04 Linear Momentum

Content Area: **Science**
Course(s):
Time Period: **Semester 1**
Length: **4 weeks**
Status: **Published**

Standards

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

Enduring Understandings

Momentum and Impulse

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

Representations of Changes in Motion

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

Open and Closed Systems: Momentum

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.

Conservation of Linear Momentum

The linear momentum of a system is conserved.

Essential Questions

1. How does pushing an object change its momentum?

2. How do interactions with other objects or systems change the linear momentum of a system?
3. How is the physics definition of momentum different from how momentum is used to describe things in everyday life?
4. How does the law of the conservation of momentum govern interactions between objects or systems?
5. How can momentum be used to determine fault in car crashes?

Knowledge and Skills

Knowledge:

1. The change in momentum of an object is a vector in the direction of the net force exerted on the object.
2. The change in momentum of an object occurs over a time interval.

    a. The force that one object exerts on a second object changes the momentum of the second object (in the absence of other forces on the second object).

    b. The change in momentum of that object depends on the impulse, which is the product of the average force and the time interval during which the interaction occurred.

3. The change in linear momentum for a constant mass system is the product of the mass of the system and the change in velocity of the center of mass.

4. The change in linear momentum of the system is given by the product of the average force on that system and the time interval during which the force is exerted.

    a. The units for momentum are the same as the units of the area under the curve of a force versus time graph.

    b. The change in linear momentum and force are both vectors in the same direction.

5. For all systems under all circumstances, energy, charge, linear momentum, and angular momentum are conserved. For an isolated or a closed system, conserved quantities are constant. An open system is one that exchanges any conserved quantity with its surroundings.

6. In a collision between objects, linear momentum is conserved. In an elastic collision, kinetic energy is the same before and after.

    a. In a closed system, the linear momentum is constant throughout the collision.

    b. In a closed system, the kinetic energy after an elastic collision is the same as the kinetic energy

before the collision

7. In a collision between objects, linear momentum is conserved. In an inelastic collision, kinetic energy is not the same before and after the collision.

a. In a closed system, the linear momentum is constant throughout the collision.

b. In a closed system, the kinetic energy after an inelastic collision is different from the kinetic energy before the collision.

8. The velocity of the center of mass of the system cannot be changed by an interaction within the system.

a. The center of mass of a system depends on the masses and positions of the objects in the system. In an isolated system (a system with no external forces), the velocity of the center of mass does not change.

b. When objects in a system collide, the velocity of the center of mass of the system will not change unless an external force is exerted on the system.

c. Included in Physics 1 is the idea that, where there is both a heavier and lighter mass, the center of mass is closer to the heavier mass. Only a qualitative understanding of this concept is required.

Skills :

1. 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
2. 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.
3. 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.
4. 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
5. Design a plan for collecting data to investigate the relationship between changes in momentum and the average force exerted on an object over time
6. Calculate the change in linear momentum of a two-object system with constant mass in linear motion from a representation of the system
7. 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.
8. 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
9. Perform an analysis on data presented as a force-time graph and predict the change in momentum of a system.
10. Define open and closed systems for everyday situations and apply conservation concepts for energy, charge, and linear momentum to those situations
11. Make qualitative predictions about natural phenomena based on conservation of linear momentum and restoration of kinetic energy in elastic collisions.
12. 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 qualitatively in two-dimensional situations.

13. 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
14. 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
15. 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
16. 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.
17. 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
18. Apply the conservation of linear momentum to a closed system of objects involved in an inelastic collision to predict the change in kinetic energy.
19. Analyze data that verify conservation of momentum in collisions with and without an external frictional force.
20. 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.
21. 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)

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