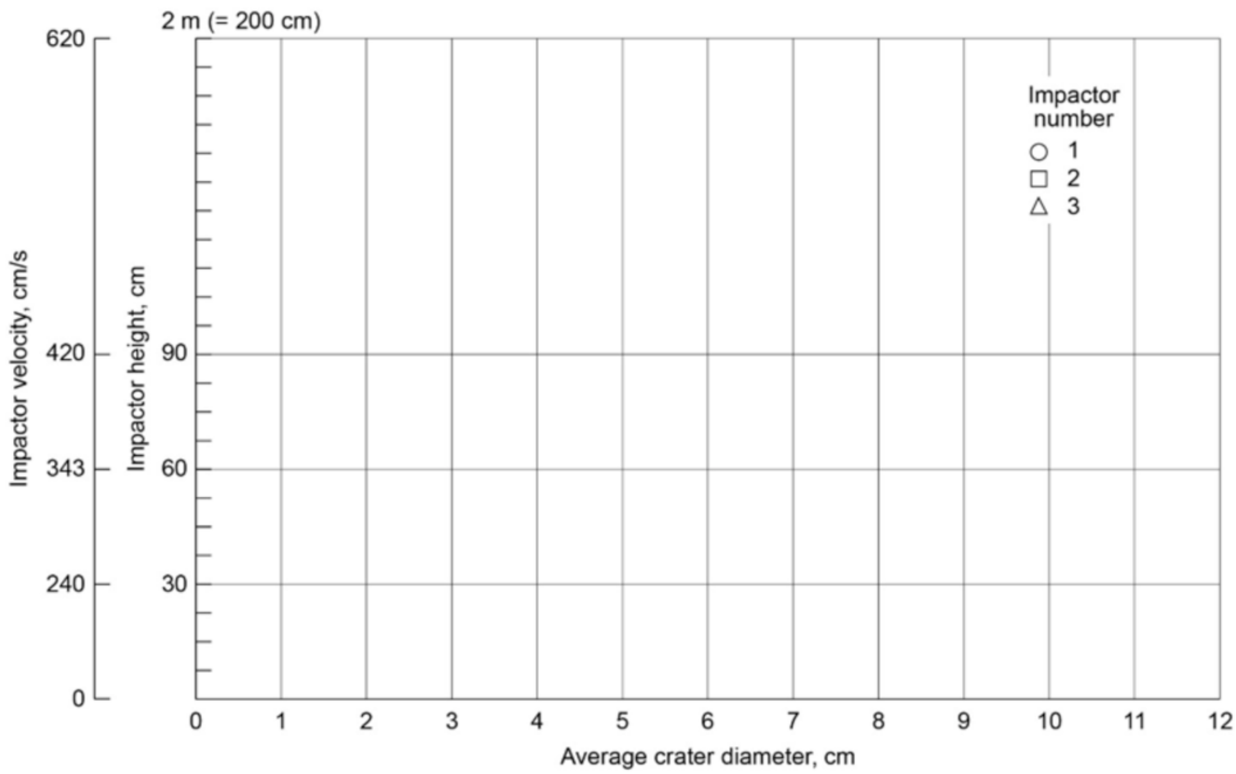
____

____

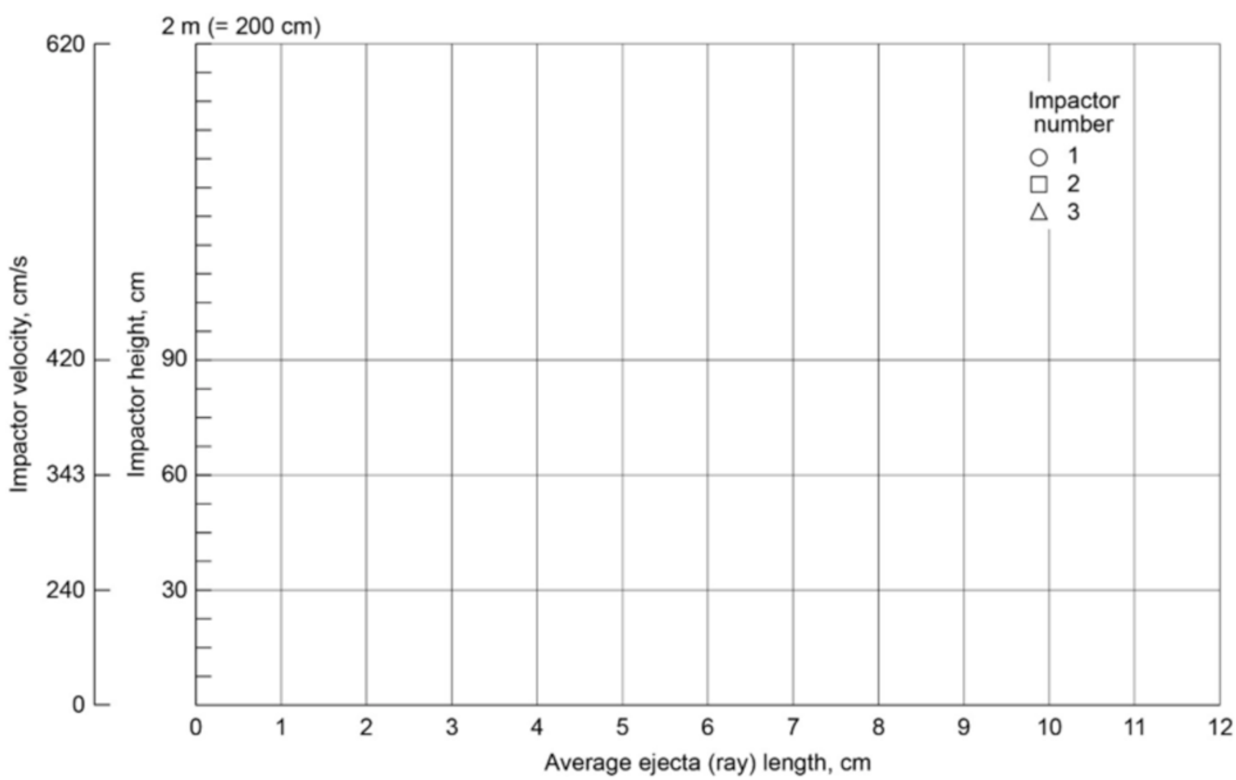
Name: ____________________________ **Impactor number:** ______ **Weight in grams:** ______

Impact Craters Data Chart

Trial	Crater diameter, cm	Crater depth, cm	Average length of rays, cm
Drop height, 30 cm; velocity, 242 cm/s			
1			
2			
3			
Total			
Average			
Drop height, 60 cm; velocity, 343 cm/s			
1			
2			
3			
Total			
Average			
Drop height, 90 cm; velocity, 420 cm/s			
1			
2			
3			
Total			
Average			
Drop height, 2 m; velocity, 626 cm/s			
1			
2			
3			
Total			
Average			



Graph 1. Average crater diameter versus impactor height and velocity.



Graph 2. Average ejecta (ray) length versus impactor height and velocity.

Finding
Impact Craters

Grades 6 to 8

INQUIRY-BASED ACTIVITY

activity

FINDING IMPACT CRATERS

Grades: 6 to 8   Prep Time: 0.5 hour   Activity Time: 1.5 hours

About This Activity

This activity was created by NASA's Landsat Education program office to allow students the opportunity to study satellite images of craters and to determine if the image does or does not show evidence of an impact event.

Next Generation Science Standards

MS–ESS2–2. Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.

Learning Objective

Learners will

- Describe how extraterrestrial objects affect the Earth's topography
- Determine whether landforms were formed by impacts or other natural phenomena
- Understand how satellite technology helps scientists to identify impact events

Video Link

https://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=2518

Materials

- Student handouts
- Images
- Iturralde video or movie stills

Background

Many people know that craters cover the surface of the Moon. In fact, *impact craters* appear on all rocky (*terrestrial*) planets and many of their moons. The Earth has been shaped by these dramatic impact events no less than other planetary bodies have been, and one can see evidence on the Earth in terms of its geology, biology, and chemistry. The knowledge we can gain from studying impact craters is fundamental and interdisciplinary.

Science is an exploratory, dynamic process, and new ideas frequently come to light. Until about 40 years ago, most geologists did not consider impacts by extraterrestrial objects to be very significant. Impact events are now recognized as more abundant, larger, older, more geologically complex, more economically important, and even more biologically significant than scientists had believed. Impact events have formed major ore deposits, generated large crustal disturbances, and produced huge volumes of igneous rock.

We know that at least one major biological extinction event was probably triggered by the impact of an extraterrestrial object and that the coastline of the Chesapeake Bay was partially shaped by an impact event. Impact events may have played a key role in the formation of the ocean basins and of the oceans themselves. Large impacts can drastically alter the chemical composition of the atmosphere.

Researchers have identified approximately 160 individual impact craters on Earth. These craters probably represent only about 25 percent of those to be found. Assuming an equal rate of impact around the globe, many more craters remain to be discovered, particularly in remote land regions of our planet and in the oceans.

NASA scientists currently study satellite images for evidence of impact events. Finding the evidence requires careful interpretation of satellite images. Wind and water have eroded away most of the evidence, various other geologic processes have concealed it, and oceans and vegetation now cover much of the rest. Satellite observation technology enables us to see landforms that we cannot see with our eyes alone. When impact craters are found in satellite images, interdisciplinary teams of scientists can go to the sites on the ground to learn more about them and how they have changed their surroundings.

These are some questions scientists are currently asking about impact events:

- How often do impacts occur? Does the rate of impacts vary over time? If so, does it vary regularly or randomly?
- Are asteroids or comets the more frequent impacting bodies?
- Have impact events caused more than one major biological extinction event?
- When will the next impact event take place? How big will it be, and how will it affect life?

Procedure

Step 1

Show students an aerial photograph of the Barringer Meteor Crater (located in Arizona) (Fig. 1). Tell them that this landform is about 1300 m (0.8 mi) in diameter and 174 m (570 ft) deep. Ask, "What do you think could have made a hole this big in the land?" Discuss as a group.

Show an artist's rendering of an impact event—Chicxulub impact site by Don Davis (Fig. 2).

Explain to students that every day the Earth encounters impacts from small debris in space. Sometimes, however, the Earth's path comes across large debris and there is an impact event of enormous force. Such an event has profound effects on rocks and soil, atmosphere, water, and living things. These types of impacts are not common, but they have occurred and will probably occur in the future.

Ask students to imagine hitting a dust particle or a fleck of paint in the air with their finger. They will understand that such a collision would not leave any lasting mark. Tell them that NASA engineers found that, because the space shuttle was orbiting very fast (17,000 mph), even tiny flakes of paint floating in space (from earlier missions) could make craters 1 cm in diameter when they hit the space shuttle windows. Emphasize that there is a lot of energy in an object traveling fast. It has been calculated that the energy required to produce the Barringer Meteor Crater was equivalent to the explosion of 15 million tons of TNT.

Have a discussion about what the students may already know about impact events. Ask the students if any of them have visited Barringer Meteor Crater. Students who have done so can describe their experience.

Step 2

Have the students read the worksheet, *When an Extraterrestrial Object Hits the Earth* and answer the questions. Once completed, as a group discuss the effects that such an event might have on the land, the atmosphere, and living things.

Step 3

Distribute *Known Effects of Impact Events*. Have the students read it quietly alone or aloud as a group and discuss as a group.

Step 4

Show either the "Iturralde Movie" or the series of three still images from the Iturralde movie. Explain that the movie is composed of Landsat images of a location in Bolivia. As the movie progresses, the data are displayed in different ways so that the impact crater becomes more visible to the viewer. The movie, and the series of still images taken from it, show very clearly how satellite technology helps scientists see landforms on the Earth's surface that we cannot see with our eyes alone.

Step 5

Place the students in groups of three to five. Then distribute the following materials:

- One set of the seven satellite images to each group
- One copy of the *Describe Satellite Images of Possible Impact Craters* student worksheet to each student

Given what students know about the evidence left by impacts, ask the groups to determine whether or not the landforms in all seven of the images appear to be impact craters. Monitor the groups as they discuss their analyses of the satellite images. Make sure that they understand that they should come to an agreement as a group about their satellite images based on their analysis of the evidence in the images.

Step 6

Have groups select a spokesperson who will report on the group's analyses. Make sure that all of the images in the set provided are covered in the discussion.

Whether or not the students believe that an image shows an impact crater, each group's spokesperson must explain their group's thinking clearly and convincingly.

Step 7

Share with the groups the actual identifications of the landforms from the *Facilitator Reference Identification of Images* sheet.

Suggestions for Differentiation

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

Support:
Show students images of features that appear to be impact events but were created by other geological events.

Complexity:
Have students visit a world map of impact craters (http://impact.scaredycatfilms.com) and answer the following questions:

- Have more impact craters been discovered in some places than in others?
- Where are these "clusters" of craters?
- Why are they where they are and not somewhere else?

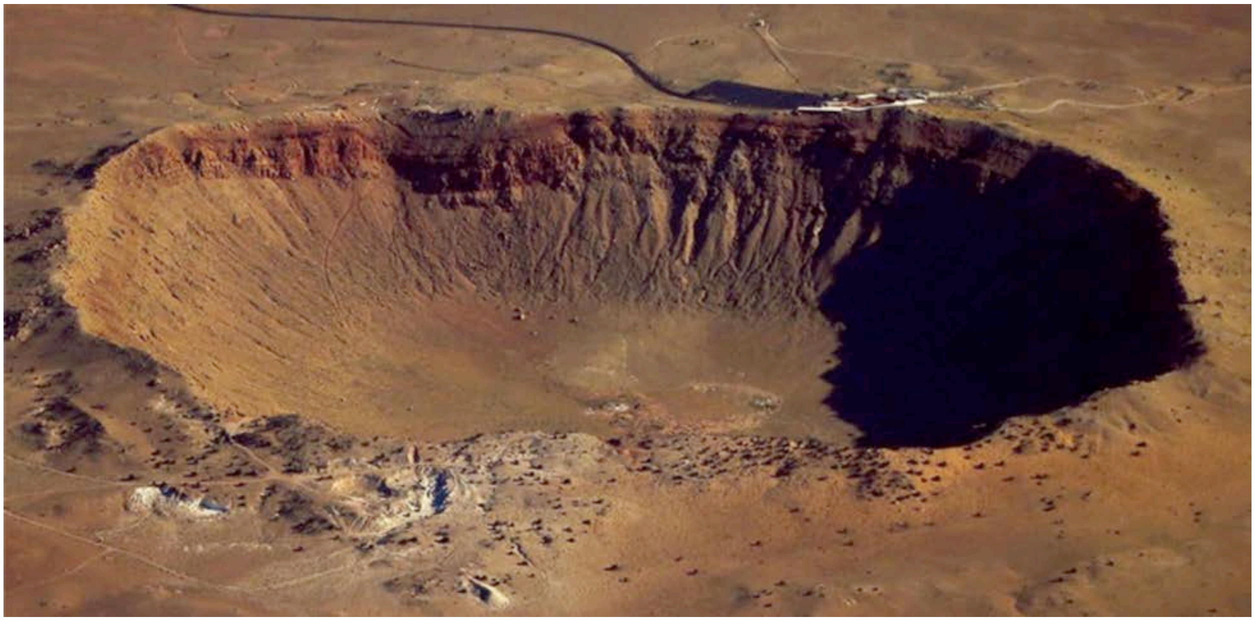
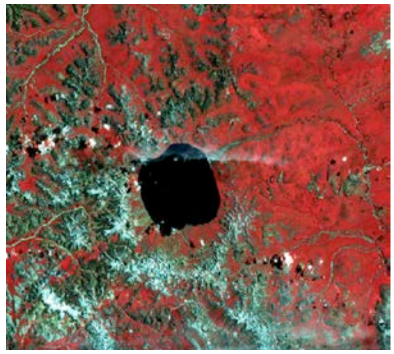


Figure 1. Barringer Crater in Arizona.

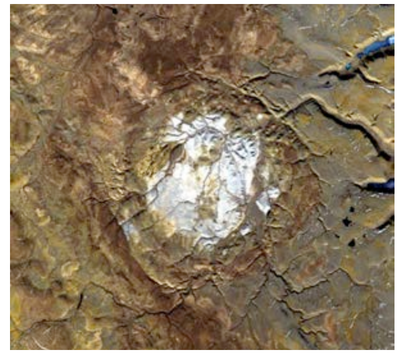
Figure 2. Painting of Chicxulub impact site by Don Davis.

Facilitator Reference Identification of Images

Aorounga (AOR) is an impact crater in Chad, Africa.



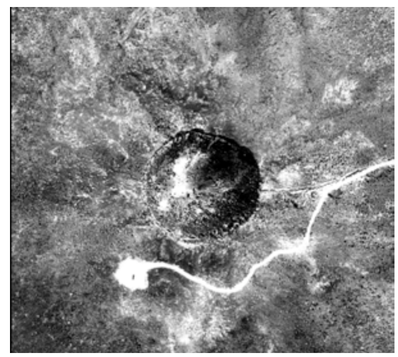
El'gygytgyn (ELG) (pronounced "el ja-ge-tin") is an impact crater in Chukotka Autonomous Okrug in northeast Siberia.



Haughton (HGH) is an impact crater on Devon Island in northern Canada.

Manicouagan (MAN) is an impact crater in Quebec, Canada.

Richat (RCH) in Mauritania, Africa, is not an impact crater but an eroded anticline (a hill formed by a fold in the Earth's surface).



Schooner (SCH) in Nevada, United States, is not an impact crater. It was created by underground nuclear testing.

Mount St. Helens (MSH) is not an impact crater. It is a volcano in Washington State, United States.

Name: ____

When an Extraterrestrial Object Hits the Earth

You would not hear it coming—a 100-ton extraterrestrial object would hit the Earth at hypervelocity, more than 11 km/s and sometimes as fast as 20 to 25 km/s. That's faster than sound (about 300 m/s). The object comes to a stop in about one-hundredth of a second. (Smaller objects slow down or are destroyed because of air resistance.)

1. There is a rapid release of a tremendous amount of kinetic energy. What would be the effect of that rapid release of energy on the solid earth, the atmosphere, and living things? What forms might that energy take and where might it go?

Effects on rocks and soil:

____

____

____

Effects on the shape of the land (topography):

____

____

____

Effects on the atmosphere (air):

____

____

____

Effects on living things:

____

____

____

2. The energy release creates a shockwave stronger than any material it hits. What could be the effects of that shockwave on rocks, soil, and large bodies of water?

____

____

____

3. What would be the effects of the impact on the object itself? Would it remain intact (in one piece)?

____

____

____

Known Effects of Impact Events

When a large object from space hits the Earth…

- There's a huge explosion.
- The impact makes a big hole or crater with a raised rim and sometimes a central peak. The hole is many times larger than the impacting object.
- There is a rapid release of a tremendous amount of kinetic energy as the object comes to a stop in about one-hundredth of a second.
- The impact releases extreme heat. Usually, the object itself is vaporized. Sometimes it melts completely and mixes with melted rocks at the site.
- If the impact occurs in water, a whole column of water is vaporized.
- The impact also produces a super-hot blast wave—a shockwave—that radiates rapidly outward from the impact point through the target rocks at velocities of a few kilometers per second.
- The shockwave is stronger than any material on Earth. It deforms rock in ways that are characteristic of an impact event. No other event on Earth deforms rock in these ways.
- Tiny glass droplets can form during the rapid cooling of molten rock that splashes into the atmosphere.
- Large impacts also crush, shatter, and/or fracture the target rocks extensively beneath and around the crater (see Fig. 1 in the Impact Craters activity).
- Hot debris is ejected from the target area and falls in the area surrounding the crater. Close to the crater, the ejecta typically form a thick, continuous layer. At larger distances, the ejecta may occur as discontinuous lumps of material.
- Very large impact events can blow out a hole in the atmosphere above the impact site, permitting some impact materials to be dispersed globally by the impact fireball, which rises above the atmosphere. The extensive dust and smoke clouds that result can cause darkness lasting for a year.
- Special carbon molecules called *Buckminsterfullerene* (or bucky-balls) can travel to the Earth in the impactor. They can hold noble gases, which indicate that material is extraterrestrial in origin.
- Large impacts can trigger earthquakes and initiate volcanic eruptions.
- The heat from the fireball ignites fires that can rage across a large region.
- Impact events can alter the chemical composition of the atmosphere. The extreme heat can generate large amounts of nitrogen oxides (NO_x), which are transformed easily into nitric acid, resulting in acid rain.

General Information About Impact Events

Impact craters are geologic structures formed when a large meteorite, asteroid, or comet smashes into a planet or a satellite.

Every day, a very large number of meteoroids enter the Earth's atmosphere—more than 100 tons of material. These meteoroids are almost always very small, just a few milligrams each. Only the largest ones reach the Earth's surface. The average meteoroid enters the atmosphere at between 10 and 70 km/s. All but the very largest are quickly decelerated to a few hundred kilometers per hour by atmospheric friction, and they hit the Earth's surface with very little fanfare. However, asteroids larger than a few hundred tons are slowed very little. Only these large (and fortunately rare) asteroid impacts make craters.

All of the inner bodies in our Solar System have been heavily bombarded by meteorites and asteroids throughout their history. On the surfaces of the Moon, Mars, and Mercury—where other geologic processes stopped millions of years ago—this bombardment is recorded clearly. On the Earth, however, where the surface has been even more heavily impacted than the Moon, craters are continually erased by erosion and deposition as well as by volcanic resurfacing and tectonic activity. Thus, only about 160 terrestrial impact craters have been recognized: the majority in geologically stable areas of North America, Europe, and Australia. Spacecraft imagery has helped to identify structures in more remote locations that can be explored for positive identification.

Extraterrestrial Objects in the Solar System

In addition to the planets, thousands, possibly millions, of objects move throughout our Solar System—each moving in its own orbit around the Sun. These objects range from microscopic dust particles to objects tens of kilometers across. We do not know how often these types of objects have hit the Earth in the past.

Energy Released by Impacting Objects

The energies of impact come chiefly from the kinetic energy of the impacting object. These energies are almost incomprehensibly large. An object only a few meters across carries the kinetic energy of an atomic bomb as it strikes another object at high velocity. The impact of an object only a few kilometers across (smaller than many known asteroids and comets) can release more energy in seconds than the whole Earth releases (through volcanism, earthquakes, tectonic processes, and heat flow) in hundreds or thousands of years.

Impact Velocity

The minimum impact velocity for collisions with Earth is 11.2 km/s. This is equal to the escape velocity for an object launched into space from Earth's surface.

Crater Sizes

Objects of less than half a kilometer in diameter can make craters 10 km in diameter.

Crater Shapes

Nearly all impact events result in circular craters. In rare cases where the angle of impact was very low (0° to 10° from the plane of the horizon), craters can be ovoid (or egg-shaped).

Finding Impact Craters on Earth

When looking for impact craters in satellite images, first pay attention to circular features in topography or bedrock geology. Look for lakes, rings of hills, or isolated circular areas.

On the ground, look for changes in the physical properties of the rocks in and around the impact structures. Fractured rock is less dense than unaltered target rock around the structure. Also, look for ejecta and shocked rock fragments on the original ground surface outside the crater and for fragments of the meteorite.

Name: ______________________________

Describe Satellite Images of Possible Impact Craters

Consider what effects an impact event might have and describe those effects on this worksheet.

The object itself: Would you expect to see any evidence of the object itself in a satellite image? What evidence might you find?

____

____

The shape of the land: What kinds of changes would that impact make to the shape of the land where it hit and around where it hit?

____

____

The effects of time: What kinds of changes will occur to the impact site over time? Remember that some changes are fast and some are slow.

____

____

What else might you see in these satellite images that could help you learn about an impact crater?

____

____

As a group, study all of the satellite images. Their abbreviations follow. After each abbreviation, write whether you believe that the image shows an impact crater or something else.

AOR ______________________
Diameter, 12.6 km

ELG ______________________
Diameter, 18 km

HGH ______________________
Diameter, 20 km

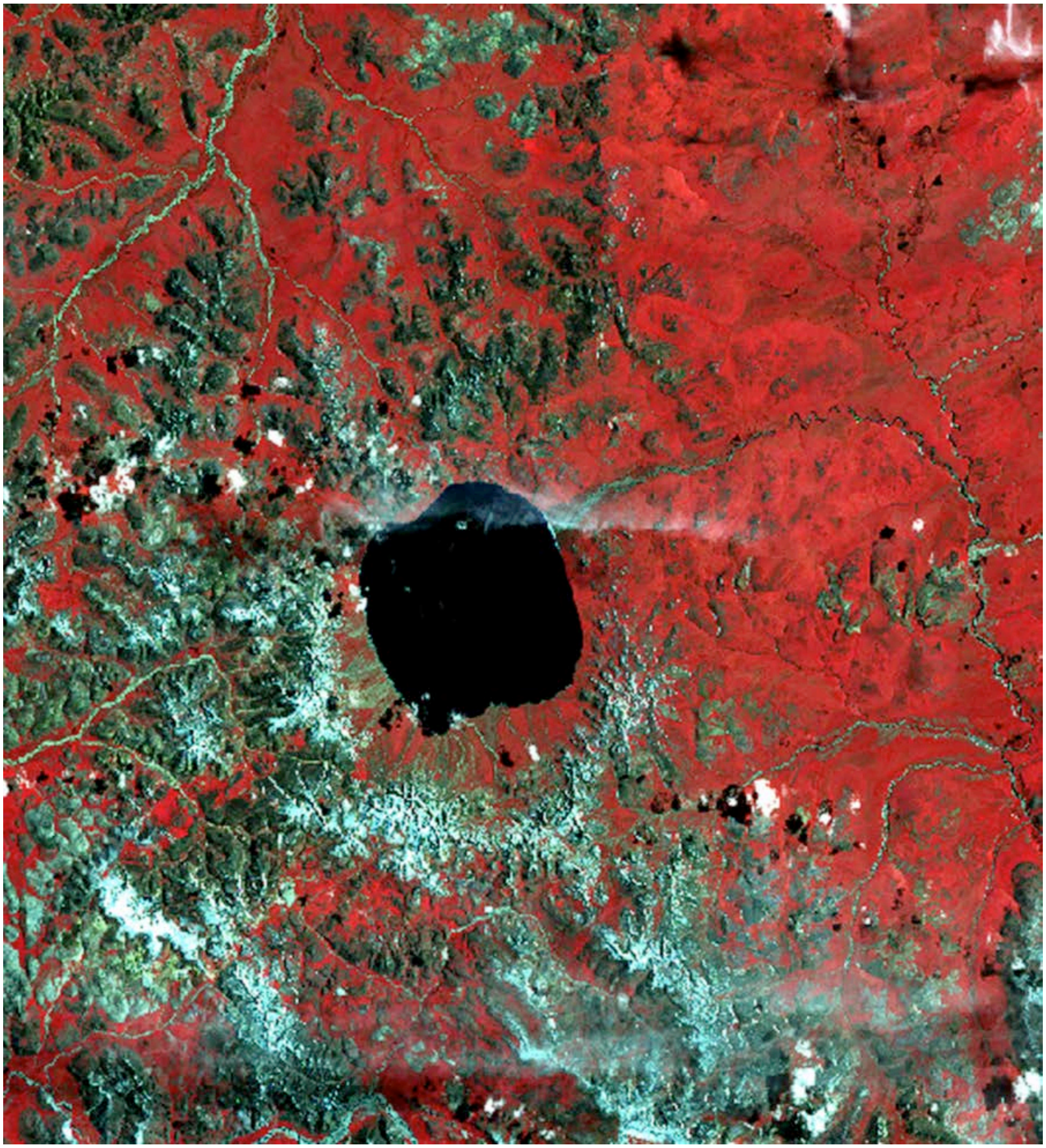
MAN ______________________
Diameter, 72 km

RCH ______________________
Diameter, 38 km

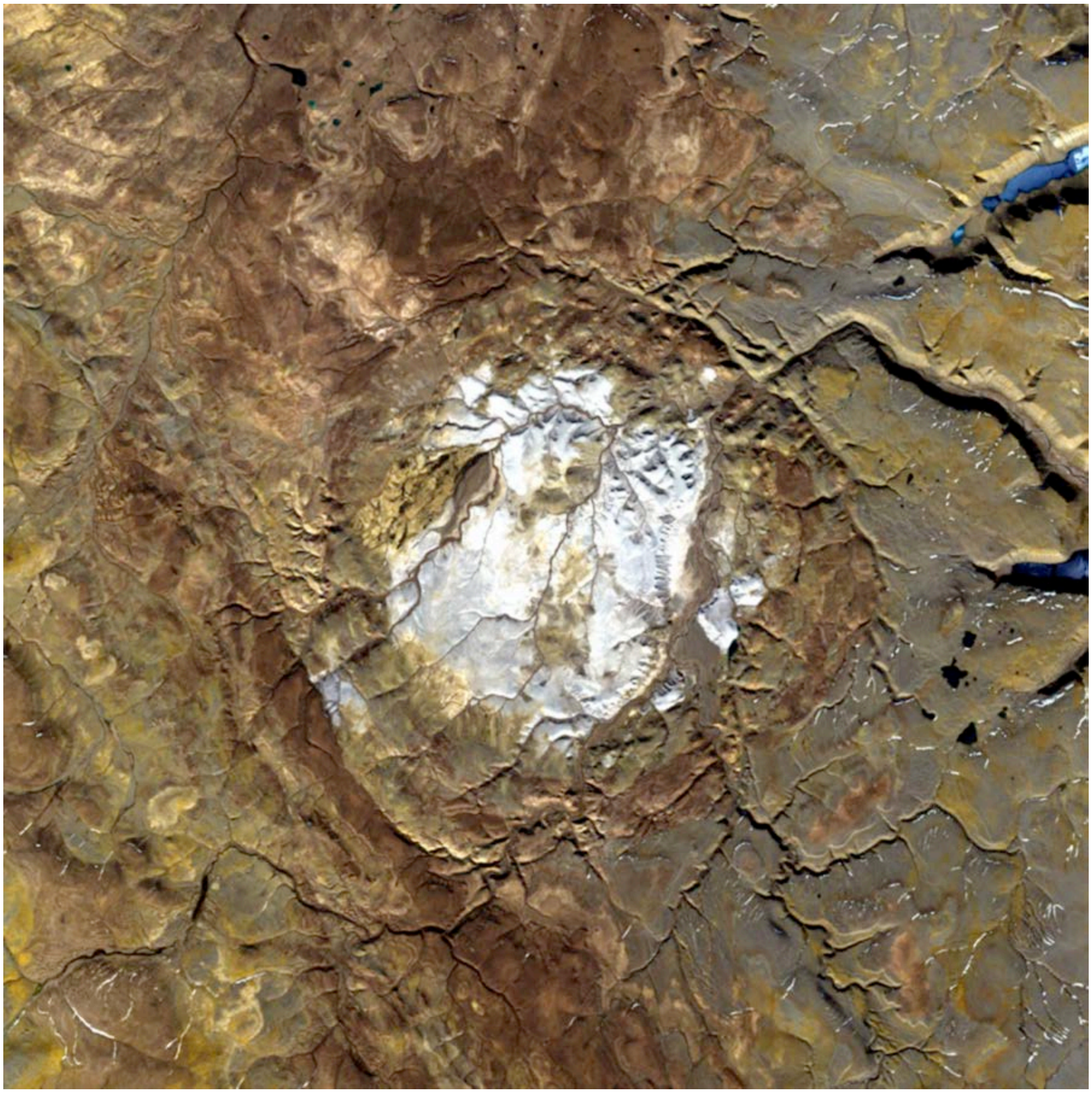
SCH ______________________
Diameter, 0.39 km

MSH ______________________
Diameter, several kilometers

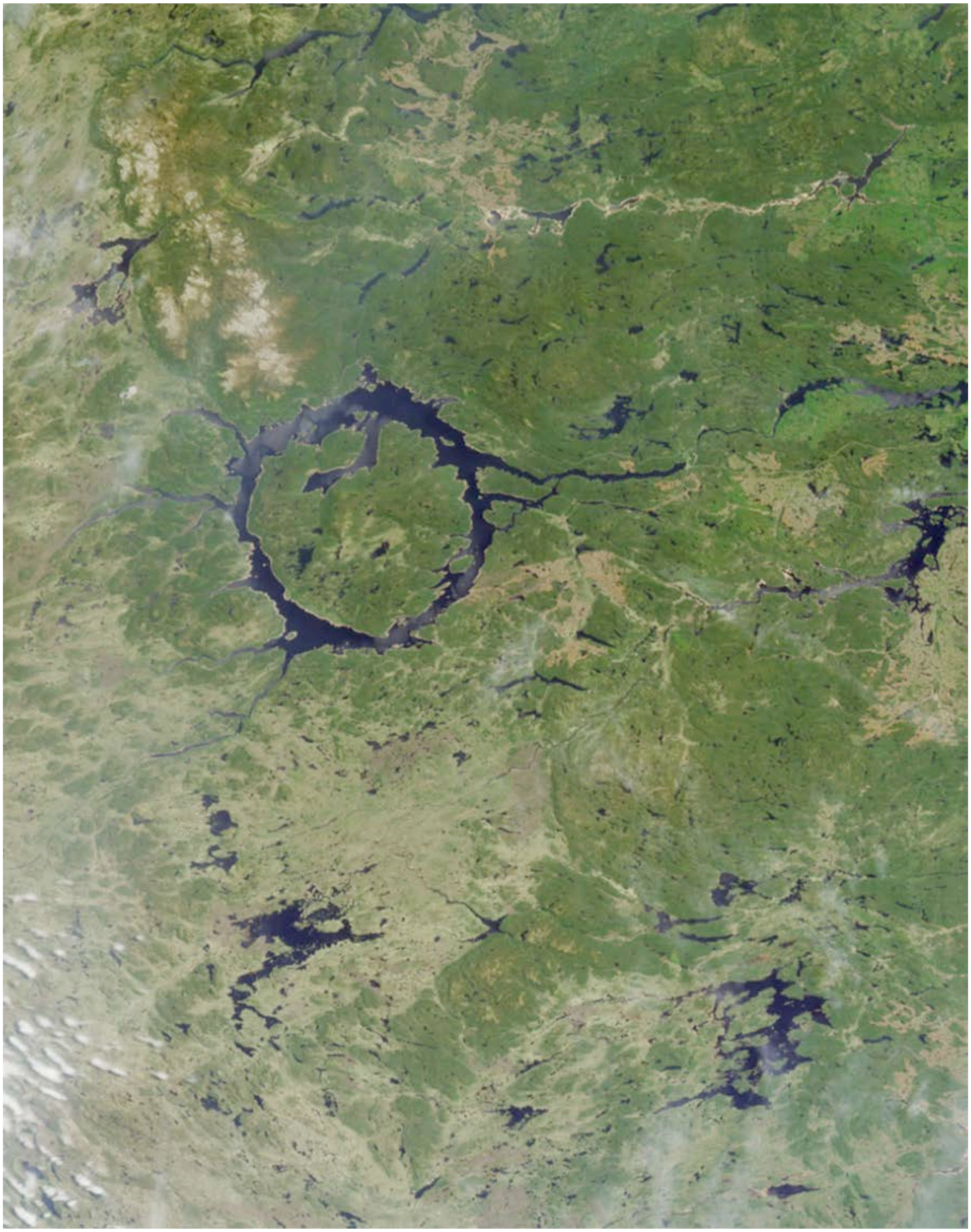
AOR



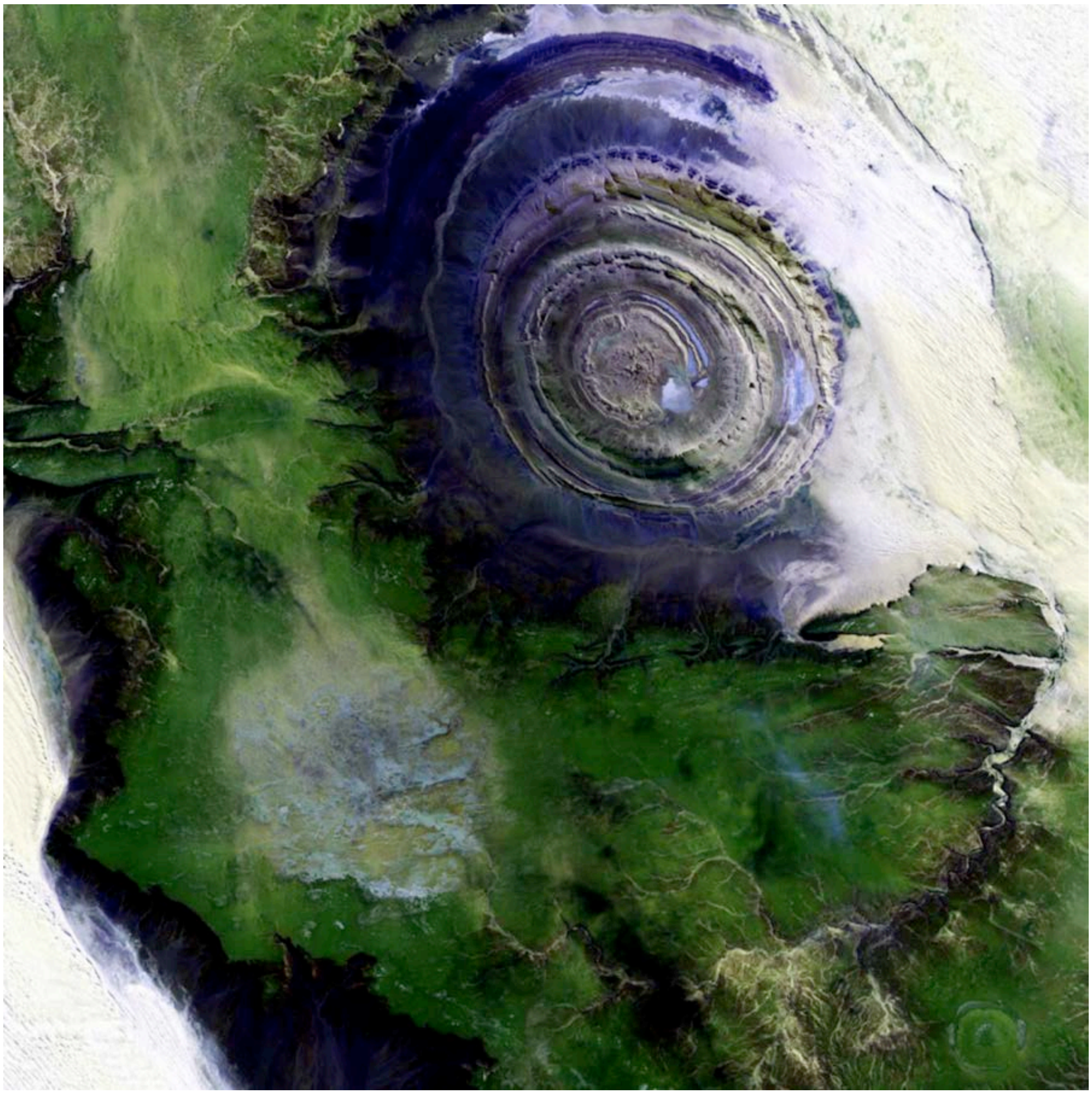
ELG



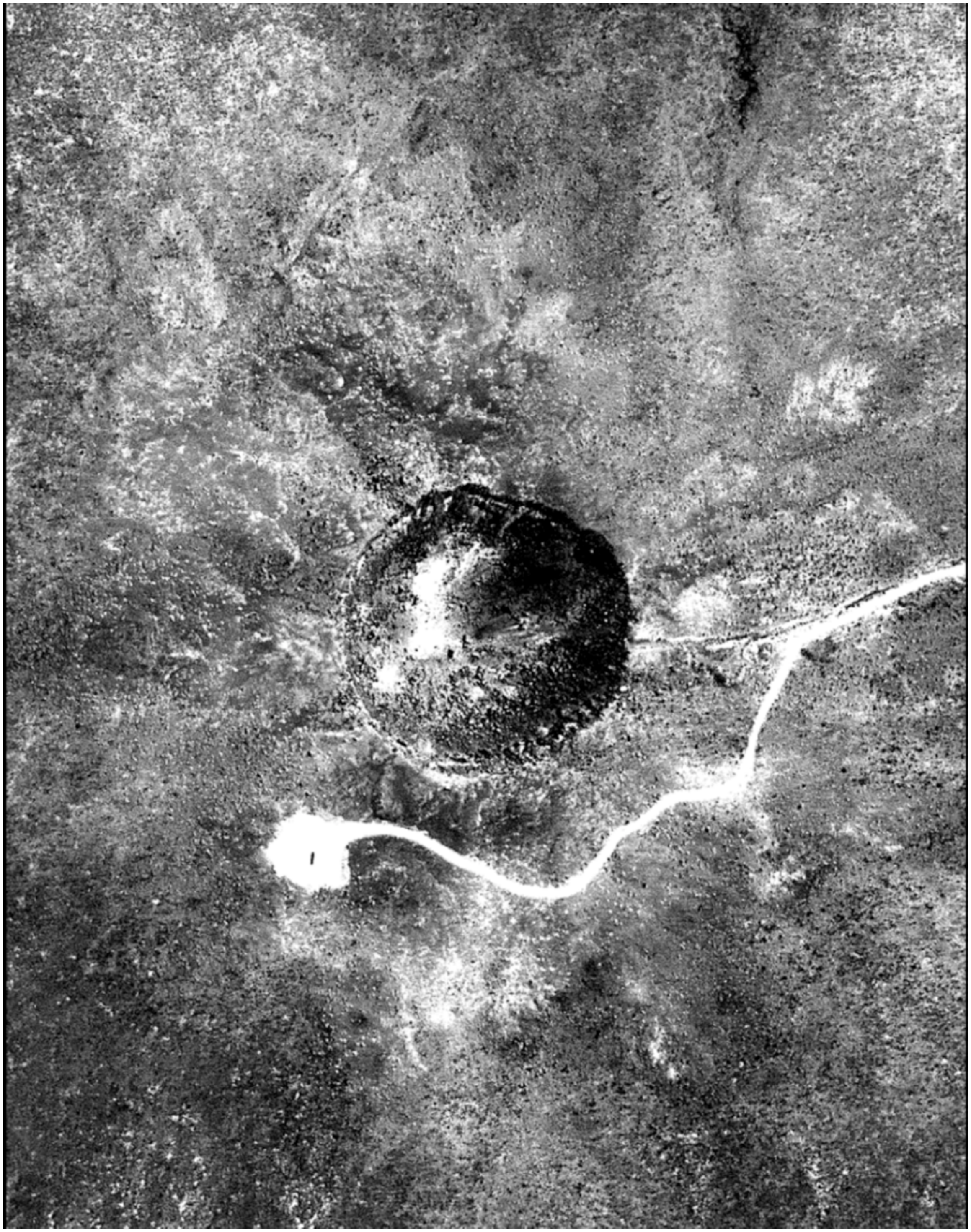
HGH



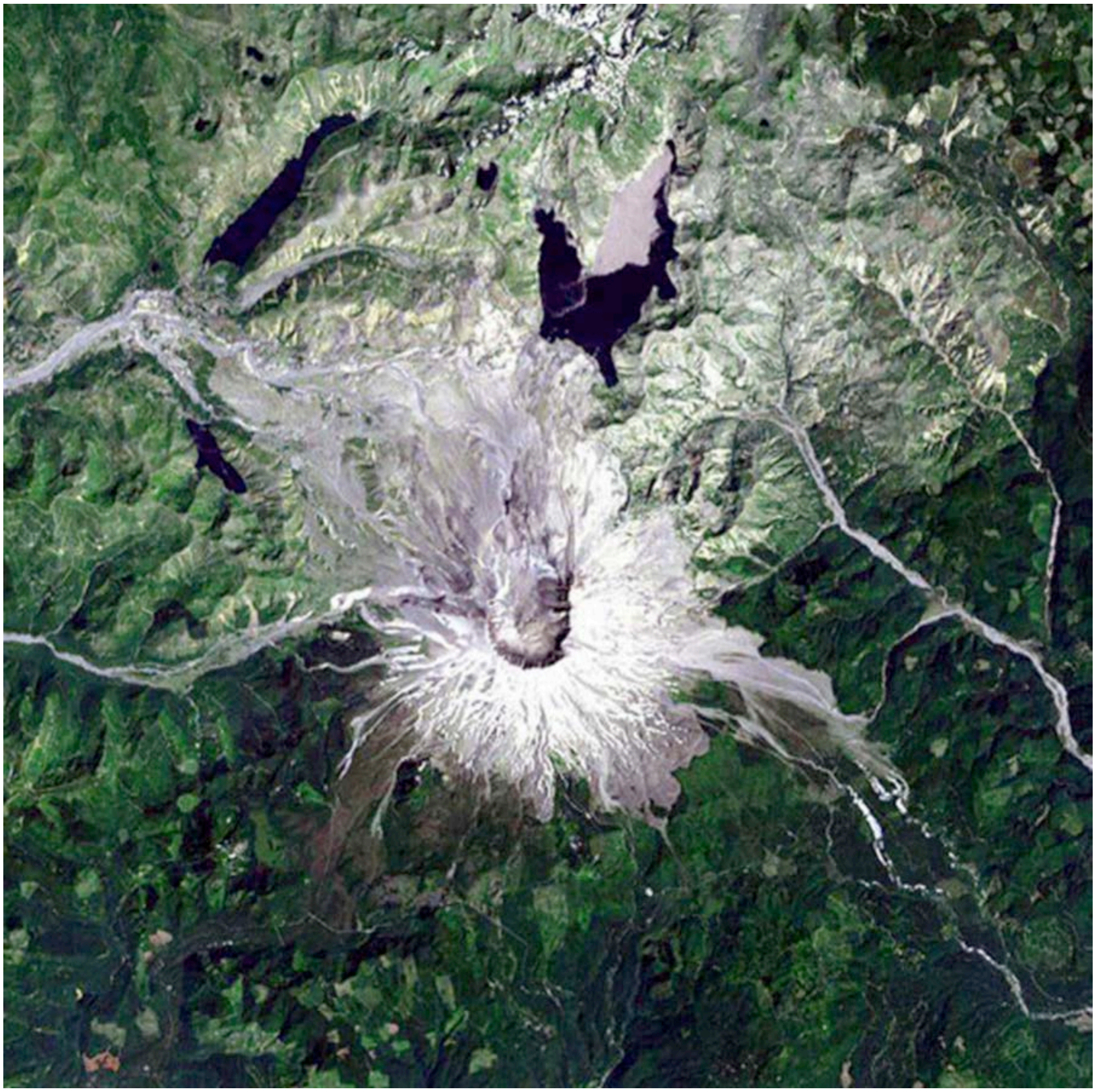
MAN



RCH



SCH



MSH

Spectroscopes

Grades 6 to 8

INQUIRY-BASED ACTIVITY

activity

SPECTROSCOPES

Grades: 6 to 8   Prep Time: 0.5 hour   Activity Time: 1.5 hours

About This Activity

This activity was taken from NASA's Afterschool Universe activity guide. Students build and calibrate a simple spectroscope and use it to examine light from different sources. This allows students to use a technique used by astronomers, who use a more complicated device called a spectrometer, to learn about the composition of objects in the Universe.

Next Generation Science Standards

PS4.B: Electromagnetic Radiation

Learning Objective

Learners will

- Build a spectroscope to identify source elements based on their spectral lines

Video Link

http://nasawavelength.org/resource/nw-000-000-002-727

Materials

- Diffraction grating (single axis; approximately 1-in. square of material per student)
- *The Electromagnetic Spectrum* printout
- Paper towel tubes or any tubes with similar dimensions (one per student)
- Aluminum foil: For each student, two 4- by 4-in. pieces and two 1- by 3-in. strips (approximate sizes)
- Tape
- Gas discharge lamp or other light sources such as an incandescent light bulb as a source of a continuous spectrum, a neon light, or a fluorescent light
- Darkened room (preferably completely darkened)

Background

Every element has its own *spectral lines* or *spectral fingerprint* that can be used to identify its presence. Astronomers use spectral fingerprints to figure out what objects, like stars and galaxies, are made of. With very powerful instruments, they can even tell how much of an element or compound is present: bright lines indicate that a lot is present; faint lines indicate that very little is present. The electromagnetic spectrum is the full range of electromagnetic radiation. In physics, some scientists refer to all electromagnetic radiation—not just visible light—as *light*.

When instruments such as the ones built in this activity are used, the Sun's spectrum (seen throughout the sky) appears essentially continuous, rather than having distinct lines. We call the light from the Sun *white light*. It is a combination of all the colors of visible light. Rainbows are the result of sunlight being diffracted (spread out) by water droplets in the air. When we talk about light, wavelength refers to the distance between the two peaks (or crests) of the light wave (Fig. 1). Longer wavelengths correspond to shorter frequencies. The wavelength and frequency of light are characteristics that define the type of light (radio, microwave, infrared (IR), visible, ultraviolet (UV), x-ray, or gamma-ray).

Gas discharge lamps are the best way to show students the fingerprints for specific elements. These lamps send an electrical charge through the gas of a certain type of element (examples: neon and mercury). The resultant light shows the spectral fingerprint of that element. It is best to view these *spectra* (plural of spectrum) in a completely darkened room. (Covering bulbs with colored paper or using colored bulbs will not change the spectral lines from that of a clear bulb because the source of the light is the filament, not the glass of the bulb.)

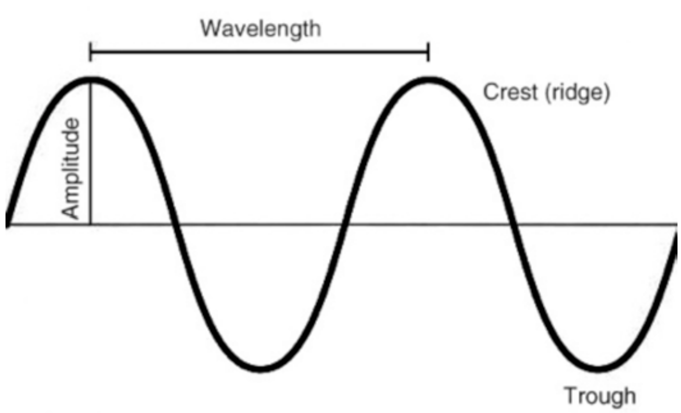


Figure 1. The wavelength of an electromagnetic wave is the distance between two crests. The amplitude is the height of a crest.

Procedure

Step 1

Put together a spectroscope and try it out in advance to make the activity much easier when going through it with students. Become familiar with the handout to help with explanations. Set up all of the light sources. Cut the foil and diffraction gratings to the correct sizes. Exact measurements are not necessary. Handle the diffraction gratings carefully with clean hands (or gloves), touching only the edges. Avoid smudges and fingerprints, which will negatively affect the function of the spectroscope.

Step 2

Ask students if they know what the word "spectroscope" means—"spectro" for *spectra* or *rainbow* and "scope" for a *viewing instrument*, as in "telescope" and "microscope." Then ask if they know what a spectrum is? Explain that it is the range of all the wavelengths of electromagnetic energy possible, from the shortest wavelengths (highest energies and frequencies) to the longest wavelengths (lowest energies and frequencies). Visible light is just a small part of the entire electromagnetic spectrum. Note that scientists often use the word "light" to refer to electromagnetic radiation in any wavelength—not just the visible range. Pass out the handout *The Electromagnetic Spectrum*. Point out the full spectrum and have a student find the small portion that is visible light. Discuss what wavelength means and how wavelength corresponds to energy and frequency.

Step 3

Distribute construction materials: paper towel tubes, aluminum foil, tape, and diffraction gratings. Explain that the diffraction gratings must only be touched on the edges because fingerprints will make the spectra produced by the gratings blurry.

Like the telescope, the spectroscope has an eyepiece end for the diffraction grating (the end that you look through) and a slit (on the opposite end) that controls the entry of light and is pointed at the object being observed.

Step 4

We recommend that you visually show and explain the directions to the group step by step. In the center of one of the 4- by 4-in. pieces of foil, tear or cut a small hole that is smaller than the square piece of diffraction grating (about the size of a nickel or dime) (Fig. 2). Place the diffraction grating over the hole and fasten the edges to the foil with the tape (remind students to only touch the edge of the diffraction grating). Do not put tape across the middle of the grating (Fig. 3).

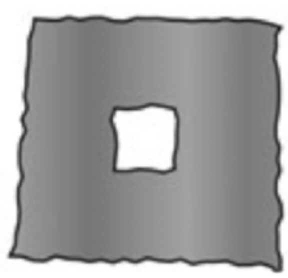


Figure 2. Hole in the center of one of the 4- by 4-in. foil pieces.

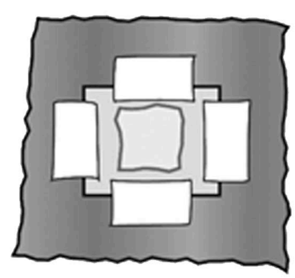


Figure 3. Diffraction grating taped over the hole in the foil square.

Step 5

Center the foil-mounted grating over one end of the tube, taped-side in (Fig. 4), press the foil around the tube so that the grating is in the center of the tube, and tape the foil to the outside of the tube (Fig. 5). Look at the room lights with the grating installed to see the effects of the grating before the spectroscope is finished.

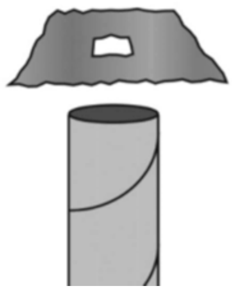


Figure 4. Placement of the diffraction grating over the end of the tube.

Figure 5. Foil wrapped around the diffraction grating end of the spectroscope. This end goes up to your eye.

Step 6

Assemble the slit end on the table. Take the other 4- by 4-in. piece of foil, and make a hole in the center as before. The diameter of the hole should be smaller than the diameter of the tube, to avoid gaps and tears.

Step 7

Carefully fold each of the two smaller strips of foil (the 1- by 3-in. pieces) in half along their lengths. Make a sharp crease at the fold of each. Lay them over the hole on the 4- by 4-in. piece of foil so that their creased edges face each other with a very small gap between them (no more than the width of a toothpick or the thickness of a coin, see Fig. 6). Tape the two creased pieces of foil in place over the hole and make sure not to cover the slit with tape (Fig. 7).

Step 8

Place the foil-mounted slit over the open end of the tube, taped side in, and wrap the foil around the end of the tube to hold it in place (Fig. 8). Do not tape the slit end to the tube. The slit allows you to select what you want to look at and to adjust the size and shape of the spectrum.

Figure 6. Placement of the pieces for the slit end of the spectroscope, with the gap about as wide as the thickness of a coin.

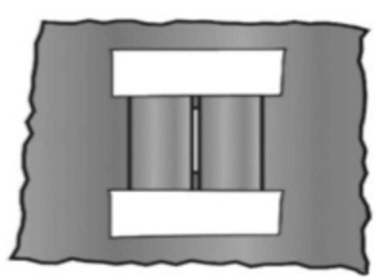


Figure 7. Construction of the slit end of the spectroscope.

Figure 8. Foiled wrapped over the slit end of the spectroscope. This end points at your light source.

Step 9

Looking through the diffraction grating end of the tube, hold and turn the foil edges of the slit end to align the slit with the diffraction grating so that there is a wide spectrum, which will be easy to see. Hold the spectroscope to look through the diffraction grating end (the plastic square should be about as close to your eye as eyeglasses or a microscope would be). Point the slit end of the spectroscope toward a light source—a light in the room or, if outside, at the sky. Do NOT look at the Sun! Look for a rainbow in the spectroscope, probably a little bit off to the side or up or down inside the tube. (The rainbow will be off-center.)

While pointing the spectroscope at the same light source and holding the tube steady, twist the slit end around until the rainbow is as “fat” or “tall” as you can make it (or twist the tube while holding the slit end steady) (Figs. 9 and 10). After you have adjusted your spectroscope, tape the sides of the foil of the slit end into position. That’s it!

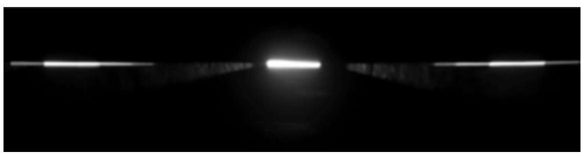


Figure 9. This smear of color is not the final state you are looking for in your spectroscope.

Figure 10. You want to see these nice orderly lines—representing a fully aligned spectroscope—before you tape the sides of the foil on the slit end.

Step 10

Have the students look through their spectroscopes at the sky, which is bright from sunlight, or for added safety, at a piece of paper that is reflecting sunlight. Ask what kind of spectrum they see. Do they have an idea of what the diffraction grating in the spectroscope is doing to the light entering it? It is separating the light into the different wavelengths (colors) that make up white light. The spectrum from white light—sunlight (or an incandescent bulb)—shows all the usual colors of the rainbow: all the wavelengths of visible light. The different colors seen inside the tube represent different wavelengths of visible light. Use ROY G BIV to help you remember the order of the colors in the visible spectrum: red, orange, yellow, green, blue, indigo, and violet.

With light sources that produce distinct bright lines, have the students look at them but do not tell them what they are looking at. If you do not have access to a gas discharge lamp, you can purchase cheap neon lights, fluorescent light bulbs and mercury bulbs for the demonstration. What differences do they notice between the Sun’s spectrum and the spectra of these artificial lights? Are all of the ROY G BIV colors present in these new spectra? Mercury fluorescent lights produce a faint continuous spectrum (like the Sun, but much dimmer) with four or five bright lines. Depending on how much your own eyes can see, one or two lines will be red, one will be green, and two will be blue-violet. These bright lines are the spectral “fingerprint” of mercury. Whenever these lines are seen at the same wavelengths, mercury is in the light source. If not seen, there is little or no mercury in that light source.

Have the students use their spectroscopes to examine light sources in their neighborhood in the evening and draw the lines of spectra. They then can go onto the Internet to look up and compare their observations with the lines of spectrum of known elements. Figures 4 and 7 show a completed spectroscope.

Step 11

Give students the *Understanding Spectroscope Data* student handout. Explain that this is how scientists use the spectroscope to identify elements.

Suggestions for Differentiation

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

Support:
Pretape the diffraction grating on the foil and preassemble the slits on the foil.

Complexity:
Have students visit the following Web site to gain a greater understanding of spectroscopy and to explore more activities using a spectroscopy.

http://imagine.gsfc.nasa.gov/science/toolbox/emspectrum1.html

Name: ____

Understanding Spectroscope Data

Identify the elements in spectra A, B, and C by comparing the bright lines present with the bright lines in the spectra for known elements. This is how scientists are able to determine what elements are present in objects that give off light. (The lines are white here but would have color when viewed with a spectroscope.)

1. Spectra A Elements: ____

2. Spectra B Elements: ____

3. Spectra C Elements: ____

Known Element Spectra

Helium

Hydrogen

Sodium

Lithium

4. If spectra A, B, and C were samples of spectroscopy data collected by a scientist of a distant planet, what could you say about the chemical composition of the planet?

____

____

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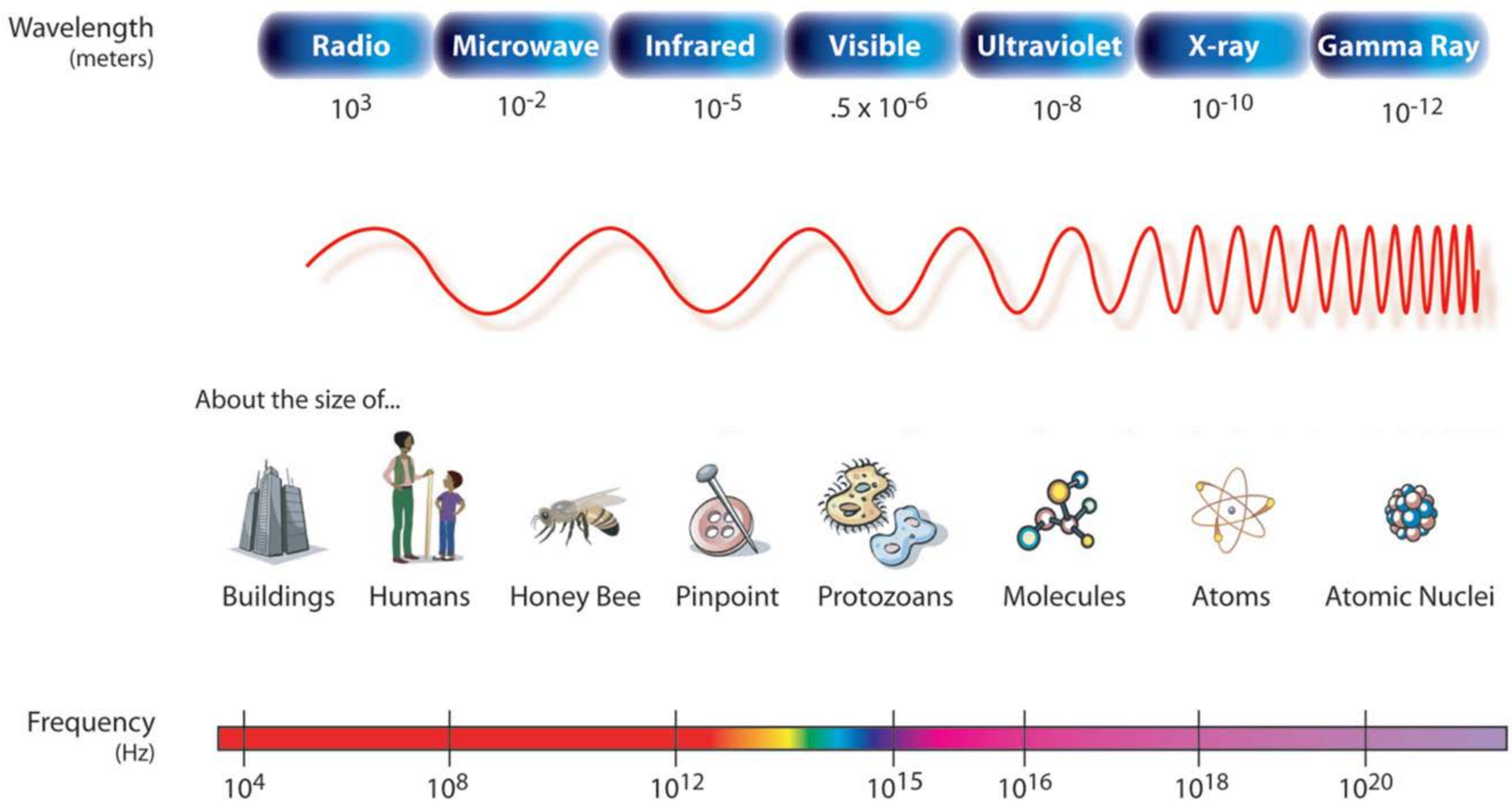
THE ELECTROMAGNETIC SPECTRUM



Invisible Light

Grades 6 to 8

INQUIRY-BASED ACTIVITY

activity

INVISIBLE LIGHT

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

About This Activity

This activity was taken from the NASA Afterschool Universe activity guide. Students experiment with different types of light at stations, which are not visible to the human eye. The different stations allow the students to experience the similarities and differences between visible, infrared (IR), and ultraviolet (UV) light. Students discover that there are types of invisible light that can be detected—but not with our eyes.

Next Generation Science Standards

MS–PS4–2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

Learning Objective

Learners will

- Explore visible and invisible light sources and detectors
- Reflect on the everyday and astronomical applications of light

Materials

- Flashlight (with batteries)
- White paper
- IR light (heat light bulb)
- Two alligator jumper clip cables (the colors don't matter)
- Photocell or solar cell
- Amplifier/speaker
- Audio cable
- Assortment of remote controls (television, VCR, radio)
- UV light source
- Digital camera (optional)
- UV reactive beads and invisible ink pens or tonic water
- Student handouts
- Pencils or pens
- Shield and transmitter materials (sheets of various materials approximately 12 by 12 in.—size not critical: clear plastic, black trash bags, cloth, cardboard, white paper, aluminum foil, wax paper, etc.)

Background

The electromagnetic (EM) spectrum is used all around us in remote controls, cell phones, microwaves, and a host of other applications. EM is made up of all the different wavelengths of radiation, which range from radio waves to gamma rays. Just as our ears can only hear certain frequencies of sound, our eyes can only see a tiny portion of the total EM spectrum: visible light (Fig. 1 and Fig. 2—handout). Some scientists use the word *light* for any wavelength of EM energy (not just visible light) and use the words *light* and *energy* interchangeably.

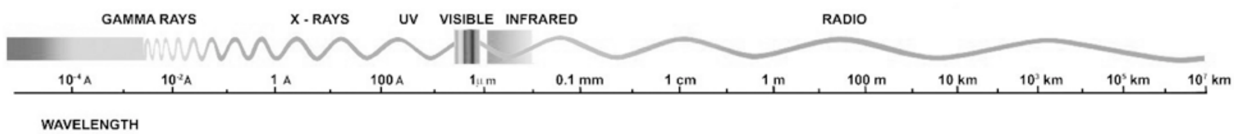


Figure 1. Full range of the electromagnetic spectrum.

Astronomical objects emit light at various wavelengths depending on their temperature. For example, the material around black holes is very hot and shines very brightly at x-ray wavelengths. Stars that are still forming are too cold to emit light at visible wavelengths, but do so at IR wavelengths. Collecting data at different wavelengths is very important in astronomy to gain a more complete picture of objects in the Universe.

The following is information related to the IR station:

In the receiver circuit, the photocell receives the IR signal from the remote and converts it to an electrical signal that is sent to the amplifier-speaker. This photocell is sensitive to light over a range of wavelengths, including visible and IR light. The photocell produces a constant electric current when exposed to light. A constant light source produces a constant current and no sound. You might hear static if anything. Speakers require a changing current to produce sound. When the light changes in brightness, the current produced by the photocell changes and the speaker produces sound. You change the brightness of the light when you move your hand back and forth in front of it, and you hear “pops” each time the light beam is blocked. (To the photocell, moving your hand across the beam is the same as turning the light off and on.)

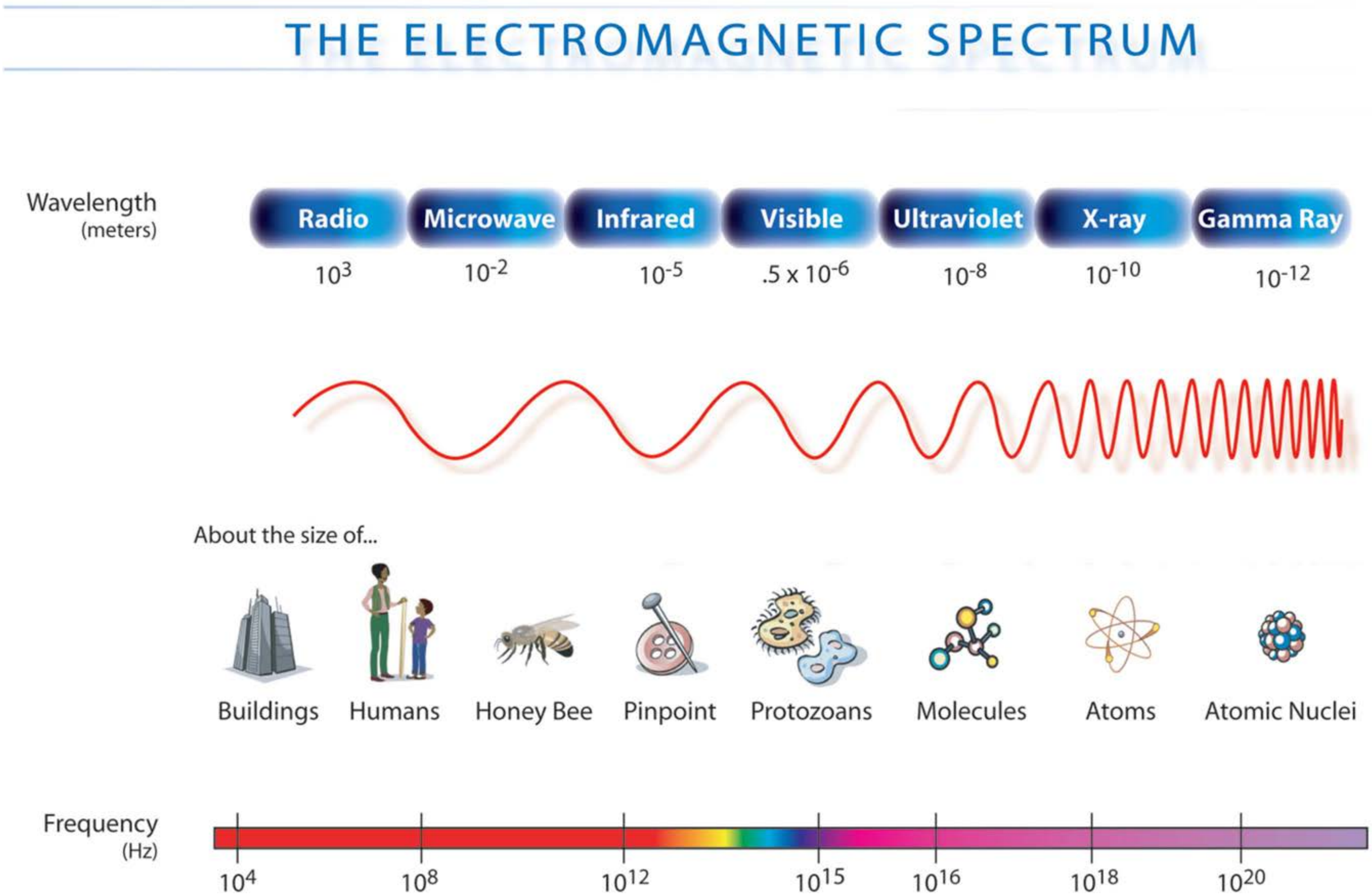


Figure 2. Wavelength size comparisons.

Procedure

Preparation Steps

Step 1

Draw the chart from the student handout on a blackboard or whiteboard so that you can record observations from your demonstration with visible light. Make copies of the *Invisible Light Tests of Possible Shielding Materials* handout for each student. Set up the four stations (as listed in the Station Materials section) at four widely separated tables with all the supplies listed under each. Label each station with its title, the electromagnetic radiation source, and the detector(s).

Station Materials

Demonstration station—Visible light

Source: Flashlight (with batteries)
Detector: Plain white paper
One set of shield and transmitter materials
Set up this station near your blackboard or whiteboard

Station 1—IR light

Source: IR light (heat light bulb)
Detector: Student's hand
One set of shield and transmitter materials
NOTE: The heat light bulb can get extremely hot, and students should handle it with care!

Station 2—IR light

Source: Remote controls
Detectors: Simple circuit or digital camera
One set of shield and transmitter materials

Station 3—UV light

Source: UV lamp or UV flashlight
Detectors: Invisible ink pen or UV beads
One set of shield and transmitter materials

Figure 3. Infrared (IR) receiver circuit.

Step 2

To make the photocell detector, you will use the jumper cable and the audio cable to connect the photocell to the amplifier/speaker.

Clip one alligator clip from a jumper cable to one of the wire leads coming from the photocell. Always clip to the exposed (wire) end of the lead. Clip the alligator clip at the other end of the jumper cable to one of the leads coming from the audio cable. (If the end is not cut, simply place one clip on a small section of the plug.)

In the same way, use a second jumper cable to connect the other lead from the photocell to the other lead of the audio cable. (If the end is not cut, simply place one clip on the large section of the plug.) Put the audio cable into the jack labeled "input." Figure 3 shows the completed circuit.

Step 3

Test the receiver. For best results, turn off any overhead fluorescent lights. They will cause the speaker to emit a constant buzz or hum, because the intensity of the light changes. Turn on the amplifier. You will hear static. (The static is noise from the detector and the amplifier as well as from the light in the room. Daylight will produce even more noise than indoor light.)

Shine a flashlight on the detector, and wave it back and forth, or “chop” the light in front of it with your hand. You should hear “pops” in the sound level now. This confirms that the photocell is reacting to the light falling on it. You have confirmed that your circuit works. Now turn off the amplifier.

Steps With Students

Step 4

Pass out *The Electromagnetic Spectrum* handout. Base yourself at the demonstration station for this discussion. Ask the students, “Why do astronomers observe the same object in space—like a star—in more than one wavelength?”

The following short fable helps to explain why:

> A group of blind men is asked to touch an elephant to learn what it is. Each one touches a different part, but only one part—the trunk, a leg, or a tail. When they compare notes, they are in complete disagreement about what they have touched: “A tree.” “A wall.” “A snake.” If they had combined all their experiences, they might have realized that they had all touched an elephant. When astronomers study the Universe, they play the parts of the blind men. They observe celestial objects in different wavelengths, and then share their information with each other. This allows them to learn much more about what they are looking at than if they had worked alone or made observations only in one wavelength.

Explain that you are going to talk about the sources and detectors of light. Shine the flashlight at the blackboard. Tell the students that the flashlight is a source of light because it produces its own light. Ask what other sources of light they can see in the room. Ask them how we know the light is there. Allow students to respond. Lead them to the answer “with our eyes.” Our eyes are detectors of visible light.

Explain that they will use transmitters and shields during this activity. Explain that materials that let light through are called *transmitters* of light, and materials that do not let light through are called light *shields*. Ask for examples of materials that let light through and materials that do not. One at a time, hold up the shield materials you have. Ask the students to predict whether the flashlight’s light will shine through them, but do not try it yet.

Have a volunteer go to the blackboard and write down the predictions for each material in that section of the table. Transmit (or partially transmit) can be recorded as “T” and shield as “S.” Then hold each material in front of the flashlight (at a distance of 3 to 4 in.), and ask what they see. Have the volunteer record the observed results in that part of the table.

Test Shield	Prediction (*T* or *S*)	Result (*T* or *S*)
List Materials Here		

Step 5

Ask the students if they can think of any sources of invisible light. They should be familiar with television remote controls. Ask if they know how a television remote “talks” to the television. Remind them to look at the handout to see the range of different types of light. Explain they will be experimenting with some types of invisible light today, and they will see how television remotes work.

Explain that they are going to see some invisible light at the three stations around the room. Each station has a source of invisible light, a detector, and a set of materials that may be shields or transmitters for the light. Point out the sources and their respective detectors and briefly explain what to do at each station.

Station 1—IR Light (heat light bulb)

Turn on the IR heat light bulb and place your hand near it. Students should just feel the heat from the bulb and ignore the small amount of visible light being emitted (the part you can see is visible light, the heat is the IR light). The skin on their hands is the detector (Fig. 4).

Infrared Light

Figure 4. Source and detector for station 1.

Station 2—IR Light (remote control)

If you are using the amplifier/speaker, turn it on. Students should shine one or more remote controls at the photocell in the simple circuit. The photocell will pick up the light and relay it to the amplifier, which converts it into sound. In this setup, the students can “hear” the IR light even though they cannot see it.

If you are using the digital camera, turn it on. Have the students point a remote control at the camera lens and push a button on the remote. They will see either a bright beam of light or flashes of light coming out of the remote control when they push a button and watch the screen of the camera. Because the camera is sensitive to IR light, it can observe the signal from the remote control, even though we cannot (Fig. 5).

Infrared Light

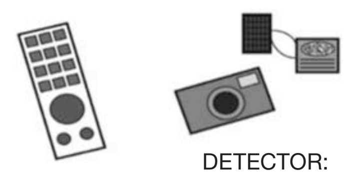


Figure 5. Source and detector for station 2.

Station 3—UV Light

If you are using the invisible ink pen, write a message on a piece of plain white paper with the invisible ink pen. Then turn on the UV light. If you hold the light over the paper, you should see the message glowing brightly. When you test various materials during the activity, you will be looking for the message to appear. If you see a message, the UV light has been transmitted through the material. If no message appears, the UV light is being shielded.

If you are using the UV beads, place the material over the beads and shine the UV light. If the beads do not change color, the material is a UV shield. If they change color, the material is a UV transmitter (Fig. 6).

Ultraviolet Light

Figure 6. Source and detector for station 3.

Step 6

Place the students in groups of two and pass out the *Invisible Light Tests of Possible Shielding Materials* student handout. Allow students time to go through each station and record their observations.

Step 7

Bring the students back together and discuss their observations.

Notice the relationship between the IR, visible, and UV light on the spectrum handout. Discuss why the UV light bulb and IR light bulb may also have had some visible "glow." This is because each source overlaps with the visible spectrum. In each light source, there is a small amount of visible light along with the invisible light that requires a special detector. Remind the students that different wavelengths of light tell us different things: Light with wavelengths shorter than those of the visible range (UV, x-rays, and gamma rays) shows us where the really hot objects are in space. Light with longer wavelengths (IR, microwave, and radio) shows us where cooler objects are in space.

Some examples follow:

- x-rays can show us where black holes are located in a galaxy.
- UV light can show us where really hot stars are located.
- IR light can show us where really cold stars and dust are located.

Suggestions for Differentiation

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

Support:
Limit the number of testable materials.

Complexity:
Have students think of other devices (e.g., radio) that use the electromagnetic spectrum, and have them devise methods for testing possible shields and transmitters with those devices.

Invisible Light Tests of Possible Shielding Materials

[*T*, transmitter or partial transmitter; *S*, shield.]

Test Shield	Light Source					
	Heat Light Bulb (infrared, IR)		Remote Control (infrared, IR)		UV Light (ultraviolet, UV)	
	Prediction (*T* or *S*)	Result (*T* or *S*)	Prediction (*T* or *S*)	Result (*T* or *S*)	Prediction (*T* or *S*)	Result (*T* or *S*)
Clear Plastic						
Black Plastic						
Aluminum Foil						
Paper						
Cloth						
Wax Paper						
Plastic Bag						
Other Material						

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