04 Linear Momentum

Content Area: **Science**
Course(s): **AP Physics 1**
Time Period: **Semester 1**
Length: **12 Periods**
Status: **Published**

Standards

	Patterns
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
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.
PS2.A	Forces and Motion
ETS1.C	Optimizing the Design Solution
	Cause and Effect
	Systems and System Models
	Scale, Proportion, and Quantity
	Using Mathematics and Computational Thinking
	Analyzing and Interpreting Data

Enduring Understandings

A force exerted on an object can change the momentum of the object.

Interactions with other objects or systems can change the total linear momentum of a system.

Certain quantities are conserved, in the sense that the changes of those quantities in a given system are always equal to the transfer of that quantity to or from the system by all possible interactions with other systems.

The linear momentum of a system is conserved.

Essential Questions

1. How is the physics definition of momentum different from how momentum is used to describe things in everyday life?

2. Can a person on an elevator that breaks loose and falls to the ground avoid harm by jumping at the last second?
3. Why will a water balloon break when thrown on the pavement, but not break if caught carefully?
4. Why is it important that cars are designed to include crumple zones?

Knowledge and Skills

4.1 Linear Momentum

Knowledge

- Linear momentum is defined by the equation $\vec{p} = m\vec{v}$.
- 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 a physical system.
- Calculate or estimate an unknown quantity with units from known quantities, by selecting and following a logical computational pathway
- Apply an appropriate law, definition, theoretical relationship, or model to make a claim.
- Compare physical quantities between two or more scenarios or at different times and locations in a single scenario

4.2 Change in Momentum and Impulse

Knowledge

- The rate of change of momentum is equal to the net external force exerted on an object or system.
- Impulse is defined as the product of the average force exerted on a system and the time interval during which that force is exerted on the system.
- 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 exerted on a system and the system'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.

Skills

- Create quantitative graphs with appropriate scales and units, including plotting data.
- Derive a symbolic expression from known quantities by selecting and following a logical mathematical pathway.
- Predict new values or factors of change of physical quantities using functional dependence between variables
- Create experimental procedures that are appropriate for a given scientific question.
- Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws

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

$$\vec{v}_{cm} = \frac{\sum_i \vec{p}_i}{\sum m_i} = \frac{\sum_i \left(m_i \vec{v}_i\right)}{\sum m_i}$$

    - 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.
- Derive a symbolic expression from known quantities by selecting and following a logical mathematical 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.

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 quantitative graphs with appropriate scales and units, including plotting data.
- 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 locations in 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.

Transfer Goals

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

Cause and Effect: 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.

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.

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.

Energy and Matter: Tracking energy and matter flows, into, out of, and within systems helps one understand their system's behavior.

Structure and Function: The way an object is shaped or structured determines many of its properties and functions.

Stability and Change: For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.

Assessments

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

Modifications

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