Unit 3 Circular Motion and Gravitation

Content Area: **Science**
Course(s): **AP Physics 1**
Time Period: **October**
Length: **10 Blocks**
Status: **Published**

Enduring Understandings

- A field associates a value of some physical quantity with every point in space. Field models are useful for describing interactions that occur at a distance (long-range forces), as well as a variety of other physical phenomena.
- Certain types of forces are considered fundamental.
- At the macroscopic level, forces can be categorized as either long-range (action-ata-distance) forces or contact forces.
- A gravitational field is caused by an object with mass.
- Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles.
- The acceleration of the center of mass of a system is related to the net force exerted on the system, where $\mathbf{a} = \Sigma\mathbf{F}/m$.
- Classically, the acceleration of an object interacting with other objects can be predicted by using $\mathbf{a} = \Sigma\mathbf{F}/m$.
- All forces share certain common characteristics when considered by observers in inertial reference frames.

Essential Questions

- How does changing the mass of an object affect the gravitational force?
- Why is a refrigerator hard to push in space?
- Why do we feel pulled toward Earth but not toward a pencil?
- How can the acceleration due to gravity be modified?
- How can Newton's laws of motion be used to predict the behavior of objects?
- How can we use forces to predict the behavior of objects and keep us safe?
- How is the acceleration of the center of mass of a system related to the net force exerted on the system?
- Why is it more difficult to stop a fully loaded dump truck than a small passenger car?

- What does it mean for a force to be fundamental?
- What force or combination of forces keeps an object in circular motion?
- How is the motion of the moon around the Earth like the motion of a falling apple?
- How does the effect of Earth's gravitational field on an object change as the object's distance from Earth changes?
- Why do you stay in your seat on a roller coaster when it goes upside down in a vertical loop?
- How is the motion of a falling apple similar to that of the moon in orbit around the Earth?
- What conditions are necessary for a planet to obtain a circular orbit around its host star?
- How can Newton's second law of motion be related to the universal law of gravitation?
- How can the motion of the center of mass of a system be altered?

Vocabulary

Vocabulary

- Period
- Frequency
- Uniform circular motion
- Centripetal acceleration
- Dynamics
- Universal Law of Gravitation
- Gravitational Constant (G)
- Gravitational Field (g)
- Field Models
- Vector Fields
- Forces at a distance (long-range forces)
- Apparent Weight
- Orbit
- Orbital motion
- Weightlessness
- Fundamental Forces
- Gravitational mass
- Inertial mass
- Inverse-square Law

Skills

Enduring Understanding	Topic	Science Practices
2.A	3.1 Vector Fields	N/A
3.G	3.2 Fundamental Forces	• 7.1: The student can connect phenomena and mode
3.C	3.3 Gravitational and Electric Forces	• 2.2: The student can apply mathematical routines t phenomena. • 7.2: The student can connect concepts in and acros and/or across enduring understandings and/or big ic
2.B	3.4 Gravitational Field/Acceleration Due to Gravity on Different Planets	• 2.2: The student can apply mathematical routines t phenomena. • 7.2: The student can connect concepts in and acros and/or across enduring understandings and/or big ic
1.C	3.5 Inertial vs. Gravitational Mass	• 4.2: The student can design a plan for collecting da question.
4.A	3.6 Centripetal Acceleration and Centripetal	• 5.3 The students can evaluate the evidence providec

	Force	scientific question.
3.B	3.7 Free-Body Diagrams for Objects in Uniform Circular Motion	• 1.1: The student can create representations and mo and systems in the domain. • 1.4: The student can use representations and model qualitatively and quantitatively. • 1.5: The student can re-express key elements of na representations in the domain. • 2.2: The student can apply mathematical routines t phenomena. • 4.2: The student can design a plan for collecting da question. • 5.1: The student can analyze data to identify patter

- Learning Objective (2.B.1.1): The student is able to apply **F** =m**g** to calculate the gravitational force on an object with mass m in a gravitational field of strength g in the context of the effects of a net force on objects and systems.
- Learning Objective (3.A.2.1): The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation.
- Learning Objective (3.A.3.1): The student is able to analyze a scenario and make claims (develop arguments, justify assertions) about the forces exerted on an object by other objects for different types of forces or components of forces.
- Learning Objective (3.A.3.3): The student is able to describe a force as an interaction between two objects and identify both objects for any force.
- Learning Objective (3.A.4.1): The student is able to construct explanations of physical situations involving the interaction of bodies using Newton's third law and the representation of action-reaction pairs of forces.
- Learning Objective (3.A.4.2): The student is able to use Newton's third law to make claims and predictions about the action-reaction pairs of forces when two objects interact.
- Learning Objective (3.A.4.3): The student is able to analyze situations involving interactions among several objects by using free-body diagrams that include the application of Newton's third law to identify forces.
- Learning Objective (3.B.1.1): The student is able to predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations with acceleration in one dimension.
- Learning Objective (3.B.1.3): The student is able to re-express a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object.
- Learning Objective (3.B.2.1): The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively.
- Learning Objective (3.C.1.2): The student is able to use Newton's law of gravitation to calculate the gravitational force between two objects and use that force in contexts involving orbital motion (for circular orbital motion only in Physics 1).

Standards

AP: Physics 1 (2021 - 2022)

Big Idea 1: Objects and systems have properties such as mass and charge. Systems may have internal structure.

- Enduring Understanding 1.C: Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles.
    - Learning Objective (1.C.3.1): Design a plan for collecting data to measure gravitational mass and to measure inertial mass and to distinguish between the two experiments. [See Science Practice 4.2]

Big Idea 2: Fields existing in space can be used to explain interactions.

- Enduring Understanding 2.A: A field associates a value of some physical quantity with every point in space. Field models are useful for describing interactions that occur at a distance (long-range forces), as well as a variety of other physical phenomena.

- Enduring Understanding 2.B: A gravitational field is caused by an object with mass.
    - Learning Objective (2.B.1.1): The student is able to apply $\mathbf{F_g} = m\mathbf{g}$ to calculate the gravitational force on an object with mass *m* in a gravitational field of strength *g* in the context of the effects of a net force on objects and systems. [See Science Practices 2.2 and 7.2]
    - Learning Objective (2.B.2.1): Apply $g = (Gm)/r^2$ to calculate the gravitational field due to an object with mass *m*, where the field is a vector directed toward the center of the object of mass *m*. [See Science Practice 2.2]
    - Learning Objective (2.B.2.2): Approximate a numerical value of the gravitational field (*g*) near the surface of an object from its radius and mass relative to those of Earth or other reference objects. [See Science Practice 2.2]

Big Idea 3: The interactions of an object with other objects can be described by forces

- Enduring Understanding 3.A: All forces share certain common characteristics when considered by observers in inertial reference frames.
    - Learning Objective (3.A.1.1): Express the motion of an object using narrative, mathematical, and graphical representations. [See Science Practices 1.5, 2.1, and 2.2]
    - Learning Objective (3.A.1.2): Design an experimental investigation of the motion of an object. [See Science Practice 4.2]
    - Learning Objective (3.A.1.3): Analyze experimental data describing the motion of an object and express the results of the analysis using narrative, mathematical, and graphical representations. [See Science Practice 5.1]
    - Learning Objective (3.A.2.1): The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. [See Science Practice 1.1]
    - Learning Objective (3.A.3.1): The student is able to analyze a scenario and make claims (develop arguments, justify assertions) about the forces exerted on an object by other objects for different types of forces or components of forces. [See Science Practices 6.4 and 7.2]
    - Learning Objective (3.A.3.3): The student is able to describe a force as an interaction between two objects and identify both objects for any force. [See Science Practice 1.4]
    - Learning Objective (3.A.4.1): The student is able to construct explanations of physical situations involving the interaction of bodies using Newton's third law and the representation of action-reaction pairs of forces. [See Science Practices 1.4 and 6.2]
    - Learning Objective (3.A.4.2): The student is able to use Newton's third law to make claims and predictions about the action-reaction pairs of forces when two objects interact. [See Science Practices 6.4 and 7.2]
    - Learning Objective (3.A.4.3): The student is able to analyze situations involving interactions among several objects by using free-body diagrams that include the application of Newton's third law to identify forces. [See

Science Practice 1.4]

- Enduring Understanding 3.B: Classically, the acceleration of an object interacting with other objects can be predicted by using **a** =**ΣF**/m.
    - Learning Objective (3.B.1.2): Design a plan to collect and analyze data for motion (static, constant, or accelerating) from force measurements, and carry out an analysis to determine the relationship between the net force and the vector sum of the individual forces. [See Science Practices 4.2 and 5.1]
    - Learning Objective (3.B.1.3): The student is able to re-express a free-body diagram representation into a mathematical representation, and solve the mathematical representation for the acceleration of the object. [See Science Practices 1.5 and 2.2]
    - Learning Objective (3.B.2.1): The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. [See Science Practices 1.1, 1.4, and 2.2]

- Enduring Understanding 3.C: At the macroscopic level, forces can be categorized as either long-range (action-at-a-distance) forces or contact forces.
    - Learning Objective (3.C.1.1): Use Newton's law of gravitation to calculate the gravitational force that two objects exert on each other and use that force in contexts other than orbital motion. [See Science Practice 2.2]
    - Learning Objective (3.C.1.2): The student is able to use Newton's law of gravitation to calculate the gravitational force between two objects and use that force in contexts involving orbital motion (for circular orbital motion only in Physics 1). [See Science Practice 2.2]
    - Learning Objective (3.C.2.2): Connect the concepts of gravitational force and electric force to compare similarities and differences between the forces. [See Science Practice 7.2]

- Enduring Understanding 3.G: Certain types of forces are considered fundamental.
    - Learning Objective (3.G.1.1): Articulate situations when the gravitational force is the dominant force and when the electromagnetic, weak, and strong forces can be ignored. [See Science Practice 7.1]

Big Idea 4: Interactions between systems can result in changes in those systems.

- Enduring Understanding 4.A: The acceleration of the center of mass of a system is related to the net force exerted on the system, where **a** =**ΣF**/m.
    - Learning Objective (4.A.2.2): Evaluate, using given data, whether all the forces on a system or whether all the parts of a system have been identified. [See Science Practice 5.3]

AP: Physics 1 (2014 -15)
AP: Physics 1

Learning objectives that were the same as the orange ones were removed.

Learning Objective (3.B.1.1): The student is able to predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations with acceleration in one dimension. [See Science Practices 6.4 and 7.2]

Modifications

- Restructure lesson using UDL principals (http://www.cast.org/our-work/about-udl.html#.VXmoXcfD_UA)
- Structure lessons around questions that are authentic, relate to students' interests, social/family background and knowledge of their community.
- Have students work with multiple representations to demonstrate their understandings (e.g. multisensory techniques-auditory/visual aids; pictures, illustrations, graphs, charts, data tables, multimedia, modeling).
- Provide opportunities for students to connect with people of similar backgrounds (e.g. conversations via digital tool such as SKYPE, experts from the community helping with a project, journal articles, and biographies).
- Provide multiple grouping opportunities for students to share their ideas and to encourage work among various backgrounds and cultures (e.g. multiple representation and multimodal experiences).
- Engage students with a variety of Science and Engineering practices to provide students with multiple entry points and multiple ways to demonstrate their understandings.
- Use project-based science learning to connect science with observable phenomena.
- Structure the learning around explaining or solving a social or community-based issue.
- Provide ELL students with multiple literacy strategies.
- Collaborate with after-school programs or clubs to extend learning opportunities.
- Provide special equipment for students with different abilities.

Career Readiness & Technology

- Students will use Google Docs, Google Sheets, and Google Forms to collect, analyze, graph, share, and revise their work.
- Students will use Vernier and Pasco technology to collect data and analyze it.
- Students will use applets such as The Physics Classroom, Phet, The Universe and More, OPhysics, etc.
- Students understand the obligations and responsibilities of being a member of a community, and they demonstrate this understanding every day through their interactions with others. They are conscientious of the impacts of their decisions on others and the environment around them. They think about the near-term and long-term consequences of their actions and seek to act in ways that contribute to the betterment of their teams, families, community and workplace. They are reliable and consistent in going beyond the minimum expectation and in participating in activities that serve the greater good.
- Students understand the interrelated nature of their actions and regularly make decisions that positively impact and/or mitigate negative impact on other people, organization, and the environment. They are aware of and utilize new technologies, understandings, procedures, materials, and regulations affecting the nature of their work as it relates to the impact on the social condition, the environment and the profitability of the organization.
- Students regularly think of ideas that solve problems in new and different ways, and they contribute those ideas in a useful and productive manner to improve their organization. They can consider unconventional ideas and suggestions as solutions to issues, tasks or problems, and they discern which ideas and suggestions will add greatest value. They seek new methods, practices, and ideas from a variety of sources and seek to apply those ideas to their own workplace. They take action on their ideas and understand how to bring innovation to an organization.
- Students readily recognize problems in the workplace, understand the nature of the problem, and devise effective plans to solve the problem. They are aware of problems when they occur and take action quickly to address the problem; they thoughtfully investigate the root cause of the problem prior to introducing solutions. They carefully consider the options to solve the problem. Once a solution is agreed upon, they follow through to ensure the problem is solved, whether through their own actions or the actions of others.
- Students consistently act in ways that align personal and community-held ideals and principles while employing strategies to positively influence others in the workplace. They have a clear understanding of integrity and act on this understanding in every decision. They use a variety of means to positively impact the directions and actions of a team or organization, and they apply insights into human behavior to change others' action, attitudes and/or beliefs. They recognize the near-term and long-term effects that management's actions and attitudes can have on productivity, morals and organizational culture.
- Students positively contribute to every team, whether formal or informal. They apply an awareness of cultural difference to avoid barriers to productive and positive interaction. They find ways to increase the engagement and contribution of all team members. They plan and facilitate effective team meetings.

Resources