AP PHYSICS 1

UNIT 1

Kinematics

10–15%
AP EXAM WEIGHTING

~12–17
CLASS PERIODS

Remember to go to **AP Classroom** to assign students the online **Progress Check** for this unit.

Whether assigned as homework or completed in class, the **Progress Check** provides each student with immediate feedback related to this unit's topics and science practices.

Progress Check 1

Multiple-choice: ~18 questions
Free-response: 4 questions

- Mathematical Routines
- Translation Between Representations
- Experimental Design and Analysis
- Qualitative/Quantitative Translation

Kinematics

ESSENTIAL QUESTIONS

- How can the idea of frames of reference allow two people to tell the truth yet have conflicting reports?
- How can we estimate the height of a very tall building with only a small rock and a stopwatch?
- Why might it seem like you are moving backwards when a car passes you on the highway?
- 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"?

Developing Understanding

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 1 by exploring the idea of acceleration and showing students how representations can be used to model and analyze scientific information as it relates to the motion of objects.

Building the Science Practices

1.A 1.C 2.A 2.B

Multiple representations are key in Unit 1. By studying kinematics, students will learn to represent motion—both constant velocity and constant acceleration—in words, in graphical (**1.A** and **1.C**) and/or mathematical forms (**2.A** and **2.B**), and from different frames of reference. These representations will help students analyze the specific motion of objects and systems while also dispelling some common misconceptions they may have about motion, such as exclusively using negative acceleration to describe an object slowing down. Additionally, students will have the opportunity to think beyond their traditional understanding of mathematics. Instead of merely evaluating equations (**2.B**), students will use mathematical representations to support their reasoning and gain proficiency in using mathematical models to describe physical phenomena.

Preparing for the AP Exam

Creating models and representations is a fundamental piece of the second question in the free-response section—Translation Between Representations (TBR) question—and the analysis of models and representations constitutes a large part of the multiple-choice section of the AP Physics 1 Exam. Physicists often use models and representations to show the behavior of objects and/or systems of objects and to illustrate physics concepts. Representations and models include, but are not limited to, sketches of the physical situation, graphs, mathematical equations, and verbal descriptions. As they encounter new scenarios through the unit, students should be encouraged to apply different representations based on the type of information given.

UNIT AT A GLANCE

Topic	Suggested Skills
1.1 Scalars and Vectors in One Dimension	**1.A** Create diagrams, tables, charts, or schematics to represent physical situations. **2.C** Compare physical quantities between two or more scenarios or at different times and locations in a single scenario. **3.B** Apply an appropriate law, definition, theoretical relationship, or model to make a claim. **3.C** Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.
1.2 Displacement, Velocity, and Acceleration	**1.C** Create qualitative sketches of graphs that represent features of a model or the behavior of a physical system. **2.B** Calculate or estimate an unknown quantity with units from known quantities, by selecting and following a logical computational pathway. **2.C** Compare physical quantities between two or more scenarios or at different times and locations in a single scenario. **3.C** Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.
1.3 Representing Motion	**1.C** Create qualitative sketches of graphs that represent features of a model or the behavior of a physical system. **2.A** Derive a symbolic expression from known quantities by selecting and following a logical mathematical pathway. **2.C** Compare physical quantities between two or more scenarios or at different times and locations in a single scenario. **3.B** Apply an appropriate law, definition, theoretical relationship, or model to make a claim.
1.4 Reference Frames and Relative Motion	**1.C** Create qualitative sketches of graphs that represent features of a model or the behavior of a physical system. **2.A** Derive a symbolic expression from known quantities by selecting and following a logical mathematical pathway. **2.B** Calculate or estimate an unknown quantity with units from known quantities, by selecting and following a logical computational pathway. **3.C** Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.

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UNIT AT A GLANCE *(cont'd)*

Topic	Suggested Skills
1.5 Vectors and Motion in Two Dimensions	**1.B** Create quantitative graphs with appropriate scales and units, including plotting data. **2.A** Derive a symbolic expression from known quantities by selecting and following a logical mathematical pathway. **2.D** Predict new values or factors of change of physical quantities using functional dependence between variables. **3.A** Create experimental procedures that are appropriate for a given scientific question. **3.C** Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.

Go to **AP Classroom** to assign the **Progress Check** for Unit 1.
Review the results in class to identify and address any student misunderstandings.

SAMPLE INSTRUCTIONAL ACTIVITIES

The sample activities on this page are optional and are offered to provide possible ways to incorporate various instructional approaches in the classroom. Teachers do not need to use these activities or instructional approaches and are free to alter or edit them. The examples below were developed in partnership with teachers from the AP community to share ways that they approach teaching some of the topics in this unit. Please refer to the Instructional Approaches section beginning on p. 153 for more examples of activities and strategies.

Activity	Topic	Sample Activity
1	1.2	**Desktop Experiment Task** Give each group a pull-back toy car. Ask students to lay out strips of paper 0.5 m apart and take a video of the car as it is released, speeds up, and slows down. Using a frame-by-frame review app to get the time each strip is passed to get x versus t data, have students make v versus t data tables out of this, and graph both position as a function of time and velocity as a function of time.
2	1.3	**Desktop Experiment Task** Have students find the acceleration of a yo-yo as it falls and unwinds using only a meterstick and stopwatch. Then, have students draw (with correct shapes and scales) distance, speed, and acceleration versus time graphs.
3	1.3	**Changing Representations** Show a curvy x versus t graph, a v versus t graph made of connected straight-line segments, or an a versus t graph made of horizontal steps. Have students sketch the other two graphs and either walk them out along a line or move a cart on a track to demonstrate the motion (Note: The track can be tilted slightly to provide constant acceleration in either direction).
4	1.5	**Changing Representations** Have students throw/launch a ball from the second or third story of a building to the ground and measure the ball's initial height, horizontal distance, and time in the air. From this, ask students to calculate initial velocity components and draw (with scales) horizontal/vertical position/velocity/acceleration versus time graphs.
5	1.5	**Create a Plan** Give each group a spring-loaded ball launcher and a meterstick. Have students launch the ball horizontally from a known height and then predict where it will land on the floor when fired at a given angle from the floor. Then, ask students to write their own set of lab instructions for the procedure they just performed, articulating each subtask and calculations needed to obtain their prediction.

TOPIC 1.1

Scalars and Vectors in One Dimension

Required Course Content

LEARNING OBJECTIVE

1.1.A

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

ESSENTIAL KNOWLEDGE

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.

1.1.A.3.i

Vectors are notated with an arrow above the symbol for that quantity.

Relevant equation:

$$\vec{v} = \vec{v}_0 + \vec{a}t$$

1.1.A.3.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:

$$v_x = v_{x0} + a_x t$$

LEARNING OBJECTIVE

1.1.B

Describe a vector sum in one dimension.

ESSENTIAL KNOWLEDGE

1.1.B.1

When determining a vector sum in a given one-dimensional coordinate system, opposite directions are denoted by opposite signs.

SUGGESTED SKILLS

1.A Create diagrams, tables, charts, or schematics to represent physical situations.

2.C Compare physical quantities between two or more scenarios or at different times and locations in a single scenario.

3.B Apply an appropriate law, definition, theoretical relationship, or model to make a claim.

3.C Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.

SUGGESTED SKILLS

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

2.B
Calculate or estimate an unknown quantity with units from known quantities, by selecting and following a logical computational pathway.

2.C
Compare physical quantities between two or more scenarios or at different times and locations in a single scenario.

3.C
Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.

TOPIC 1.2
Displacement, Velocity, and Acceleration

Required Course Content

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
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:* $\Delta x = x - x_0$
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:* $\vec{v}_{avg} = \frac{\Delta \vec{x}}{\Delta t}$ **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:* $\vec{a}_{avg} = \frac{\Delta \vec{v}}{\Delta t}$

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LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
1.2.B Describe the velocity and acceleration of an object.	**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.

SUGGESTED SKILLS

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

2.A
Derive a symbolic expression from known quantities by selecting and following a logical mathematical pathway.

2.C
Compare physical quantities between two or more scenarios or at different times and locations in a single scenario.

3.B
Apply an appropriate law, definition, theoretical relationship, or model to make a claim.

TOPIC 1.3
Representing Motion

Required Course Content

LEARNING OBJECTIVE

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

ESSENTIAL KNOWLEDGE

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:

$$v_x = v_{x0} + a_x t$$

$$x = x_0 + v_{x0}t + \frac{1}{2}a_x t^2$$

$$v_x^2 = v_{x0}^2 + 2a_x(x - x_0)$$

Note: The equations above are written to indicate motion in the x-direction, but these equations can be used in any single dimension as appropriate.

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

$$a_g = g \approx 10\ m/s^2.$$

1.3.A.4
Graphs of position, velocity, and acceleration as functions of time can be used to find the relationships between those quantities.

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LEARNING OBJECTIVE

1.3.A

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

ESSENTIAL KNOWLEDGE

1.3.A.4.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.

1.3.A.4.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.

1.3.A.4.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).

1.3.A.4.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 $g \approx 10\ m/s^2$ will be used. However, students will not be penalized for correctly using the more precise commonly accepted values of $g = 9.81\ \text{m/s}^2$ or $g = 9.8\ \text{m/s}^2$.

SUGGESTED SKILLS

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

2.A
Derive a symbolic expression from known quantities by selecting and following a logical mathematical pathway.

2.B
Calculate or estimate an unknown quantity with units from known quantities, by selecting and following a logical computational pathway.

3.C
Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.

TOPIC 1.4

Reference Frames and Relative Motion

Required Course Content

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
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. **1.4.B.2.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. **1.4.B.2.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.

TOPIC 1.5

Vectors and Motion in Two Dimensions

Required Course Content

LEARNING OBJECTIVE

1.5.A

Describe the perpendicular components of a vector.

ESSENTIAL KNOWLEDGE

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.

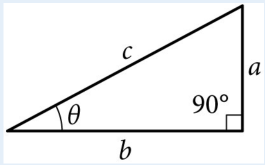
Relevant equations:

$$\sin\theta = \frac{a}{c}$$

$$\cos\theta = \frac{b}{c}$$

$$\tan\theta = \frac{a}{b}$$

$$a^2 + b^2 = c^2$$



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SUGGESTED SKILLS

1.B Create quantitative graphs with appropriate scales and units, including plotting data.

2.A Derive a symbolic expression from known quantities by selecting and following a logical mathematical pathway.

2.D Predict new values or factors of change of physical quantities using functional dependence between variables.

3.A Create experimental procedures that are appropriate for a given scientific question.

3.C Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
1.5.B Describe the motion of an object moving in two dimensions.	**1.5.B.1** 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.