The Orrery
Questions & Answers

Eli Whitney museum & workshop

1.
The Earth travels around the Sun in approximately 365 ¼ days. How long does the Moon take to revolve around the earth?

Approximately 28 days pass between a full moon and the next one, but the answer may not be that simple. During a full moon the earth and the moon line up on a radius drawn from the sun through the Earth. During those twenty-eight days the Earth has progressed 15 degrees further alone its orbit around the sun. Therefore, between full moons the Moon has traveled 360 degrees around the earth plus the 15 degrees that the earth has moved. (minus 15 degrees, if the orbit of the moon is opposite the orbit of the Earth) A more correct answer may be 27 days or 29 days dependent on the direction of the orbits.

2.
The same side of the Moon is always facing the Earth. Does the Moon spin on it axis? How fast, if at all?

In order for the same side of the moon to face us, the Moon must rotate at the same rate that it orbits the Earth. From full moon to full moon is 29.5 days or 12.3 times in a year. The Earth orbits once in a year, which must be added to the moon's revolution, so in the end the Moon rotates 13.3 times in a year.

3.
The base of the orrery has four sides. Could those sides represent the four seasons?

Yes, the four sides of the base model the four seasons very well. When viewed from the Earth's North Pole, the Earth moves in a counter-clockwise direction. Therefore, the sides of the base should be labeled winter, spring, summer and fall in a clockwise order.

4.
Are the relative sizes of the moon, the planets and the sun accurate?

Oh, no. The Earth is modeled with a 0.9-inch diameter ball. Venus is just about the same size as the Earth and so it makes sense that it is a 0.9-inch ball as well. Mercury has a diameter that is 40% of Earth, so using the same scale it should have a diameter of .4 x .9 or 0.36-inch. The actual size of the Mercury model in 0.4 inches, which is only slightly larger than it should be. The Moon should be 27% of the Earth and it measures 0.25 inches. 0.27 x 0.9 = 0.24. That dimension is very close to the size it should be. Now, the Sun… The actual Sun is 110 times larger in diameter than the Earth. So if the Earth is 0.9 inches, the Sun should be 99 inches in diameter. Wow! The Sun should be a ball a little over eight feet in diameter (the height of most ceilings). The model is way too small for the Sun.

5.
Are the distances accurate?

The reported distances of the planets from the Sun are: Earth - 149 million kilometers, Venus – 108, Mercury – 58. The distance from the Earth to the Moon is 0.38 million kilometers. On the model the distance from the Sun to the Earth is 7.5 inches. Students can use proportions to verify the following dimensions for the model. Sun to Mercury should be 3 inches and the Sun to Venus should be 5 ¼ inches. Using this same proportion, the distance from the Earth to the Moon should be only 0.019 inches (less than 1/32nd of an inch). This dimension is not scaled correctly at all.

6.
A day is 24 hours long. Does this fact mean that the earth rotates exactly 360 degrees in 24 hours?

Well, not exactly… The earth actual rotates 360 degrees in 4 minutes less than 24 hours. The reason for this effect is that the Earth is moving one degree each day in its orbit around the Sun. The Earth has to rotate 361 degrees between noon on one day to noon on the next day. The 360-degree rotation is called the sidereal day.

7.
Textbooks usually describe the periods of rotation and revolution for the planets and the moon, but rarely do they identify the direction of movement. Can you make observations or plan experiments to determine which way the moon orbits the Earth? .... which way the Earth orbits the Sun?

You can determine the direction of rotation of the Earth without setting up an experiment. The sun rises in the East. Therefore, the Earth must spin counter-clockwise when viewed from the North Pole. Using your orrery mark a position on the Earth. Mark the direction toward the East. Spin the Earth in both directions and determine which direction shows the Sun in the East when the position moves from what would be the dark half (night) to the light half (day).

Figuring out the direction of orbit for the Moon may be a little more difficult. In the evening set up a stick or series of two sticks that point at the Moon. Record the time. On the next night (or subsequent nights) at the same time of day determine whether the Moon is at the same position or further to the East or West. You should observe that the Moon is further to the East. Accordingly, the Moon will rise later each night. It orbits the Earth in a counter-clockwise sense.

You can determine the direction of Earth's orbit similarly by observing the movement of the stars from night to night. You should pick a star that is in the Eastern or Western sky. Measure whether the star moves to the East or the West. You should find that the stars move toward the West indicating that the Earth's orbit in also counter-clockwise. This experiment requires more precise measurement and often many days between readings. Remember the Earth only moves one degree each day in its trip around the Sun.

Do you see a pattern? Most everything rotates or revolves in a counter-clockwise direction in our solar system, but not everything. Venus spins clockwise or retrograde. Can you give an explanation?

8.
Is there "day" and "night" (a period of light followed by a period of dark) on the moon? How long is a "Moon day?"

The moon has day and night just like on Earth. However, each lasts for about 15 days on the moon. A "Moon day" lasts 29.5 days.

9.
The tides are predominately caused by the motion of the Moon. The Earth rotates approximately once every 24 hours. Yet, if a high tide is at 9am one day, on the next day there will be a high tide at about 10am. How could this be?

The oceans of the Earth are pulled toward the Moon. When the Earth spins each day, the Moon moves around in its orbit too. When combining both effects, a position on the Earth points toward the Moon once every 25 hours instead of every 24. For this reason the tides are approximately one hour later each day. There are usually two sets of tides each day. The second set of tides is a rebounding phenomenon due to the specific shape and size of our oceans.

10.
The arms that support Earth, Mercury and Venus are fixed length. Is this accurate?

Yes. The orbits of most of the planets including all the inner planets are very circular.

11.
What causes the earth to have different seasons? Is this characteristic accurately modeled with this Orrery?

The seasons on Earth are caused by the tilt of its axis relative to its orbit. The direction of the tilt stays the same relative to the stars as the earth orbits around the Sun. In this way the North Pole leans toward the Sun in summer and away from the Sun in winter. During summer in the Northern Hemisphere there are more daylight hours and the Sun is more perpendicular (more overhead). The seasons are NOT caused by the Earth moving closer and further away from the Sun. This orrery does not model the tilt of the earth.

12.
From antiquity the circle has always had 360 degrees. What did one degree represent?

One degree represents the angle the Earth travels around the Sun in one day.

13.
In summer daylight lasts longer. In winter nighttime is longer. Is this true in the Southern Hemisphere as well? Is there any place on Earth where the amount of daylight does't change throughout the year?

Sunlight falls on half the Earth. The other half is in darkness. The line marking the boundary between the two is a circle perpendicular to the line connect the Earth with the Sun. Because the axis of the Earth's rotation is tilted some 23 ½ degrees, the North and South Poles are not usually on this boundary circle. In summer the North Pole is in the sunlight side and any place in the Northern Hemisphere will spend more than half a day in the sunlight side. In fact there will be no nighttime at the North Pole at all. While the North is in summer the Southern Hemisphere will be in winter and nighttime will be longer than half a day. The affect of the tilt on the length of sunlight decreases toward the equator until when you are on the equator. At the equator daylight and nighttime are both 12 hours all year long.

14.
In the United States the Sun rises in the East and sets in the West. In Australia are those directions reversed?

No. The Sun everywhere on Earth rises in the East and sets in the West. What is different is where the Sun appears in the sky. In the United States the Sun is in the southern half of the sky. In Australia the Sun is in the Northern half.

15.
Venus, and especially Mercury, either set in the West soon after dusk or rise in the East just before dawn. They never appear in the night sky directly over head. Why is that?

The orbits of both Mercury and Venus are inside the orbit of Earth. As those two planets travel around the Sun, the furthest they can appear away from the Sun is when their position in their orbit is perpendicular to Earth. In this position Venus has a maximum angle of 35 degrees from the Sun and Mercury has a maximum angle of 21 degrees. If the Sun was just on the horizon, the highest Venus could be is 35 degrees up. In reality, to view the Stars and the Planets, the Sun must have set for some period of time – about an hour or so. An hour relates to 15 degrees of the Earth's rotation. When that 15 degrees is factored in, the result is that Venus is not seen higher than about 20 degrees and mercury not higher than 5 degrees. By the way, you can tell the difference between the stars and the planets, because the planets all track in the same area as the Sun and the Moon (called the ecliptic) and the planets don't twinkle.

16.
When there is a "new moon," will the lit section of the moon be on the East or West section of the moon.

Knowing that counter-clockwise is the direction for both Earth's spin and the Moon's orbit, you can place the Moon in a position where it is just visible at dusk. The lit side of the Moon will be towards the West.

17.
What are the positions of the Earth and the Moon when there is an eclipse of the Sun?

The Moon will between the Earth and the Sun.

18.
What are the positions of the Earth and the Moon when there is an eclipse of the Moon?

The Earth will between the Moon and the Sun.

19.
Where are the Earth and the Moon when there is a Full Moon? If you are on the Moon where are their positions when there is a "Full Earth?"

In a full moon the Moon will be away from the Sun so the Earth will see the whole sunlit side. This position is same as in an eclipse of the Moon. However, an eclipse does not occur every time there is a full moon. The orbit of the Moon wobbles up and down. An eclipse will only occur when the Moon is directly in line with the Earth.

20.
Why are shadows longer in the winter than in the summer?

In winter the tilt of the Earth is pointed away from the Sun. The Sun will be lower in the sky and shadows will be longer. The earth in this model is ¾ inch in diameter. If the Sun were modeled to this same scale, how big would it be?