

Unit 05: Linear Momentum (3 Weeks)

Content Area: **Template**
Course(s):
Time Period: **Full Year**
Length: **FY**
Status: **Published**

Standards Alignment

New Jersey Student Learning Standards

Practice 1. Asking questions (for science) and defining problems (for engineering)

Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.

Ask questions that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.

Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships.

Ask questions to determine relationships, including quantitative relationships, between independent and dependent variables.

Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.

Practice 2. 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/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.

Practice 3. Planning and carrying out investigations

Planning and carrying out investigations 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.

Select appropriate tools to collect, record, analyze, and evaluate data.

Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated.

Practice 4. Analyzing and interpreting data

Analyzing data in 9–12 builds on K–8 experiences 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.

Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation

coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.

Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data.

Practice 5. Using mathematics and computational thinking

Mathematical and computational thinking in 9-12 builds on K-8 experiences 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, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as mg/mL, kg/m³, acre-feet, etc.).

Practice 6. Constructing explanations (for science) and designing solutions (for engineering)

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.

Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.

Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

Practice 7. Engaging in argument from evidence

Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.

Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence, challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining additional information required to resolve contradictions.

Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence.

Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Crosscutting Statements

1. Patterns – Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.

Mathematical representations are needed to identify some patterns.

2. Cause and Effect: Mechanism and Prediction – Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

Changes in systems may have various causes that may not have equal effects.

3. Scale, Proportion, and Quantity – In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.

Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).

4. Systems and System Models – A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.

When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

PS2: Motion and Stability: Forces and Interactions

PS2.A: Forces and Motion

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. (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)

SCI.3-PS2	Motion and Stability: Forces and Interactions
SCI.3.PS2.A	Forces and Motion
SCI.HS-PS2	Motion and Stability: Forces and Interactions
SCI.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.
SCI.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.

Integration of Career Readiness, Life Literacies and Key Skills

CRP.K-12.CRP1	Act as a responsible and contributing citizen and employee.
CRP.K-12.CRP2	Apply appropriate academic and technical skills.
CRP.K-12.CRP3	Attend to personal health and financial well-being.
CRP.K-12.CRP4	Communicate clearly and effectively and with reason.
CRP.K-12.CRP5	Consider the environmental, social and economic impacts of decisions.
CRP.K-12.CRP6	Demonstrate creativity and innovation.
CRP.K-12.CRP7	Employ valid and reliable research strategies.
CRP.K-12.CRP8	Utilize critical thinking to make sense of problems and persevere in solving them.
CRP.K-12.CRP9	Model integrity, ethical leadership and effective management.
CRP.K-12.CRP10	Plan education and career paths aligned to personal goals.
CRP.K-12.CRP11	Use technology to enhance productivity.
CRP.K-12.CRP12	Work productively in teams while using cultural global competence.

Technology / Integration of Computer Science and Design Thinking

TECH.8.2.12	Technology Education, Engineering, Design, and Computational Thinking - Programming:
-------------	--

All students will develop an understanding of the nature and impact of technology, engineering, technological design, computational thinking and the designed world as they relate to the individual, global society, and the environment.

TECH.8.2.12.A	The Nature of Technology: Creativity and Innovation: Technology systems impact every aspect of the world in which we live.
TECH.8.2.12.A.2	Analyze a current technology and the resources used, to identify the trade-offs in terms of availability, cost, desirability and waste.
TECH.8.2.12.B	Technology and Society: Knowledge and understanding of human, cultural and society values are fundamental when designing technology systems and products in the global society.
TECH.8.2.12.B.4	Investigate a technology used in a given period of history, e.g., stone age, industrial revolution or information age, and identify their impact and how they may have changed to meet human needs and wants.
TECH.8.2.12.C	Design: The design process is a systematic approach to solving problems.
TECH.8.2.12.C.2	Analyze a product and how it has changed or might change over time to meet human needs and wants.
TECH.8.2.12.E	Computational Thinking: Programming: Computational thinking builds and enhances problem solving, allowing students to move beyond using knowledge to creating knowledge.
TECH.8.2.12.E.1	Demonstrate an understanding of the problem-solving capacity of computers in our world.

Interdisciplinary Connections: NJSL for ELA, Social Studies, Science and/or Math Section

Key Ideas and Details

LA.K-12.NJSLSA.R1 Read closely to determine what the text says explicitly and to make logical inferences and relevant connections from it; cite specific textual evidence when writing or speaking to support conclusions drawn from the text.

Integration of Knowledge and Ideas

LA.K-12.NJSLSA.R7 Integrate and evaluate content presented in diverse media and formats, including visually and quantitatively, as well as in words.

LA.RI.11-12.1 Accurately cite strong and thorough textual evidence, (e.g., via discussion, written response, etc.), to support analysis of what the text says explicitly as well as inferentially, including determining where the text leaves matters uncertain.

LA.K-12.NJSLSA.W

Writing

Text Types and Purposes

LA.K-12.NJSLSA.W1 Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.

LA.K-12.NJSLSA.W2 Write informative/explanatory texts to examine and convey complex ideas and information clearly and accurately through the effective selection, organization, and analysis of content.

LA.K-12.NJSLSA.W3 Write narratives to develop real or imagined experiences or events using effective technique, well-chosen details, and well-structured event sequences.

Production and Distribution of Writing

LA.K-12.NJSLSA.W4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

LA.K-12.NJSLSA.W5	Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach.
LA.RI.11-12.7	Integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a question or solve a problem. Text Types and Purposes
LA.W.11-12.1	Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
LA.W.11-12.2	Write informative/explanatory texts to examine and convey complex ideas, concepts, and information clearly and accurately through the effective selection, organization, and analysis of content.
LA.W.11-12.3	Write narratives to develop real or imagined experiences or events using effective technique, well-chosen details, and well-structured event sequences.
LA.W.11-12.4	Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. (Grade-specific expectations for writing types are defined in standards 1–3 above.)
LA.W.11-12.5	Develop and strengthen writing as needed by planning, revising, editing, rewriting, trying a new approach, or consulting a style manual (such as MLA or APA Style), focusing on addressing what is most significant for a specific purpose and audience.

Integration of Diversity, Equity and Inclusion; Climate Change; Informational and Media Literacy

see Crosswalks

21st Century Life and Careers

Stage I: Desired Results

Transfer/Overview/Rationale

Transfer / Overview / Rationale

Unit Rationale

The purpose of this unit...

Linear momentum, and its conservation, allows for the making of predictions about the motion of objects before and after colliding where energy methods may not be valid.

Meaning

Essential Questions

Essential Questions

- When can a small object have the same momentum as a significantly larger object?
- How is the concept of impulse used to prevent injuries?
- How does the conservation of momentum determine how objects move after interacting?

Enduring Understanding/Indicators of Understanding

Enduring Understanding/Indicators of Understanding

Students will understand that:

- Momentum describes how difficult it is to stop a moving object.
- Impulse is the change in momentum and is a derivation from Newton's Second Law.
- Momentum of a closed system is always conserved.

Acquisition (Student Learning Objectives)

Knowledge

Knowledge

Students will know...

- Momentum is Inertia in motion.
- A force is required to change momentum.
- Impulse is the product of a force and the time over which it is applied.
- Newton's Second Law in terms of momentum: Force is the rate of change of momentum
- The impulse-momentum theorem.

- Conservation of momentum is implied by Newton's third law.
- The various types of collisions, and identify the implications of each collision.
- The total momentum of a given system is always conserved, even in 2-dimensions.

Skills

Skills

Student will be skilled at ...

- The student is able to justify the selection of data needed to determine the relationship between the direction of the force acting on an object and the change in momentum caused by that force.
- The student is able to justify the selection of routines for the calculation of the relationships between changes in momentum of an object, average force, impulse, and time of interaction.
- The student is able to 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.
- The student is able to analyze data to characterize 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.
- The student is able to design a plan for collecting data to investigate the relationship between changes in momentum and the average force exerted on an object over time.
- The student is able to calculate the change in linear momentum of a two-object system with constant mass in linear motion from a representation of the system (data, graphs, etc.).
- The student is able to analyze data to find the change in linear momentum for a constant-mass system using the product of the mass and the change in velocity of the center of mass.
- The student is able to apply mathematical routines to calculate the change in momentum of a system by analyzing the average force exerted over a certain time on the system.
- The student is able to perform analysis on data presented as a force-time graph and predict the change in momentum of a system.
- The student is able to define open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations.
- The student is able to make qualitative predictions about natural phenomena based on conservation of linear momentum and restoration of kinetic energy in elastic collisions.
- The student is able to apply the principles of conservation of momentum and restoration of kinetic energy to reconcile a situation that appears to be isolated and elastic, but in which data indicate that linear momentum and kinetic energy are not the same after the interaction, by refining a scientific question to identify interactions that have not been considered. Students will be expected to solve qualitatively and/or quantitatively for one-dimensional situations and only qualitatively in two-dimensional situations.
- The student is able to apply mathematical routines appropriately to problems involving elastic collisions in one dimension and justify the selection of those mathematical routines based on conservation of momentum and restoration of kinetic energy.
- The student is able to design an experimental test of an application of the principle of the conservation of linear momentum, predict an outcome of the experiment using the principle, analyze data generated by that experiment whose uncertainties are expressed numerically, and evaluate the match between the prediction and the outcome.
- The student is able to classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum and restoration of kinetic energy as the appropriate principles for analyzing an elastic collision, solve for missing variables, and calculate their values.
- The student is able to qualitatively predict, in terms of linear momentum and kinetic energy, how the outcome of a collision between two objects changes depending on whether the collision is elastic or inelastic.
- The student is able to plan data collection strategies to test the law of conservation of momentum in a two-object collision that is elastic or inelastic and analyze the resulting data graphically.
- The student is able to apply the conservation of linear momentum to a closed system of objects involved in an inelastic collision to predict the change in kinetic energy.

- The student is able to analyze data that verify conservation of momentum in collisions with and without an external friction force.
- The student is able to classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum as the appropriate solution method for an inelastic collision, recognize that there is a common final velocity for the colliding objects in the totally inelastic case, solve for missing variables, and calculate their values.
- The student is able to predict the velocity of the center of mass of a system when there is no interaction outside of the system but there is an interaction within the system (i.e., the student simply recognizes that interactions within a system do not affect the center of mass motion of the system and is able to determine that there is no external force).

Stage 3: Learning Plan

Resource and Mentor Texts

Resources and Mentor Texts

- Douglas Ingram & David Anderson. OpenStax College Physics for AP® Course 1. 1st ed. OpenStax.
- Knight, Jones, Field College Physics a strategic approach AP Edition 3rd ed Pearson
- Giancoli, D.C. Physics: Principles with Applications. Englewood Cliffs, NJ: Pearson Education.
- New Jersey Center for Teaching and Learning AP Physics 1 Course
- Hieggelke, Curtis, David Maloney, and Stephen Kanim. Newtonian Tasks Inspired by Physics Education Research: nTIPERs. Upper Saddle River, NJ: Pearson, 2012
- PhET Interactive Simulations <https://phet.colorado.edu/en/simulations/category/physics>

Formative Assessment Strategies

Formative Assessment Strategies

- Hand Signals - students use hand signals to indicate their understanding
- One-Minute Essay
- Misconception Check - students are presented with a common misconception about a concept and then asked to agree or disagree and explain why.
- Student Conference - one on one conversation with students to check for understanding
- Observation - observe students as they work to check for learning

- Exit Card - written student responses to questions posed at the end of a class or learning activity.
- Quiz
- Choral Response - students respond verbally at the same time in response to a question
- Debriefing - students reflect on their work immediately following an activity

Learning Activities/Unit of Study

Learning Activities/Unit of Study

- One Minute Essay: students summarize material from the previous class or homework assignment in 3 to 5 sentences.
- Review/Check Homework
- Lecture
- Thumbs up/down/sideways - quick formative assessment to gauge students level of understanding
- Problem solving in small groups
- Guided inquiry laboratory assignments - results are presented via digital poster
- Open inquiry laboratory assignments - results are presented via digital poster
- Round Robin Labs - multiple stations with different labs, each group is responsible for performing and presenting for one of the labs.
- Newtonian Tasks Inspired by Physics Education Research (nTIPERs) such as:
 - Bar Chart Tasks
 - Changing Representations Tasks
 - Comparison Tasks
 - Conflicting Contentions Tasks
 - Linked Multiple Choice Tasks
 - Qualitative Reasoning Tasks
 - Ranking Tasks
 - Troubleshooting Tasks
 - What, if anything, is Wrong Tasks
 - Working Backwards Tasks
- PhET Interactive simulations using chromebooks
- YouTube videos from "Flipping Physics"
- Review and practice skills using a variety of materials - (text, workbook, chromebook, games, activities, discussion)
- Practice AP style multiple choice and free response questions

Modifications and/or Accommodations

Suggested Modifications (ELL, Sp. Ed, Gifted, At-risk of Failure)

English Language Learners

Native language support: The teacher provides auditory or written content to students in their native language.

Adjusted Speech: The teacher changes speech patterns to increase student comprehension. This could include facing the students, paraphrasing, clearly indicating the most important ideas, and speaking more slowly.

Visuals: The teacher uses graphics, pictures, visuals, and manipulatives. This helps ELL students better understand and comprehend the subjects at hand.

Front-Loading Vocabulary: The teacher front loads vocabulary. This means providing students with a list of important vocabulary words they will need to know for a book, lesson, etc. prior to the lesson being taught. Including pictures to go with the vocabulary words is also very beneficial for the students.

Special Education Students

Chunking: The teacher presents information in a way that makes it easy for students to understand and remember. Chunking is based on the presumption that our working memory is easily overloaded by excessive detail. The best way to deliver information is to organize it into meaningful units. Because students with special needs get overloaded easily, chunking is an effective strategy to use with them.

Checking for Understanding: It is important to constantly check for understanding, especially for students who have accommodations. Teachers want to make sure students understand the concepts being covered in a way that makes sense to them.

Extra time: The teacher provides students with special needs extra time to complete work or answer questions. It is important to give students enough time to process their thoughts.

Oral Reading: The teacher will read work orally to students. Class work such as tests and literature circles may need to be read aloud to the student.

Timers: The teacher will use timers as an instructional tool. The use of timers is beneficial for students who have trouble completing tasks. Timers can be helpful so the student is aware of how much time they have to complete an assignment.

Students with 504 Plans

Chunking: The teacher presents information in a way that makes it easy for students to understand and remember. Chunking is based on the presumption that our working memory is easily overloaded by excessive detail. The best way to deliver information is to organize it into meaningful units. Because students with special needs get overloaded easily, chunking is an effective strategy to use with them.

Checking for Understanding: It is important to constantly check for understanding, especially for students who have accommodations. Teachers want to make sure students understand the concepts being covered in a way that makes sense to them.

Extra time: The teacher provides students with special needs extra time to complete work or answer questions. It is important to give students enough time to process their thoughts.

Gifted & Talented Strategies

Extensions/Enrichments: Teachers will provide gifted and talented students with extension/enrichment projects. Students will be challenged to further their understanding, to apply acquired knowledge, and/or to produce something in reference to acquired knowledge.

Modify/Change Activities: Teachers will monitor and modify activities to accommodate those students who need to be challenged further. Additional reading, problem-solving, writing, or project work is necessary for those students who are ready to move on at a rate more accelerated than their peers. In this way, G & T students are provided the same opportunity for support as special needs students.

Students at Risk of School Failure

Directions or Instructions: Make sure directions and/or instructions are given in limited numbers. Give directions/instructions verbally and in simple written format. Ask students to repeat the instructions or directions to ensure understanding occurs. Check back with the student to ensure he/she hasn't forgotten.

Peer Support: Peers can help build confidence in other students by assisting in peer learning. Many teachers use the 'ask 3 before me' approach. This is fine, however, a student at risk may have to have a specific student or two to ask. Set this up for the student so he/she knows who to ask for clarification before going to you.

Alternate or Modified Assignments: Always ask yourself, "How can I modify this assignment to ensure the students at risk are able to complete it?" Sometimes you'll simplify the task, reduce the length of the assignment or allow for a different mode of delivery. For instance, many students may hand something in, the at-risk student may jot notes and give you the information verbally. Or, it just may be that you will need to assign an alternate assignment.

Increase One to One Time: When other students are working, always touch base with your students at risk and find out if they're on track or needing some additional support. A few minutes here and there will go a long way to intervene as the need presents itself.

Contracts: It helps to have a working contract between you and your students at risk. This helps prioritize the tasks that need to be done and ensure completion happens. Each day write down what needs to be completed, as the tasks are done, provide a checkmark or happy face. The goal of using contracts is to eventually have the student come to you for completion sign-offs.

Hands On: As much as possible, think in concrete terms and provide hands-on tasks. This means a child doing math may require a calculator or counters. The child may need to tape record comprehension activities instead of writing them. A child may have to listen to a story being read

instead of reading it him/herself.

Tests/Assessments: Tests can be done orally if need be. Break tests down in smaller increments by having a portion of the test in the morning, another portion after lunch and the final part the next day.

Seating: Seat students near a helping peer or with quick access to the teacher. Those with hearing or sight issues need to be close to the instruction which often means near the front.