

# Orbital Motion

## Instructional Objectives

After viewing the program and participating in the accompanying activities, the student will be able to:

1. apply the principle of centripetal force to explain how a satellite is able to orbit the earth.
2. describe the shape of a planet's orbit.
3. explain why a planet varies in speed along its orbit.

## Synopsis

What keeps satellites in orbit? Why don't they fall back to earth or fly out into space? These central questions are the focus of study for this program. Through detailed animated graphics, the students will observe the nature of a satellite's orbit.

The program illustrates Newton's classic example of a cannonball being shot into space to explain the vertical and horizontal velocities of an orbit. The centripetal force of gravity is described as the component which gives a satellite its vertical velocity. Similarities are drawn among the orbits of the Hubble Space Telescope, the earth's moon, and the planets of the solar system. The shape of a planet's orbit is illustrated along with its variation in speed around the sun. A correlation is made between the time that it takes a planet to make one revolution around the sun and the size and shape of the planet's orbit. Planning Scientist at the Space Telescope Science Institute, Mark Buie, is spotlighted in the Science Career Profile. The students will observe various aspects of his position at the Institute and learn about his specialized research with planet Pluto.

## Vocabulary

*Acceleration* - Any change in the speed or in the direction of an object.

*Centripetal Force* - The inward pull on a satellite from the gravitational field of the sun or a planet.

*Ellipse* - The shape of an orbit. An ellipse contains two foci; for a planet's orbit, the sun is located at one focus while the other is empty space.

*Orbit* - The path of one moving body around another.

*Revolution* - One orbit around a celestial body.

*Satellite* - An object that is in orbit around another object such as a moon, a planet, a star, or an artificial projectile.

*Velocity* - Speed with direction. A change in velocity may mean a change of speed or a change in direction or both.

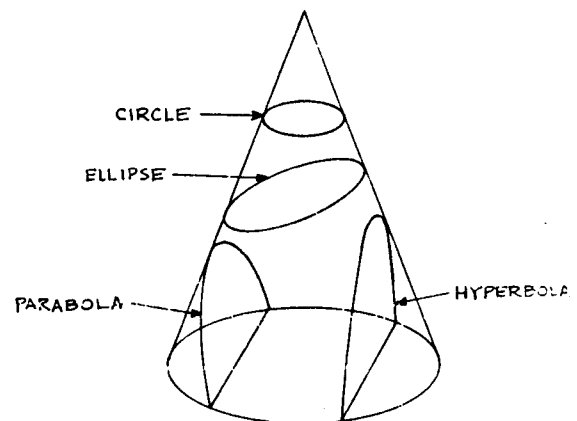


## Previewing

Students can observe the simulated path of an orbit by wadding up a few sheets of 8 1/2" x 11" paper and pitching them in a horizontal manner into a waste can. While some students are pitching, have others draw the path of the projectile on a sheet of paper. Did the students draw a straight line or a curved path? What is causing the projectile to curve? Have students add vector arrows to their curves to show the horizontal and vertical directions of the projectile. What would happen to the wad of paper without the influence of the earth's atmosphere or gravitational field?

Describe and demonstrate the nature of centripetal force. Place a marble under a clear cake cover. Swirl the cover so that the marble follows a circular path along the cover's edge. Raise one side of the cake cover and have the students plot the marble's path on a sheet of paper. Does it continue to move in a circular motion, fly out into "space," or move in a straight line tangent to the cover's circumference?

Describe the shape of an ellipse. Demonstrate the various eccentricities of an ellipse as well as the curves of a parabola and hyperbola. A cone made of clay and a cheese slicer can be used to produce conic sections of the different forms (see diagram).



If available, project a drawing of the gravitational field strength around the sun. Overlay a drawing of the earth's orbit.

Discuss the nature of the orbit in terms of shape and effect that the displacement of the sun's gravitational field has on the earth's orbital speed. Initiate a similar discussion with an overlay of Neptune's orbit. How do the two orbits differ?

### Postviewing

Ask the students to explain how centripetal force affects a satellite's orbit. Have them mention various occasions where centripetal force can be observed on earth.

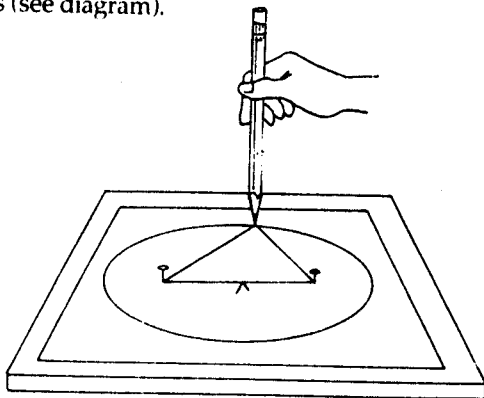
Distribute a diagram that shows an overhead view of the solar system. Have the students label the planets. Discuss the differences in the speeds and shapes of the orbits of the inner planets and the outer planets. For a copy of "Solar System Worksheet," contact: NASA Goddard Space Flight Center; Attn: Teacher Resource Laboratory; c/o Mary Buck; MS 130-3; Greenbelt, Maryland 20771; 301/286-8570.

Have the students research and report on the progressive contributions made by Tycho Brahe, Johannes Kepler, Issac Newton, and Albert Einstein to the study of orbital motion.

Ask the students to mention some interesting aspects of the career of planning scientist, Mark Buie.

### Active Involvement

Have the students draw an ellipse using a sheet of paper, a pencil, a string, two push pins and a sheet of cardboard (for the pins). The pencil represents a planet; one push pin is the sun while the other is empty space. Have students draw various ellipses with different eccentricities as they lengthen and shorten the distance between the two push pins (see diagram).



Have the students research the length of time that it takes each planet to revolve around the sun.

"Orbit II" is a computer program which simulates the orbit of satellites around the earth. The user must estimate the proper launch speed and launch angle to achieve a prescribed orbit. "Orbital Mech" is a computer program which simulates the motion of the space shuttle in orbit above the earth. The user maneuvers the orbiter by changing its altitude and by firing reaction control engines. To obtain the catalogue, Software for Aerospace Education, which lists these and other computer programs, contact: NASA Office of Educational Technology; Educational Affairs Division; Code XET; National Aeronautics and Space Administration; Washington, DC 20546.

### Bibliography

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Moche, Dina. *Astronomy Today*. New York: Random House, 1982.

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# See for Yourself: Experiments/Projects

## Can You Launch a Satellite Into Orbit?

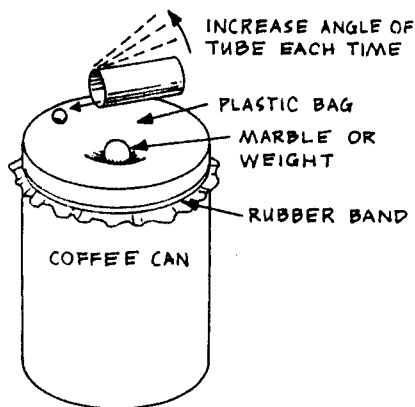
### ► MATERIALS:

- coffee can, 26 oz. or 39 oz.
- plastic bag, gallon size
- scissors
- rubber band
- marble or small round weight
- BB, ball bearing, or small round pebble
- cardboard tube (approx. 5" long) from a roll of toilet paper or cut from a roll of paper towels or wrapping paper

### ► DIRECTIONS:

Cut the plastic bag into a single sheet that can be stretched over the coffee can. Place the rubber band around the bag and the can to securely hold the bag in place. Place a marble or small weight into the center of the liner to create a vortex effect. A vortex is like a whirlpool which sucks things into the center. The center weight can represent the earth while the plastic bag can represent the gravitational field of the earth. The BB or ball bearing or small pebble will simulate a satellite.

1. Place a BB near the edge of the gravitational field. What happens to the BB? Record your observation.



2. Now launch the BB "satellite" using the cardboard tube. Position the tube at the edge of and tangent to the "gravitational field" as shown in the diagram. Place the BB in the tube so that it will slide down at a very low angle. Draw the "orbit" that is created by the satellite.

# STARFINDER

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3. Launch the satellite several times, gradually increasing the angle of the tube each time. Draw each orbit observed. How do the different orbits compare to each other?
4. Try to find the best tube position that will cause the satellite to remain in orbit for the longest time. What factors are involved in launching the simulated satellite into orbit? Discuss how these factors may be similar or different for a satellite which is launched from a space shuttle.

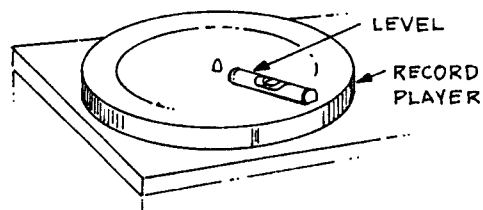
## Can Centripetal Force Be Seen?

### ► MATERIALS:

- record player
- small level
- masking tape

### ► DIRECTIONS:

1. Notice how a level works. Place the level on a flat surface such as a table. The bubble in the level should be in the center of the glass viewer. Tip one end of the level slightly upward. In what direction does the bubble travel? Record this observation. Tip up the other end of the level. Record the direction that the bubble has moved.
2. Use some masking tape to attach the small level to the outer edge of a record player as shown in the diagram. Make certain that the bubble is in the center of the level when it is attached (see diagram). Now turn the player on at medium speed and watch what happens to the bubble.



- In what direction does the bubble move? Record your observation.
- Change the speed of the player noting any changes in the bubble's movement when the player turns slower and faster.
- Describe any relationship that can be found between the speed of the record player and the movement of the bubble.
- Describe how the movement of the bubble demonstrates the nature of centripetal force of gravity.
- With your left hand, hold the ruler and swing the rubber stopper overhead. The stopper has now become a "satellite." Notice that the centripetal force in this experiment is the tension of the string that pulls the satellite toward the center of its orbit.
- Hold the end of the rubber band with the thumb of your right hand. Since the stretch of the rubber band will alter the orbit, note the location of the knot tied to the rubber band and keep it in the same position on the ruler at all times. The centripetal force of the string will be measured by the amount of stretch applied to the rubber band.

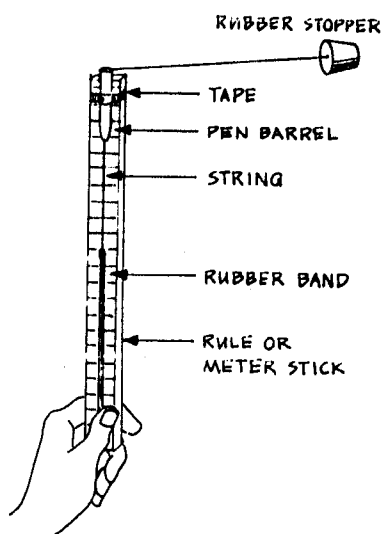
### How Can You Measure Centripetal Force?

#### ► MATERIALS:

- 3 foot (1 meter) wooden ruler
- tape
- strong nylon string, four feet in length
- ballpoint pen
- rubber band
- small rubber stopper
- clock or watch with a second hand or a stopwatch

#### ► DIRECTIONS:

- Dismantle the ballpoint pen, keeping only the barrel portion. Thread the string through the barrel, then securely tape the barrel to one end of the ruler. Tie the rubber band to the end of the string that hangs down the ruler. To the other end of the string, attach the rubber stopper (see diagram).



- While a partner uses a clock or watch to time the revolutions for 10 seconds, count the number of revolutions that the satellite makes during that time. (A revolution is one time around the circular orbit.) Take care that your partner is out of range of the swinging stopper. Determine your orbital speed by dividing the number of revolutions counted by ten. (Orbital speed will be the number of revolutions your satellite makes in one second.) Record your answer.
- Determine how centripetal force is affected when the speed or mass of the satellite changes. Create a table to record your findings.
- How will doubling your speed change the amount of centripetal force? Double the number of revolutions per second and measure the centripetal force by measuring the length of the rubber band. Record the measurement on your table.
- How will doubling the mass of your satellite change the amount of centripetal force? Attach a small rubber stopper to the first. While maintaining your original speed, measure the length of the rubber band and record your results on the table.
- What relationships can you find between the measurements of centripetal force made and the addition of speed or mass to your satellite?

# Science Career Profile

**MARC BUIE**

Planning Scientist

Hubble Space Telescope Science Institute

Education: Ph.D., Planetary Science

B.S., Physics



## **Chief Responsibilities**

Marc Buie's job responsibilities are divided between his scientific research on Pluto and his duties as a planning scientist. In his capacity as a planning scientist, Marc is involved in putting together a long-term schedule of proposed research projects for the Hubble Space Telescope. He must first organize the proposals so that objects are observed in a logical order to obtain the best observation time for researchers. Then, he must put together a calendar of all of the approved programs that will involve the use of the HST.

Buie's responsibilities as a planning scientist also involve reviewing program proposals and identifying any problems that could prevent those proposals from being placed on the schedule. As part of this process, he must review each proposal to determine if the strategies developed for acquiring the targets are going to work, if the proposed camera exposures are long enough, and if the instructions that have been written to execute a research project on the HST are going to produce the anticipated results for the researcher.

Marc also serves as a consultant to scientists outside of the Science Institute, who need information about how to carry out a successful research project using the HST. His specialty is providing advice to scientists on putting together proposals related to observing planets.

In addition to his responsibilities as a planning scientist, Marc has different projects that he works on related to his research on Pluto. One of these projects involves reconstructing a map of Pluto's surface. This work is based on ground observations from data that come in from the University of Hawaii's 88-inch telescope on top of Mauna Kea. This is a very involved project. He takes measurements of light based on how much light is lost as a result of the depth of eclipses of Pluto's moon. The timing for Marc's research is extremely important because, right now, Pluto is at its closest point to the sun along its orbit and is at its warmest temperature—about 50-55 degrees Kelvin. In 125 years, it will be at its farthest point from the sun and only 25-30 degrees Kelvin.

## **A Typical Day**

Marc's day is split between his scientific research projects on Pluto and his direct support to the mission of the Hubble Space Telescope. He likes to start his workday early, usually around 7:30 in the morning, when there are few interruptions. He begins his day by checking his electronic bulletin board to see the scope of the projects that he has to work on. During the morning hours, Marc is busy conducting his scientific research on Pluto.

Unlike Marc's morning, which is well-planned and defined, his afternoons are unpredictable. This is the time that he carries out his responsibilities as a planning scientist with the HST. As part of the proposal review process, Marc handles anywhere from three hundred to four hundred proposals. His afternoon is spent processing those proposals by tracking down files on computers, reviewing the proposals, trying to see if the proposal dates are correct and that the projects are completed in the appropriate order.

Also during the afternoon, Marc reads and responds to his electronic mail in which messages are received from all over the world. On the average, Marc receives fifty messages a day that are anywhere from a paragraph to three or more pages in length. Marc's main concern during this time is to read his messages and type out his responses quickly so that he doesn't spend too much of his afternoon just answering his mail.

## Career Viewpoint

In Marc's position as a planning scientist, he feels that it is very important to absorb a tremendous amount of information and material related to completing a successful research study using the HST. He uses this knowledge as an adviser, not to take over projects for researchers, but to teach them how to develop creative proposals for themselves.

Marc believes that motivation plays a strong part in doing a job well. He is most excited about his work on Pluto, particularly because it is such an excellent time to observe the eclipses of Pluto's satellite, Charon. He likes the stability and predictability of his research studies—the fact that he can look ahead to the next month, three months, or even a year to know what he is going to work on. He finds it satisfying to be able to set the pace of his research, and to know that if an emergency comes up, he can take care of it.

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