TOPIC 7.1
Gravitational Forces

SUGGESTED SKILLS

Representing Data and Phenomena

3.D Create appropriate diagrams to represent physical situations.

Data Analysis

4.E Explain how the data or graph illustrates a physics principle, process, concept, or theory.

Theoretical Relationships

5.E Derive a symbolic expression from known quantities by selecting and following a logical algebraic pathway.

AVAILABLE RESOURCES

Classroom Resources >

- AP Physics Featured Question: Projectile Concepts
- AP Physics Featured Question: Raft with Hanging Weights
- Critical Thinking Questions in Physics
- Physics Instruction Using Video Analysis Technology
- Quantitative Skills in the AP Sciences
- Teaching Strategies for Limited Class Time

Required Course Content

ENDURING UNDERSTANDING

FLD-1

Objects of large mass will cause gravitational fields that create an interaction at a distance with other objects with mass.

LEARNING OBJECTIVE

FLD-1.A

Calculate the magnitude of the gravitational force between two large spherically symmetrical masses.

ESSENTIAL KNOWLEDGE

FLD-1.A.1

The magnitude of the gravitational force between two masses can be determined by using Newton's universal law of gravitation.

$$\left|\vec{F}_G\right| = \frac{Gm_1m_2}{r^2}$$

LEARNING OBJECTIVE

FLD-1.B

Calculate the value for g or gravitational acceleration on the surface of the Earth (or some other large planetary object) and at other points outside of the Earth.

ESSENTIAL KNOWLEDGE

FLD-1.B.1

Using Newton's laws it can be shown that the value for gravitational acceleration at the surface of the Earth is:

$$g = \frac{GM_e}{R_e^2}$$

and if the point of interest is located far from the earth's surface, then g becomes:

$$g = \frac{GM_e}{r^2}$$

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LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
FLD-1.C Describe the motion in a qualitative way of an object under the influence of a variable gravitational force, such as in the case where an object falls toward the Earth's surface when dropped from distances much larger than the Earth's radius.	**FLD-1.C.1** The gravitational force is proportional to the inverse of distance squared; therefore, the acceleration of an object under the influence of this type of force will be nonuniform.

SUGGESTED SKILLS

Representing Data and Phenomena

3.C Sketch a graph that shows a functional relationship between two quantities.

Theoretical Relationships

5.D Determine or estimate the change in a quantity using a mathematical relationship.

Mathematical Routines

6.C Calculate an unknown quantity with units from known quantities by selecting and following a logical computational pathway.

Argumentation

7.F Explain how potential sources of experimental error may affect results and/or conclusions.

AVAILABLE RESOURCES

Classroom Resources >

- **AP Physics Featured Question: Projectile Concepts**
- **AP Physics Featured Question: Raft with Hanging Weights**
- **Critical Thinking Questions in Physics**
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- **Quantitative Skills in the AP Sciences**
- **Teaching Strategies for Limited Class Time**

TOPIC 7.2
Orbits of Planets and Satellites

Required Course Content

ENDURING UNDERSTANDING

CON-6
Angular momentum and total mechanical energy will not change for a satellite in an orbit.

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
CON-6.A Calculate quantitative properties (such as period, speed, radius of orbit) of a satellite in circular orbit around a planetary object.	**CON-6.A.1** The centripetal force acting on a satellite is provided by the gravitational force between satellite and planet. a. The velocity of a satellite in circular orbit is inversely proportional to the square root of the radius and is independent of the satellite's mass.
CON-6.B Derive Kepler's third law for the case of circular orbits.	**CON-6.B.1** In a circular orbit, Newton's second law analysis can be applied to the satellite to determine the orbital velocity relationship for satellite of mass *m* about a central body of mass *M*. a. With proper substitutions, this can be reduced to expressing the period's dependence on orbital distance as Kepler's third law shows: $T^2 = \frac{4\pi^2}{GM} r^3$

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LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
CON-6.C Describe a linear relationship to verify Kepler's third law.	**CON-6.C.1** Verifying Kepler's third law with actual data provides experimental verification of the law.
CON-6.D Calculate the gravitational potential energy and the kinetic energy of a satellite/ Earth system in which the satellite is in circular orbit around the earth.	**CON-6.D.1** The gravitational potential energy of a satellite/ Earth system (or other planetary/satellite system) in orbit is defined by the potential energy function of the system: $U_g = -\frac{Gm_e m_{sat}}{r}$ a. The kinetic energy of a satellite in circular orbit can be reduced to an expression that is only dependent on the satellite's system and position.
CON-6.E Derive the relationship of total mechanical energy of a satellite/earth system as a function of radial position.	**CON-6.E.1** The total mechanical energy of a satellite is inversely proportional to the orbital distance and is always a negative value and equal to one half of the gravitational potential energy.
CON-6.F a. Derive an expression for the escape speed of a satellite using energy principles. b. Describe the motion of a satellite launched straight up (or propelled toward the planet) from the planet's surface, using energy principles.	**CON-6.F.1** In ideal situations, the energy in a planet/ satellite system is a constant. a. The gravitational potential energy of a planet/satellite system is defined to have a zero value when the satellite is at an infinite distance (very large planetary distance) away from the planet. b. By definition, the "escape speed" is the minimum speed required to escape the gravitational field of the planet. This could occur at a minimum when the satellite reaches a nominal speed of approximately zero at some very large distance away from the planet.

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LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
CON-6.G Calculate positions, speeds, or energies of a satellite launched straight up from the planet's surface, or a satellite that is projected straight toward the planet's surface, using energy principles.	**CON-6.G.1** In ideal nonorbiting cases, a satellite's physical characteristics of motion can be determined using the conservation of energy.
CON-6.H Describe elliptical satellite orbits using Kepler's three laws of planetary motion.	**CON-6.H.1** The derivation of Kepler's third law is only required for a satellite in a circular orbit.
CON-6.I a. Calculate the orbital distances and velocities of a satellite in elliptical orbit using the conservation of angular momentum. b. Calculate the speeds of a satellite in elliptical orbit at the two extremes of the elliptical orbit (perihelion and aphelion).	**CON-6.I.1** In all cases of orbiting satellites, the total angular momentum of the satellite is a constant. a. The conservation of mechanical energy and the conservation of angular momentum can both be used to determine speeds at different positions in the elliptical orbit.