# Lesson 5.2: How Does a Satellite Stay in Orbit?

## Objectives:

- Students will learn about placing a satellite into an orbit.
- Students will learn about the forces needed to keep an object in orbit.
- Students will learn that satellites orbit in paths that are elliptical and will learn about properties of ellipses.
- Students will learn Kepler's 3rd Law of Planetary Motion

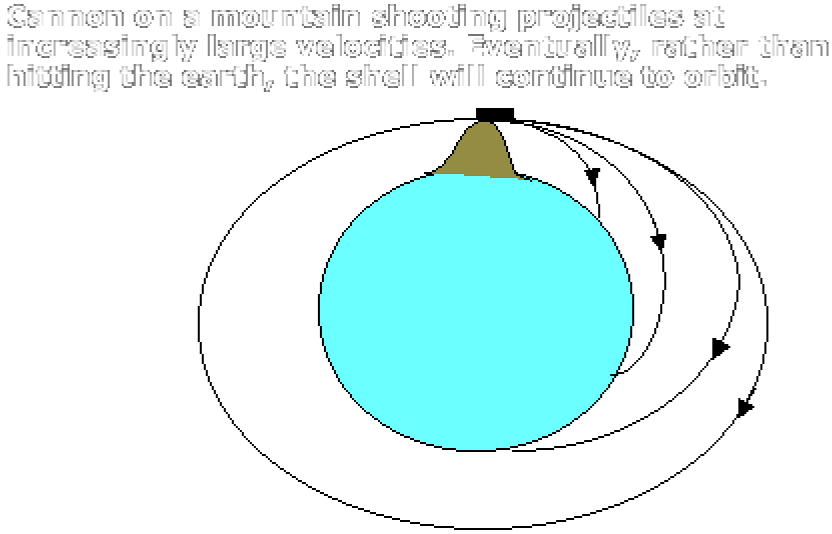
## Estimated Lesson Time:

Four classes (4 hours)

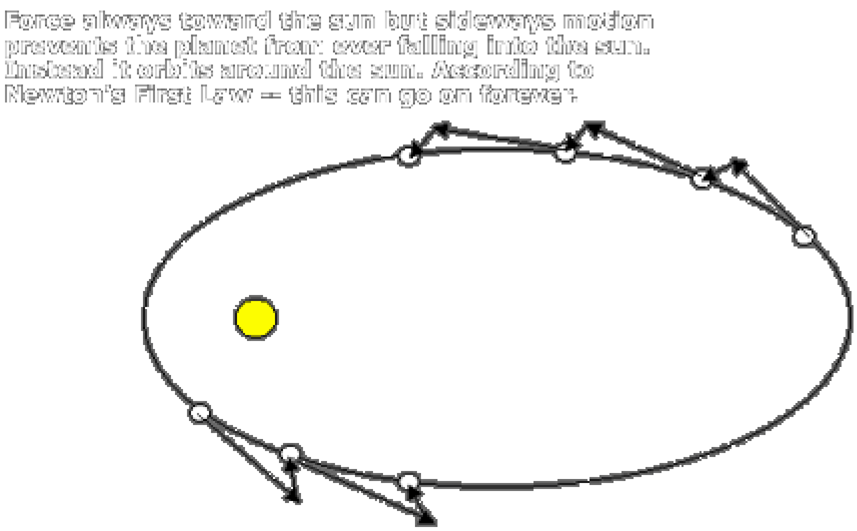
## Classroom strategies:

Have students add more "firsts" to timeline. Focus on the ability of man to put men and women in orbit by noting the first people to go into space orbit: Yuri Gagarin (April 12, 1961) circled Earth in Vostok-1, Alan Shepard (May 6, 1961) went suborbital to space in Frienship-1, John Glenn (Feb. 20, 1962) orbited Earth three times in five hours on Friendship-7 and was the first American in orbit; Valentina Tereshkova was first woman to orbit on Vostok-6 (June 16, 1963); Sally Ride (June 1983) was first American woman in space on Space Shuttle. Use timeline as motivation for discussion of how things stay in orbit. Use activities to reinforce elliptical orbits and orbital motions.

## Science Background Information:




Johannes Kepler was the first to accurately describe the mathematical shape of the orbits of planets. Our Moon and the planets travel in orbits that are very close to being circular. A circle is a special kind of ellipse. By definition, an ellipse is a geometrical figure that has two foci. In a circle, both foci of the ellipse are at the same point. Orbits of artificial satellites can be elliptical or circular.




A satellite that stays in orbit with just the right speed will retrace its path, just like the Moon continues to orbit the Earth. Artificial satellites also need just the right speed to stay in orbit around the Earth. Those with a smaller speed will return to the Earth as gravity pulls it down, those with a large enough speed can actually leave the Earth's gravitational tug and travel into deep space.

To make this point, imagine a baseball pitcher standing on a 100-mile-high mound above the Earth. If the pitcher throws the ball horizontally at 100 miles/hour, the speed is not great enough to stay in orbit so the ball will travel outward some distance but then fall back to Earth. Now, if the pitcher throws the ball at approximately 18,000 miles/hour straight out, then the ball will have just the right speed to orbit the Earth. In this case, the ball will circle the Earth and hit the pitcher in the back of the head one orbital period later (about 90 minutes later)! You can imagine it as continuously falling around the Earth in a circle.

### Vocabulary:

1. Orbit -
2. Ellipse -
3. Focus (Foci) -
4. Period - the time needed for a satellite to complete one orbit
5. Elliptical -

### Materials and Equipment:

String, push pins, pens, paper, corkboard, ball (object to throw), whiffle ball

### Advance Preparation:

Gather appropriate materials.

### Activities:

Making Ellipses: Demonstrate the shape of an ellipse by drawing some with the aid of two pins and a loop of string. First show them how to construct a circle. Put one pin on the corkboard with a piece of paper under the pin; the pin defines a "focus." Put a pencil in the loop of string that is looped around the pin. Now pull the string tightly and trace the pencil around the center point. This will produce a circle (a circle is an ellipse with both foci at one point). Now draw a line through where the center of the circle is (where the pin was) so that it intersects both sides of the circle. Put the two pins at two points along this line, equidistant from the center and within the circle. Now repeat the exercise with the string looped around both pins this time. The student will now have traced an ellipse. Have the students change the position of the pins to create different shaped ellipses. Have them explore how the shape changes as the pins are moved closer to and further from the center.

Demonstration: Teacher whirls a Whiffle ball (or something light) on string around head to demonstrate circular orbit. Tell the students that the string holding the ball exerts a centripetal force that is like (but not the same as) gravity pulling on the satellite. Ask them to predict what will happen if the string breaks and is no longer holding onto the ball. Will it continue to go in a circle? Then teacher lets go of the string. The students should observe how the ball behaves. When the string is let go, the ball will fly straight off in the last direction it was moving when the string was held. The ball does not continue to move in a circle; it moves in a straight line. (Hint: spin the ball fast enough that it hits the wall before it drops too far as gravity pulls it down.) Ask them how Newton's Laws describe these motions (when the string is let go, the force of the string is no longer acting on the ball to accelerate it in a circular orbit - $2^{nd}$ Law, and the ball continue in a straight line since no force is acting on it to keep it in a circle - $1^{st}$ Law).

## Homework Assignment:

Have students research and determine what objects the following satellites (both artificial and natural) orbit around: the Moon (the Earth), the Earth (the Sun), Halley's Comet (the Sun), Io (Jupiter), Mimas (Saturn), Galileo (an artificial satellite orbiting Jupiter), Phobos (Mars), Charon (Pluto), GPS (Earth), Vesta (an asteroid in orbit around the Sun), Triton (Neptune). (Use a worksheet for this exercise)

**Creative writing**. What would happen if for some reason, the Earth's speed around the Sun suddenly increased? Describe how the life on the Earth would be different?

**Research.** Have students research the life of Johannes Kepler and his contribution to planetary orbits. They should include information about his three Laws of planetary motion and how they simplified earlier ideas of Earth-centered universe as described by Ptolemy.

## References:

Blueprint For Space, (Smithsonian Institute Press)

Spaceflight (Smithsonian Guides)

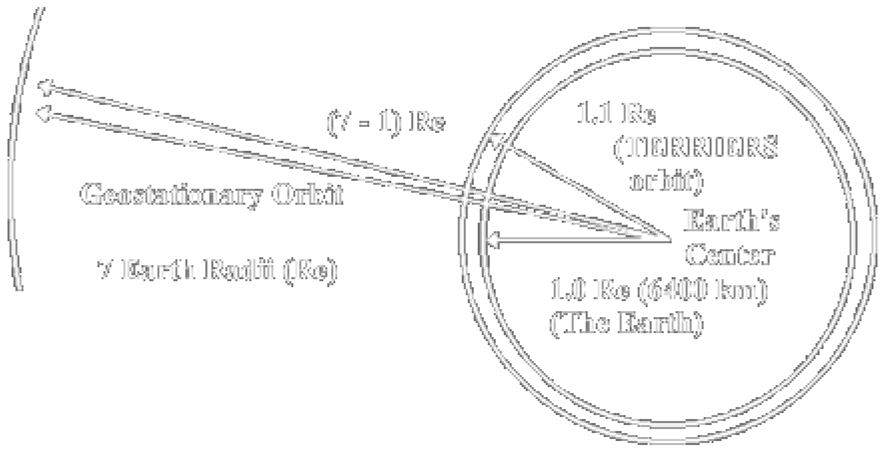
StarDate, Guide to the Solar System (University of Texas, Austin)

Need references for Ptolemy and Kepler

## Connections:

Math enrichment: Kepler's $3^{rd}$ law of planetary motion is given by $P^2 = k A^3$, where P is the period, and A is the orbital radius, and k is a constant. TERRIERS will orbit the Earth with a period of 1.5 hours and having an orbital radius of 1.1 Earth radii. At what orbital radius would a satellite have to be so that it would have an orbital period of exactly 24 hours? This is called a geostationary orbiting satellite. Find out the Earth's radius in kilometers. What is the height of the geostationary orbit above the Earth's surface?

Answer: First, solve for the constant k = $(1.5^2/1.1^3)$ = 1.69; Now solve for A using an orbital period of 24 hours $A^3 = 24^2/1.69$; A = Approximately 7 Earth radii. Earth's radius is approximately 6,400 km. The height therefore, is approximately, (7 - 1) * 6400 km or 38,400 km above the Earth's surface.




**Literature:** The Right Stuff (Tom Wolfe), see the following Web page for a list of historical books about space flight (http://www.chron.com/content/interactive/space/archives/89/890716-4.html)

**Music:** Will It Go 'Round in Circles (Billy Preston)

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