Unit 6: Momentum
UNIT PLAN

TABLE OF CONTENTS

UNIT NARRATIVE

This unit begins with an Anchoring Event and Essential Question chosen to give students an opportunity to be curious about a real-world event that embodies the key concepts they must understand about Momentum. Then students are asked to individually create initial models about how and why the Anchoring Event happens using their prior knowledge only. Several times during this unit students should use their Summary Tables to connect their learning from individual lessons back to the Anchoring Event and Essential Question. The unit ends with a lesson where students will create a Seamless Explanation of the Anchoring Event and Essential Question using their initial models, summary tables and multiple rounds of writing with peer feedback. This structure is based on the Ambitious Science Teaching model.

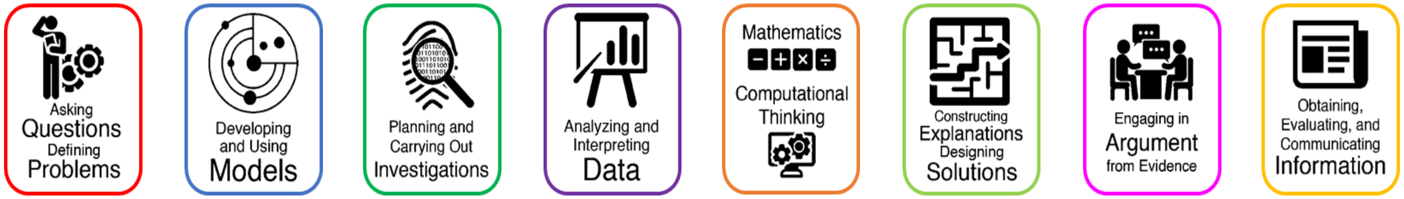
NOTE – There are two Anchoring Event options included with this unit. Anchoring Event 1: Throwing and catching a heavy ball while on a low friction cart and Anchoring Event 2: Explain why a Newton's Cradle acts the way that it does. Teachers should choose only one of the anchoring events.

After introducing the Anchoring Event there are two days of guided discovery with teacher demonstrations of a series of cart collisions. To guide students in creating a model to describe collisions they will be prompted to describe the quantity that remains the same before and after a collision. Students will start with a simple and incomplete model of collisions; the final model will define momentum and the conservation of momentum. Then students will practice applying the conservation of momentum in several ways; by drawing momentum bar charts and solving for unknown variables, with a card sort to match narrative, graphical and mathematical models of scenarios and with simulation experimentation to verify the conservation of momentum and classify different collisions based on changes in kinetic energy.

The second half of this unit focuses on how forces create changes in momentum and the Impulse-Momentum Theorem. Students will explore the variables that affect change in momentum using a virtual simulation to conduct an experiment, as a preview of Impulse-Momentum. Then students will experimentally determine the equivalency between the change in momentum of a one-car collision and the area under the Force-Time graph. Then students will use this graphical relationship along with the mathematical model of Average Force * time = change in momentum to make predictions about forces and momentum changes in different scenarios. Finally, students will explore the relationship between Force and Time in constant change of momentum collisions with a Design Challenge to create a bumper that minimizes the force of a cart collision.

Focus on Disciplinary Literacy

In science, disciplinary literacy is synonymous with the science and engineering practices. The SEPs are the context through which all science concepts should be taught. In the lessons, you will find the Science and Engineering practices icons when the SEPs are being explicitly used by students.



UNPACKED CONTENT STANDARDS

Texas TEKS Physics Standards

Standard ID	Standard Description
C.7	The student knows that changes occur within a physical system and applies the laws of conservation of ~~energy~~ and momentum. The student is expected to:
C.7.A	calculate and describe the impulse and momentum of objects in physical systems such as automobile safety features, athletics, and rockets; and
C7.B	analyze the conservation of momentum qualitatively in inelastic and elastic collisions in one dimension using models, diagrams, and simulations.

College Board AP Physics Standards

Topic		Learning Objective		Essential Knowledge	
4.1	Linear Momentum	4.1.A	Describe the linear momentum of an object or system.	4.1.A.1	Linear momentum is defined by the **equation -->** $p = mv$
				4.1.A.2	Momentum is a vector quantity and has the same direction as the velocity.
				4.1.A.3	Momentum can be used to analyze collisions and explosions. i. 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. ii. As only the initial and final states of a collision are analyzed, the object model may be used to analyze collisions. iii. An explosion is a model for an interaction in which forces internal to the system move objects within that system apart.
		BOUNDARY STATEMENT: *Unless otherwise stated, the general term "momentum" will refer specifically to linear momentum.*			
4.2	Change in Momentum and Impulse	4.2.B	Describe the impulse delivered to an object or system.	4.2.B.1	The rate of change of momentum is equal to the net external force exerted on an object or system. **Relevant equation -->** $F_{net} = \frac{\Delta p}{\Delta t}$
				4.2.B.2	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. **Relevant equation -->** $J = F_{avg}\Delta t$
				4.2.B.3	Impulse is a vector quantity and has the same direction as the net force exerted on the system.

				4.2.B.4.	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.
				4.2.B.5	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.
4.3	Conservation of Linear Momentum	4.3.A	Describe the behavior of a system using conservation of linear momentum.	4.3.A.1	A collection of objects with individual momenta can be described as one system with one center-of-mass velocity. i. For a collection of objects, the velocity of a system's center of mass can be calculated **using the equation -->** $v_{cm} = \frac{\Sigma p_i}{\Sigma m_i} = \frac{\Sigma(m_i v_i)}{\Delta m_i}$ ii. The velocity of a system's center of mass is constant in the absence of a net external force.
				4.3.A.2	The total momentum of a system is the sum of the momenta of the system's constituent parts.
				4.3.A.3	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. i. 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. ii. A system may be selected so that the total momentum of that system is constant. iii. If the total momentum of a system changes, that change will be equivalent to the impulse exerted on the system. **Relevant equation -->** $J = \Delta p$
				4.3.A.4	Correct application of conservation of momentum can be used to determine the velocity of a system immediately before and immediately after collisions or explosions.
		BOUNDARY STATEMENT: *AP Physics 1 includes a quantitative and qualitative treatment of conservation of momentum in one dimension and a semiquantitative treatment of conservation of momentum in two dimensions. Exam questions involving solution of simultaneous equations are not included in AP Physics 1, but the AP Physics 1 Exam may include questions that assess whether students can set up the equations properly and reason about how changing a given mass, speed, or angle would affect other quantities. AP Physics 2 includes a full treatment of conservation of momentum in two dimensions for problems that include one unknown final velocity.*			
		4.3.B	Describe how the selection of a system determines whether the momentum of	4.3.B.1	Momentum is conserved in all interactions.
				4.3.B.2	If the net external force on the selected system is zero, the total momentum of the system is constant.
				4.3.B.3	If the net external force on the selected system is nonzero, momentum is transferred between the system and the environment.

			that system changes.		
4.4	Elastic and Inelastic Collisions	4.4.A	The linear momentum of a system is conserved.	4.4.A.1	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.
				4.4.A.2	In an elastic collision, the final kinetic energies of each of the objects within the system may be different from their initial kinetic energies.
				4.4.A.3	An inelastic collision between objects is one in which the total kinetic energy of the system decreases.
				4.4.A.4	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.
				4.4.A.5	An inelastic collision between objects is one in which the total kinetic energy of the system decreases.

KEY UNDERSTANDINGS AND QUESTIONS

Important big ideas and processes for the unit.

Key Understandings
• Momentum is the product of mass and velocity and is often conserved during collisions, whereas KE is not, so it is useful in making predictions about collisions. • Momentum is conserved for all types of collisions, as long as no forces from outside the system are significant. • Kinetic energy is conserved only for elastic collisions, as long as no forces from outside the system are significant. • Change in momentum is equal to the product of force and time (Impulse). • Force and time are inversely related when the change in momentum remains the same. The motion of the center of mass of a system of objects is only changed by forces outside the system (forces internal to the system have no effect).

Key Questions
• What is momentum and how is it different than kinetic energy? • When is momentum conserved during a collision? • When is Kinetic Energy conserved during a collision? • Why are some collisions likely to cause damage/injury and others are not? • How does conservation of momentum help us make predictions about collisions? • How do forces create changes in momentum of an object or a system of objects?

VERTICAL STANDARDS

This section details the **progression** of key student standards in the courses **before** this course. This will help you understand what **prior knowledge skills to build upon**.

These vertical standards are EXACTLY the same as Unit 3: Energy. Not every vertical standard applies but most of the energy and Work concepts are still relevant for momentum.

5th Grade Science	6/7 Grade Hybrid Science	8th Grade Science
3-5(7) Force, motion, and energy. The student knows the nature of forces and the patterns of their interactions. The student is expected to: 5.7A investigate and explain how equal and unequal forces acting on an object cause patterns of motion and transfer of energy. **3-5(8) Force, motion, and energy. The student knows that energy is everywhere and can be observed in cycles, patterns, and systems. The student is expected to:** 5(8)(A) investigate and describe the transformation of energy in systems such as energy in a flashlight battery that changes from chemical energy to electrical energy to light energy; 5(8)(B) demonstrate that electrical energy in complete circuits can be transformed into motion, light, sound, or thermal energy and identify the requirements for a functioning electrical circuit; and	**6(8) Force, motion, and energy. The student knows that the total energy in systems is conserved through energy transfers and transformations. The student is expected to:** 6(8)(A) compare and contrast gravitational, elastic, and chemical potential energies with kinetic energy; 6(8)(B) describe how energy is conserved through transfers and transformations in systems such as electrical circuits, food webs, amusement park rides, or photosynthesis; and **7(8) Force, motion, and energy. The student understands the behavior of thermal energy as it flows into and out of systems. The student is expected to:** 7(8)(A) investigate methods of thermal energy transfer into and out of systems, including conduction, convection, and radiation; 7(8)(B) investigate how thermal energy moves in a predictable pattern from warmer to cooler until all substances within the system reach thermal equilibrium; and	None

	7(8)(C) explain the relationship between temperature and the kinetic energy of the particles within a substance.	

VOCABULARY GLOSSARY

Domain-specific words and definitions for this unit.

Key Content Vocabulary
Momentum Bar Charts – a visual model of the momentum of a system at two different positions/times **Momentum (p)** (linear) – the product of mass and velocity of an object. Represented as p in formula. $$p = mv$$ **Change in Momentum (Δp)** – The change in momentum of an object or system at two different points in time. Often designated Before/After or Initial/Final. Often due to changes $$\Delta p = mv_F - mv_I$$ **Conservation of Momentum** – for a closed system the total momentum of the system will remain constant (usually before and after a collision) $$p_I = p_F$$ $$m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1F} + m_f v_{2F}$$ **Closed system** – a system that is not impacted by forces outside the system (usually friction or air resistance). **Open system** – a system that is subject to forces from outside the system (usually friction or air resistance). **Internal Force –** forces that result from the interaction of objects that are part of the defined system. These forces cannot affect the total momentum (or energy) of the system but will change the individual momentum (and energy) of objects during two object collisions. **External (Outside) Force –** force that results from objects outside of the defined system interacting with objects that are inside the defined system. These forces can change the total momentum (and energy) of the system. Friction and Air resistance are common outside forces in AP Physics 1. **Impulse (I)** – the product of average Force and time force is applied $$Impulse = Force * time$$ $$I = Ft$$ **Center of Mass -**

Related Vocabulary				
Collision Types: Elastic Inelastic Perfectly Inelastic Explosion	Center of Mass			