Hands On Astronomy

Arkansas Leadership Workshop
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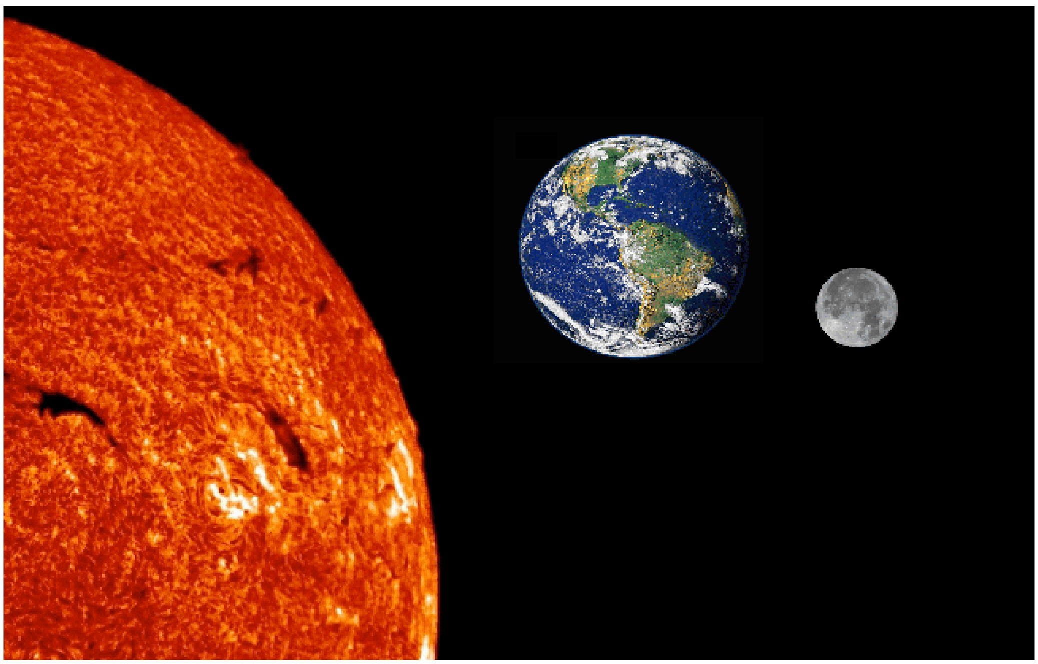
Linda S. Shore
lindas@exploratorium.edu



Astronomy Activities and Connections to the Arkansas Curriculum Framework

Contents

A "Handy" Measuring Tool

Learn how to use your hands to measure the size to distance ratio of a familiar astronomical object-- the Moon.

Materials Needed

- your hand
- your arm
- meter sticks
- a partner

What To Do:

Using Your "Handy Tool" To Find The Distance To Your Partner

- To start, use the meter stick to measure the height of your partner's head. Measure from their chin to the top of their head. Save this measurement -- you'll need it later.

- Make a fist. You will use the *width of your fist* as a unit of measure. Carefully measure the length of your arm (from wrist to the top of your shoulder) in "fists." Write down this number -- for example, the arm measured in Figure 1 is "6 fists" long (see **Figure 1**).

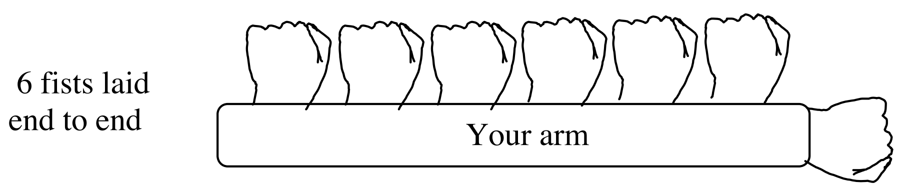


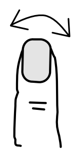
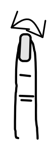
Figure 1

- Extend your arm straight out in front of you and make a fist. Close one eye and look at your fist, extended at arms length. Move your partner away from you until your closed fist just barely covers their head. Believe it or not, you now have enough information to estimate how far away your partner is standing from you.

- Let's say that your arm is 6 fists long. That means that anything you can barely cover with your closed fist is 6 times further away than it is high. So, in this example, your partner's head would also be 6 times further away than it is high.

- Using the height of your partner's head (measured earlier) and the length of your arm in fists, estimate how far your partner is away from you. Check your answer with the meter stick.

- Below is a table of other "handy measuring tools" and the distance to size ratios for each. For example, anything you can just cover with the tip of your outstretched thumb will be 30 x farther away from you than it is big.

Part Of Hand To Compare …	Sketch	Distance to size ratio	Angular Degrees (approximate)
Outstretched Thumb & Pinkie		3:1	20°
Clenched Fist		6:1	10°
Thumb		30:1	2°
Pinkie		60:1	1°

<u>Using Your "Handy Tool" To Find The Distance To The Moon</u>

- Look at a calendar and find a night when the Moon will be full. (During this phase, the Moon will rise at sunset and set at sunrise.) Before going outside to look at the full moon, make the following guess -- what part of your hand (extended at arm's length) will you need to hold out in front of you to just barely cover the full moon? Your fist? Your thumb? Your pinkie? Less than a pinkie? More than your clenched fist?

- Find the full moon and check your prediction. *Were you surprised that the full moon appeared smaller than any of your fingers?*

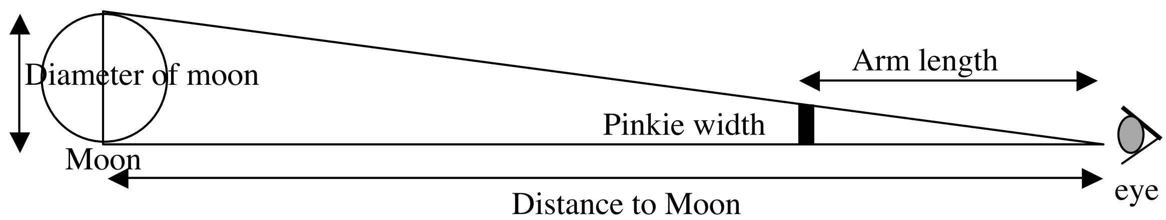
- As best you can, estimate the apparent size of the full moon in "pinkie nail widths." For most people, the full moon is about 1/2 pinkie nail widths in apparent size.

- The Moon is about 2000 miles in diameter. Let's say that the moon looked like it was about 1/2 pinkie nail width in apparent size. Anything you can just barely cover with the tip of your entire pinkie is 60 times farther away than its diameter. Since the moon appeared to be only 1/2 pinkie in size, this means that the moon is 120 times further away than it is big. In other words, the moon is *120 X 2000 miles = 240,000 miles away from the Earth.*

What's Going On?
These activities make use of similar triangles and linear proportion. When you extend your arm and clench your fist, you are forming a triangle. The base of this triangle if your arm and the

height is your clenched fist. When you use your fist to cover a distant object, you are essentially forming another triangle -- its base is the distance between your eye and the object and the height is the height of the object itself. These two triangles are ***similar triangles*** . This is because the angles making up one triangle are the same as the angles making up the other triangle (**Figure 2**).

Figure 2



When two triangles are similar, the lengths of their sides are proportional. Mathematically, this is written as:

$$\frac{\text{Height (triangle A)}}{\text{Base (triangle A)}} = \frac{\text{Height (triangle B)}}{\text{Base (triangle B)}}$$

Let's apply this relationship to the Moon problem. In this example, triangle A is the triangle formed by half your pinkie nail (height A) your arm (base A). Triangle B is the triangle formed by the actual diameter of the Moon (height B) and its distance away from your eye (base B). Rewriting the relationship above, we have

$$\frac{\text{half pinkie width}}{\text{arm length}} = \frac{\text{diameter of the moon}}{\text{distance to the moon}}$$

In this example, we know three of the parameters -- the half pinkie nail width, arm length, and diameter of the moon. The fourth parameter (distance to the moon) is the variable we solve for.

Earth And Moon

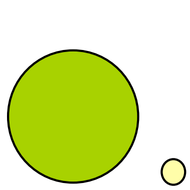
How large is the moon compared to the earth? What is the distance between the earth and moon? The answers might surprise you.

Materials Needed

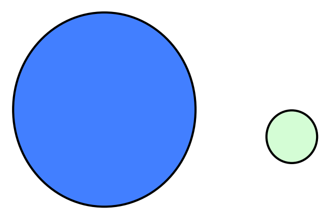
- an assortment of spherical objects (e.g. golf balls, tennis balls, basketballs, baseballs, racket balls, small marbles, larger marbles, etc.)
- rulers, tape measures, and meter sticks
- thin string
- modeling clay or double stick tape

Preparation:

- To start, you'll need to assemble a box of assorted balls. These can be purchased cheaply at large toy stores, warehouse type stores, and even some large chain convenience stores. *It is very important to purchase some combinations where one sphere is 4x the diameter of another sphere.* For example, the following sets of objects have this 4:1 ratio:



Tennis Ball & Small Marble



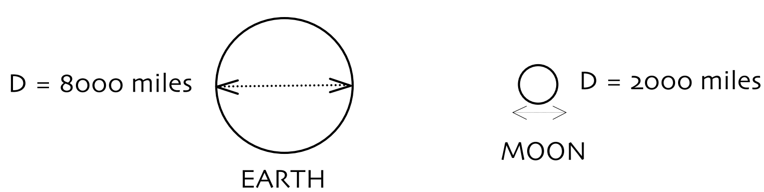
Plastic Toy Ball & Large Marble

What To Do:

Size of the Earth and Moon

- Have students work in pairs. Tell the students that they are going to be making a scale model of the earth and moon using the balls you are providing. Each pair selects the two spheres that they *believe* are closest to being the right relative sizes. *Reassure the students that they are making educated guesses*. Once the students have made their selections, ask each pair to take a moment to describe why they made the choices they made.

- Now tell students what the "correct" answer is. The diameter of the earth is about 8000 miles (12,800 km). The diameter of the moon is about 2000 miles (3,200 km). Did the students make the right choice? They will need to make measurements to determine how close they are. If they did not get the right pair of spheres, they can return to the box of balls you provided and pick another set of objects.



Have each pair of students to use the measuring devices available to them to determine which sets of balls have diameters with a 4:1 ratio. There are many ways to go about this, and students should be encouraged use whatever technique (or multiple techniques) they wish to use to find the right balls to represent the earth and moon. Here are ways that the students might try…

1. **Measuring Circumference:**
   Let's consider the equation that describes the circumference of a sphere:

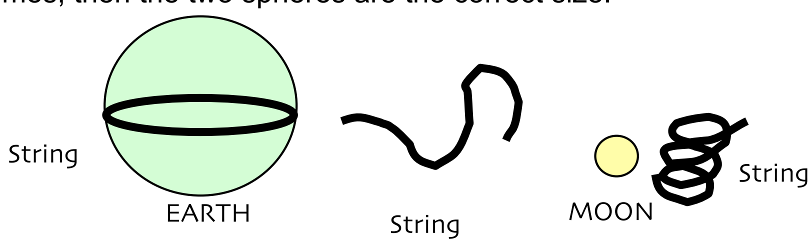
$$\text{Circumference (C)} = 2 \times p \times \text{radius} = p \times \text{diameter (D)}$$
$$C = pD$$

$$\frac{C\ \text{earth}}{C\ \text{moon}} = \frac{pD\ \text{earth}}{pD\ \text{moon}}$$

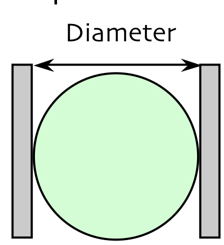
$$\frac{C\ \text{earth}}{C\ \text{moon}} = \frac{4 \times D\ \text{moon}}{D\ \text{moon}}$$

$$\boxed{C\ \text{earth} = 4 \times C\ \text{moon}}$$

   So, if the earth's diameter is 4 times larger than the moon's diameter, then the earth's circumference will also be 4 times larger than the moon's. Students can use the string to measure the circumference of the earth by wrapping it around the girth of the ball representing our planet. If this same length of string wraps around the ball representing the moon four times, then the two spheres are the correct size.

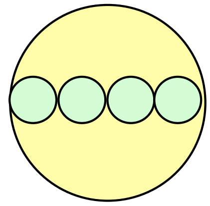


2. **Measuring Diameter:**
   Measuring the diameter of a sphere is not as easy as it seems. Be careful – many students will think that the diameter is measured directly along the circumference of the sphere and not through the sphere's center. To measure the diameter of the balls, students should use the "caliper" method and pinch each of the spheres between two parallel surfaces. The distance between the parallel surfaces will give students the diameter of the spheres. Books or pieces of stiff cardboard work well for the "calipers."

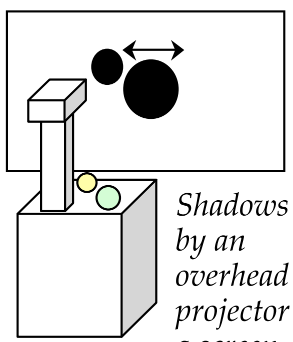


3. **Lining Up Moons:**
   If the earth has a diameter that is 4 times larger than the moon's then 4 moons laid "end to end" will equal the diameter of the earth. Students may want to check the accuracy

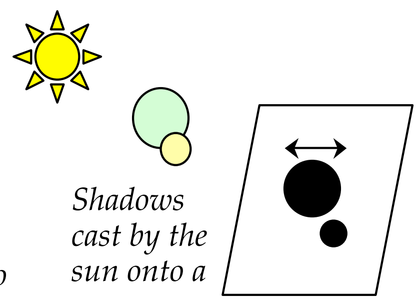
of their scale model by lining up 4identical moon models “end to end” and comparing the total length of this lunar line up to the diameter of their earth model.



4. **Using Shadows:**
Here’s a clever way to do the “line up” method described above. Sometimes students have trouble judging whether the 4 moon models laid “end to end” equals the diameter of the sphere representing the earth. That’s because the objects are three dimensional it is hard for many people to concentrate on just two dimensions at a time. Closing one eye to confound your perception of depth sometimes helps, and students should be strongly encouraged to try this. But another way to eliminate one of the dimensions is to examine shadows cast by the moon and earth models. You can cast shadows of the spheres by taking the models outside and using the sun as a light source. You can also place objects representing the earth and moon on an overhead projector and examine the shadows that will be cast on a screen. By measuring the diameter of the shadows, you can also determine whether you have the correct scale models.



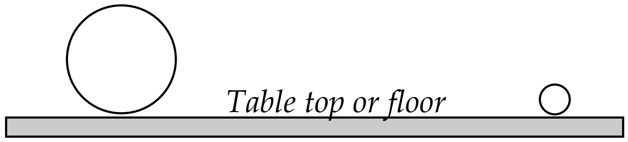
Shadows cast by an overhead projector onto a screen



Shadows cast by the sun onto a screen

Distance between the Earth and Moon

- Now that the students have found objects that represent the earth and moon at the proper scaled size, it’s time for the students to *guess* at how far apart the two spheres should be to represent the distance between the earth and the moon. *Again, remind the students that they are making an educated guess*. Have the students place the two spheres on the floor (or on a flat table top) and use a small piece of clay (or double-stick) tape to keep the balls from rolling away.



Example of a student guess at the distance between the earth and moon models.

- Now tell the students what the correct answer is. The distance between the earth and moon is 240,000 miles (385,000 km). Since the earth's diameter is 8000 miles, then 240,000 miles ÷ 8000 miles = 30 . That means that 30 earth models laid "end to end" will give you the scaled distance between the earth and the moon models. Have students determine the diameter of their earth model and use meter sticks or tape measures to figure out how far away the moon model should be placed from the earth model.

  (Students can measure the diameter of the earth model using one of the techniques described in the first section. Then they can multiply the diameter by 30 to get the distance between the earth and the moon models.)

- Have students examine the distance between the earth and moon models. Are they surprised at how far apart the two objects are?

What's Going On?
Most people are very surprised when they see the scaled size and distance between the earth and the moon. Studies of the astronomy misconceptions held by students (and even adults!) reveal that most people believe that the moon is much larger and closer to the earth than it actually is. In fact, in a survey of thousands of US high school and college level students who had successfully completed an astronomy course, about 65% believed that the earth and moon were six earth diameters apart or less (the study was conducted by the Harvard Smithsonian Center for Astrophysics in 1989).

Why is this misconception so prevalent in students who have successfully completed astronomy courses where the "right" answer was covered in the curriculum? The answer lies in the diagrams found in most high school and college level texts. Most astronomy books fail to show the correct size and scale of the earth and moon. In fact, the majority of these books show the earth and moon as being less than 6 earth diameters apart – exactly what most students believe!

The power that text illustrations have in propagating misconceptions can not be underestimated. That is why it is important for students to articulate their beliefs about the size and scale of the moon and have experiences like this one that directly challenge their beliefs.

Size of the Earth and Moon

Diameter ~ 8000 miles

Diameter ~ 2000 miles

Distance between the Earth and Moon

Distance ~ 240,000 miles

"It's Only A Playdough™ Moon . . . "

How many moons could fit into the earth's volume? With modeling clay , your students can learn something about the size of the moon while learning something about volumes at the same time!

Materials:	two small cans of Playdough™
plastic knives
a tape measure.

What To Do:

1. Have each pair of students open one of the cans of Playdough™ and roll the entire volume of clay into a ball. This ball of clay will represent the earth (**Figure 1**).

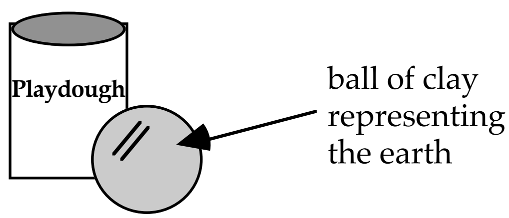


Figure 1

2. Now tell the students that they are going to use the clay in the remaining can to create the moon. Their moon needs to be the correct scale size. Remind the students that the circumference of the earth is about 24,000 miles (40,000 kilometers) while the circumference of the moon is about 6000 miles (10,000 kilometers). In other words, the earth's circumference is four times larger than the moon's. Have the students guess how much clay they will need to make a moon that is the correct scale size—half the can, a quarter of the can, an eighth of the can, 1/16th of the can, or something even smaller?

3. Based on their guesses, have the students use their plastic knives to divide the clay in the second can. For instance, if they believe that the moon will be a *quarter* the earth's volume, then they should cut the Playdough™ into *four* equal parts and roll one of the parts into a ball to represent the moon (**Figure 2**).

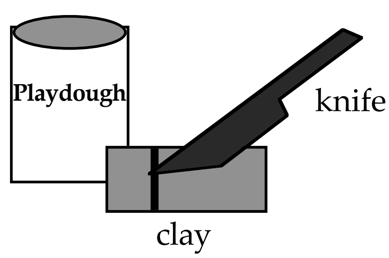


Figure 2

4. Now students should have two clay balls—one representing the earth (from the full can of clay) and the other representing their guess as to how large the moon should be (from the second can of clay). Using their tape measures, have the students measure the circumference of their earth and moon models. Is the earth's circumference about four times larger than the moon's?

5. The earth is actually 64 times larger in volume than the moon! How many students got it right? Have students try again. Take all the clay from the second can and combine it into a single lump of clay. Now divide the clay into 64 roughly equal parts. Take one of these small pieces and roll it into a ball representing the moon. Is this moon model a quarter of the circumference of the earth model? It should be pretty close. Are your students surprised?

What's Going On?

Your students may not correctly guess how much clay they needed to make a moon model to scale. That's because few students understand how volumes of spheres scale up or scale down. Many of your students may have believed that if the earth's circumference is four times larger than the moon's circumference, than the volume of the earth must also be four times greater—a commonly held misconception.

Let's do some simple mathematics. If the earth's circumference ($C_{(earth)}$) is 4 times larger than the moon's circumference ($C_{(moon)}$), then:

$$C_{(earth)} = 4\ C_{(moon)}$$

But the circumference of a sphere is equal to 2πR, where R is the radius. So

$$2\pi R_{(earth)} = 4\ [2\pi R_{(moon)}]$$
$$R_{(earth)} = 4R_{(moon)}$$

So the radius of the earth is 4 times larger than the moon's radius. What does that do to the volumes? The volume of the earth is equal to

$$V_{(earth)} = 4/3\ \pi\ R_{(earth)}^3.$$

Since the earth's radius is equal to 4 times the moon's radius, then

$$V_{(earth)} = 4/3\ \pi\ [4R_{(moon)}]^3$$
$$V_{(earth)} = 64\ \{4/3\ \pi\ [R_{(moon)}]^3\}$$

or

$$\boxed{V_{(earth)} = 64\ V_{(moon)}}$$

Hole Punch Earth

Create a scale model of the earth and sun using a hole punch as the Earth! Thanks to Coral Clark, who shared this idea with us.

Materials: (per pair)
- a hole punch circle (what you normally discard when you use a hole punch)
- metric ruler or meter stick
- large square of butcher paper (about 1 meter x 1 meter)
- 1 pair of scissors
- about 50 cm string
- 2 pencils
- calculator

To Do and Notice:
Provide students with the following information:

Earth's Diameter = 12,756 km
Sun's Diameter = 1,392,000 km
Earth Distance To The Sun = 149,600,000 km

Give each pair of students a hole punch circle, explaining that it represents the planet earth. Students measure the diameter of the circle. Students find the correct scaling factor or set up a proportion to determine the diameter of the sun. For example, if the hole punch has a diameter of 1 cm, the following would be a way to find the scaling factor:

$$\frac{1 \text{ cm}}{12{,}756 \text{ km}} = \frac{1 \text{ cm}}{12{,}756 \text{ km}} \cdot \frac{1 \text{ km}}{100{,}000 \text{ cm}} = \frac{1}{1{,}275{,}600{,}000}$$

This scaling factor (which has no units) can be multiplied by the actual diameter of the sun to find the size of the scaled down version.
To set this up as a proportion, we can compare the two size/distance ratios and solve for the unknown diameter of the scaled down sun, *x*:

$$\frac{1 \text{ cm } \textit{(scaled dia. of earth)}}{x \text{ cm } \textit{(scaled dia. of sun)}} = \frac{12{,}756 \text{ km } \textit{(diameter of earth)}}{1{,}392{,}000 \text{ km } \textit{(diameter of sun)}}$$

Once the students have found the scaled down sun's diameter, they can draw it on the butcher paper. Show them how to use two pencils and string as a giant compass. Remind students of the definitions of radius and diameter. Students cut out their suns, which should be about 100 times the diameter of their hole punch earth. If you have the time and space (large outdoor area), have students then determine the correct scaled distance between the earth and sun. After they have made their calculations, they can measure or pace the distance outside.

What's Going On?
The sun is much larger and farther away than most people realize. The sun is about 100 earth diameters across and about 100 sun diameters away from earth. If the hole punch "earth" is .7 cm in diameter, then the correctly scaled sun should be about 70 cm in diameter. The correct distance for this particular earth/sun model would be about 70 meters!

Earth's Diameter:
12,756 km

Sun's Diameter:
1,392,000 km

Earth - Sun Distance
149,600,000 km

Toilet Paper Solar System

An unforgettable way to learn about the size and scale of the nine planets in our solar system

Materials: A roll of toilet paper (the cheap, less absorbent kind is best!)
A pen
A very large area (school yard) you can use to roll out the toilet paper.

What To Do:

(1) Using the roll of toilet paper, we will be constructing a scale model of the solar system. *In this model, one square of toilet paper equals 1,000,000 kilometers.*

(2) On the first square of toilet paper, draw the Sun. *Note that the sun has a diameter of about 1,400,000 kilometers.*

(3) Using the table below as your guide, roll out the toilet paper and mark the position of each of the nine planets and the asteroid belt. If you can, try to draw the planets to scale as well.

Name of Object	**Diameter (x 1000km)**	**Diameter (toilet paper squares)**	*Mean Distance To Sun (x 10^6 km)*	*TP Distance (# squares)*
The Sun	1400	1.4	***	***
Mercury	4.8	0.0048	58	58
Venus	12.1	0.0121	108	108
Earth	12.8	0.0121	150	150
Mars	6.8	0.0068	228	228
Asteroid Belt	***	***	(330 - 500)*	(330 - 500)*
Jupiter	144	0.144	778	778
Saturn	120	0.120	1427	1427
Uranus	51	0.051	2870	2870
Neptune	49	0.049	4497	4497
Pluto	2.3	0.0023	5900	5900

* distances of objects orbiting in the asteroid belt

What's Going On?

Were you able to fit the entire solar system on a roll of toilet paper? You might discover that the typical roll of toilet paper runs out somewhere after Saturn.

What Else Can I Do?

Select a scale so that the toilet paper rolls actually display the entire solar system.

SCALE MODEL OF THE SOLAR SYSTEM

The distance to the nine planets compared to the diameter of the sun.

Mercury = 43 solar diameters

Venus = 79 solar diameters

Earth = 110 solar diameters

Mars = 167 solar diameters

Jupiter = 572 solar diameters

Saturn = 1048 solar diameters

Uranus = 2111 solar diameters

Neptune = 3300 solar diameters

Pluto = 4348 solar diameters

Proxima Centauri (nearest star to sun) = 29,780,000 solar diameters
(If the sun were a 1 inch marble, then this star would be about 470 miles away.)

SIZE OF THE PLANETS IN OUR SOLAR SYSTEM

The size of the nine planets compared to the diameter of the sun.

If the Sun were the size of a 9-foot sphere . . . then

Mercury = 2/5th inch

Venus = 9/10th inch

Earth = 1 inch

Mars = 1/2 inches

Jupiter = 11 inches

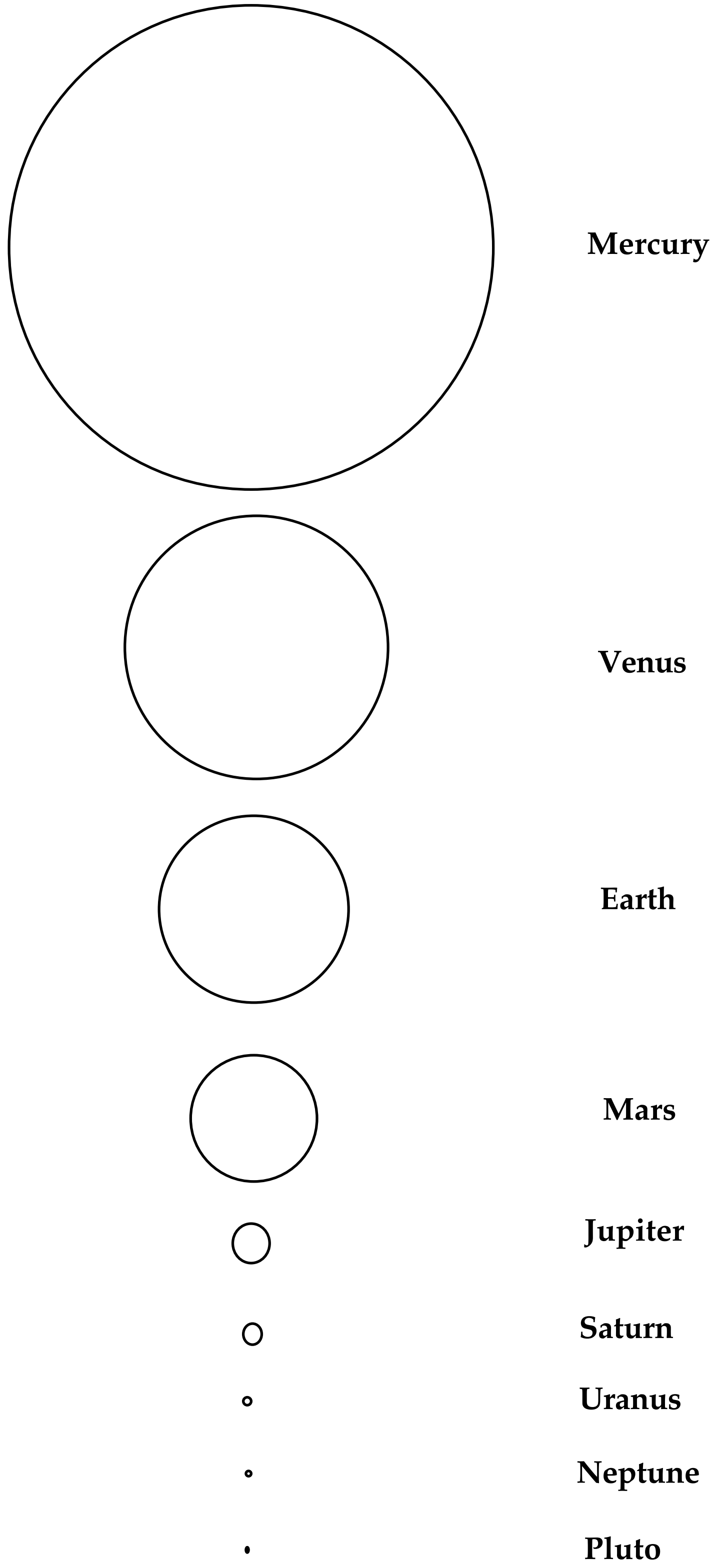
Saturn = 9 1/2 inches

Uranus = 4 inches

Neptune = 4 inches

Pluto = 1/5th inch

The Apparent Size of the Sun as Seen from the Nine Planets



Hold this page about 9 feet away from you.

Phases of the Moon

“First you wax your car, then it wains.” Tien Huynh-Dinh

Materials
A Styrofoam ball, 5 cm in diameter or larger.
Pushpin
A lamp with an unfrosted bulb

Assembly
Push the pushpin into the Styrofoam ball.

To Do and Notice
Turn on the lamp. Darken the room. Hold the Styrofoam ball by its pushpin just to the left side of the line between you and the lamp. Notice that you see an illuminated crescent moon. This is the waxing crescent.

Continue moving the moon around you to the left, counterclockwise viewed from above your head. When it is 90 degrees from the line between you and the lamp notice that half of the moon is illuminated. This is the first quarter moon.

Rotate counterclockwise more. When the moon is opposite the sun it comes within the shadow of your head, this would be a total lunar eclipse. Most months however the moon passes above or below the shadow of the earth and is seen fully illuminated as a full moon.

Continue rotating. The moon begins to wain, it becomes half illuminated again at third quarter. Then becomes a crescent.

When you reach the line between your eye and the lamp look around at other people, notice that the shadow of the moon falls on their faces. This is a total solar eclipse. Usually the shadow of the moon falls above or below the earth and there is a new moon without an eclipse.

What's Going On?
Many people think that the moon's phases are caused by the earth’s shadow. Emphasize the difference between the night side of the moon (the phases), and the shadow *of the earth on the moon* that causes a lunar eclipse.

Etc.
The moon and the sun subtend 1/2° each. The exact match in angular size leads to spectacular solar eclipses. The moon's orbit tilts at an angle of 5° with respect to the plane of the ecliptic, the plane of the earth's orbit about the sun. This means that most of the time the moon passes above or below the sun in the sky.

Orbits of the Planets

How can you draw an ellipse? And how can you draw an ellipse representing the orbits of the planets? This activity will help you find out.

Materials Needed (for every student)

- pushpins
- thread or thin string
- paper
- ruler
- pencil or pen
- Styrofoam board or thick cardboard

Background

What is an ellipse? *An ellipse is a curve for which the sum of the distances from any point along the curve to each foci inside the ellipse are always equal*. **Figure 1** below shows the geometry of an ellipse. Note that ellipses have two *foci*, a *semi-major axis* (a), and a *major axis* (2a). The *eccentricity* (e) of an ellipse is the ratio of the distance between the two foci and the length of the major axis.

e = (Distance between the foci)/(Length of the major axis)

We will use this information to investigate the eccentricity (e) of different kinds of ellipses.

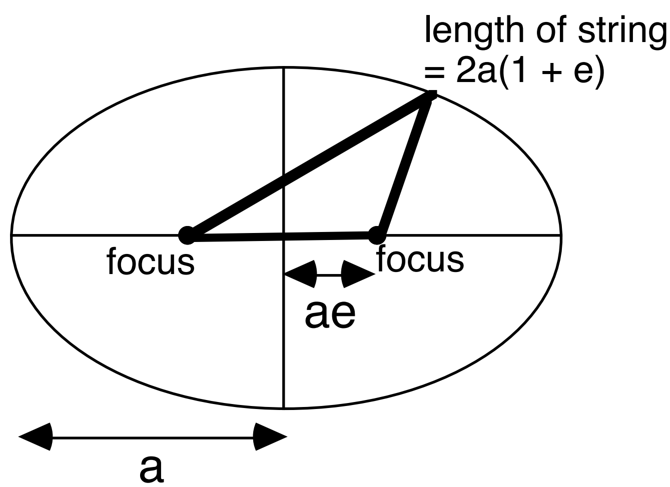


Figure 1

What To Do

- Place a large sheet of paper on a Styrofoam board or piece of cardboard. Place the thumbtacks some distance apart in the center of the paper. *Cut a length of string that is more than twice as long as the distance between the thumb tacks*. Fold the length of string in half and tie the ends together so you have a loop of string.

- Put the loop around the pins. Using a pencil as shown in **Figure 2**, sketch out the shape of the orbit.

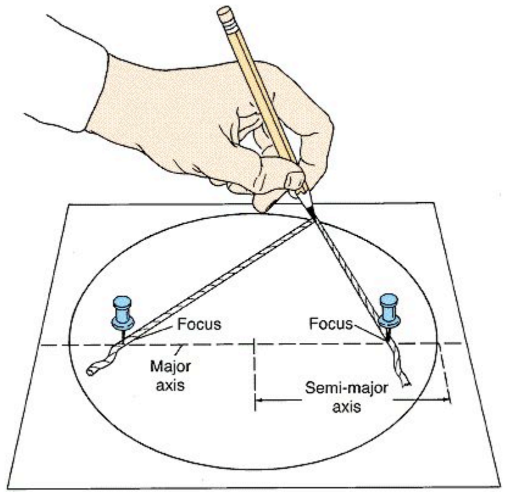


Figure 2

- Measure the major axis (widest part) of the ellipse. Measure the distance between the pushpins. Calculate the eccentricity of the ellipse that you drew by using the following formula:

e = distance between push pins ÷ length of the widest part of the ellipse

- Have students write the eccentricity (e) on their sheets of paper and post the ellipses they drew around the room. Have the students examine the drawings. What can be inferred say about the eccentricity of ellipses. *When the eccentricity (e) gets close to zero, the shape of the ellipse becomes circular. As e gets close to 1, the ellipse becomes flat.*

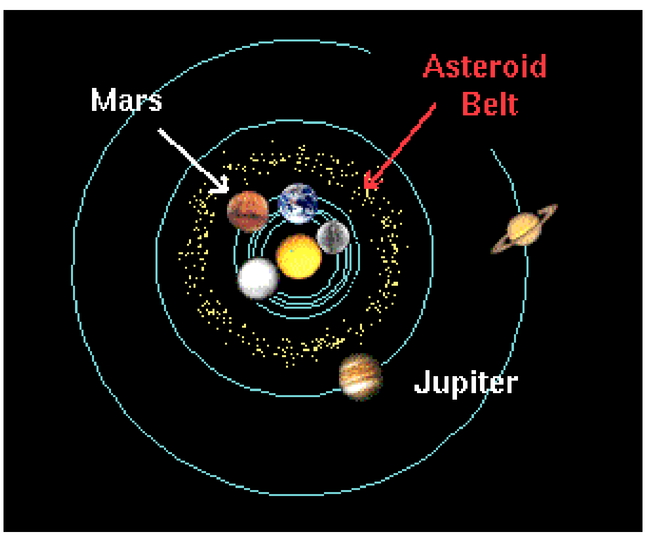
Planet	e (eccentricity)
Mercury	**0.200**
Venus	**0.001**
Earth	**0.017**
Mars	**0.093**
Jupiter	**0.048**
Saturn	**0.056**
Uranus	**0.047**
Neptune	**0.008**
Pluto	**0.250**

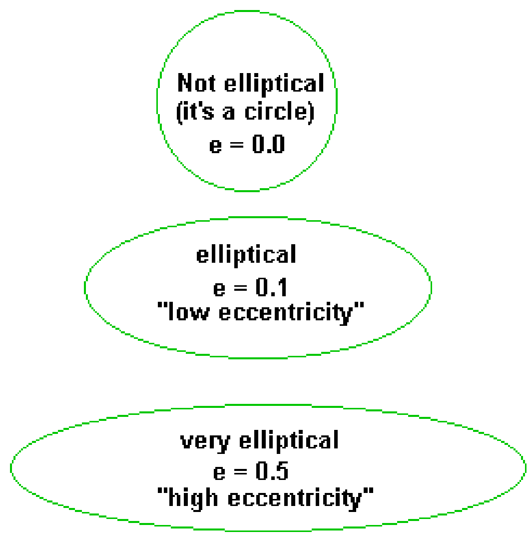
- Look at the table on the previous page. This table shows the eccentricity for the orbits of each of the nine planets. Which drawings posted of the walls are closest to representing the orbit of one of the nine planets. If none of them are close, can the students use their knowledge of ellipses to draw a figure that approximates the correct shape of the orbits? Which planet has the most circular orbit (*e nearest to zero*)? Which has the orbit that is most flattened (*e nearest to one*)?

What's Going On?
Because of misleading diagrams often seen in books other astronomy reference materials, most people believe that the orbits of the planets are highly elliptical – almost cigar shaped. In fact, the orbits of the planets are very nearly circular.

The problem with this misconception about planetary orbits is that it leads many students to erroneously believe that the cause of the earth's seasons has something to do with changing distance to the sun. After all, if the earth's orbit were as elliptical as these students believe, we would in fact be much closer to the sun during certain times of the year and much further away at other times.

The fact is that the earth's orbit is very close to being circular. At our closest approach to the sun, we are 147,000,000 kilometers away. At farthest approach to the sun, we are 152,000,000 kilometers away. Our distance from the sun varies by only 3% – not enough to account for changes in how the earth is heated by the sun during the year.





Modeling the Seasons

Students model the seasons with their own earth globes.

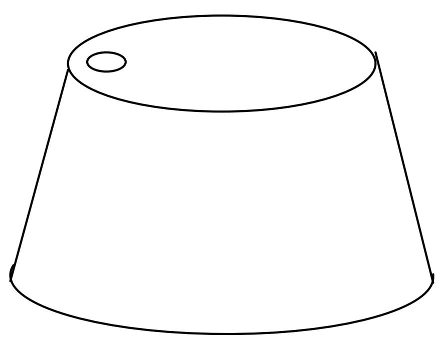
Materials:
For the whole group, you will need:

One 150 – 200 Watt not frosted light bulb
One lamp or socket for the bulb
An extension cord
A room that can be made dark

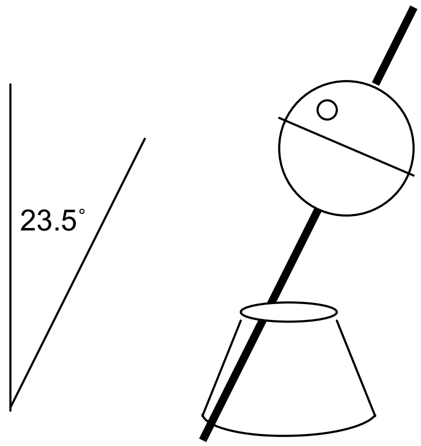
For each student or pair of students, you will need:

A styrofoam ball
A large straw
A rubber band
A flexible plastic cup (e.g. Dixie 5.5 oz)
Scissors
Tape
Tack or sticky dot
Protractor

The Set up:
Making a model of the earth:
Push straw through the center of the styrofoam ball. This represents the axis about which the earth rotates. One end is North and the other end is South. Place a rubber band around the earth's equator. Find your approximate latitude, and place the tack or dot there. (San Francisco is at 37.75˚ North, so placing the tack not quite half way between the equator and the N pole is an acceptable approximation.) Use the scissors to make a hole in the bottom of the plastic cup, near the side, as shown. It should be *just* large enough to accommodate the diameter of the straw.



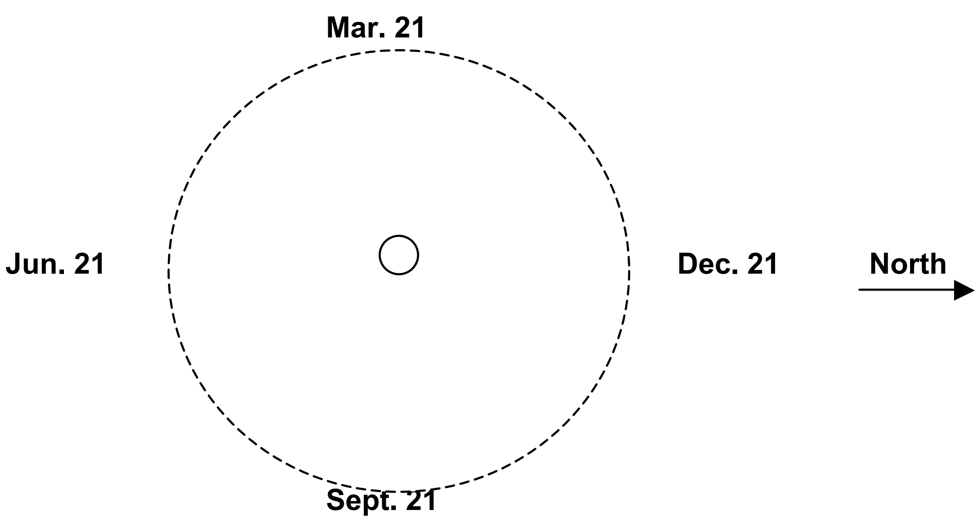
Take an 8 cm piece of tape and stick a 2 cm piece to the center of the longer piece (sticky sides together). Place the straw into the hole in the cup, and use the modified tape to hold the straw against the side of the cup, yet still allowing the straw to rotate in the hole.
Your model should look something like this. Use a protractor to check the angle of the earth's tilt. It should be 23.5˚



Setting Up the Room:
Use one bright lamp for the whole group, or use flashlights for small groups. Designate some visual reference as Polaris, the North Star. All straws point to Polaris throughout the activity. Set up light in the center of the group. Before darkening the room, make sure all earth models are oriented correctly. Darken room.

To Do and Notice: Model a "day" on earth.
Each student should turn the straw so that the earth spins counter clockwise (when viewed from the North) for one rotation. They should notice that the sticky dot is in light (day) for about 1/2 of the rotation and is in shadow (night) for about 1/2 of the rotation.

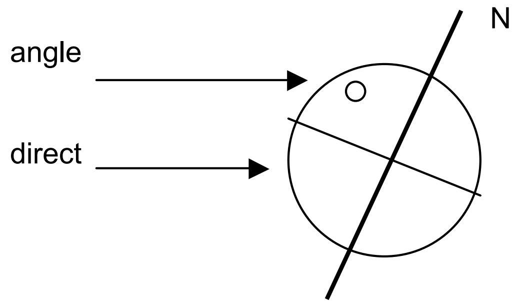
Modeling the seasons.
Divide class into four groups. Have each group move to one of the four seasonal positions: Dec. 21, Mar. 21, Jun. 21, and Sept. 21. Seen from above:



Have each group model a day at each position. At each position, they should notice:
• What fraction of the day is the sticky dot in the light? More than half? Less than half? About half?
• What fraction of the day is the North Pole in the light?

• How is the light from the sun striking the dot? Is it direct or at an angle?

For example, on December 21:
Angle at or above equator, direct below equator (Tropic of Capricorn)



Modeling a year:
After students have been to each of the four dates: Dec. 21, Mar. 21, Jun. 21, and Sept. 21, they will have modeled a year: one earth revolution around the sun.

What's Going On?
Many people think the seasons are caused by variations in our distance from the sun. While the earth's orbit is slightly elliptical, it is very close to circular, and the variation in distance between the earth and sun is not enough to account for our seasons. The seasons are caused by the tilt of the earth. The earth holds its rotation axis (tilt) fixed in space as it moves around the sun. In the summer, the Northern Hemisphere tilts toward the sun. It is warmer because 1) there are more hours of daylight, providing us with more heat energy, and 2) the midday sun shines more directly head on, increasing the amount of solar energy the earth receives. In the winter, when the Northern Hemisphere tilts away from the sun, the sun's rays strike the earth at a lower angle, and the energy from the sunlight is spread out over a larger area, which reduces its effectiveness at heating the ground. Combined with shorter daylight hours, the temperatures are cooler in winter. The seasons in the Northern and Southern Hemispheres are reversed.
Light from the sun travels away from the sun, out in all directions, in straight lines. The sun's light and energy travel through space to the earth.

The Age Of Aquarius?

What does it really mean to be a "Leo," "Cancer," or Taurus"? How did the ancients get these "sun signs"? With this activity, you can help your students answer these questions..

Materials Needed (per set up)

- 2 small Styrofoam balls, one larger than the other
- index cards
- constellation pictures (see attached)
- small binder clips
- butcher paper
- pens or pencils

What To Do

(1) Use the metal washers as stands for the Styrofoam balls. In this activity, the larger ball will represent the sun and the smaller ball will represent the earth. See **Figure 1**.

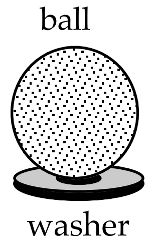


Figure 1

(2) Place a large piece of butcher paper on a large table. Draw a 3 foot diameter circle on the paper. This will represent the earth's orbit around the sun. Place the sun in the center of the circle and label the earth's position during the months of June, September, December, and March (see **Figure 2**).

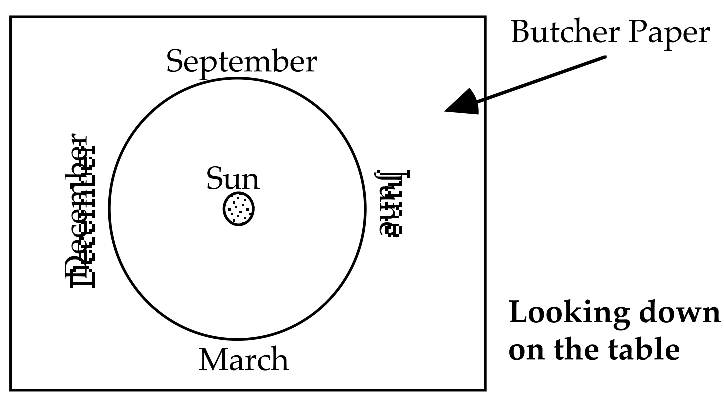


Figure 2

(3) Label each of the twelve index cards with a zodiacal constellation. You can decorate the card anyway you wish, or you can cut out the attached diagrams of the constellations.

(4) Place a binder clip on each of the cards. This will serve as a stand for your cards (**Figure 3**).

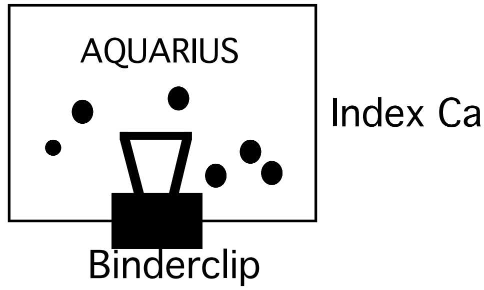


Figure 3

(5) Look at **Table 1**. This table lists the names of each of the twelve constellations of the zodiac and gives the month that the sun appears to pass through each of these star patterns. Of course, you can't see the sun pass through these constellations because you can't see stars in the daytime. But you have to imagine that we could dim the sun's light so you *could* see the sun pass through these star patterns.

Arrange these 12 cards in a circle outside the orbit of the earth. This circle should represent the position of the 12 zodiacal constellations relative to the earth's orbit about the sun. (see **Figure 4**).

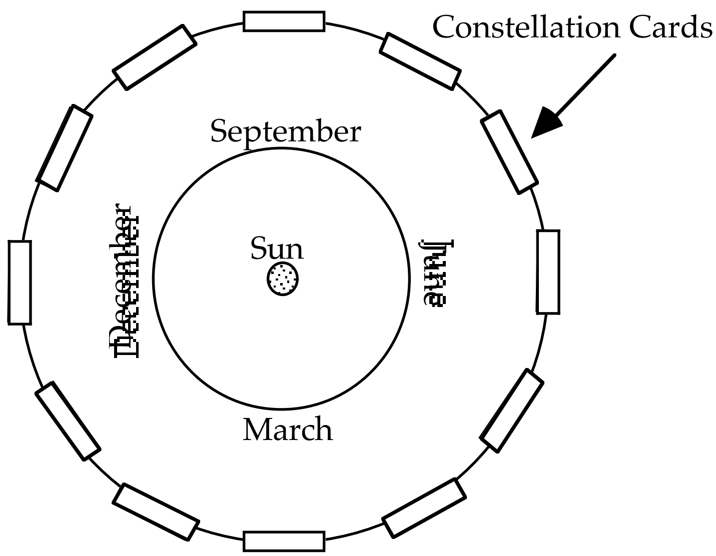


Figure 4

Table 1: The Constellations of the Zodiac

Name Of The Constellation	The Sun Will Appear To Be In That Constellation From . . .
Capricorn	Jan 21 - Feb 21
Aquarius	Feb 21 - Mar 21
Pisces	Mar 21 - April 21
Aries	April 21 - May 21
Taurus	May 21 - June 21
Gemini	June 21 - July 21
Cancer	July 21 - Aug 21
Leo	Aug 21 - Sept 21
Virgo	Sept 21 - Oct 21
Libra	Oct 21 - Nov 21
Scorpio	Nov 21 - Dec 21
Sagittarius	Dec 21 - Jan 21

What Going On:

During the course of a year, the sun appears to drift against a background of 12 constellations. These twelve constellations are called the Zodiacal Constellations. Each one takes up about 30° of the sky -- together they make up a 360 circle. You probably recognize these constellations as the 12 astrological signs. Yours is no doubt among them.

Of the 88 constellations recognized today, the zodiacal constellations are the most ancient. It was the Babylonians who invented astrology. Astrology, as practiced today, is about 2000 years old! According to astrology, the position of the sun and planets relative to these 12 constellations on the day of you birth determine your character -- and even your future.

You may have noticed that the actual dates when the sun will pass through these constellations does not seem to match the dates of your particular sun sign. For example, if you are an Aquarius, the sun was actually in Capricorn when you were born. What's going on?

It turns out that the sun signs used today are the same sun signs that were used 2000 years ago. When astrology was invented, an Aquarius was really born between Jan 21 and Feb

21. But back then, the earth's axis was pointing toward a different part of the sky. The earth's axis is wobbling like a top. The axis completes one "wobble" every 26,000 years. So, in the last 2000 years, the earth has gone 1/12th of the way around. We are now almost exactly one sign out of phase with the original astrological signs -- but our modern sun signs don't reflect this difference. This is just one of many criticisms that scientists express toward the belief in astrology.

Life Cycles Of The Stars

This activity helps students conceptualize the time scales involved in astronomical processes – such as the life cycles of the stars.

Materials Needed

• Star histories (see attached sheets)
• Pens, pencils, crayons, stickers, marking pens (to decorate the timelines)
• Rulers and/or meter sticks
• Register tape, in rolls

What To Do:

1. Have students work together in groups of 3 - 5. Give each group one of the six star histories attached. Each of these is a history of a real star in the sky. All are main sequence stars – that is, stars that are currently fusing hydrogen in their cores and have not yet depleted their reserves of fusible hydrogen.

2. Each group will construct a time line showing the life cycle of their star. For each group, there are at least 5 key events that groups need to include in their time lines: (1) **Conception** (t=0) – when gases that will one day form the star start to gravitationally collapse within a giant cloud of gas (called a nebula). (2) **Birth** – when hydrogen fusion begins within the core and the new star ignites. (3) **Old Age** – when the hydrogen within the core is exhausted. (4) **Death** – when the star "dies, usually through the expulsion of the outer layers of gas or with a huge explosion. (5) **The Corpse** – what remains in space shortly after the star "dies".

3. In constructing the timelines, students should let:

1/10th cm (1mm) = 1,000,000 years	(1million years)
1 cm = 10,000,000 years	(10 million years)
10 cm = 100,000,000 years	(100 million years)
100 cm (1 meter) = 1,000,000,000 years	(1 billion years)

4. After the groups have constructed their time lines, have each group share their "histories" with the rest of the class. What do they notice about the life span of massive stars compared to the life spans of less massive stars? Since the age of the universe is about 15 billion years, what does this say about the kind of stars most likely to have remained from the beginnings of the universe?

What's Going On?

In this activity, you can see that the very massive stars live much shorted "lives" compared to the smaller, less massive stars. Why is that?

Large stars, like all stars, form inside giant gaseous nebulae. An example of such a nebula is the Great Nebula in Orion (see photo). Inside nebulae, particles of gas and dust are attracted to each other through gravitational attraction. But at the same time, thermal motion (motion due to the temperature of the surrounding gases) competes with gravitational attraction – making it harder for the particles to "stick together." In a "cool" nebula (with little motion due to temperature, young stars can gather up a great deal of mass before igniting. In cold nebulae, these "baby stars" can collect this mass very quickly since there is little else to compete with the gravitational forces. *This explains why massive stars spend less time in the "conception" phase compared to smaller stars.*

Large stars also exhaust their reserves of hydrogen quickly compared to smaller stars. Temperatures in the cores of large stars are much higher than the core temperatures of smaller stars. The higher the temperature inside a star, the faster hydrogen nuclei move. And the faster hydrogen nuclei move, the more likely it is that two nuclei will hit each other and fuse. So even though larger stars have more hydrogen reserves, they fuse hydrogen into helium at a much higher rate. *This explains why large stars don't spend much time as main sequence stars (compared to smaller stars).*

Finally, large stars have quick and explosive deaths compared to smaller stars. All stars are pulled inward by tremendous gravitational forces. The outward pressure produced by nuclear fusion inside the core exactly balances the inward force of gravity. As long as these forces are in balance, the star does not expand or shrink in size. But when nuclear fusion stops, there is nothing to balance the inwardly directed force of gravity. For large stars, this inward force is tremendous – producing a spectacular contraction and spectacular explosion (e.g. a nova or super nova). What is left behind is a weird stellar fragment left when the outer layers of the star compress the core to unimaginably high densities (e.g. black holes, neutron stars, white dwarves…).

Box-O-Math

In case you are wondering whether there are any equations that describe the life span of a star – of course there is! The length of time that a star spends in the "main sequence" (adulthood) is given by the following equation:

Main sequence lifetime = fuel / fuel consumption rate ~ mass / luminosity.

But since luminosity ~ mass $^{3.5}$

Main sequence life span ~ 1 / $M^{2.5}$

If you plug in the mass of the star in terms of the solar masses (the number of times that the star is heavier than our own star), then your answer will be in terms of "solar lifetimes," where 1 "solar lifetime" = 10^{10} years = 10 billion years.

Life Histories Of Some Stars

Star: A_{crux}
Constellation: Crucis
Mass: 15x mass of sun
Radius: 4.77 radius of sun

Conception (time from nebula to ignition of hydrogen): 100,000 yrs
Adulthood (time from ignition of hydrogen to giant); 10,000,000 yrs
Old Age (time from giant stage to star death): 1,000,000 yrs

Type of Death: Supernova
Remains of the Star: Neutron Star

Star: Vega
Constellation: Lyra
Mass: 5x mass of sun
Radius: 2.61 x radius of sun

Conception (time from nebula to ignition of hydrogen); 1,000,000 yrs
Adulthood (time from ignition of hydrogen to giant): 100,000,000 yrs
Old Age (time from giant stage to star death): 10,000,000 yrs

Type of Death: Supernova
Remains of the Star: Neutron Star

Star: Sirius
Constellation: Canis Major
Mass: 2x mass of sun
Radius: 1.6x radius of sun

Conception (time from nebula to ignition of hydrogen): 10,000,000 yrs
Adulthood (time from ignition of hydrogen to giant): 1,000,000,000 yrs
Old Age (time from giant stage to star death): 100,000,000 yrs
Type of Death: Nova
Remains of the Star: White Dwarf

Star: Alpha Centauri A
Constellation: Centaur
Mass: 1x mass of sun
Radius: 1x radius of sun

Conception (time from nebula to ignition of hydrogen): 40,000,000 yrs
Adulthood (time from ignition of hydrogen to giant): 10,000,000,000 yrs
Old Age (time from giant stage to star death): 1,000,000,000 yrs

Type of Death: Formation of a planetary (ring) nebula
Remains of the Star: White dwarf

Star: Alpha Centauri B
Constellation:
Mass: 0.8x mass of the sun
Radius: 0.68x radius of the sun

Conception (time from nebula to ignition of hydrogen): 100,000,000 yrs
Adulthood (time from ignition of hydrogen to giant): 20,000,000,000 yrs
Old Age (time from giant stage to star death): 2,000,000,000 yrs

Type of Death: Formation of planetary (ring) nebula
Remains of the Star: White dwarf