01 Kinematics

Content Area: **Science**
Course(s): **AP Physics C**
Time Period: **Semester 1**
Length: **3 weeks**
Status: **Published**

Textbook Resources

Core Resource:

Textbook: Halliday, Resnick, and Walker, *Fundamentals of Physics*, 11th ed.

Lecture notes

Supplemental Resources:

Flipping Physics videos

iLectureOnline videos

AP Classroom

Standards

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.
	Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object sliding down a ramp, or a moving object being pulled by a constant force.
	Analyzing and Interpreting Data
PS2.A	Forces and Motion
	Cause and Effect

AP Physics C Learning Objectives

Note: Learning Objectives are taken verbatim from the AP Physics C - Mechanics Course and Exam Description. The verb "describe" could refer to a variety of different methods of expression (e.g. words, diagrams, graphs, mathematical expressions), as appropriate.

Describe a scalar or vector quantity using magnitude and direction, as appropriate.

Describe a change in an object's position

Describe the average velocity and acceleration of an object.

Describe the instantaneous position, velocity, and acceleration of an object as a function of time.

Describe the position, velocity, and acceleration of an object using representations of that object's motion.

Describe the reference frame of a given observer.

Describe the motion of an object moving in two or three dimensions.

Enduring Understandings

Interactions produce changes in motion.

There are relationships among the vector quantities of position, velocity, and acceleration for the motion of a particle in a straight line.

There are multiple simultaneous relationships among the quantities of position, velocity, and acceleration for the motion of a particle moving in more than one dimension with or without net forces.

Essential Questions

How can the motion of objects be predicted and/or explained?

How can the idea of frames of reference allow two people to tell the truth yet have conflicting reports?

How can we use models to help us understand motion?

Why is the general rule for stopping your car "when you double your speed, you must give yourself four times as much distance to stop"?

Knowledge and Skills

Topic 1.1 Scalars and Vectors
Knowledge:

- Scalars are quantities described by magnitude only; vectors are quantities described by both magnitude and direction.
- Vectors can be visually modeled as arrows with appropriate direction and lengths proportional to their magnitude.
- Distance and speed are examples of scalar quantities, while position, displacement, velocity, and

acceleration are examples of vector quantities.
- Vectors can be expressed in unit vector notation or as a magnitude and a direction.
- Unit vector notation can be used to represent vectors as the sum of their constituent components in the *x*-, *y*-, and *z*-directions, denoted by *i*, *j*, and *k*, respectively.
- The position vector of a point is given by *r*, and the unit vector in the direction of the position vector is denoted *r*.
- A resultant vector is the vector sum of the addend vectors' components.
- In a given one-dimensional coordinate system, opposite directions are denoted by opposite signs.

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.
- 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.

Topic 1.2 Displacement, Velocity, and Acceleration

Knowledge:

- 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.
- Displacement is the change in an object's position.
- Averages of velocity and acceleration are calculated considering the initial and final states of an object over an interval of time.
- Average velocity is the displacement of an object divided by the interval of time in which that displacement occurs.
- Average acceleration is the change in velocity divided by the interval of time in which that change in velocity occurs.
- An object is accelerating if either the magnitude and/or direction of the object's velocity are changing.
- 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.
- As the time interval used to calculate the average value of a quantity approaches zero, the average value of that quantity approaches the value of the quantity at that instant, called the instantaneous value.
- Instantaneous velocity is the rate of change of the object's position, which is equal to the derivative of position with respect to time.
- Instantaneous acceleration is the rate of change of the object's velocity, which is equal to the derivative of velocity with respect to time.
- Time-dependent functions and instantaneous values of position, velocity, and acceleration can be determined using differentiation and integration.

Skills:

- Create quantitative graphs with appropriate scales and units, including plotting data.
- Calculate or estimate an unknown quantity with units from known quantities, by selecting and following a logical computational pathway.

- Compare physical quantities between two or more scenarios or at different times and/or locations within a single scenario.
- 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.

Topic 1.3 Representing Motion

Knowledge:

- Motion can be represented by motion diagrams, figures, graphs, equations, and narrative descriptions.
- For constant acceleration, three kinematic equations can be used to describe instantaneous linear motion in one dimension.
- 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 $a_g = g \approx 10\ m/s^2$.
  Graphs of position, velocity, and acceleration as functions of time can be used to find the relationships between those quantities.
- 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.
- 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.
- 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).
- 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.

Skills:

- Create qualitative sketches of graphs that represent features of a model or the behavior of the physical system.
- 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.

Topic 1.4 Reference Frames & Relative Motion

Knowledge:

- The choice of reference frame will determine the direction and magnitude of quantities measured by an observer in that reference frame.
- Measurements from a given reference frame may be converted to measurements from another reference frame.
- The observed velocity of an object results from the combination of the object's velocity and the velocity of the observer's reference frame.

- Combining the motion of an object and the motion of an observer in a given reference frame involves the addition or subtraction of vectors.
- The acceleration of any object is the same as measured from all inertial reference frames.

Skills:

- Create diagrams, tables, charts, or schematics to represent physical situations.
- Calculate or estimate an unknown quantity with units from known quantities, by selecting and following a logical computational pathway.
- Compare physical quantities between two or more scenarios or at different times and/or locations within a single scenario.
- Apply an appropriate law, definition, theoretical relationship, or model to make a claim.

Topic 1.5 Motion in Two or Three Dimensions
Knowledge:

- Motion in two or three dimensions can be analyzed using one-dimensional kinematic relationships if the motion is separated into components.
- Velocity and acceleration may be different in each dimension and may be nonuniform.
- Motion in one dimension may be changed without causing a change in a perpendicular dimension.
- 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.

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.

Transfer Goals

The world is made up of objects that are in a constant state of motion. To understand the relationships between objects, students must first understand movement. Unit 1 introduces students to the study of motion and serves as a foundation for all of AP Physics C: Mechanics by exploring the idea of acceleration and teaching students how representations can be used to model and analyze scientific information as it relates to the motion of objects.

Assessments

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

Modifications

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