UNIT: _Forces and Motion_
GRADE: _10-11_
DURATION: _18 weeks_

TOPICS: DESCRIBING AND GRAPHING OTION, CIRCULAR MOTION, MOMENTUM

Science Curriculum Guide

Orange Public Schools

Grade: 10-11

Topic:

Table of Contents

Next Generation Science Standards Alignment

Physical Science

Performance Expectations	
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.** [Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.] [*Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.*]
HS-PS2-2.	**Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.** [Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.] [*Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.*]
HS-PS2-3.	**Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.*** [Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.] [*Assessment Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.*]
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.** [Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.] [*Assessment Boundary: Assessment is limited to systems with two objects.*]

NGSS Science and Engineering Practices

Analyzing and Interpreting Data
Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.
- Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. (HS-PS2-1)

Using Mathematics and Computational Thinking
Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.
- Use mathematical representations of phenomena to describe explanations. (HS-PS2-2),(HS-PS2-4)

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 ideas to solve a design problem, taking into account possible unanticipated effects. (HS-PS2-3)

Disciplinary Core Ideas

PS2.A: Forces and Motion
- Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1)
- Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (HS-PS2-2)
- If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. (HS-PS2-2),(HS-PS2-3)

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. (HS-PS2-4)
- 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. (HS-PS2-4),(HS-PS2-5)

ETS1.A: Defining and Delimiting an Engineering Problem
- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. *(secondary to HS-PS2-3)*

ETS1.C: Optimizing the Design Solution
- Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. *(secondary to HS-PS2-3)*

Cross Cutting Concepts

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-PS2-4)

Cause and Effect
- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes

and effects. (HS-PS2-1),(HS-PS2-5)

- Systems can be designed to cause a desired effect. (HS-PS2-3)

Systems and System Models

- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (HS-PS2-2)

Science and Engineering Practices

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical and empirical models.

- Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS2-5)

Analyzing and Interpreting Data

Analyzing data in 9–12 builds on K–8 and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data.

- Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. (HS-PS2-1)

Using Mathematics and Computational Thinking

Mathematical and computational thinking at the 9–12 level builds on K–8 and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.

- Use mathematical representations of phenomena to describe explanations. (HS-PS2-2),(HS-PS2-4)

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 ideas to solve a design problem, taking into account possible unanticipated effects. (HS-PS2-3)

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Connections to Nature of Science

Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

- Theories and laws provide explanations in science. (HS-PS2-1),(HS-PS2-4)
- Laws are statements or descriptions of the relationships among observable phenomena. (HS-PS2-1),(HS-PS2-4)

Disciplinary Core Ideas

PS2.A: Forces and Motion

- Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1)
- Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (HS-PS2-2)
- If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. (HS-PS2-2),(HS-PS2-3)

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. (HS-PS2-4)
- 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. (HS-PS2-4),(HS-PS2-5)

PS3.A: Definitions of Energy

- "Electrical energy" may mean energy stored in a battery or energy transmitted by electric currents. *(secondary to HS-PS2-5)*

ETS1.A: Defining and Delimiting an Engineering Problem

- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. *(secondary to HS-PS2-3)*

ETS1.C: Optimizing the Design Solution

- Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. *(secondary to HS-PS2-3)*

Crosscutting Concepts

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-PS2-4)

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS2-1),(HS-PS2-5)
- Systems can be designed to cause a desired effect. (HS-PS2-3)

Systems and System Models

- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (HS-PS2-2)

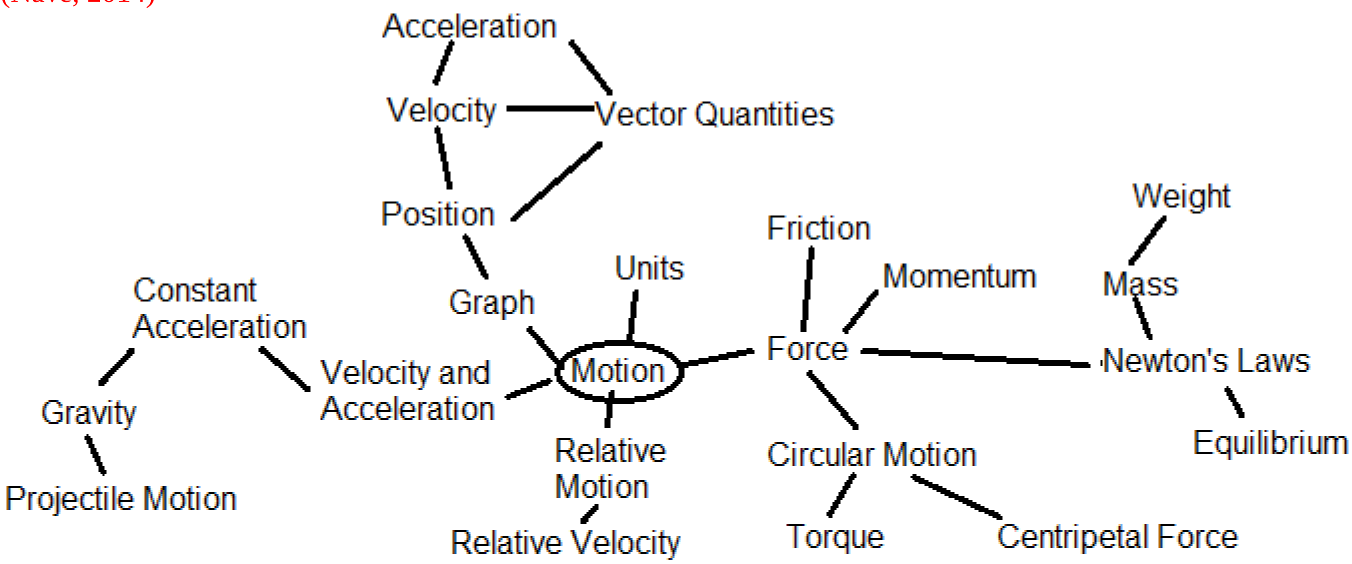
Connections to other DCIs in this grade level:

Common Core State Standards

CCSS: English Language Arts	
Reading Informational Text	
WHST.11-12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-PS2-3),(HS-PS2-5)
WHST.11-12.8	Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS2-5)
CCSS: Writing-	
RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS2-1)
WHST.11-12.9	Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS2-1),(HS-PS2-5)
CCSS: Speaking and Listening:	
RST.11-12.7	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. (HS-PS2-1)
CCSS: Mathematics	
MP.2	Reason abstractly and quantitatively. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4)
MP.4	Model with mathematics. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4)
HSN.Q.A.1	Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4),*(HS-PS2-5)*
HSN.Q.A.2	Define appropriate quantities for the purpose of descriptive modeling. *(HS-PS2-1),(HS-PS2-2),(HS-PS2-4),(HS-PS2-5)*
HSN.Q.A.3	Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS2-1),(HS-PS2-2),(HS-PS2-4),*(HS-PS2-5)*
HSA.SSE.A.1	Interpret expressions that represent a quantity in terms of its context. (HS-PS2-1),(HS-PS2-4)
HSA.SSE.B.3	Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. (HS-PS2-1),(HS-PS2-4)
HSA.CED.A.1	Create equations and inequalities in one variable and use them to solve problems. (HS-PS2-1),(HS-PS2-2)
HSA.CED.A.2	Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. *(HS-PS2-1),(HS-PS2-2)*
HSA.CED.A.4	Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. *(HS-PS2-1),(HS-PS2-2)*
HSF-IF.C.7	Graph functions expressed symbolically and show key features of the graph, by in hand in simple cases and using technology for more complicated cases. *(HS-PS2-1)*
HSS-IS.A.1	Represent data with plots on the real number line (dot plots, histograms, and box plots). *(HS-PS2-1)*

CONCEPTUAL FLOW CHART/MAP

(Nave, 2014)



Forces and Motion

Topic/Subject
18 weeks

Unit Overview

Newton's second law accurately predicts changes in the motion of macroscopic objects, but it requires revision for subatomic scales or for speeds close to the speed of light. Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. In any system, total momentum is always conserved (p. 116, Framework).

Background Information

A Guide To Introductory Physics Teaching by Arnold B. Arons lays out misconceptions and common gaps that inhibit student understanding. An understanding of graphing and interpreting graphs. An understanding of the forces between objects is important for
describing how their motions change, as well as for predicting stability or
instability in systems at any scale (p.114, Framework).

Enduring Understanding:	*Essential Questions: Overarching*	*Cross Cutting Concepts*
PS2.A: Forces and Motion • Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1) • Momentum is defined for a particular frame of reference; it is the mass times the velocity of the object. (HS-PS2-2) • If a system interacts with objects outside itself, the total momentum of the system can change; however, any such change is balanced by changes in the momentum of objects outside the system. (HS-PS2-2),(HS-PS2-3) **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. (HS-PS2-4) • 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. (HS-PS2-4),(HS-PS2-5) **ETS1.A: Defining and Delimiting an Engineering Problem** • Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. *(secondary to HS-PS2-3)*	How can one predict an object's continued motion, changes in motion, or stability (p.114, Framework)	**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-PS2-4) **Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS2-1),(HS-PS2-5) • Systems can be designed to cause a desired effect. (HS-PS2-3) **Systems and System Models** • When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (HS-PS2-2)

ETS1.C: Optimizing the Design Solution • Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed. *(secondary to HS-PS2-3)*		

STUDENT OUTCOMES
PS2.A Given a graph of position or velocity as a function of time, recognize in what time intervals the position, velocity and acceleration of an object are positive, negative, or zero and sketch a graph of each quantity as a function of time. *[Clarification Statement: Students should be able to accurately move from one representation of motion to another.]* Represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. Understand and apply the relationship between the net force exerted on an object, its inertial mass, and its acceleration to a variety of situations. Predict the change in momentum of an object from the average force exerted on the object and the interval of time during which the force is exerted. Make qualitative predictions about natural phenomena based on conservation of momentum and restoration of kinetic energy in elastic collisions.
Key Vocabulary
Position, Velocity, Acceleration, Force, Tension, Friction, Kinematics, Average, Instantaneous, Free Fall, Dynamics,
Vectors, Mass
Weight, Inertia, Free Body Diagrams, Projectile Motion, Frame of Reference
Preconception /Misconceptions
A ratio for velocity is “meter per second” without indicating one second.
Use variables as labels or units.
Instant means “short time interval.”
Acceleration is “how fast an object is going.”
That a fast moving object has more acceleration than a slow moving object because of the high velocity and not the change in velocity.

Describing and Graphing Motion **6 weeks**		
CHAPTER Overview Given a graph of position or velocity as a function of time, recognize in what time intervals the position, velocity and acceleration of an object are positive, negative, or zero and sketch a graph of each quantity as a function of time.		
Background Information Chapter		
A Guide To Introductory Physics Teaching by Arnold B. Arons lays out misconceptions and common gaps that inhibit student understanding. An understanding of graphing and interpreting graphs. An understanding of the forces between objects is important for describing how their motions change, as well as for predicting stability or instability in systems at any scale (p.114, Framework).Khan Academy is an online tool that will assist in mathematical gaps.		
Enduring Understanding:	***Essential Questions: Overarching***	***Cross Cutting Concepts***
• Given a graph of position or velocity as a function of time, recognize in what time intervals the position, velocity and acceleration of an object are positive, negative, or zero and sketch a graph of each quantity as a function of time. *[Clarification Statement: Students should be able to accurately move from one representation of motion to another.](PS2.A)* • Represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation (PS2.A) • The motion of an object can be described verbally, with a graph, dot diagrams, and equations by using position, velocity, and acceleration. • Positive and negative signs on the vectors shows direction and is separate from the number line. • Simplifications and idealizations are used to solve complex problems. • The forces will describe what is occurring but the net force will dictate the motion. • Vectors act independently in orthogonal directions. • An inertial reference frame is needed to determine real forces from fictions forces.	• Why does a projectile always form a parabola? • How can projectile motion keep a satellite up in the atmosphere? • How to hovercrafts balance the forces? • How do spaceships overcome the downward force? • How do objects fall to the ground? • How does acceleration affect velocity?	**Cause and Effect** • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-PS2-1),(HS-PS2-5)
STUDENT OUTCOMES		
Given a graph of position or velocity as a function of time, recognize in what time intervals the position, velocity and acceleration of an object are positive, negative, or zero and sketch a graph of each quantity as a function of time. *[Clarification Statement: Students should be able to accurately move from one representation of motion to another.]*		

Represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation.

Understand and apply the relationship between the net force exerted on an object, its inertial mass, and its acceleration to a variety of situations.

Essential Question	Resources
• Why does a projectile always form a parabola? • How can projectile motion keep a satellite up in the atmosphere? • How to hovercrafts balance the forces? • How do spaceships overcome the downward force? • How do objects fall to the ground? • How does acceleration affect velocity?	Physics Principles and Problems Pg. 30-160

Knowledge:	***Skills:***
Student will Know…. (refer to SEP's) • Identify contact, noncontact, passive, and active force and how they interact with each other by drawing a diagram. • An object that changes direction in one dimension must have an instantaneous velocity of 0 m/s. • Define velocity and acceleration. • Define displacement, velocity, and acceleration as vectors. • Tension is the magnitude of force acting on both sides of a small segment of string. • The normal force only equals mass times gravity when the only force acting on it is the weight of the object, this is just a special case. • When the forces in opposite directions are equal, there is no acceleration. • Normal force is always perpendicular to the surface providing the passive force. • Net acceleration and net force are always in the same direction. • The force of friction can range from zero to the maximum value. • Force of friction opposes the slippage. • Forces are detected by the acceleration of an object. • Objects at rest may still have forces acting on them. • A more massive object experiencing the same net force as a less massive object has a smaller acceleration, and a larger net force on a given object produces a correspondingly larger acceleration.	***Students will be able to…*** (refer to SEP's) • Calculate the net acceleration and force. • Represent forces in free body diagrams . • Make a Rube Goldberg machine that lasts at least 15 seconds and scores a basket. • Express the motion of an object using narrative, mathematical, and graphical representations. • Design an experiment investigating of the motion of the object and analyze the data. • Describe a force as an interaction between two objects and identify those forces. • Predict the motion of an object based off the forces acting on it. • Graph the data and describe its representation.

Referenced Activity/link
Resources

Physics Principles and Problems Pg. 30-160

Evidence of Understanding:	
Identify what students will produce to demonstrate that they have met the challenge, learned content, and employed 21st century skills. Additionally, identify the audience they will present what they have produced to.	
Products Free Body Diagrams.	**Audience:** ☐Peers ☐Experts / Practitioners ☐Teacher(s)
Process Model Revision.	**Audience:** ☐Peers ☐Experts / Practitioners ☐Teacher(s)
Actions Measure data and use to analyze and make predictions.	**Audience:** ☐Peers ☐Experts / Practitioners ☐Teacher(s)
Performance Presentation of works is solving solutions and modeling.	**Audience:** ☐Peers ☐Experts / Practitioners ☐Teacher(s)
Others	**Audience:** ☐Peers ☐Experts / Practitioners ☐Teacher(s)

STEM Specialist Connection
A civil engineer would be able to describe how they must consider the angle of forces to make sure that an appropriate weight can be held up. A pilot can discuss the forces needed for lift off and how projectile motion is used in flying a plane and extend that to how satellites stay in the sky. A sky diver can discuss terminal velocity with air resistance in terms of free fall.

Key Vocabulary
Position, Velocity, Acceleration. Force, Tension, Friction, Kinematics, Average, Instantaneous, Free Fall, Dynamics, Vectors, Mass, Weight, Inertia, Free Body Diagram, Projectile Motion, Frame of Reference

Suggested Resources
https://www.njctl.org/courses/science/algebra-based-physics/

Preconception /Misconceptions
A ratio for velocity is “meter per second” without indicating one second.
Use variables as labels or units.
Instant means “short time interval.”
Acceleration is “how fast an object is going.”
That a fast moving object has more acceleration than a slow moving object because of the high velocity and not the change in velocity.
Motion in orthogonal directions is “not independent.”

The meaning of slope can be determined by the values of the y and x axis and the area under the curve is the value for the derivative.

<table>
<tr><td colspan="3" align="center"><u>Circular Motion</u>
<u>6 weeks</u></td></tr>
<tr><td colspan="3"> <u>CHAPTER Overview</u> Gravity keeps the Earth in a nearly circular ellipse around the Sun while the moon orbits the Earth. Humans can bear witness to this as the Sun appears to rise and fall while the moon goes through its phases.

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. [Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.] [Assessment Boundary: Assessment is limited to systems with two objects.]</td></tr>
<tr><td colspan="3" align="center"><u>Background Information Chapter</u></td></tr>
<tr><td colspan="3" align="center">Students will have a background in the concept of forces and using vectors to describe the forces acting on an object.
Students will know the acceleration due to gravity and relate it to centripetal acceleration.</td></tr>
<tr><td><u>Enduring Understanding:</u></td><td><u>Essential Questions: Overarching</u></td><td><u>Cross Cutting Concepts</u></td></tr>
<tr><td>• Understand and apply the relationship between the net force exerted on an object, its inertial mass, and its acceleration to a variety of situations.
• Gravity is a fundamental attractive force between masses.
• Gravity causes masses to attract to the center of mass.
• Gravity is proportional to the product of the masses and inversely proportional to the square of the distance between them.</td><td>• Why does the moon and Earth stay in their orbits?
• What is gravity?
• Why do humans feel a force push from the opposite direction of turning?
• How can “artificial gravity” be created?</td><td>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-PS2-4)</td></tr>
<tr><td colspan="3" align="center"><u>STUDENT OUTCOMES</u></td></tr>
<tr><td colspan="3">Represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation.

Understand and apply the relationship between the net force exerted on an object, its inertial mass, and its acceleration to a variety of situations.</td></tr>
</table>

Essential Questions	Resources
• Why does the moon and Earth stay in their orbits? • What is gravity? • Why do humans feel a force push from the opposite direction of turning? • How can “artificial gravity” be created?	Physics Principles and Problems Pg. 170-218

Knowledge:	***Skills:***
Student will Know…. (refer to SEP's) • Gravity is a noncontact force but centripetal forces are usually contact force. • The moon does not break away or collide with Earth because of the tangential velocity.	***Students will be able to…*** (refer to SEP's) • Predict how the distance between two objects will change the force and how that will change the motion. • Predict if the student's weight will be more or less on certain planets. • Calculate an unknown variable using Newton's Law of Gravitation • Draw vectors to represent the forces in circular motion.

Referenced Activity/link
Resources Physics Principles and Problems Pg 170-218

Evidence of Understanding: Identify what students will produce to demonstrate that they have met the challenge, learned content, and employed 21st century skills. Additionally, identify the audience they will present what they have produced to.	
Products Free Body Diagrams, Model of Gravity	**Audience:** ☐Peers ☐Experts / Practitioners ☐Teacher(s)
Process Showing all work in problem solving.	**Audience:** ☐Peers ☐Experts / Practitioners ☐Teacher(s)
Actions Experiments.	**Audience:** ☐Peers ☐Experts / Practitioners ☐Teacher(s)
Performance Presentations.	**Audience:** ☐Peers ☐Experts / Practitioners ☐Teacher(s)
Others	**Audience:** ☐Peers ☐Experts / Practitioners ☐Teacher(s)

STEM Specialist Connection
Physicists who researches one of the theories of gravity and what they need to prove for their theory to be accepted. NASA astronaut Kelly who is participating in research on how gravity (or the lack of it) affects the human body from prolonged periods of time. Engineer from Six Flags Great Adventure and how he uses turns to create g forces on riders that makes their adrenaline go without hurting the participants. Fighter get from the Air Force who can explain techniques used to not black out while making turns.

Key Vocabulary
Rotational Inertia, Torque, Centripetal Force, Centrifugal Force, Gravity, Tangential Velocity

Suggested Resources
https://www.njctl.org/courses/science/algebra-based-physics/

Preconception /Misconceptions
Tension is a separate force than cannot also be the centripetal force.
Constant tangential speed means there is not acceleration even though a direction changes.
Using a up/down and left/right scale instead of clockwise and counterclockwise.

Momentum
5 weeks

CHAPTER Overview

A net force over a time interval is needed to change the momentum of an object. This produces a change in momentum, otherwise known as an impulse. The net impulse determines the direction of the momentum and can be graphed using the force and time and finding the area under the curve.

HS-PS2-2.Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. [Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.] [Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.]

Background Information Chapter

Students will have a background in the concept of forces and time to describe changes in momentum. Knowledge from car designs and crashes will help students imagine the forces at play.

Enduring Understanding:	***Essential Questions: Overarching***	***Cross Cutting Concepts***
• Momentum is a quantity of motion that depends on the mass and velocity of the object. • Total momentum is always conserved. • Impulse can be increased by a small force over a long period of time or a large force in a short amount of time.	• Why must people wear seat belts in a car but not on a bus? • How are cars designed to be safer?	Systems and System Models When investigating or describing a system, the boundaries and initial conditions of the system need to be defined. (HS-PS2-2)

STUDENT OUTCOMES

- Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. [Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.] [Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.]
- Predict the change in momentum of an object from the average force exerted on the object and the interval of time during which the force is exerted.
- Make qualitative predictions about natural phenomena based on conservation of momentum and restoration of kinetic energy in elastic collisions.
- Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.* [Clarification Statement: Examples of evaluation and refinement could include determining the success of the device at protecting an object from damage and modifying the design to improve it. Examples of a device could include a football helmet or a parachute.] [Assessment Boundary: Assessment is limited to qualitative evaluations and/or algebraic manipulations.]

Essential Questions	Resources
• Why must people wear seat belts in a car but not on a bus?	Physics Principles and Problems Pg. 228-246

• How are cars designed to be safer?	
Knowledge:	***Skills:***
Student will Know…. (refer to SEP's) • The time it takes for the impact changes the force felt. • An object of large mass will tend to have a lot of momentum even at slow speeds.	***Students will be able to…*** (refer to SEP's) • Calculate the change in velocity of an object before and after a collision. • Use conservation of momentum to solve collision problems.

Referenced Activity/link
Resources Physics Principles and Problems Pg. 228-246

Evidence of Understanding: Identify what students will produce to demonstrate that they have met the challenge, learned content, and employed 21st century skills. Additionally, identify the audience they will present what they have produced to.	
Products Solve problems.	**Audience:** ☐Peers ☐Experts / Practitioners ☐Teacher(s)
Process Using energy to solve for final velocities.	**Audience:** ☐Peers ☐Experts / Practitioners ☐Teacher(s)
Actions Modeling elastic and inelastic collisions.	**Audience:** ☐Peers ☐Experts / Practitioners ☐Teacher(s)
Performance Demonstrating collisions.	**Audience:** ☐Peers ☐Experts / Practitioners ☐Teacher(s)
Others	**Audience:** ☐Peers ☐Experts / Practitioners ☐Teacher(s)

STEM Specialist Connection
An engineer that works on car safety.
Key Vocabulary
Elastic Collision, Inelastic Collisions, Impulse, Momentum, Kinetic Energy
Suggested Resources
https://www.njctl.org/courses/science/algebra-based-physics/
Preconception /Misconceptions
If two objects are coming toward each other, both are considered "positive."