THE ORBITER

The *Orbiters* are scientific working models representing the sun, Earth, and Moon and their relationships. They are designed to demonstrate basic Earth and Moon motions and to explain the causes of day and night, seasons, and phases of the Moon. The sun demonstrates the earth's light source and indicates areas of day and night at different seasons. Many of the important relationships that can be demonstrated with the *Orbiters* are outlined below.

The *Orbiters* have been scaled to show relative sizes, distances, and motions of the Earth and Moon; however, true scale is virtually impossible to show with a model of this size.

The Earth and Moon are, however, shown in true scale. The scale is 1 inch = 2,000 miles. If the sun were to be shown at the same scale, it would be approximately 36 feet in diameter.

The distance scale of the *Orbiters* is only relative. It shows that the distance between the sun and Earth is greater than the distance between the Earth and Moon. The true scale distance between the Earth and Moon would be approximately 10 feet assuming the sizes were as shown by the *Orbiters*. If this were the case, the sun would be approximately 36 feet in diameter as mentioned above and would be approximately 3,920 feet from the earth. Actual sizes and distances are given in Figure 1.

The Moon revolves around the Earth approximately once a month. The Moon also rotates once on its axis during each revolution. The *Orbiter* does not show the earth rotating the correct number of times in a month, nor the correct number of times in a year. It is important to know this in order to avoid a misconception regarding the Earth's rotation. The periods of rotation and revolution of the Earth and Moon are also given in Figure 1.

BASIC INVESTIGATIONS WITH THE ORBITER

1. How the Earth's rotation causes day and night.
2. How the Earth's revolution around the sun and the tilt of its axis causes seasons.
3. Why the sun rises in the east and sets in the west.
4. How the Earth's revolution around the sun and the tilt of its axis changes the length of day and night.
5. Why the length of twilight changes the length of day and night.
6. Why there is a midnight sun.
7. Why there are phases of the Moon.
8. Why we only see one side of the Moon.
9. Why there are eclipses of the sun and Moon.
10. Why there are tides.

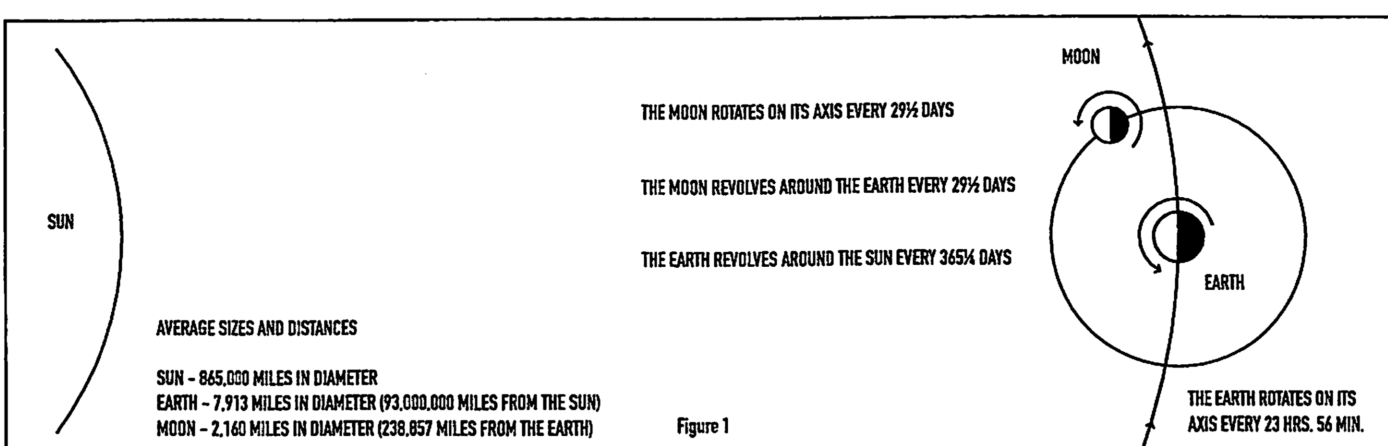
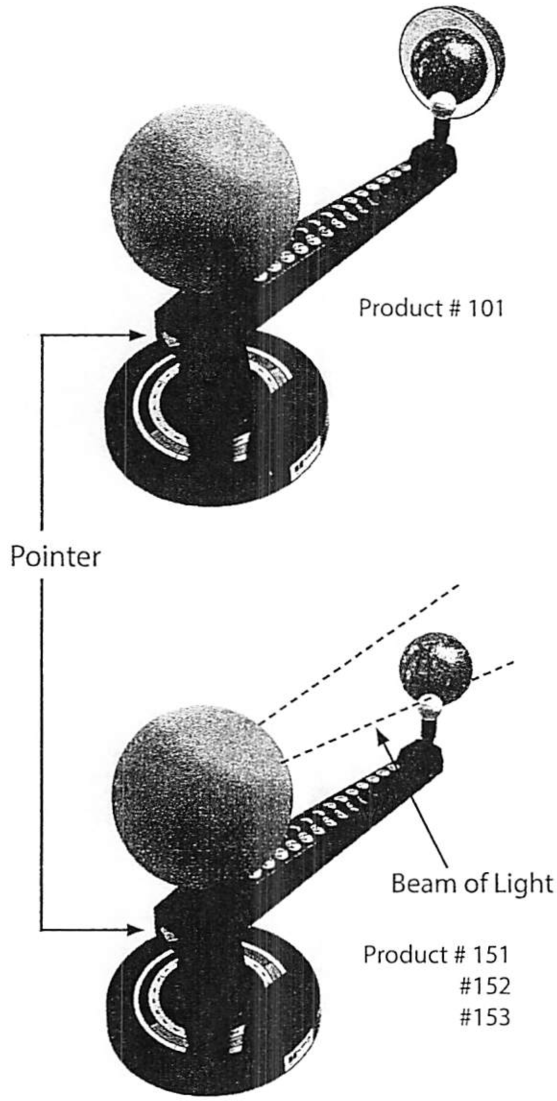


Figure 1

Printed in the U.S.A.



REPLACING THE LIGHT (PRODUCT 151)

The light bulb can be easily replaced by removing the sun from the base. Carefully lift the sun from the base and slide over the socket and lamp. Turn the lamp to remove and replace with a standard 7 watt 120 volt bulb. After replacing the lamp, slide the sun over the socket. Turn the sun so that the light opening is facing the Earth.

REPLACING THE LIGHT (PRODUCT 153)

Remove sun from orbiter. Remove screw on back of clear tube near the bottom. Slide the clear tube off and unscew bulb. Screw in new bulb. Use 1, 6 volt 3.3 watt mini lamp. When re-attaching the sun it may be helpful to coat the inside of the rubber grommet with a solution of dish soap and water.

BATTERY REPLACEMENT (PRODUCT 153)

Turn the orbiter over and remove the two scews holding the base plate on. Remove batteries and replace with new ones. Reattach base plate. Uses four AA batteries.

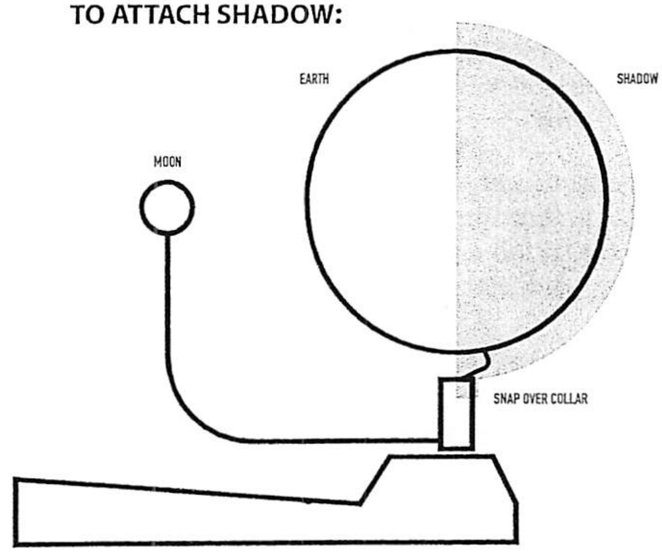
ORBITER

The *Orbiter* has four main parts: the sun, Earth, shadow, and Moon. The sun is represented by a 6-inch yellow sphere, the Earth by a 4-inch globe, and the Moon by a smaller sphere.

The movements of the Earth and Moon are manually operated. The gear drive causes the Earth to revolve around the sun with its axis in true relationship to the sun. The Earth globe is moved by hand to demonstrate its rotation. The Moon can also be moved by hand to show its rotation about the earth.

A special transparent hemisphere (shadow) around the half of the Earth away from the sun represents night. The date dial can be used to show the exact Earth-sun relationship for any time of the year. (Product #101 only)

TO ATTACH SHADOW:



*** Shadow for #101 ONLY**

ILLUMINATED ORBITER (product 151, 152, & 153)

The basic components of the *Illuminated Orbiter* are similar to the regular *Orbiter* in that the sun is represented by a 6-inch yellow sphere, the Earth by a 4-inch globe, and the Moon by a 1-inch diameter reproduction of the Moon. The sun is illuminated and the *Orbiter* is geared to show simultaneous motions of the Earth and Moon as the Earth revolves.

The sun may be illuminated to demonstrate that the sun is the light source of the earth and Moon. When the *Orbiter* is illuminated in a darkened room, the light and dark portions of the Earth and Moon are clearly defined. To operate the *Orbiter*, the support arm should be moved from month to month along the date dial.

Day and Night

One of the most important and basic demonstrations is the explanation of day and night. The sun's rays always illuminate the half of the Earth facing the sun. This is the day side. The half of the earth facing away from the sun is always dark. This is the night side. If the *Orbiter* is being used, the translucent night hemisphere represents the half of the earth in darkness or night. If the *Illuminated Orbiter* is being used, illuminate the sun and darken the room to reveal the light and dark portions of the earth.

To show day and night, turn the Earth one complete rotation and observe that your location on the Earth passes through day and night in one rotation. Turn the globe from west to east by hand when using the regular *Orbiter* (counter-clockwise looking down on the North Pole).

SUNRISE AND SUNSET

As the Earth rotates from west to east, notice that when your location enters night, the sun appears to the west of it. This explains why the sun sets in the west. As the Earth continues to rotate, notice that when your location enters the day side, the sun would appear to the east of your location. This explains why the sun rises in the east. Observe that the sun does not move. It is the Earth's rotation that causes the apparent motion of the sun from east to west.

LENGTH OF DAY

Changes in the length of day and night in various parts of the Earth as the earth revolves around the sun maybe be easily demonstrated with the *Orbiters*. For the earth as a whole, the days are longer in summer and shorter in winter, although at the equator day and night always last 12 hours each.

The *Orbiters* will show the hours of day and night at any location and at any date. For example, to demonstrate the length of day in New York on June 21, set the Earth for June 21 and rotate it so that New York is in day. Count the meridians in daylight along the parallel of New York as shown in Figure 3. The distance between the meridians on this globe is 15°, the distance the Earth rotates in one hour. To define areas of day and night, illuminate the sun with the *Illuminated Orbiter* and use the night hemisphere with the *Orbiter*. You will see that there are approximately 15 hours of day and 9 hours of night on June 21st in New York. Revolve the Earth to the February 10th position and count the hours of day for New York. You will see that there are approximately 10 hours of day and 14 hours of night. This same method may be used to show the length of day for any date at any location.

It is possible to find the approximate time of sunrise and sunset for any location at any date. For example, to find the time of sunset and sunrise for New York on June 21, follow the steps outlined above. The length of day is found to be 15 hours, and since half of the day is before noon and half after noon, it is easily determined that the sun sets 7 1/2 hours after noon, or approximately 7:30, and rises 7 1/2 hours before noon, or approximately 4:30 a.m.

THE MIDNIGHT SUN

The midnight sun may also be demonstrated with the *Orbiters*. Revolve the Earth to the June 21 position. Observe that the region north of the Arctic Circle never passes into night. This area has 24 hours of day and is known as the Land of the Midnight SSun. Observe the area near the South Pole never passes into day on June 21. Revolve the Earth halfway around the sun to the December 22 position and note that the South Polar regions will have 24 hours of day and the North Polar regions will have 24 hours of night.

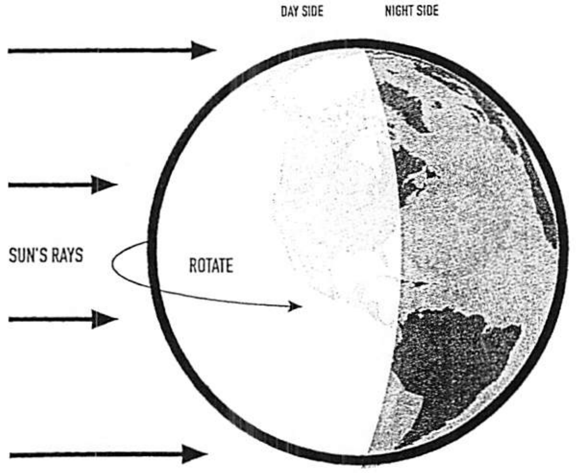


Figure 2

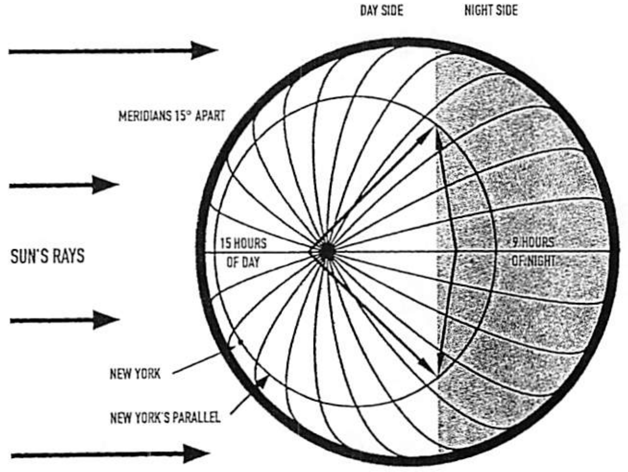


Figure 3

TWILIGHT AND DAWN

As your location passes from day into night or from night into day, there is a period of twilight or dawn between the time the sun is at the horizon and total darkness. There is darkness when the sun's center is 18° below the horizons. Study Figure 4. The diagram shows the twilight zone on March 21 or September 23. It can be seen that the period of twilight varies at different latitudes. At 75° north and 75° south latitudes, there are 12 hours of twilight; at 45° north and 45° south latitudes, there are 90 minutes of twilight; and at the equator there are 70 minutes of twilight.

Set the *Orbiter* at different dates and visualizing an 18° zone of twilight, observe that the period of twilight varies not only with the latitude but also with the seasons. it will be seen that the length of twilight is longer at high latitudes and during the summer months.

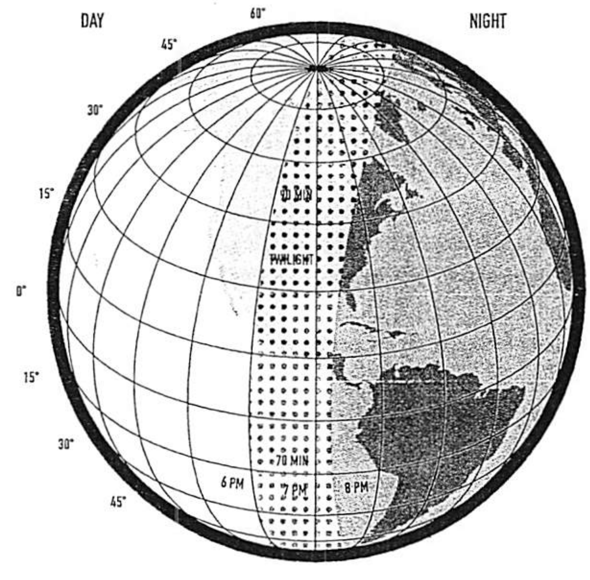


Figure 4

The Seasons

Setting the *Orbiter* at different dates and visualizing an 18° zone of twilight, observe that the period of twilight varies not only with the latitude but also with the seasons. The length of twilight is longer at high latitudes and during the summer months.

As the Earth rotates on its axis, it also revolves around the sun. The Earth's axis is always tilted at an angle of 23 1/2° to the plane of its revolution around the sun. It always points to the same direction in space, marked by the North Star. This combination of tilt and revolution causes the change in seasons.

To demonstrate why there are different seasons, move the arm carrying the Earth so that the pointer indicates June 21 on the date dial. The Northern Hemisphere is then tilted towards the sun, and it is seen that the sun's rays are concentrated on the Northern Hemisphere. It is then summer in the Northern Hemisphere and winter in the Southern Hemisphere.

Remove the Earth counter-clockwise around the sun until the pointer reaches September 23 on the date dial. The noon sun is then directly over the equator, and it is autumn in the Northern Hemisphere and spring in the Southern Hemisphere.

Continue to revolve the Earth counter-clockwise until the pointer reaches December 22 on the date dial. The North Pole is tilted away from the sun, and the sun's rays are concentrated on the Southern Hemisphere. It is then winter in the Northern Hemisphere and summer in the Southern Hemisphere.

Continue to revolve the Earth to the March 21 position. The sun is again directly above the equator. It is autumn in the Southern Hemisphere and spring in the Northern Hemisphere. Now complete the Earth's revolution around the sun by returning to June 21. You have demonstrated one full year of time.

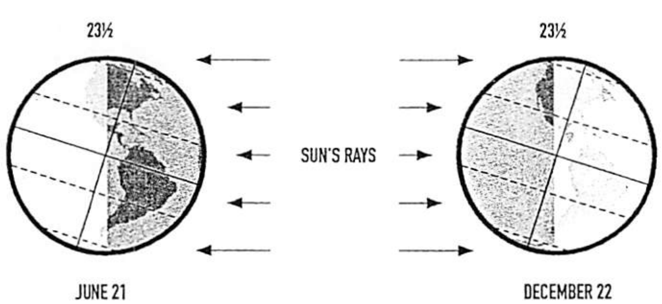


Figure 5

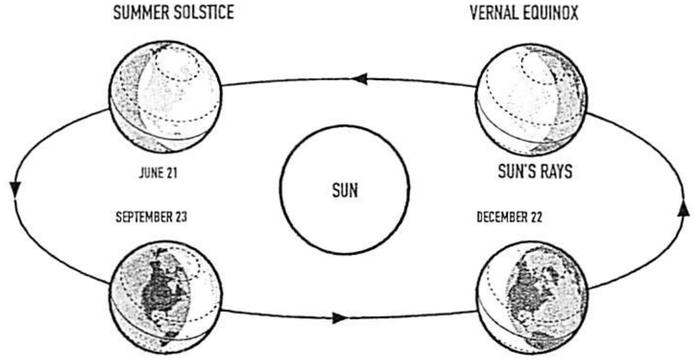


Figure 6

The Moon

At a mean distance of 238,000 miles, the Moon is our closest neighbor. With practically no atmosphere, its day temperature drops to about -212° F; its night temperature drops to about -250° F. Most numerous and most characteristic of the Moon's features are its craters over all parts of its surface. The most conspicuous features to the naked eye are large plains called maria (lunar "seas"), which are darker in color than the rest of the Moon's visible surface and cover about half of it. Its lunar mountain ranges rise to more than 20,000 feet. The Moon is devoid of life - a desert more barren and inhospitable than any on earth.

The basic motions, phases, and eclipses of the Moon may be demonstrated with the *Orbiters*. As the Earth is moved from month to month, the Moon revolves around the Earth in a counterclockwise direction when seen from above. The real Moon revolves around the Earth once every 29 1/2 days. During this time, it rotates once on its axis, also in a counter-clockwise direction. These motions are shown in Figure 7. The month of 29 1/2 days from full Moon to full Moon is called the Synodic Month. The actual period of revolution is 27 1/3 days. The additional time between full Moons results from the Earth moving about 1/13 of its distance in its orbit around the sun during the month.

ONE SIDE VISIBLE

Since the Moon makes only one complete rotation on its axis each time it revolves around the Earth, we are only able to see one side. To demonstrate this with the *Illuminated Orbiter*, move the pointer from month to month and notice that the same side of the Moon always faces the Earth. Move the Moon manually when using the regular *Orbiter*. If the Moon did not rotate or if it rotated more than once per revolution, we would see all sides of it. Actually we see 59% of the Moon's surface over a period of time due to its inclined orbit and its slight wobble as it moves around the Earth.

MOON PHASES

The half of the Moon facing the sun is always illuminated except during a lunar eclipse. When viewed from the Earth, the illuminated portion changes shape as the Moon revolves around the Earth. To demonstrate the phases of the Moon with the *Orbiter*, revolve the Moon around the Earth holding the Moon so that the light half is always towards the sun. To demonstrate phases with the *Illuminated Orbiter*, illuminate the sun, darken the room, and slowly move the pointer along the date dial to show the Moon at different positions. The phases are also shown on the arm sticker.

View the Moon as though you were on the model Earth as the Moon is moved to its different positions. Observe that the illuminated portion changes from a crescent shape to a full Moon as shown in Figure 8.

ECLIPSES

When using the *Orbiter*, it appears that the shadow of the Moon should reach the Earth at each new Moon and that the shadow of the Earth should reach the Moon at each full Moon. However, this seldom occurs in the real universe because the Earth and Moon do not revolve on the same plane. The Moon's orbit is inclined approximately 5° to the Earth's orbit. See Figure 9. The resulting shadows usually fall into space because the Moon is generally above or below the shadows when the Earth, sun, and Moon are in line.

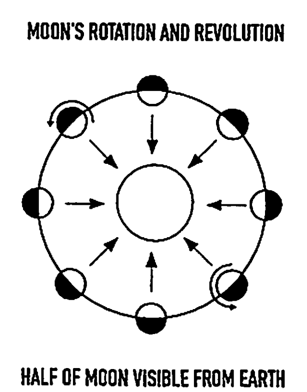


Figure 7

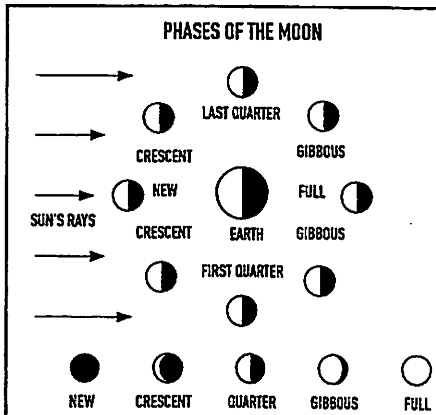


Figure 8

TIDES

The ocean's surface at any given point rises and falls twice each day due to the gravitational force of the Moon and sun upon the Earth. The rising and falling of the ocean produce tides. There are two high tides and two low tides each day, with the waters rising about six hours and falling for about six hours. The gravitational pull of the Moon is about twice that of the sun due to the much greater distance of the sun from Earth.

When the sun and Earth and Moon are in line or almost in line, there is maximum gravitational force and therefore maximum tides. This occurs twice each month at full Moon and new Moon. Tides at this time are called Spring Tides. At first quarter and last quarter, when the Moon and sun are at right angles, their gravitational forces do not work together so tidal height is at a minimum. Tides at this time are called Neap Tides. Figure 10 illustrates Spring Tides and Neap Tides. (Incidentally the term Spring Tides has nothing to do with the seasons.)

While the Orbiters cannot demonstrate tides, they can be used to show the relative positions of the sun, Moon, and Earth for various types of tides.

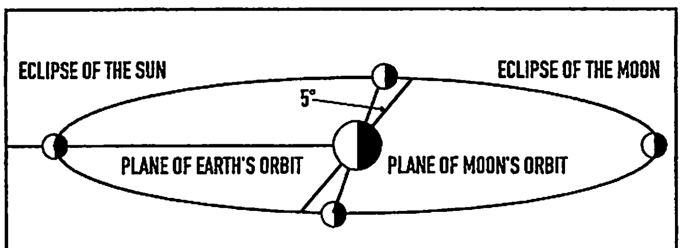


Figure 9

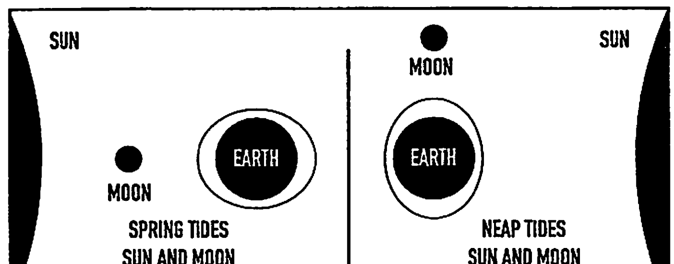


Figure 10

Observations and Activites

THE EARTH IS A SPHERE

Probably one of the most convincing proofs that the Earth is spherical is the way in which ships gradually seem to sink out of sight over the curve of the ocean. If you mounted a telescope on a cliff at the seashore and watched an outgoing ship, you would see the hull disappear first and top of masts last (Figure 11). Take a classroom globe and move a ship around it to understand what happens. Then compare this by sighting a ship on a flat surface and notice the difference as the ship is moved away. What other ways can we prove the Earth is spherical?

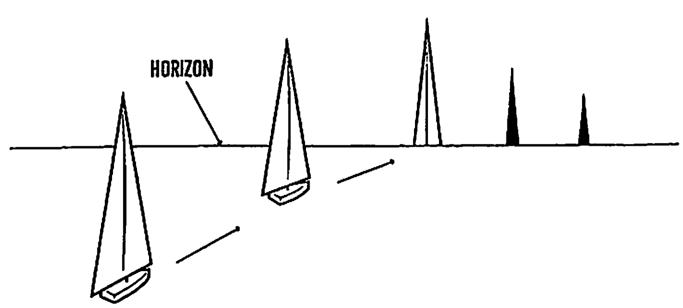


Figure 11

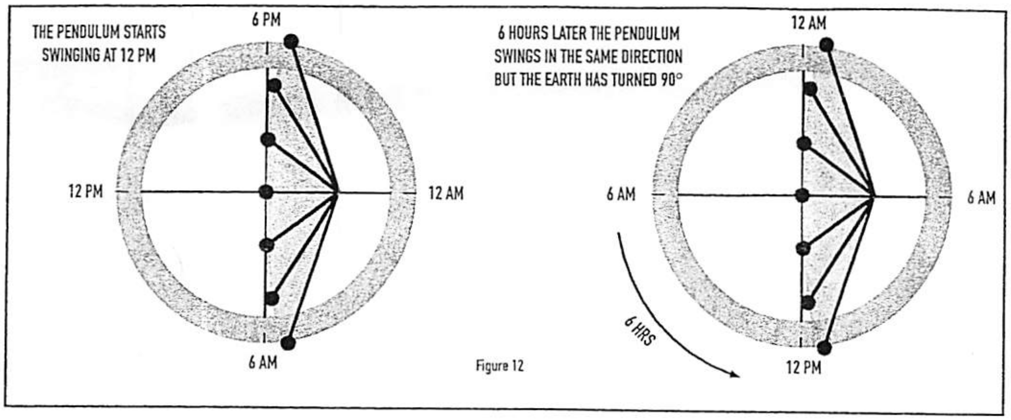


Figure 12

THE EARTH SPINS ON ITS AXIS

To prove that the earth rotates, J.B.L. Foucault developed a pendulum experiment. During each swing, the pendulum appeared to shift its line gradually clockwise. Since he knew that the line in which the pendulum swings did not shift, Foucalt inferred that the floor beneath the pendulum must be turning or more correctly that the earth was rotating. For this observation, a cord or wire 10 feet long or longer, and a plumb bob weighing at least 5 pounds are needed. Locate it in a high stairwell, away from air currents. Start the pendulum swinging in a straight line. Draw a chalk line in the direction the ball is initially swinging. After 15-20 minutes, notice that the pendulum no longer has the same path as at the start but moves at a slight angle to the first one. Actually the line of swing is as it was but the floor has moved beneath it.

At the poles, the earth will make one complete rotation a day beneath the pendulum, whereas at the equator, there will be no shift in the pendulum's path. Figure 12 shows a pendulum's path in relation to the rotating earth.

THE TILT OF THE EARTH'S AXIS CAUSES SEASONS

The change of seasons is entirely dependent upon the tilt of the earth's axis and its revolution around the sun. This can be observed by cutting a ¾ inch square opening in a card and using either the *Illuminated Orbiter* or the ordinary *Orbiter* with a flashlight. Position the *Orbiter* for June 21st. Now the Northern Hemisphere tilts towards the sun, and it is in summer. Passing the beam of light through the square hole, it can be observed concentrated on a spot almost square. Its heating effect is therefore intense a the sun's rays fall directly onto the Northern Hemisphere's surface. Reverse the *Orbiter* pointer to December 22nd and perform the same experiment. Move the card slightly so that the light falls on the Northern Hemisphere. Now the light is diffused over a larger area with slanting rays and its heating effect is correspondingly lessened. The Norther Hemisphere is now in winter. Figure 13.

THE EARTH REVOLVES AROUND THE SUN

The apparent eastward motion of the sun along the ecliptic in the sky throughout the year is due to the earth's revolution around the sun, but it is not proof of the earth's motion. The ancient astronomer, Ptolemy, theorized that the sun revolved around the earth, and this theory was accepted for centuries. In the sixteenth century, Copernicus proposed that the sun was the center of the solar system and that the earth revolved around the sun. This theory was later proved correct.

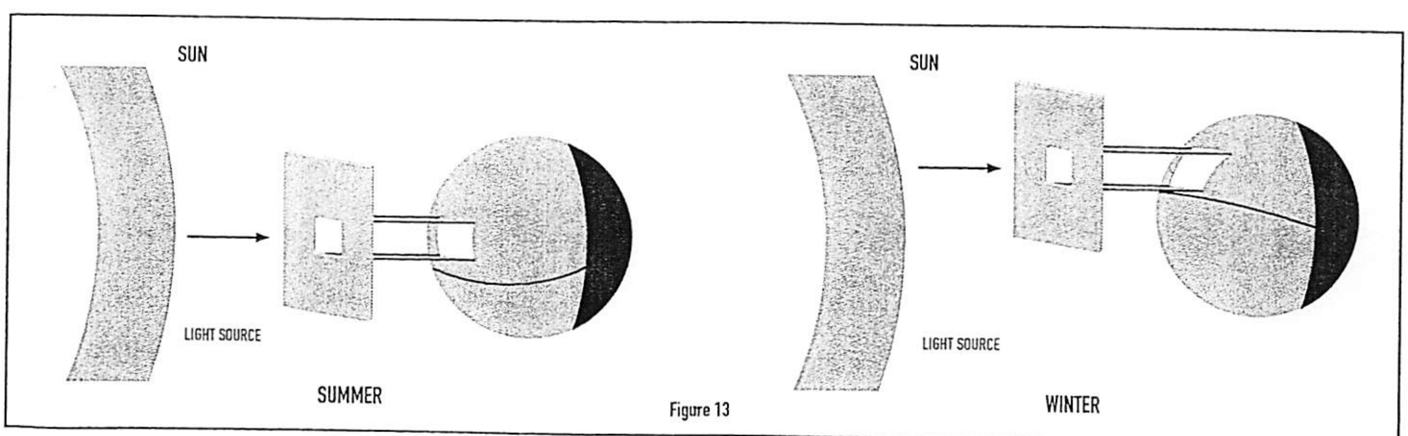


Figure 13

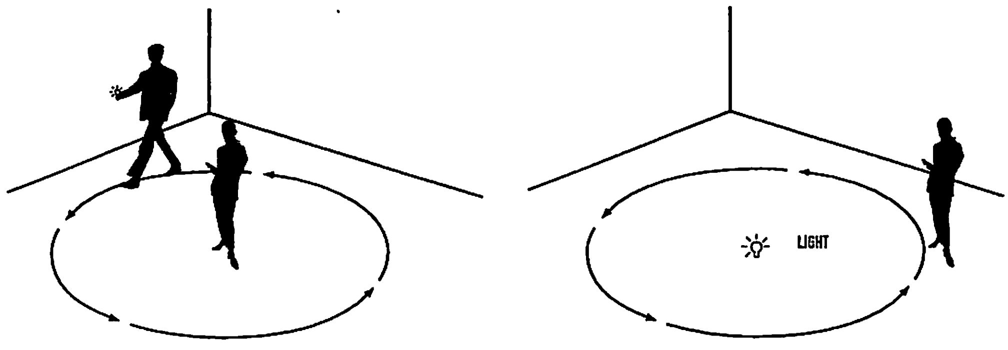


Figure 14

It is possible to demonstrate the sun's apparent motion against a background of stars and the different theories of Ptolemy and Copernicus. You can picture this by standing in the center of a room to represent a person on Earth and have someone carry a lamp representing the sun and circle counter-clockwise around you. The light appears to move in the same manner past the pictures on the wall. Figure 14 compares this demonstration to the Earth, sun, and stars.

MEASURING THE SIZE OF THE EARTH

Finding the Earth's size by direct measurement is almost impossible; therefore, indirect measurement must be used. A Greek astronomer, Erathosthens, approximated the Earth's diameter in 250 B.C. using simple geometric principles. He knew that in the city of Aswan (A), the sun was directly overhead on the summer solstice (no shadows). On the same day at the same time in another city, Alexandria (B), the sun produced a shadow indicating that it was not directly overhead. The shadow showed that the sun was 7 1/3° from the overhead position. Concluding that rays of light on the Earth from such a distant source are essentially parallel rays and measuring the distance between the cities as 490 miles, Eratosthenes was able to compute the Earth's size as follows:

7 1/5° is about 1/50 of the 360° in the circumference of the Earth. The Earth's circumference must therefore be 50 X 490 miles (distance between Aswan and Alexandria) = 24,000 miles. Since the diameter of a sphere is about a third as large as the circumference, he concluded the diameter of the Earth to be about 8,000 miles.

PROJECTS

Numerous study projects and experiments may be conducted with the *Orbiters* to expand interest and increase knowledge of the subject. Several projects are given below, and many others may be developed from them.

1. Find the direction of the sun at sunrise and sunset as seen from your location in December and June.
2. Determine the same directions for Buenos Aires, Argentina.
3. Estimate the approximate hours of daylight and darkness for your location on June 21 and December 22.
4. Determine the approximate time of sunrise and sunset for your location on these dates.
5. Determine the time of sunrise and sunset in Melbourne, Australia, on these dates.
6. Determine the approximate altitude of the sun at your location at noon on June 21 and December 22. (This may be determined by setting a protractor on the globe with the 90° mark pointing to the zenith of the location. The elevation of the center of the sun may be sighted on the protractor.)
7. Determine the same information for Singapore.
8. Locate the portion of the Earth that has 24 hours of darkness on November 1.
9. Locate the portion of the Earth that has 24 hours of daylight on November 1.