Unit 1: 1D Kinematics
UNIT PLAN

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UNIT NARRATIVE

This unit begins with a focused review of experimental design skills that students will rely on throughout the year, including identifying independent, dependent, and control variables, conducting controlled investigations, and determining variable relationships through graphical analysis. These two days of foundational work are essential in setting the stage for experimental discovery of physics concepts throughout the course.

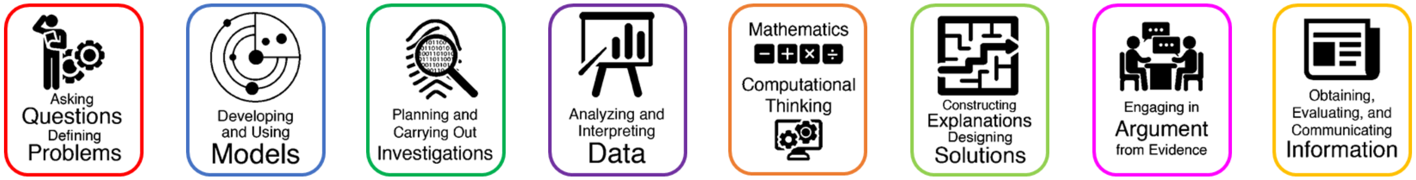
The foundation of all physics depends on a robust conceptual and mathematical understanding of motion in one dimension. Students begin by exploring motion in one dimension by distinguishing between scalar and vector quantities, specifically comparing distance versus displacement. This distinction introduces the idea that direction is critical for many physical quantities in physics, setting the groundwork for future study of velocity, acceleration and many other vector quantities throughout the course. Students learn to represent constant velocity and constant acceleration motion using a variety of models—position-time and velocity-time graphs, narrative descriptions, motion maps, and kinematics equations. Through hands-on and virtual lab activities, students collect data, create graphical representations of 1D motion, and learn to interpret these graphs to describe and predict motion. Throughout the unit, students practice quantitative analysis, model-based predictions, and using physics reasoning —skills that are essential in physics and align with core science practices.

The unit is sequenced to build from simple to more complex concepts. Students start with constant velocity motion because it is the simplest type of motion, represented only by straight lines on position-time graphs and horizontal lines on velocity-time graphs. By creating, analyzing and translating between motion graphs and other representations of motion students have the opportunity to develop conceptual understanding about motion graphs for constant velocity motion. This allows students to determine the main characteristics and differences between the two primary types of motion graphs before introducing more complex motion. Students will then progress to constant acceleration motion, where they learn to interpret curved position-time graphs and sloped velocity-time graphs and then segmented motion which combines constant velocity and constant acceleration motion in different segments of a graph. As students become more confident in interpreting motion graphs, they start analyzing motion graph quantitatively, calculating slope and area to extract meaningful quantities such as velocity, acceleration, and displacement. This scaffolding ensures that each concept logically builds on the previous one, supporting deep understanding and skill development.

Students will now conduct a lab investigation of free fall motion where, using both graphical and equation-based models to describe the acceleration of gravity for free falling objects. With multiple opportunities for practice, feedback, and application, students leave the unit with the confidence and ability to describe, represent, and predict one-dimensional motion in a scientifically rigorous way. In the final phase of the unit, students are introduced to the kinematic equations as tools for making predictions about constant acceleration motion scenarios. By this point, students are equipped to connect these equations to their graphical understanding, reinforcing the idea that all models of motion should "tell the same story."

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

TEKS Physics Standards

Standard ID	Standard Description
C.5	The student knows and applies the laws governing motion in a variety of situations. The student is expected to:
C.5.A	analyze different types of motion by generating and interpreting position versus time, velocity versus time, and acceleration versus time using hand graphing and real-time technology such as motion detectors, photogates, or digital applications;
C.5.B	define scalar and vector quantities related to one- and two-dimensional motion and combine vectors using both graphical vector addition and the Pythagorean theorem;
C.5.C	describe and analyze motion in one dimension using equations with the concepts of distance, displacement, speed, velocity, frames of reference, and acceleration;

College Board AP Physics Standards

Note – Learning Objectives in Orange are included in AP Physics Unit but will not be covered in until Advanced Physics Unit 2.

Learning Objective				Essential Knowledge	
Topic #	**Topic**	**LO #**	**Learning Objective**	**EK #**	**Essential Knowledge**
1.1	**Scalars and Vectors in One Dimension**	1.1.A	Describe a scalar or vector quantity using magnitude and direction, as appropriate.	1.1.A.1	Scalars are quantities described by magnitude only; vectors are quantities described by both magnitude and direction.
				1.1.A.2	Vectors can be visually modeled as arrows with appropriate direction and lengths proportional to their magnitude.
				1.1.A.3	Distance and speed are examples of scalar quantities, while position, displacement, velocity, and acceleration are examples of vector quantities. i. Vectors are notated with an arrow above the symbol for that quantity. **Relevant Equation -->** $\boldsymbol{v = v_0 + at}$ ii. Vector notation is not required for vector components along an axis. In one dimension, the sign of the component completely describes the direction of that component. **Derived Equation -->** $\boldsymbol{v_x = v_{x0} + a_x t}$
		1.1.b	Describe a vector sum in one dimension.	1.1.B.1	When determining a vector sum in a given one-dimensional coordinate system, opposite directions are denoted by opposite signs.
1.2	**Displacement, Velocity, and Acceleration**	1.2.A	Describe a change in an object's position.	1.2.A.1	When using the object model, the size, shape, and internal configuration are ignored. The object may be treated as a single point with extensive properties such as mass and charge.
				1.2.A.2	Displacement is the change in an object's position. **Relevant Equation -->** $\boldsymbol{\Delta x = x - x_0}$

		1.2.B	Describe the average velocity and acceleration of an object.	1.2.B.1	Averages of velocity and acceleration are calculated considering the initial and final states of an object over an interval of time.
				1.2.B.2	Average velocity is the displacement of an object divided by the interval of time in which that displacement occurs. **Relevant Equation -->** $\boldsymbol{v_{avg} = \frac{\Delta x}{\Delta t}}$
				1.2.B.3	Average acceleration is the change in velocity divided by the interval of time in which that change in velocity occurs. **Relevant Equation -->**$\boldsymbol{a_{avg} = \frac{\Delta v}{\Delta t}}$
				1.2.B.4	An object is accelerating if the magnitude and/or direction of the object's velocity are changing.
				1.2.B.5	Calculating average velocity or average acceleration over a very small time-interval yields a value that is very close to the instantaneous velocity or instantaneous acceleration.
1.3	**Representing Motion**	1.3.A	Describe the position, velocity, and acceleration of an object using representations of that object's motion.	1.3.A.1	Motion can be represented by motion diagrams, figures, graphs, equations, and narrative descriptions.
				1.3.A.2	For constant acceleration, three kinematic equations can be used to describe instantaneous linear motion in one dimension. **THREE KINEMATIC EQUATIONS -->** $\boldsymbol{v_x = v_{x0} + a_x t}$ $\boldsymbol{x = x_0 + v_{x0}t + \frac{1}{2}at^2}$ $\boldsymbol{v_x^2 = v_{x0}^2 + 2a_x(x - x_0)}$
				1.3.A.3	Near the surface of Earth, the vertical acceleration caused by the force of gravity is downward, constant, and has a measured value approximately equal to **g = 10 m/s²**
				1.3.A.4	Graphs of position, velocity, and acceleration as functions of time can be used to find the relationships between those quantities. i. An object's instantaneous velocity is the rate of change of the object's position, which is equal to the slope of a line tangent to a point on a graph of the object's position as a function of time. ii. An object's instantaneous acceleration is the rate of change of the object's velocity, which is equal to the slope of a line tangent to a point on a graph of the object's velocity as a function of time. iii. The displacement of an object during a time interval is equal to the area under the curve of a graph of the object's velocity as a function of time (i.e., the area bounded by the function and the horizontal axis for the appropriate interval). ~~iv. The change in velocity of an object during a time interval is equal to the area under the curve of a graph of the acceleration of the object as a function of time.~~
		BOUNDARY STATEMENT: AP Physics 1 does not expect students to quantitatively analyze nonuniform acceleration. However, students will be expected to be able to qualitatively analyze, sketch appropriate graphs of, and discuss situations in which acceleration is nonuniform.			

		BOUNDARY STATEMENT: For all situations in which a numerical quantity is required for g, the value g = 10 m/s^2 will be used. However, students will not be penalized for correctly using the more precise commonly accepted values of **g = 9.8 or 9.81 m/s^2**			
1.4	**Reference Frames and Relative Motion**	1.4.A	Describe the reference frame of a given observer.	1.4.A.1	The choice of reference frame will determine the direction and magnitude of quantities measured by an observer in that reference frame.
		1.4.B	Describe the motion of objects as measured by observers in different inertial reference frames.	1.4.B.1	Measurements from a given reference frame may be converted to measurements from another reference frame.
				1.4.B.2	The observed velocity of an object results from the combination of the object's velocity and the velocity of the observer's reference frame. i. Combining the motion of an object and the motion of an observer in a given reference frame involves the addition or subtraction of vectors. ii. The acceleration of any object is the same as measured from all inertial reference frames.
		BOUNDARY STATEMENT: *Unless otherwise stated, the frame of reference of any problem may be assumed to be inertial.* *Adding or subtracting vectors to find relative velocities is restricted to motion along one dimension for AP Physics 1.*			
1.5	**Vectors and Motion in Two Dimensions**	1.5.A	Describe the perpendicular components of a vector.	1.5.A.1	Vectors can be mathematically modeled as the resultant of two perpendicular components.
				1.5.A.2	Vectors can be resolved into components using a chosen coordinate system.
				1.5.A.3	Vectors can be resolved into perpendicular components using trigonometric functions and relationships.
		1.5.B	Describe the motion of an object moving in two dimensions.	1.5.B1	Motion in two dimensions can be analyzed using one-dimensional kinematic relationships if the motion is separated into components.
				1.5.B.2	Projectile motion is a special case of two-dimensional motion that has zero acceleration in one dimension and constant, nonzero acceleration in the second dimension.

UNDERSTANDINGS AND QUESTIONS

Important big ideas and processes for the unit.

Key Understandings
❑ The Independent Variable (IV) is manipulated by the experimenter. ❑ The Dependent Variable (DV) responds to the changes made to the Independent Variable. ❑ Control Variables (CV) must be held at a constant value during all trials of an experiment. All variables other than the IV and DV are Control Variables. ❑ When experimental DV vs IV data is graphed the shape of the graph will indicate the variable relationship. ❑ For a Linear/Directly Proportional Relationship when X changes by a multiple of change Y changes by the same multiple. ❑ For an Inverse Relationship when X changes by a certain multiple Y changes by the inverse of that multiple of change, $\frac{1}{multiple\ of\ change)}$. ❑ For a Quadratic Relationship when X changes by a certain multiple Y changes by the square of the multiple of change, $(multiple\ of\ change)^2$. ❑ For an Inverse Square Relationship when X changes by a certain multiple of change Y changes by the inverse square of the multiple of change, $\frac{1}{(multiple\ of\ change\ )^2}$. ❑ Scalars are quantities that do not require directions to be fully described. ❑ Vectors are quantities that require both a magnitude and direction to be fully described. ❑ For 1-dimensional motion the direction is indicated as positive (+) or negative (-). ❑ For convenience we will typically consider motion to the right/up as positive and motion to the left/down as negative. ❑ Distance is a scalar measurement (does not need/include direction). ❑ Displacement is a vector measurement of distance that is equal to the final position minus the initial position. ❑ A Position-time (p-t) graph shows the position/location on the y-axis object over a range of time on the x-axis. ❑ Initial position on a p-t graph is located at the y-intercept (where the graph crosses the y axis). ❑ Displacement can be determined from a p-t graph by subtracting the initial position from the final position. ❑ The slope of a p-t graph indicates the direction (+/-) and the magnitude of the velocity. ❑ Constant velocity motion is characterized by an object moving the same displacement each unit of time (typically per second). ❑ Constant velocity motion is ALWAYS a straight line on a p-t graph. ❑ A Velocity-time graph shows the velocity of an object on the y-axis over a range of time on the x-axis. ❑ Constant velocity is ALWAYS a horizontal line on a v-t graph. ❑ Motion maps show vector arrows representing the velocity of an object at different locations. ❑ A motion detector collects position and time data to calculate velocity and acceleration. ❑ Constant acceleration motion has constant change in velocity per second. ❑ The p-t graph for constant acceleration motion is ALWAYS a curve (never a line). ❑ The v-t graph for constant acceleration motion is ALWAYS a line with slope (not a flat line).

- ❑ Positive v-t graphs (above the x-axis) indicate motion to the right/up.
- ❑ Negative v-t graphs (above the x-axis) indicate motion to the left/down.
- ❑ The slope of a v-t graph indicates the magnitude and direction of the acceleration.
- ❑ Increasing velocity on a p-t graph is a curve that becomes more steep/vertical.
- ❑ Decreasing velocity on a p-t graph is a curve that becomes less step/more flat.
- ❑ Increasing velocity on v-t graph is when the graph is moving away from the x-axis.
- ❑ Decreasing velocity on a v-t graph is when the graph moves away from the x-axis.
- ❑ The slope of a p-t graph (direction and magnitude of velocity) is calculated using $\frac{rise}{run} = \frac{\Delta x}{\Delta t} = v$
- ❑ The slope of a v-t graph (direction and magnitude of acceleration) is calculated using $\frac{rise}{run} = \frac{\Delta v}{\Delta t} = a$
- ❑ The area between a v-t graph and the x-axis (area under the curve) is calculated by summing the area of the geometric shapes (triangles and rectangles).
- ❑ Free Fall motion is constant acceleration motion.
- ❑ Mass has no effect on free fall acceleration.
- ❑ Shape has no effect on free fall acceleration.
- ❑ Free fall acceleration (acceleration of gravity) is ALWAYS a constant magnitude of 9.81 m/s/s (rounded to 10.0 m/s/s in this course for simplicity of calculations)
- ❑ The Kinematics Equations apply to constant acceleration motion ONLY.
- ❑ Variable relationships identified from the Three Kinematics Equations can be used to calculate quantitative predictions about displacement, velocity, acceleration and time for constant acceleration motion.

Key Questions

- How can we determine if motion is constant velocity or constant acceleration experimentally? Graphically?
- What does the slope of a position-time graph represent?
- What does the slope a velocity-time graph represent?
- What does the area under a velocity-time graph represent?
- What is the acceleration of a free-falling object?
- How can we calculate quantitative predictions about position, time and velocity for constant velocity motion?
- How can we calculate quantitative predictions about position, time, and velocity for constant acceleration motion?

VERTICAL STANDARDS

This section details the **progression** of key student expectations/standards** in the courses **before** and **after** this course. This will help you understand what **prior knowledge skills to build upon** and guide you in knowing what **skills you are preparing your students** for in the subsequent course.

5th Grade Science	6/7 Grade Hybrid Science	8th Grade Science
5.7A investigate and explain how equal and unequal forces acting on an object cause patterns of motion and transfer of energy; and	7.7A calculate average speed using distance and time measurements from investigations; 7.7B distinguish between speed and velocity in linear motion in terms of distance, displacement, and direction; 7.7C measure, record, and interpret an object's motion using distance-time graphs; and	8.7A calculate and analyze how the acceleration of an object is dependent upon the net force acting on the object and the mass of the object using Newton's Second Law of Motion; and

VOCABULARY GLOSSARY

Domain-specific words and definitions for this unit.

Key Content Vocabulary
Independent variable – the variable that is intentionally manipulated by the scientist/experimenter. **Dependent variable –** the variable that the scientist/experimenter wants to measure to determine how it changes in relationship to changes in the independent variable. **Control variable -** an experimental element which is held constant and unchanged throughout the course of the investigation. **Linear relationship –** when the independent variable increases/decreases the dependent variable increases/decreases proportionally **Inverse relationship –** when the independent variable increases/decreases the dependent variable changes in the opposite way proportionally **Quadratic relationship –** when the independent variable increases/decreases the dependent variable increases/decreases proportionally to the square of the dependent variable's change **Scalar** – a quantity that can be measured/described with a magnitude only (without a direction) **Vector** – a quantity that requires both a magnitude and direction to be properly measured/described **Distance** – a scalar measure of the distance an object travel (meters) **Displacement** – a vector measure of the distance and object travels (the vector distance between the starting position and the end position of an object, meters) $displacement = change\ in\ position = x_f - x_i$ **Speed** – a scalar measure of how far an object travels per unit of time (meters/second **Velocity** – a vector measure of how far an object travels per unit of time (meters/second) $velocity\ (v) = \frac{change\ in\ position}{time} = \frac{displacement}{time} = \frac{\Delta x}{\Delta t}$ **Acceleration** – a vector measure of how the velocity of an object changes per unit of time (meters/second/second) $acceleration\ = \frac{change\ in\ velocity}{time} = \frac{\Delta v}{\Delta t}$ **Free Fall** – Constant acceleration motion that is the result of the force of gravity only **Acceleration of gravity (little g)** - the acceleration of an object in free fall within a vacuum (and thus without experiencing air resistance/drag). A conventional standard value is defined exactly as 9.80665 m/s^2 (32.1740 ft/s^2). In this course 10.0 m/s^2 will be used for simplicity.

Related Vocabulary

Constant velocity Constant acceleration	Slowing down Speeding up	Inertia