NATIONAL MUSEUM OF THE UNITED STATES AIR FORCE®

CENTRIPETAL FORCES AND SATELLITE ORBITS—Demonstration

Students will learn how mass, radius and period are related to the centripetal force needed to keep a satellite in orbit.

LESSON PLAN

Introduction
As a satellite orbits the Earth, Earth's gravity keeps the satellite from flying off into space. The initial push from a rocket gets the satellite into space and the satellite's orbital speed keeps it in space. At the same time, gravity constantly pulls at the satellite and keeps it in orbit. There is an optimum orbital speed a satellite must maintain; otherwise, it is pulled closer and closer to Earth. The farther away from Earth a satellite is traveling, the weaker the Earth's gravitational pull. Because the pull of gravity is less, the satellite can then orbit at a slower speed without being pulled back to Earth.

Lesson Objective
In this lesson, students will learn how mass, radius and period are related to the centripetal force needed to keep a satellite in orbit.

Learning Objectives:

The students will
- Learn about centripetal force.
- Learn about the effects of mass on keeping a satellite in orbit.
- Learn how changes in radius affect the orbit.
- Build and experiment with a simple demonstration model.

Procedures:
- Build the demonstration model. The rubber stopper will represent a satellite. Washers or nuts suspended from the string attached to the "satellite" will supply the centripetal force. The narrow tube provides a grip for the student to control the movement.
- Take the ball-point pen apart. Remove the ink cartridge and use the barrel of the pen or narrow tube as a grip to swing the "satellite."
- Thread the piece of string through the barrel of the pen. (Use the smoother end of the barrel as the upper end around which the string will move in a circle.) Tie upper end of the string to the rubber stopper. To the lower end of the string tie a washer or nut. The weight of these washers or nuts provides the centripetal force needed to make the satellite move along a circular orbit.
- Arrange the rubber stopper satellite so that its center is about 3 feet from the top of the pen or narrow tube.

Grade Level: 6—8

National Math Standards:
Number and Operations, Algebra, Geometry, Measurement, Problem Solving, Communications and Connections.

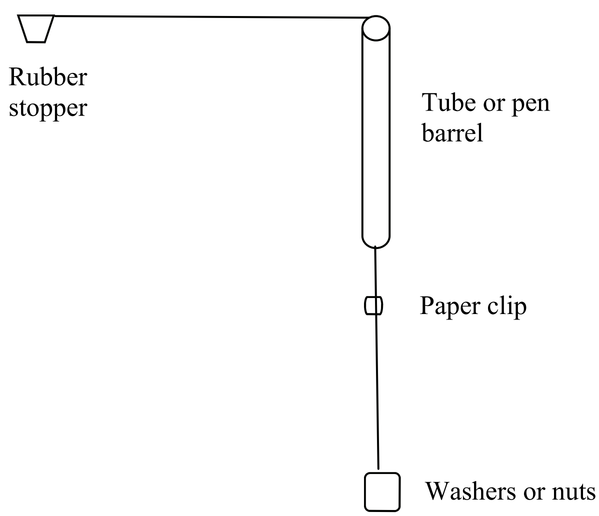
National Science Education Standards:
Unifying Concepts and Processes, Science as Inquiry, Physical Science, Earth and Space Science, Science and Technology, Science in Personal and Social Perspective, History and Nature of Science.

Technology Content Standards (from STL):
Technology and Society, Design, Abilities for a Technological World, and The Designed World.

Materials Required:
- Narrow rigid tube (ballpoint pen barrel, straw, etc.)
- Piece of string about 6' long
- Two rubber stoppers
- Washers or nuts from bolts
- Two paper clips
- Tape
- Allow plenty of space for the orbits and safety glasses should be worn

Procedures, continued

- A paper clip can be attached to the string about an inch below the barrel or tube.
- When the student swings the satellite in its orbit, keep this paper clip about an inch below the barrel to ensure that the radius of the orbit remains constant.
- Once the student has the satellite moving smoothly at a radius of 3 feet, he/she should count the number of revolutions made by the satellite in 30 seconds. (A revolution is one time around the circular orbit.) The time required for the satellite to make one revolution is its period. Determine the period by dividing 30 seconds by the number of revolutions that were counted.
- Ask the students: What is the period of your satellite? Why is it better to measure the time for many revolutions rather than just one?
- What is the period of your satellite if you double the centripetal force but keep the radius the same? Have the students double the force by doubling the number of washers or nuts at the bottom of the string.
- Ask the students: How would you make the centripetal force four times as big? How much force is needed to halve the satellite's period? If you halve the radius of the orbit, what force is needed to keep the period the same?
- From Newton's Second Law of Motion, students might reason that if you doubled the mass of the satellite, you would need twice as much force to keep the satellite moving along the same orbit with the same period.
- Have the students tape or tie another identical rubber stopper to the first one to double the mass of the satellite. With the same orbital radius of 3 feet, ask the students if the period remains about the same when you double the centripetal force acting on twice the mass?



Extension:

Have the students change the radius of the orbit and observe the results.

MEASURING CENTRIPETAL FORCES

Count the number of revolutions made by the satellite in 30 seconds. ________________________
(A revolution is one time around the circular orbit.)

The time required for the satellite to make one revolution is its period.
Determine the period by dividing 30 seconds by the number of revolutions that were counted._________

What is the period of your satellite? _________________

Why is it better to measure the time for many revolutions rather than just one?_____________________

What is the period of your satellite if you double the centripetal force but keep the radius the same? _____
(To double the force, then double the number of washers or nuts at the bottom of the string.)

How would you make the centripetal force four times as big?___________________________________

How much force is needed to halve the satellite's period? ______________________________________

If you halve the radius of the orbit, what force is needed to keep the period the same?________________

Based on Newton's Second Law of Motion, double the mass of the satellite.

How much force you would need to keep the satellite moving along the same orbit with the same period?

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Resources:

- National Aeronautics and Space Administration (NASA)
- Shoot a Cannonball into Orbit! Simulation http://spaceplace.nasa.gov/how-orbits-work/redirected/
- http://www.nasa.gov/audience/forstudents/5-8/features/what-is-orbit-58.html
- http://science-edu.larc.nasa.gov/SCOOL/orbits.html
- http://spaceplace.nasa.gov/geo-orbits/redirected/