AEROSPACE PALACE ACADEMY, NIGERIA
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LESSON 50:
THE LENGTH OF A DAY ON DIFFERENT PLANETS

The circadian rhythm—the rising of the sun, its passage across the sky, its setting, and then the dark of night—is such an integral part of our lives that we often do not stop to think about it. All the planets in the Solar System have sunrise, daytime, sunset, and nighttime, but they do not all have them the way Earth does. In this lesson, we explore a few of these planetary foibles.

Next Generation Science Standards (NGSS):

- Discipline: Earth and Space Sciences.
- Crosscutting Concept: Scale, proportion, and quantity.
- Science & Engineering Practice: Using mathematics and computational thinking.

GRADES K-2

NGSS Earth's Place in the Universe: Use observations of the sun, moon, and stars to ~~describe patterns that can be predicted.~~

As the Earth turns on its axis, any point on its surface will come around to where it is lit by the Sun. Somebody standing there will see this as the Sun rising. As the Earth continues to turn, the person will see the Sun moving across the sky from east to west. Sometime later, as the point on the Earth's surface moves around to the dark side away from the Sun, the person will see the Sun setting. If you have a globe and a lamp, you may want to illustrate this concretely by putting a paper doll on the globe and rotating the globe around on its axis.

Other planets in the Solar System also rotate on their axes and thus have sunrise, daytime, sunset, and nighttime. There are many variations on this, however; they do not all have sunrise and sunset the way Earth does. For example, the planet Venus rotates in the opposite direction; it takes a little longer to make a full rotation on its axis than it does to move around the Sun once. Thus on Venus, the Sun rises in the west a little less than twice a Venusian year, or once every 2802 hours, or 116 (Earth) days and 18 hours. (Venus is shrouded by thick clouds, though, and so a person standing on its surface would not see the Sun at all.)

Mars' period of rotation is almost the same as that of the Earth—about 24 hours and 37

GRADES K-2 (CONTINUED)

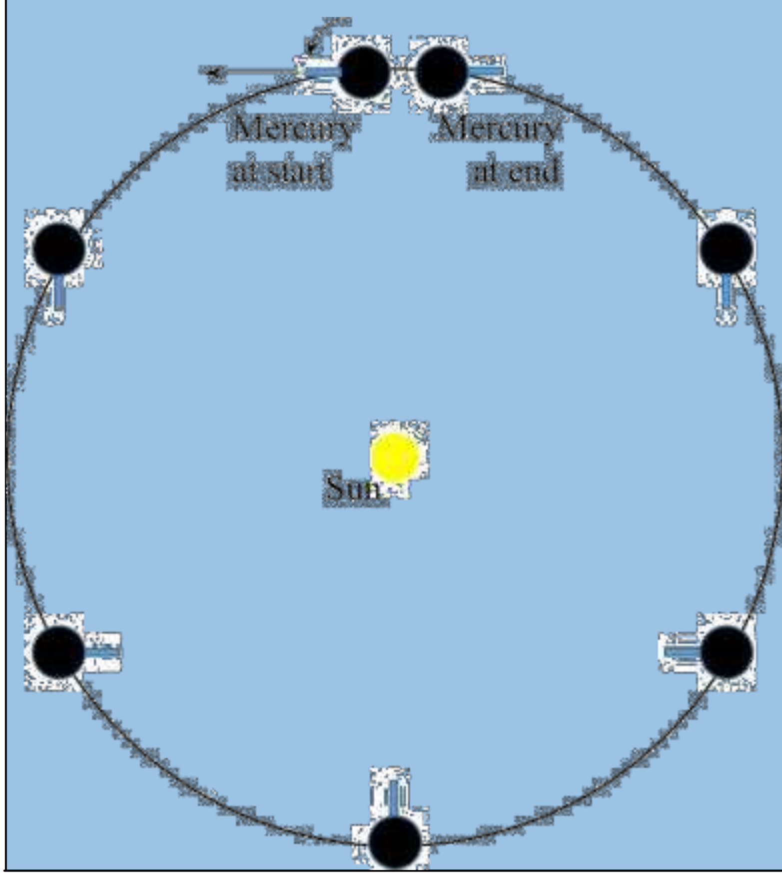
minutes. Jupiter, in spite of being the largest of the planets, also spins the most quickly and has a day that is only 9 hours 55 minutes long. Saturn's day is almost as short, being about 10 hours 33 minutes long.

Suggested Activity: NASA has a web page aimed at elementary school children showing how one can create a chart of the lengths of the planets' rotation periods. Teachers may also wish to read the book, *What Makes Day and Night?* by Franklyn Branley. It describes in age-appropriate detail the movement of the Earth, sun and moon.

GRADES 3-5

NGSS Earth's Place in the Universe: Represent data in graphical displays to reveal patterns of daily changes in length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky.

Another planet with an unusually slow rotation period is Mercury. It makes one rotation on its axis in exactly two-thirds of the time it takes to revolve around the Sun. You can illustrate it using a drawing like this:



In the picture, the blue rectangle on the left-hand circle at the top represents somebody watching the sun rise as the Mercury year begins. Half a Mercury year later, the planet is on the opposite side of the Sun (at the bottom of the picture) and the planet has made three-quarters of a rotation on its axis. (This would be a good opportunity to practice fractions.) Between the half revolution and the three-quarter rotation, the person is seeing the Sun at noon. At the end of the Mercury year, the person is seeing the Sun set. Thus one year on the planet Mercury is half the length of a Mercurian day and a day on Mercury lasts two

GRADES 3-5 (CONTINUED)

years. This web page includes a video made from pictures taken by the Messenger spacecraft of a day on Mercury's South Pole.

Interestingly, until 1962 scientists thought that Mercury's rotation rate on its axis was the same (on average) as the rate it revolved around the Sun. Were this the case, Mercury would always keep one side facing the Sun and the other side facing away from the Sun, as the Moon does to the Earth. It was only with radar observations of Mercury's surface (it is too close to the Sun in the sky for large optical telescopes to view it safely) in 1962 and 1965 that scientists figured out the correct rotation rate.

Universe Today has a good discussion of the rotation rates of the different planets.

Suggested Activity: You may wish to create the comparison chart mentioned in the previous lesson. You may also wish to have students calculate their age on the various planets. There is a helpful worksheet for this activity from the Museums Victoria in Australia.

GRADES 6-8

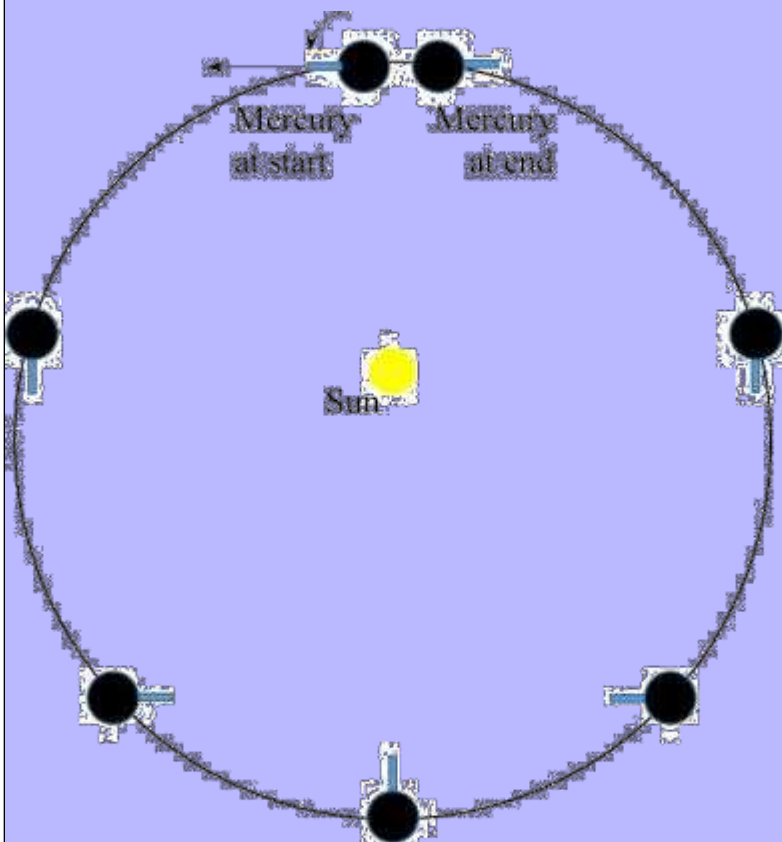
NGSS Earth's Place in the Universe Patterns can be used to identify cause-and-effect relationships.

The length of a day on the planet Mercury is actually a bit more complicated than described in the Grades 3-5 lesson. Because Mercury's orbit is quite elliptical, the effects of the planet's moving more quickly at perihelion (when it is closest to the Sun) and more slowly at aphelion (when it is farthest from the Sun) are quite pronounced. The situation is more like the one shown in this picture:

At the beginning of the year on Mercury, we consider the planet to be at perihelion. (This is an arbitrary setting; I do not know of any Mercurian calendar that marks the beginning of its year at any position in its orbit.) As the planet moves around the Sun, its closeness to the Sun makes it revolve faster in its orbit than it is rotating. What this means is that the person who is watching the Sun rise in the east will actually see the Sun move backward in the sky, set briefly, and then rise again. Similarly, somebody on the other side of the planet watching the Sun set would see it pause, move backward briefly in the sky (rising back above the horizon if it has just set), and then move forward in the sky again. The term

GRADES 6-8 (CONTINUED)

"briefly" is relative; the time from when the sun starts appearing to move backward to the time that it finishes is just over eight Earth days, out of an 88-Earth-day year. The video showing the progression of Mercury's day at its South Pole shows the advance of the sunlit portion pause and resume about halfway through and again at the video's end. The apparent size of the Sun in the sky also decreases by about a third as the planet moves from perihelion to aphelion and then increases again as the planet moves back to perihelion.



Perhaps the strangest day/night cycle of a planet is that of Uranus. While its rotation period of 17 hours 14 minutes is nothing unusual, its axis is tilted at an angle of almost 98 degrees relative to the plane of its orbit around the Sun. This means that strictly speaking, its rotation is retrograde (backwards) like that of Venus with an axial tilt of over 82 degrees. This means that at the equinox, somebody on Uranus' equator will see the Sun rise (in the east? in the west? one must define one's cardinal directions very carefully), pass directly overhead, and set. As the year progresses, the points of the Sun's rising and setting will move away from the east-west direction towards one of the poles until finally at the solstice the Sun will be tracing out a circle 16 degrees in diameter, centered on the horizon towards the north or south pole. For someone standing on one of the poles, the sun rises at one equinox and traces a slowly-ascending horizontal circle in the sky until that circle is 16 degrees in diameter and centered at the zenith at the solstice. On Uranus, the equivalent to the Tropic of Cancer and Tropic of Capricorn are at 82.2 degrees north and south latitude while the equivalent to the Arctic and Antarctic Circles are at 7.7 degrees north and south latitude.

Suggested Activity: Divide students into groups and have each group attempt to draw the sky from the perspective of an observer at different locations and times of year.

***G*RADES 9-12**

NGSS Science and Engineering Processes: Use mathematical or computational representations of phenomena to describe explanations.

The unusual lengths of days and rotation axes of some of the planets cry out for explanation. Since no scientists were watching the Solar System form, we are restricted to theorizing and figuring out whether the consequences of the theories match what we see today. The most widely-accepted theory of the creation of the Solar System says that the planets accreted from a disk of gas and dust that surrounded the Sun. The Law of Conservation of Angular Momentum (which flows from Newton's laws of motion) requires that as a rotating mass gets concentrated around its center of rotation, its rate of rotation must increase. This would presumably explain the rotation rates of Earth, Mars, Jupiter, Saturn, and Neptune, all of which give days that are a couple of tens of hours long. This leaves explanations required for Mercury, Venus, and Uranus. While Pluto is not considered a planet, its day of 153 hours 18 minutes is longer than usual and so is also of interest.

Mercury's rotation rate is caused by its rotation being tidally locked to its orbit around the Sun, much the same way that the Moon's rotation is tidally locked in its orbit around the Earth. The correspondence is not perfect, though, because the Moon always keeps one face toward the Earth while Mercury does not keep one face toward the Sun. Instead, while Mercury does have a tidal bulge as the Moon does, at one perihelion one end of the bulge is pointed at the Sun while at the next perihelion the other end of the bulge is pointed at the Sun. Mercury's orbit is so elliptical that the tidal torques are more than three times stronger at perihelion than they are at aphelion. As such, Mercury has a much greater tendency to have its rotation rate and revolution rate the same at perihelion; this is exactly what we see with its "Joshua moment" of the sun standing still and backing up slightly.

There is no single accepted explanation for Venus' slow, backwards rotation. One theory is that it was dealt a glancing blow by a large asteroid which reversed its spin. Another theory is that tidal effects from the Sun (similar to the Sun's effect on Mercury) combined with a resonance effect from the Earth to slow and eventually reverse the rotation. It is worth pointing out that the time it takes Venus to rotate 360 degrees is 243.02 days, which is two-thirds of an Earth year; this may be a red herring, though, because what would matter more is the Earth-Venus synodic period, which is 538.92 days. Adding to the

GRADES 9-12 (CONTINUED)

mystery is that Venus' rotation rate appears to be slowing down such that it is now 6.5 minutes longer than it was sixteen years ago. Indeed, it may be (and this is pure speculation) that Venus' rotation is chaotic as are the rotations of the planetary moons Hyperion and Nix but the time scale of the chaos is long enough—millions of years, or thousands or even hundreds of years—that we have not measured any great variations yet.

It is pretty well accepted—although not universally—among scientists that the planet Uranus was hit by something that tipped its axis of rotation to its present place. While the standard theory speaks of a single object with a few times the mass of the Earth, another ~~theory says that there were multiple impacts by smaller objects~~.

Pluto's period of rotation is explained by tidal locking like Mercury, but in Pluto's case the locking is with its moon Charon. Pluto and Charon are similar enough in mass that the balance point about which they both rotate is actually outside of Pluto. Charon has raised a tidal bulge in Pluto (and Pluto has done so in Charon) just as the Sun has raised a tidal bulge in Mercury. These tidal bulges in Pluto and Charon keep the two bodies facing each other as they revolve around each other.

Suggested Activity: Have students chart out the rotational day and orbit of each planet in the solar system as well as Pluto (you may wish to add additional columns of information as well). Ask students to calculate the average for each category, and then ask them to describe the characteristics of the "average" planet for our solar system.

Sixty Years Ago in the Space Race:

November 19, 1957: The Americans launched an Aerobee sounding rocket in support of Operation Smoke Puff, which created a temporary "artificial ionosphere" by releasing a cloud of potassium nitrate and aluminum.