Lesson Plan: Solar & Lunar Eclipses

Background

The Earth is a planet that, together with seven other planets, forms our solar system in which all of the planets revolve around the Sun. The time that it takes for the Earth to revolve around the Sun is 365 days, or one year. The Earth also rotates around its own axis, making a complete rotation every 24 hours, or one day. The Earth has one Moon, which revolves around the Earth once every month, or approximately every 30 days. The revolution of the Moon around the Earth is not perfectly circular, but it follows an elliptical (or oval-shaped) path. When their revolutions cause the Sun, Earth and Moon to be aligned, special events called "*eclipses*" occur. A **solar eclipse** occurs when part or all of the Sun is blocked out by the Moon as viewed from the Earth (**Figure 1**). This occurs on average 1-2 times per year (see **Note 1** for solar eclipses in 2020-2021). A **total solar eclipse** occurs when the entire Sun is blocked by the Moon due to the alignment of the Sun, Earth and Moon, and a **partial solar eclipse** occurs when only part of the Sun is blocked by the Moon when it crosses the path of the light of the Sun onto Earth. Your location on Earth at the time of the eclipse determines whether you see a total or partial eclipse. An **annular solar eclipse** occurs when the Moon is at its farthest point in its elliptical path of orbit around the Earth, so it is only capable of blocking out part of the Sun, leaving the periphery of the Sun still visible.

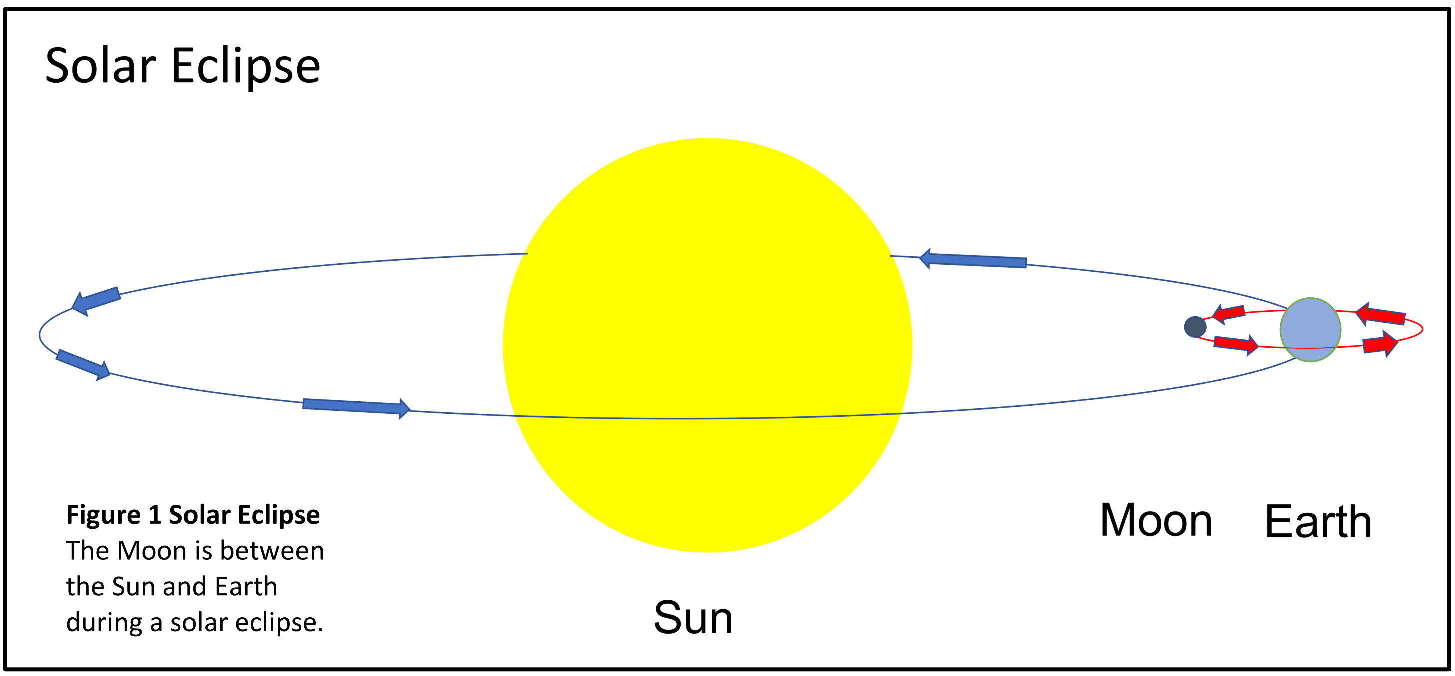


Figure 1 Solar Eclipse
The Moon is between the Sun and Earth during a solar eclipse.

A **lunar eclipse** occurs during a full Moon as the Moon passes through the Earth's shadow and sunlight on the Moon is blocked by the Earth (**Figure 2**). This differs from a solar eclipse: instead of the Moon blocking light from the Sun onto Earth, the Earth blocks light from the Sun onto the Moon, so that the Moon cannot be seen from Earth. A **penumbral lunar eclipse** occurs when the Sun, Earth and Moon are not fully aligned and the Moon passes through the shadow of the Earth, but it does not pass through the darkest part of the Earth's shadow. A **total lunar eclipse** occurs when the entire moon is in the Earth's darkest shadow. A **partial lunar eclipse** occurs when only part of the Moon is within the Earth's darkest shadow. Lunar eclipses usually occur around 2-3 times per year (see **Note 2** for lunar eclipses in 2020-2021).

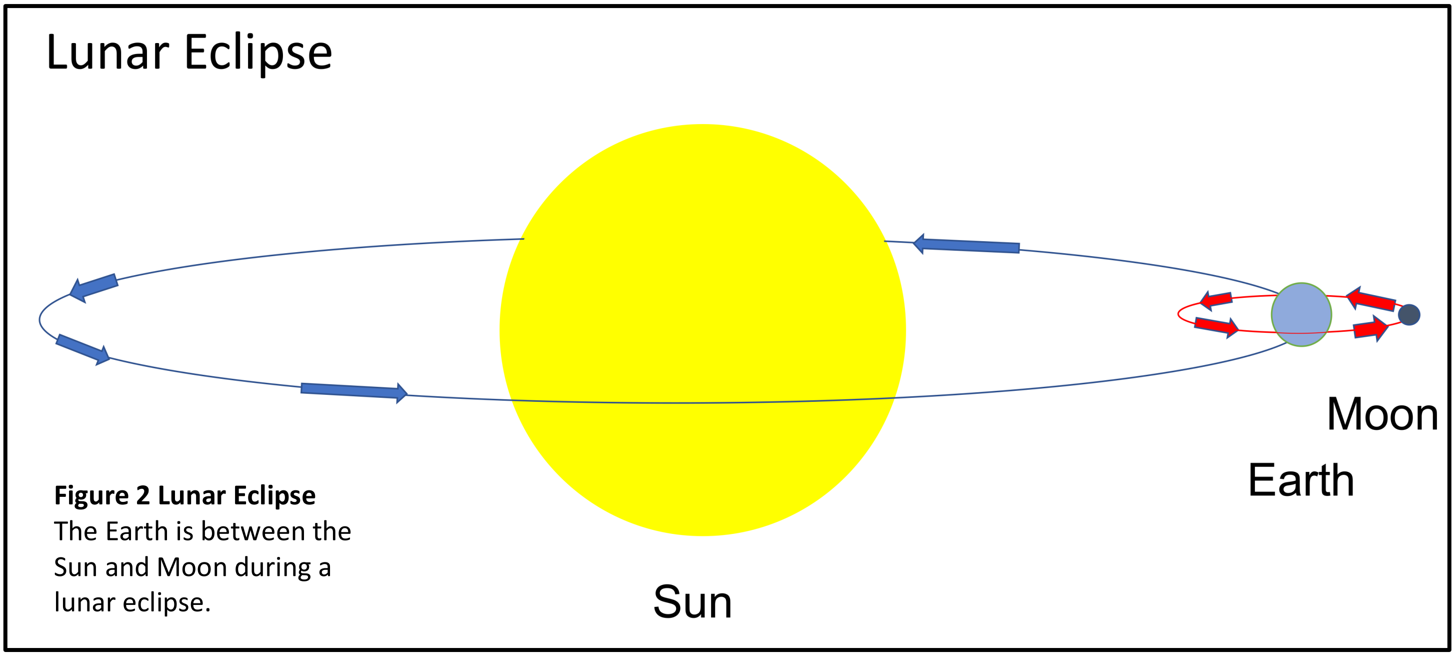


Figure 2 Lunar Eclipse
The Earth is between the Sun and Moon during a lunar eclipse.

In this lesson plan, we will model the movements of the Earth and Moon relative to the Sun during a solar and lunar eclipse. We will also make a pinhole camera to show the how light from the Sun onto the Earth is blocked by the Moon during a solar eclipse. Finally, we will demonstrate how to view a solar eclipse safely.

Objectives & Grade Level

Illustrate that the Earth revolves around the Sun and that the Moon revolves around the Earth, and show how the positions of the Sun, Earth and Moon with respect to one another can cause solar and lunar eclipses. Demonstrate how to make a safe viewer for a solar eclipse. Appropriate for middle school to first year high school science classes.

Materials

Model of the Sun, Earth and Moon

- Spheres for the Sun, Earth and Moon (e.g., 3 styrofoam spheres of different sizes; see **Note 3** for relative sizes of the Sun, Earth and Moon)
- Wood strips to support the planets (e.g., from a recycling store)
- String to suspend the planets, ~10 ft; hooks made from bent paper clips; glue
- Yard stick to measure planet diameters and distances of the planet from one another

Simulation of Solar Eclipse

- Light source – flashlight or cell phone light
- Camera (e.g., cell phone camera)

Solar Eclipse Viewer

- Cardboard box, medium size
- Small square aluminum foil, ~ 2 in x 2 in
- Pin or thumb tack, scissors, Scotch tape
- White paper, 1 sheet

Procedure

Model of the Sun, Earth and Moon

1. Design a model of the planets using wood strips as supports and string to suspend the planets, as shown below in **Figure 3** (see **Note 4)**:

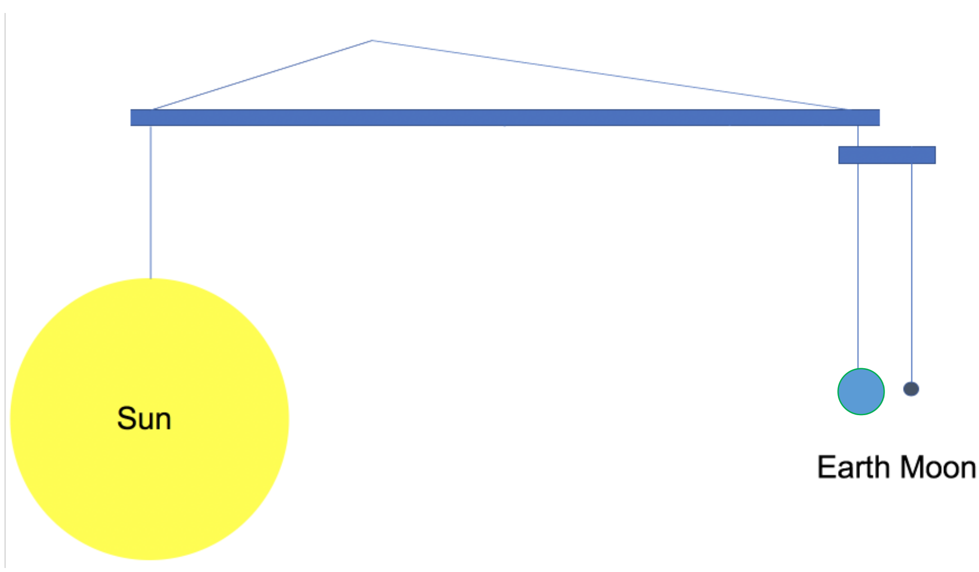


Figure 3 Model of the Sun, Earth and Moon Three spheres are suspended by string from wood strips so that the Earth and Moon can revolve around the Sun and the Moon can revolve around the Earth.

2. Assemble the model, making sure that the Earth and Moon can each revolve around the next larger sphere, as well as rotate around its own axis. If you are having problems with the assembly, you can simply position the spheres on a surface, as shown below, and move them relative to one another:

Simulation of Solar Eclipse

1. Using a small flashlight or a cell phone light, project light from the Sun onto the Earth while rotating the Moon around the Earth.
   At which position of the planets does the Moon block light from the Sun onto the Earth? View the three planets from the side to see the relative configuration of the three planets. *Are the planets aligned with one another?*

   Where would you have to be standing on your model of Earth to see a total eclipse of the Sun? Where would you have to be standing to see a partial eclipse of the Sun?

2. Rotate the planets relative to one another to find the configuration in which the Earth blocks light from the Sun onto the Moon. *How does this configuration of the planets differ from that in which the Moon blocks light from the Sun onto the Earth?*

   Where would you have to be standing on your model of Earth to see a total eclipse of the Moon? Where would you have to be standing to see a partial eclipse of the Moon?

   Where would the Moon have to be relative to the Earth and Sun for you to see a penumbral lunar eclipse in which the Moon passes through the Earth's shadow but not through the darkest part of the Earth's shadow?

Solar Eclipse Viewer

Bright light from the Sun can be harmful, causing sunburns and damage to your skin. Your eyes are much more sensitive to bright sunlight than your skin and, because of this, it is not safe to look directly into the Sun even for a short time without protecting your eyes from damage by the Sun. This makes viewing a solar eclipse problematic, as you will want to look at the Sun to see when the Moon blocks the light from the Sun. However, it is possible to view a solar eclipse safely with a special Solar Eclipse Viewer. This viewer can be easily made from a cardboard box and aluminum foil so that you can watch the Moon passing between the Sun and Earth during the solar eclipse without looking directly at the Sun and hurting your eyes.

To make a Solar Eclipse Viewer (**Figure 4A**), follow the steps below:

1. Take a medium-sized cardboard box and cut two small eye-sized holes of ~½ inch diameter in one end of the box, positioning the holes so that you can look through a hole with one eye and a friend can look through the other hole at the same time. *Be careful not to hurt your hand with the scissors! If you have trouble with this step, ask a parent or your teacher to help you make the holes.*

2. Cut a ¾ inch by ¾ inch square in the same end of the box.

3. Cover the hole with small square of aluminum foil of approximately 2 inches by 2 inches, taping the edges to the box. Poke a small hole in the aluminum foil with a pin or thumb tack. *Be careful not to poke your finger!*

4. Tape white paper onto the inside of the box on the side opposite to the eye holes. You should be able to see an image of the eclipse on the white paper at the back of the box when you stand with your back to the Sun and look into the Solar Eclipse Viewer through one of the eye holes and the light enters the pinhole (**Figure 4B**). Another way of viewing an eclipse safely is to look at the sidewalk under a leafy tree: the small gaps between the leaves act like the pinhole in the Solar Eclipse Viewer so that sunlight passing through the leaves will produce many images of the Moon passing in front of the Sun (**Figure 4C**). A pinhole camera without an enclosed box can also be used to project images of a solar eclipse onto a sheet of white paper (**Figure 4D**).

5. Test your viewer by asking a friend to shine a flashlight or light from a cell phone onto the pin hole while you and another friend look through the eye holes at the white paper (or you can block the other eye hole with the inside flap of the cardboard box).

   What do you see?

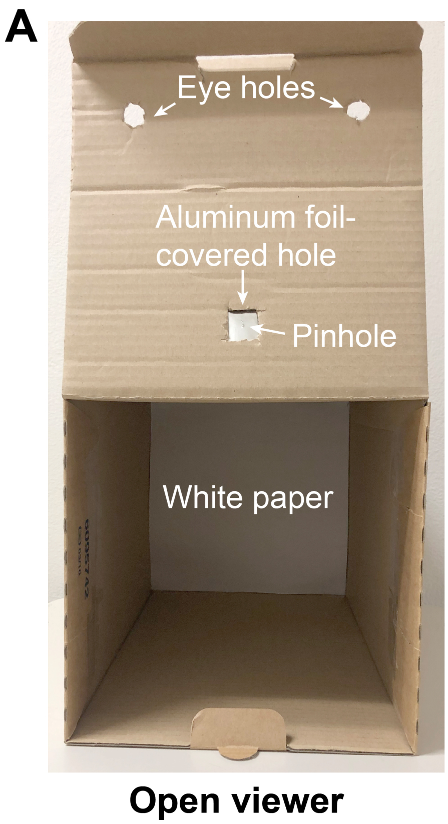
   Now ask your friend with the light to hold the Moon from your model of the Sun, Earth and Moon between the light and you so that the light is partially or completely blocked. This simulates the peak of a solar eclipse.

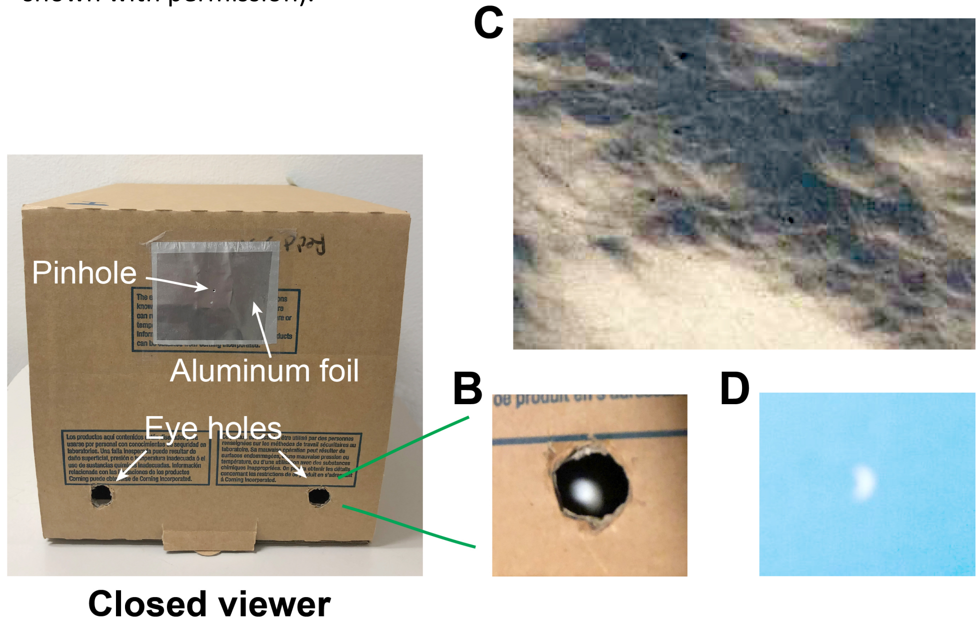
   *What do you see when you look at the white paper at the back of the box through the eye hole? See **Figure 4B** for an example of what you might see.*

   Finally, ask your friend to hold the light and move the Moon through the light path, while you and another friend look into the viewer. This simulates the movement of the Moon during a solar eclipse.

   Can you see the partial silhouette of the Moon as it passes in front of the light and then forms a mirror image silhouette on the other side of the light?

Figure 4 Solar Eclipse Viewer A) Eclipse viewer made from a cardboard box (8½ in^2 opening). Sunlight through the pinhole forms an image on the paper in the box which is viewed through the eye holes. **B**) Solar eclipse simulated by shining a bright light onto a planet representing the Moon; the light enters through the pinhole and is viewed through an eye hole. **C**) Solar eclipse viewed through leaves of a tree or **D**) by projecting the image from a pinhole camera onto a sheet of paper without a box (photos in **C** and **D** by S. Han & L. Fee, shown with permission).





Notes

1. Solar Eclipse Dates (see https://www.timeanddate.com/eclipse/list.html)

Solar Eclipse	Date	Location
Annular Eclipse	June 21, 2020	Africa (Central African Republic, Congo, Ethiopia), Pakistan, India, China
Total Eclipse	Dec 14, 2020	South America (Chile, Argentina), Pacific Ocean, Atlantic Ocean
Annular Eclipse	June 10, 2021	Russia, Greenland, Canada
Total Eclipse	Dec 4, 2021	Antarctica

2. Lunar Eclipse Dates (see https://www.timeanddate.com/eclipse/list.html)

Lunar Eclipse	Date	Location
Penumbral Eclipse	June 5, 2020	Asia, Australia, Europe, Africa
Penumbral Eclipse	July 5, 2020	North America, South America, Africa
Penumbral Eclipse	Nov 30, 2020	North America, South America, Australia, Asia
Total Eclipse	May 26, 2021	Australia, North America, South America, Asia

3. Relative Sizes and Distances of the Sun, Earth and Moon

Planet	Diameter (*D*)	*D*, Relative to Moon *D*
Moon	3,476 *km*	1
Earth	12,756 *km*	~3.5
Sun	1,392,000 *km*	~400

	Distance (*d*)	*d*, Relative to Moon *D*
Earth to Moon	384,000 *km*	~110
Earth to Sun	150,000,000 *km*	~43,000

4. We used a 3D printer to make spheres representing the Sun, Earth and Moon with diameters of 175 mm, 57 mm and 15 mm. The Sun is smaller by ~10-fold relative to the Earth and Moon because of the maximum size the 3D printer could print; however, the Earth and Moon are scaled to their actual sizes relative to one another. The STL file that we used to 3D print the planets is available with this lesson plan. The 3D printed planets were made on a Ultimaker 2+ 3D printer with PLA filament, printing at 210°C extruder temperature, 70°C bed temperature, 5% infill, 0.4 mm wall thickness and 0.2 mm layer height. The STL file was imported three times; the sizing was changed each time and the planets were printed to the sizes given above.

5. Our model of the Sun, Earth and Moon during a solar and lunar eclipse is shown below:

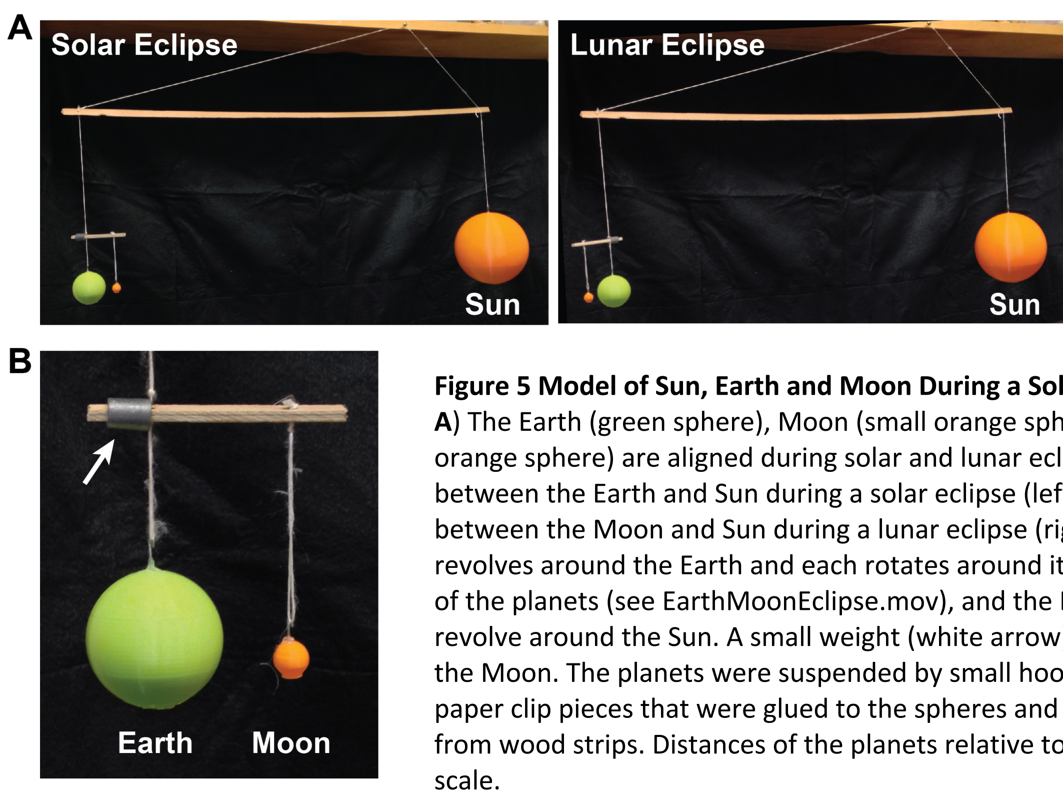


Figure 5 Model of Sun, Earth and Moon During a Solar and Lunar Eclipse
A) The Earth (green sphere), Moon (small orange sphere) and Sun (large orange sphere) are aligned during solar and lunar eclipses. The Moon is between the Earth and Sun during a solar eclipse (left), and the Earth is between the Moon and Sun during a lunar eclipse (right). **B**) The Moon revolves around the Earth and each rotates around its own axis in our model of the planets (see EarthMoonEclipse.mov), and the Earth with the Moon can revolve around the Sun. A small weight (white arrow) provides balance for the Moon. The planets were suspended by small hooks made from bent paper clip pieces that were glued to the spheres and suspended by string from wood strips. Distances of the planets relative to one another are not to scale.

Accompanying Files

3DPlanets.stl	STL file for 3D printing planets
EarthMoonEclipse.mov	Movie showing model of Earth rotating as the Moon revolves around the Earth

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