

Teacher Toolkit - Satellite Motion

Objectives:

1. State and explain the meaning of Kepler's three laws of planetary motion.
2. Explain the reason that a satellite can be thought of as a projectile that falls around the Earth instead of into it; and to compare and contrast a circular orbit with an elliptical orbit in terms of the force, acceleration and velocity vectors.
3. Use equations to calculate the orbital speed, orbital acceleration and orbital period for a satellite that orbits a central body of known mass a known distance away.
4. Discuss the meaning and the cause of weightlessness and to explain why an orbiting astronaut would experience weightless sensations.
5. Use an energy analysis to explain both the changes in speed and the constant speed of a satellite in an elliptical and a circular orbit.

Readings: [The Physics Classroom Tutorial, Circular and Satellite Motion Chapter, Lesson 4](#)

Interactive Simulations:

1. Orbital Motion <http://www.physicsclassroom.com/Physics-Interactives/Circular-and-Satellite-Motion/Orbital-Motion>
The Orbital Motion Interactive simulates the elliptical motion of a satellite around a central body. The eccentricity of the orbit can be altered. Velocity and force vectors are shown as the satellite orbits.
2. OSP: Kepler System Model <http://www.opensourcephysics.org/items/detail.cfm?ID=9757>
This robust model will let your students visualize all three of Kepler's Laws. The First and Second Law are especially well-modeled for the beginner, mostly because of the array of tools for viewing.
3. OSP: Newton's Mountain Model <http://www.opensourcephysics.org/items/detail.cfm?ID=13106>
As Newton pondered, what would happen if you launched a projectile from a VERY tall mountain on Earth? This HTML sim lets you explore the idea of Newton's Mountain.
4. Elevator Ride <http://www.physicsclassroom.com/Physics-Interactives/Circular-and-Satellite-Motion/The-Elevator-Ride>
The Elevator Ride simulation depicts the forces acting upon an elevator rider while ascending and descending. The emphasis is on communicating the sensations of *weightlessness* and *weightiness* experienced by a rider.

Video:

1. History Channel –Gravity <http://www.history.com/shows/the-universe/videos/the-universe-gravity>
This well-produced 45-minute video from The History Channel details the concept of universal gravitation.
2. Gravity Visualized <https://www.youtube.com/watch?v=MTY1KJe0yLg>
Learn to build an inexpensive model to help students visualize gravitation on the cosmic scale.
3. Veritasium: Why Are Astronauts Weightless? <https://www.youtube.com/watch?v=iQOHRKKNLQ>
Physicist Derek Muller debunks the myth that astronauts in the ISS are in a zero-gravity environment.

Background Information on Space Flight

1. NASA Jet Propulsion Lab: The Basics of Space Flight <http://www2.jpl.nasa.gov/basics/bsf1-1.php>
For teachers wanting a deep dive into the fundamentals of space exploration, this is your resource.

Animations:

1. Physlet Physics: Projectile and Satellite Orbits http://www.compadre.org/Physlets/mechanics/illustration12_1.cfm
This interactive animation lets you change the launch speed of a projectile fired from a VERY tall imaginary building on Earth (simulating Newton's Mountain idea).
2. Physlet Physics: Circular and Noncircular Motion http://www.compadre.org/Physlets/mechanics/illustration12_3.cfm
A green planet orbits an orange star in two animations – one depicting uniform circular motion (circular orbit) and the other showing an elliptical orbit. The velocity vector is shown in blue and the acceleration vector in red.
3. Physlet Physics: Orbits and Planetary Mass http://www.compadre.org/Physlets/mechanics/illustration12_2.cfm
This animation simulates a Sun/Jupiter-like system with variable mass ratios: 1000:1, 100:1, 10:1, 2:1, and 1:1.
4. Physlet Physics: Kepler's Second Law http://www.compadre.org/Physlets/mechanics/illustration12_5.cfm
This animation displays total area swept out per unit of time. Ask students to choose any time increment (2 years, 3 years, 5 years) and watch the planet sweep out equal areas even though its orbital path is not uniform.
5. Physlet Physics: Planetary Orbits http://www.compadre.org/Physlets/mechanics/ex12_1.cfm
This exploration with student worksheet shows 10 identical planets orbiting a star. You can change initial position or initial velocity of the planets and watch what happens to the orbits.

This is the *To Go* version of the Teacher Toolkit; it is an abbreviated version of the complete Toolkit.

6. Physlet Physics: Heliocentric vs. Geocentric http://www.compadre.org/Physlets/mechanics/illustration12_6.cfm
The motion of the planets as seen from the reference frame of the Sun is pretty simple. But from the perspective of each individual planet (the geocentric reference frame), it gets complicated. This animation explores both.

Labs and Investigations: See Complete Toolkit on The Physics Classroom website for more details.
The Physics Classroom, The Laboratory <http://www.physicsclassroom.com/lab#circ>
Satellite Motion Simulation The Law of Harmonies Analysis
Jupiter's Moons Analysis Mass of Saturn Analysis The Mini Drop Lab

Video Analysis Exercise See Complete Toolkit on The Physics Classroom website for more details.
1. Angry Birds in Space <http://www.opensourcephysics.org/items/detail.cfm?ID=11788>

Elsewhere on the Web See Complete Toolkit on The Physics Classroom website for more details.
1. Give Me A Boost – Gravity Assist http://www.messenger-education.org/teachers/Modules/Lessons/MissionDesign_G9-12_L2.pdf

Minds On Physics Internet Modules <http://www.physicsclassroom.com/mop>
The Minds On Physics Internet Modules are a collection of interactive questioning modules that target a student's conceptual understanding. Each question is accompanied by detailed help that addresses the question.
Ass't CG8 - Satellite Motion Ass't CG9 - Weightlessness Ass't CG10 - Kepler's Laws

Concept Building Exercises: <http://www.physicsclassroom.com/curriculum/circles>
The Curriculum Corner, Circular Motion and Gravitation:
1. Satellite Motion 2. Weightlessness 3. Kepler's Laws of Planetary Motion

Problem-Solving Exercises: <http://www.physicsclassroom.com/calcpad/circgrav/problems>
1. The Calculator Pad, Circular Motion and Gravitation Section, Problems #19 - #27

Science Reasoning Activities: <http://www.physicsclassroom.com/reasoning/circularmotion>
1. Kepler's Law of Harmonies

Common Misconceptions See Complete Toolkit on The Physics Classroom website for more details.
1. Satellites as Projectiles 2. Causes of Weightlessness

Standards:

- A. Next Generation Science Standards (NGSS) – Grades 9-12**
Performance Expectations – High School Physical Science
Forces and Motion HS-PS2-4 and Forces and Motion HS-PS2-2 and Energy HS-PS3-1
Disciplinary Core Ideas – High School Physical Science
Forces and Motion-Types of Interactions HS-PS2.B.i and HS-PS2.B.ii
Forces and Motion - Momentum HS-PS2.A.ii and HS-PS2.A.iii
Conservation of Energy HS-PS3.B.i and HS-PS3.B.ii
Relationship Between Energy and Forces HS-PS3.C.i
NGSS Engineering and Technology Standards (ETS)
High School-ETS1.A.i and ETS1.A.ii
Crosscutting Concepts
Scale, Proportion, and Quantity
Systems and System Models
Science and Engineering Practices
Practice #1: Analyzing and Interpreting Data
Practice #2: Developing and Using Models
Practice #3: Planning and Carrying Out Investigations
Practice #4: Constructing Explanations
Practice #5: Using Mathematics and Computational Thinking
- B. Common Core Standards for Mathematics (CC) – Grades 9-12**
See Complete Toolkit on The Physics Classroom website for more details.
- C. Common Core Standards for English/Language Arts (ELA) – Grades 9-12**
See Complete Toolkit on The Physics Classroom website for more details.