(2026) 02 Momentum and Energy

Content Area: **Science**
Course(s): **Physics A**
Time Period: **Semester 1**
Length: **10 weeks**
Status: **Published**

Standards

SCI.HS.ETS1.C	Optimizing the Design Solution
SCI.HS.PS2.A	Forces and Motion
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.
SCI.HS.ETS1.A	Defining and Delimiting Engineering Problems
SCI.HS.PS3.A	Definitions of Energy
SCI.HS-PS3-2	Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).
SCI.HS-PS3-3	Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.
SCI.HS.PS3.B	Conservation of Energy and Energy Transfer
	Using Mathematics and Computational Thinking
	Cause and Effect
	Engaging in Argument from Evidence
SCI.HS.PS3.D	Energy in Chemical Processes
	Constructing Explanations and Designing Solutions
	Developing and Using Models
	Systems and System Models
	Energy and Matter
SCI.HS-ESS3-2	Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.
SCI.HS.ESS3.A	Natural Resources
SCI.HS-ETS1-1	Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
SCI.HS-ETS1-2	Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
SCI.HS-ETS1-4	Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.
SCI.HS.ETS1.B	Developing Possible Solutions

Enduring Understandings

1. Students will understand that because total momentum is absolutely conserved within a closed system, engineers can precisely quantify external boundary impulses to design and optimize safety technologies that mitigate human risk during collisions.

2. Students will understand that all macroscopic energy manifestations are conserved and modeled microscopically as either particle motion or field storage, allowing scientists to utilize computational simulations and mathematical models to predict complex system behaviors before physical prototyping.

3. Students will understand that while total energy is conserved, macroscopic systems naturally degrade useful energy into ambient thermal waste heat, forcing engineers to utilize trade-off matrices to optimize machine efficiency against real-world constraints like cost, durability, and reliability.

4. Students will understand that because energy availability strictly limits system capabilities, solving global resource and pollution crises requires breaking complex problems down into simpler components to evaluate engineered solutions against long-term environmental, geopolitical, and socio-cultural impacts.

Essential Questions

1. How can we mathematically use momentum conservation within a specific frame of reference to predict whether a complex system will maintain structural stability or undergo sudden changes in motion?

2. How would you construct an argument to defend the absolute conservation of energy when everyday macroscopic observations suggest that energy is actively "used up" or "destroyed" by society?

3. How do changes in particle motion and the physical configurations of force fields (gravitational, electric, and magnetic) explain the underlying mechanisms of how energy is stored and transferred?

4. How do engineers systematically define a global or local challenge—such as the need for clean water or low-pollution energy—by establishing quantifiable criteria and constraints before designing a solution?

5. How does a design team utilize a numerical weighting system to objectively critique, compare, and rank multiple proposed solutions when desired qualities are in direct conflict?

6. Why must engineering design be an iterative process of testing, troubleshooting, and computer simulation

rather than a linear race to find a single, immediate solution?

7. How do we evaluate the true thermodynamic efficiency of a machine, and how can we optimize its design to minimize the degradation of energy into less useful environmental waste heat?

8. How do human dependencies on Earth's resources guide the development of technology, and how must we balance short-term economic benefits against long-term geopolitical, environmental, and socio-cultural costs?

Knowledge and Skills

Knowledge:

1. Analyze how defining a system boundary (isolated vs. open) determines whether total linear momentum remains constant or changes due to an external net impulse
2. Deconstruct the mechanics of a collision by analyzing how kinetic energy transforms into internal energy during inelastic and totally inelastic events, compared to elastic collisions where kinetic energy is conserved.
3. Evaluate how the arbitrary choice of system boundaries dictates whether a force is classified as internal (converting mechanical energy to internal energy, like friction) or external (performing work to change the system's total energy).
4. Justify macroscopic forms of energy (kinetic, gravitational potential, elastic potential) by modeling them at the microscopic scale as either the kinetic motion of particles or energy stored within fields due to relative configurations.
5. Analyze the continuous conservation, transport, and conversion rate (Power) of energy within a system, noting that uncontrolled systems naturally evolve toward more stable, uniform energy distributions.
6. Evaluate the distinction between absolute energy conservation and the structural degradation of energy into less useful ambient thermal waste heat.
7. Formulate a framework for problem-solving where engineering criteria (desirable qualities) and constraints (safety, cost, reliability, aesthetics, and social/environmental impacts) are broken down systematically to prioritize trade-offs.

Skills :

1. Analyze multi-object interactions using vector math and systems definitions to prove that the total momentum of a system is conserved when the net external impulse is zero.
2. Create, test, and refine a physical device within strict constraints that minimizes impact force during a collision by maximizing the time interval of momentum transfer.

3. Construct qualitative and quantitative energy models (such as energy bar charts) to account for all energy transfers into, out of, or within a system across macro and micro scales.
4. Evaluate and critique competing real-world energy-resource management proposals by analyzing cost-benefit ratios alongside geopolitical, environmental, and socio-cultural impacts.
5. Utilize and manipulate computer simulations to model how modifying specific criteria and constraints within a complex, multi-system problem impacts the overall performance and efficiency of the proposed solution.

Assessments

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

Modifications

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