Unit 4: Circular Motion and Universal Gravitation

Content Area: **Science**
Course(s):
Time Period: **Marking Period 2**
Length: **3 Weeks**
Status: **Published**

Summary

Students will investigate circular motion from the perspective of Newton's Laws and kinematics. Circular motion will then be applied to planetary motion. Newton's Law of Universal Gravitation will be derived from data (or conceptually, depending on the level of the class). Kepler's Laws will be discussed, as well as a brief history of astronomical discovery during the Renaissance period in Europe. Why models are used and what it takes to finally discard them will be emphasized as part of the history of science.

Revised: July 2026

1	Make sense of problems and persevere in solving them
L.SS.11–12.1.A	Apply the understanding that usage is a matter of convention, can change over time, and place, and is sometimes contested.
2	Reason abstractly and quantitatively
9.4.12.CI.1	Demonstrate the ability to reflect, analyze, and use creative skills and ideas (e.g., 1.1.12prof.CR3a).
3	Construct viable arguments and critique the reasoning of others
4	Model with mathematics
L.KL.11–12.2.A	Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level.
5	Use appropriate tools strategically
L.VL.11–12.3	Determine or clarify the meaning of unknown and multiple-meaning words and phrases based on grades 11–12 reading and content, including technical meanings, choosing flexibly from a range of strategies.
9.4.12.CT.2	Explain the potential benefits of collaborating to enhance critical thinking and problem solving (e.g., 1.3E.12profCR3.a).
6	Attend to precision
R	Reading
RL.CR.11–12.1	Accurately cite strong and thorough textual evidence and make relevant connections to strongly support a comprehensive analysis of multiple aspects of what a literary text says explicitly and inferentially, as well as interpretations of the text; this may include determining where the text leaves matters uncertain.
RI.CR.11–12.1	Accurately cite a range of thorough textual evidence and make relevant connections to strongly support a comprehensive analysis of multiple aspects of what an informational text says explicitly and inferentially, as well as interpretations of the text.
RL.CI.11–12.2	Determine two or more themes of a literary text and analyze how they are developed and refined over the course of the text, including how they interact and build on one another to produce a complex account or analysis; provide an objective summary of the text.
RI.CI.11–12.2	Determine two or more central ideas of an informational text and analyze how they are developed and refined over the course of a text, including how they interact and build on one another to provide a complex account or analysis; provide an objective summary of

	the text.
RL.IT.11–12.3	Analyze the impact of the author's choices as they develop ideas throughout the text regarding how to develop and relate elements of a story or drama (e.g., where a story is set, how the action is ordered, how the characters are introduced and developed).
RI.IT.11–12.3	Analyze the impact of an author's choices as they develop ideas throughout the text regarding a complex set of ideas or sequence of events, and explain how specific individuals, ideas, or events interact and develop.
RL.TS.11–12.4	Evaluate the author's choices concerning the structure and the effectiveness of specific parts of a text (e.g., the choice of where to begin or end a story, the choice to provide a comedic or tragic resolution) and how they contribute to its overall structure and meaning, as well as its aesthetic impact.
RL.PP.11–12.5	Evaluate perspectives/lenses from two or more texts on related topics and justify the more cogent viewpoint (e.g., different accounts of the same event or issue, use of different media or formats).
RL.MF.11–12.6	Synthesize complex information across multiple sources and formats to develop ideas, resolve conflicting information, or develop an interpretation that goes beyond explicit text information (e.g., express a personal point of view, new interpretation of the author's message).
RI.MF.11–12.6	Synthesize complex information across multiple sources and formats to develop ideas, resolve conflicting information, or develop an interpretation that goes beyond explicit text information (e.g., express a personal point of view, new interpretation of the concept).
W.AW.11–12.1.A	Introduce precise, knowledgeable claim(s), establish the significance of the claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that logically sequences claim(s), counterclaims, reasons, and evidence.
W.AW.11–12.1.D	Establish and maintain a style and tone appropriate to the audience and purpose (e.g., formal and objective for academic writing) while attending to the norms and conventions of the discipline in which they are writing.
W.AW.11–12.1.E	Provide a concluding paragraph or section that supports the argument presented (e.g., articulating implications or the significance of the topic).
SL.PE.11–12.1.B	Collaborate with peers to promote civil, democratic discussions and decision-making, set clear goals and assessments (e.g., student developed rubrics), and establish individual roles as needed.
HS-PS2	Motion and Stability: Forces and Interactions
HS-PS2-1	Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.
PS2.A	Forces and Motion
	Newton's second law accurately predicts changes in the motion of macroscopic objects.
	Cause and Effect
	Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
HS-PS2-4	Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.
	Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.
	Assessment is limited to systems with two objects.
PS2.B	Types of Interactions
	Newton's law of universal gravitation and Coulomb's law provide the mathematical

	models to describe and predict the effects of gravitational and electrostatic forces between distant objects.
	Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.
	Patterns
	Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.
HS-PS3	Energy
	Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.
	Developing and Using Models
	Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.
	Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system.
PS3.C	Relationship Between Energy and Forces
	When two objects interacting through a field change relative position, the energy stored in the field is changed.
HS-ESS1	Earth’s Place in the Universe
HS-ESS1-1	Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun’s core to release energy that eventually reaches Earth in the form of radiation.
	Emphasis is on the energy transfer mechanisms that allow energy from nuclear fusion in the sun’s core to reach Earth. Examples of evidence for the model include observations of the masses and lifetimes of other stars, as well as the ways that the sun’s radiation varies due to sudden solar flares (“space weather”), the 11-year sunspot cycle, and non-cyclic variations over centuries.
ESS1.A	The Universe and Its Stars
	The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years.
	Scale, Proportion, and Quantity
	The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.
HS-ESS1-2	Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.
ESS1.A	The Universe and Its Stars
	The study of stars’ light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.
	The Big Bang theory is supported by observations of distant galaxies receding from our own, of the measured composition of stars and non-stellar gases, and of the maps of spectra of the primordial radiation (cosmic microwave background) that still fills the universe.
	Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.

	Energy and Matter
	Energy cannot be created or destroyed—only moved between one place and another place, between objects and/or fields, or between systems.
HS-ESS1-3	Communicate scientific ideas about the way stars, over their life cycle, produce elements.
	Obtaining, Evaluating, and Communicating Information
	Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs.
ESS1.A	The Universe and Its Stars
	The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth.
	Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode.
HS-ESS1-4	Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.
	Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons.
ESS1.B	Earth and the Solar System
	Kepler's laws describe common features of the motions of orbiting objects, including their elliptical paths around the sun. Orbits may change due to the gravitational effects from, or collisions with, other objects in the solar system.
HS-ESS1-6	Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history.
	Constructing Explanations and Designing Solutions
	Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.
	Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.

Essential Questions/Enduring Understandings

Essential Questions

How do we "know" so much about our universe when we haven't been to any other solar systems or galaxies?

How did society and contemporary norms influence the development of European astronomy, and how does society influence scientific discovery today?

Enduring Understandings

Any two masses in the universe are gravitationally attracted to each other, and this interaction can be modeled as a force.

Objects moving in a circular path are accelerating even if their speed remains constant, and the acceleration is caused by a force directed towards the center of the circle.

Objectives

Students will know how to describe circular motion in terms of velocity, acceleration, and force.
Students will be skilled at calculating centripetal acceleration for objects moving in a circle.
Students will know Newton's Law of Universal Gravitation and how to use it to calculate the attraction between any two masses.
Students will know Kepler's Laws of Planetary Motion.
Students will know how to describe Cavendish's experiment and explain why it is important.
Students will be skilled at relating weightlessness to objects in free fall.
Students will know what gravitational fields are.
Students will know how black holes form, what causes seasons, and why we see solar and lunar eclipses.

Learning Plan

Through powerpoints, discussions and group work students will determine the relationships between centripetal acceleration, tangential velocity, radius, and the sum of forces (centripetal force) through vector analysis, established mathematical relationships, observational experiments, and testing experiments.

Students will read non-fiction texts about historical figures in Renaissance Europe and their contributions to astronomy and in groups, discuss the sociatal influences on their work at the time. This will transition into group discovery of Kepler's Laws and Newton's Law of Universal Gravitation using observational numerical data.

A review of scientific notation may be necessary at this point.

The experimental techniques used to determine the universal gravitation constant and the people behind the original experiments will be discussed.

The idea of a weightless environment will be investigated using footage from the ISS and force diagrams based on the ISS's orbital path.

Satellite motion and practical applications will be discussed, with videos as support for learning.

PhET simulations such as Gravity Force Lab and Gravity and Orbits will be used as laboratory activities to test Newton's Law of Universal Gravitation and to determine the gravitational constant G experimentally.

The Nova Special: The Pluto Files will be shown to continue the discussion of society influencing science and scientific understanding changing as new information becomes available.

Assessment

Formative: Students will show their understanding of circular motion in class during group work and white board presentations.

Students will demonstrate their understanding of the development of astronomical knowledge through history by participating in class discussions and group discussions.

Homework that is graded for completion and reviewed in class so that they can self-assess.

Summative: Labs include some or all of the following: Circular Motion Lab (either using physical equipment or a simulation), Gravity Force Lab (PhET), and/or Gravity and Orbits (PhET). Unit test.

Benchmark: midterm exam

Alternative: Student Presentation or Project on Circular Motion & Universal Gravitation and its relationship to Astronomy

Materials

Computer with PowerPoint/Google Slides and internet access

Textbook Physics: Principles and Problems, Glencoe

Calculators, rulers, meter sticks, colored pencils, graph paper, Chromebooks for students, whiteboards for collaborative work, dry erase markers and erasers for student groups, string, large mass objects that can hang, small mass objects that can hang, bucket and access to water, large piece of fabric, bowling ball, marble.

Integrated Accommodations and Modifications

Integrated Accommodation and Modifications, Special Education students, English Language Learners, At-Risk students, Gifted and Talented students, Career Education, and those with 504s

https://docs.google.com/spreadsheets/d/18XhAi7Rm-E8LJwO4uMQS7ZEh0dh3NxYbTFH2IoHLH7Y/edit?usp=sharing