04 Linear Momentum

Content Area:	**Science**
Course(s):	**AP Physics C**
Time Period:	**Semester 1**
Length:	**2 weeks**
Status:	**Published**

Standards

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.A	Forces and Motion
	Using Mathematics and Computational Thinking
SCI.HS.PS3.A	Definitions of Energy
SCI.HS.PS3.B	Conservation of Energy and Energy Transfer
	Systems and System Models
	Energy and Matter

AP Physics C Learning Objectives

Note: Learning Objectives are taken verbatim from the AP Physics C - Mechanics Course and Exam Description. The verb "describe" could refer to a variety of different methods of expression (e.g. words, diagrams, graphs, mathematical expressions), as appropriate.

Describe the linear momentum of an object or system.

Describe the impulse delivered to an object or system.

Describe the relationship between the impulse exerted on an object or system and the change in momentum of the object or system.

Describe the behavior of a system using conservation of linear momentum.

Describe how the selection of a system determines whether the momentum of that system changes.

Describe whether an interaction between objects is elastic or inelastic.

Enduring Understandings

Interactions produce changes in motion.

Forces characterize interactions between objects or systems.

Conservation laws constrain interactions.

An impulse exerted on an object will change the linear momentum of the object.

In the absence of an external force, the total momentum within a system can transfer from one object to another without changing the total momentum in the system.

Essential Questions

Why does water move a ship forward when its propellers push water backward?

Why are cannon barrels so much longer and heavier than cannonballs?

Why might a person land in the water instead of on the dock when trying to exit a canoe?

Knowledge and Skills

Topic 4.1 Linear Momentum

Knowledge:

- Linear momentum is defined by the equation $p = mv$.
- Momentum is a vector quantity and has the same direction as the velocity.
- Momentum can be used to analyze collisions and explosions.
- A collision is a model for an interaction where the forces exerted between the involved objects in the system are much larger than the net external force exerted on those objects during the interaction.
- As only the initial and final states of a collision are analyzed, the object model may be used to analyze collisions.
- An explosion is a model for an interaction in which forces internal to the system move objects within that system apart.

Skills:

- Create qualitative sketches of graphs that represent features of a model or the behavior of the physical system.
- Calculate or estimate an unknown quantity with units from known quantities, by selecting and following a logical computational pathway.
- Predict new values or factors of change of physical quantities using functional dependence between variables.
- Apply an appropriate law, definition, theoretical relationship, or model to make a claim.

Topic 4.2 Change in Momentum and Impulse

Knowledge:

- The rate of change of a system's momentum is equal to the net external force exerted on that system.
- Impulse is defined as the integral of a force exerted on an object or system over a time interval.
- Impulse is a vector quantity and has the same direction as the net force exerted on the system.
- The impulse delivered to a system by a net external force is equal to the area under the curve of a graph of the net external force exerted on the system as a function of time.
- The net external force exerted on a system is equal to the slope of a graph of the momentum of the system as a function of time.
- Change in momentum is the difference between a system's final momentum and its initial momentum.
- The impulse–momentum theorem relates the impulse delivered to an object and the object's change in momentum.
- The impulse exerted on an object is equal to the object's change in momentum.
- Newton's second law of motion is a direct result of the impulse–momentum theorem applied to systems with constant mass.
- The impulse–momentum theorem also describes the behavior of a system in which the velocity is constant but the mass changes with respect to time.

Skills:

- Create qualitative sketches of graphs that represent features of a model or the behavior of the physical system.
- Derive a symbolic expression from known quantities by selecting and following a logical mathematical pathway.
- Compare physical quantities between two or more scenarios or at different times and/or locations within a single scenario.
- Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.

Topic 4.3 Conservation of Linear Momentum

Knowledge:

- A collection of objects with individual momenta can be described as one system with one center-of-mass velocity.
- For a collection of objects, the velocity of a system's center of mass can be calculated using the equation .
- The velocity of a system's center of mass is constant in the absence of a net external force.
- The total momentum of a system is the sum of the momenta of the system's constituent parts.
- In the absence of net external forces, any change to the momentum of an object within a system must be balanced by an equivalent and opposite change of momentum elsewhere within the system. Any change to the momentum of a system is due to a transfer of momentum between the system and its surroundings.
- The impulse exerted by one object on a second object is equal and opposite to the impulse exerted by the second object on the first. This is a direct result of Newton's third law.

- A system may be selected so that the total momentum of that system is constant.
- If the total momentum of a system changes, that change will be equivalent to the impulse exerted on the system.
- Correct application of conservation of momentum can be used to determine the velocity of a system immediately before and immediately after collisions or explosions.
- Momentum is conserved in all interactions.
- If the net external force on the selected system is zero, the total momentum of the system is constant.
- If the net external force on the selected system is nonzero, momentum is transferred between the system and the environment.

Skills:

- Create diagrams, tables, charts, or schematics to represent physical situations.
- Create quantitative graphs with appropriate scales and units, including plotting data.
- Compare physical quantities between two or more scenarios or at different times and/or locations within a single scenario.
- Create experimental procedures that are appropriate for a given scientific question.
- Apply an appropriate law, definition, theoretical relationship, or model to make a claim.

Topic 4.4 Elastic and Inelastic Collisions

Knowledge:

- An elastic collision between objects is one in which the initial kinetic energy of the system is equal to the final kinetic energy of the system.
- In an elastic collision, the final kinetic energies of each of the objects within the system may be different from their initial kinetic energies.
- An inelastic collision between objects is one in which the total kinetic energy of the system decreases.
- In an inelastic collision, some of the initial kinetic energy is not restored to kinetic energy but is transformed by nonconservative forces into other forms of energy.
- In a perfectly inelastic collision, the objects stick together and move with the same velocity after the collision.

Skills:

- Create diagrams, tables, charts, or schematics to represent physical situations.
- Calculate or estimate an unknown quantity with units from known quantities, by selecting and following a logical computational pathway.
- Predict new values or factors of change of physical quantities using functional dependence between variables.
- Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.

Transfer Goals

Unit 4 introduces students to the relationships between force, time, impulse, and linear momentum via calculations, data analysis, designing experiments, and making predictions. Students will learn how to use new models and representations to illustrate the law of conservation of linear momentum of objects and systems while gaining proficiency using previously studied representations. Using the law of conservation of linear momentum to analyze physical situations provides students with a more complete picture of forces and opportunities to revisit misconceptions surrounding Newton's third law. Students will also have the opportunity to make connections between momentum and kinetic energy of objects or systems and see under what conditions these quantities remain constant.

Assessments

https://docs.google.com/document/d/1wR7bQF-8AQoRrt0g4C3hKja0yjwDjC9_BiAmONWbTcI/edit?usp=sharing

Modifications

https://docs.google.com/document/d/1ODqaPP69YkcFiyG72fIT8XsUIe3K1VSG7nxuc4CpCec/edit?usp=sharing