AP PHYSICS 1

UNIT 1

Kinematics

10–16%
AP EXAM WEIGHTING

~16–19
CLASS PERIODS

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

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

Personal Progress Check 1

Multiple-choice: ~15 questions
Free-response: 2 questions

- Experimental Design
- Paragraph Argument Short Answer

UNIT 1

10–16% AP EXAM WEIGHTING | **~16–19** CLASS PERIODS

Kinematics

BIG IDEA 3
Force Interactions **INT**

- How can the motion of objects be predicted and/or explained?
- Can equations be used to answer questions regardless of the questions' specificity?
- How can the idea of frames of reference allow two people to tell the truth yet have conflicting reports?

BIG IDEA 4
Change **CHA**

- 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?"

Unit Overview

The world is in a constant state of motion. To understand the world, 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 beginning to explore the complex idea of acceleration and showing them how representations can be used to model and analyze scientific information as it relates to the motion of objects. By studying kinematics, students will learn to represent motion—both uniform and accelerating—in narrative, graphical, and/or mathematical forms 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 go beyond their traditional understanding of mathematics. Instead of solving equations, students will use them to support their reasoning and tighten their grasp on the laws of physics. Lastly, students will begin making predictions about motion and justifying claims with evidence by exploring the relationships between the physical quantities of acceleration, velocity, position, and time. This is an important starting point for students, as these fundamental science practices will spiral throughout the course and appear in multiple units.

Preparing for the AP Exam

On the AP Physics 1 Exam, there is an experimental design question in the free-response section that is worth 12 points. Students must be able to justify their selection of the kind of data needed to answer the question and then design a plan to collect that data.

When presented with an experimental design question, students often do not know where to start. Students should be given scaffolded opportunities to determine the appropriate data needed to answer a scientific question. To create laboratory experiments for students who struggle with identifying the data needed to answer a particular question, please refer to the learning objectives linked to this unit.

UNIT AT A GLANCE

Enduring Understanding	Topic	Science Practices	Class Periods ~16–19 CLASS PERIODS
3.A	1.1 Position, Velocity, and Acceleration	1.5 The student can re-express key elements of natural phenomena across multiple representations in the domain. 2.1 The student can justify the selection of a mathematical routine to solve problems. 2.2 The student can apply mathematical routines to quantities that describe natural phenomena. 4.2 The student can design a plan for collecting data to answer a particular scientific question. 5.1 The student can analyze data to identify patterns or relationships.	
4.A	1.2 Representations of Motion	1.2 The student can describe representations and models of natural or man-made phenomena and systems in the domain.* 1.4 The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively. 2.2 The student can apply mathematical routines to quantities that describe natural phenomena. 2.3 The student can estimate quantities that describe natural phenomena.* 6.4 The student can make claims and predictions about natural phenomena based on scientific theories and models.	

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

*Indicates a science practice not assessed with its paired topic on this unit's Personal Progress Check.

AVAILABLE RESOURCES FOR UNIT 1

- Classroom Resources > ***AP Physics 1 and 2 Inquiry-Based Lab Investigations: A Teacher's Manual***
- Classroom Resources > **Multiple Representations of Knowledge: Mechanics and Energy**
- Classroom Resources > **Graphical Analysis**
- Classroom Resources > **AP Physics Featured Question: Projectile Concepts**
- Classroom Resources > **Critical Thinking Questions in Physics**
- Classroom Resources > **Physics Instruction Using Video Analysis Technology**
- Classroom Resources > **Teaching Strategies for Limited Class Time**

SAMPLE INSTRUCTIONAL ACTIVITIES

The sample activities on this page are optional and are offered to provide possible ways to incorporate various instructional approaches 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. 173 for more examples of activities and strategies.

Activity	Topic	Sample Activity
1	1.1	**Desktop Experiment Task** Have students find the acceleration of a yo-yo as it falls and unwinds using only a meterstick and stopwatch. Students then draw (with correct shapes and scales) distance, speed, and acceleration versus time graphs.
2	1.1	**Identify Subtasks** Each group is given a spring-loaded ball launcher and a meterstick. 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. Have students articulate subtasks and then perform each one.
3	1.2	**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 (the track can be tilted slightly to provide constant acceleration in either direction).
4	1.2	**Changing Representations** Students throw/project a ball from the second or third story to the ground and measure the ball's initial height, horizontal distance, and time in the air. From this, students calculate initial velocity components and draw (with scales) horizontal/vertical position/velocity/acceleration versus time graphs.
5	1.2	**Desktop Experiment Task** Give each group a pull-back toy car. Students lay out strips of paper 0.5 m apart and take a phone 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.

Unit Planning Notes

Use the space below to plan your approach to the unit.

SCIENCE PRACTICES

Modeling

1.5

The student can re-express key elements of natural phenomena across multiple representations in the domain.

Mathematical Routines

2.1

The student can justify the selection of a mathematical routine to solve problems.

2.2

The student can apply mathematical routines to quantities that describe natural phenomena.

Experimental Method

4.2

The student can design a plan for collecting data to answer a particular scientific question.

Data Analysis

5.1

The student can analyze data to identify patterns or relationships.

TOPIC 1.1
Position, Velocity, and Acceleration

Required Course Content

ENDURING UNDERSTANDING

3.A

All forces share certain common characteristics when considered by observers in inertial reference frames.

LEARNING OBJECTIVE

3.A.1.1

Express the motion of an object using narrative, mathematical, and graphical representations. **[SP 1.5, 2.1, 2.2]**

3.A.1.2

Design an experimental investigation of the motion of an object. **[SP 4.2]**

3.A.1.3

Analyze experimental data describing the motion of an object and be able to express the results of the analysis using narrative, mathematical, and graphical representations. **[SP 5.1]**

ESSENTIAL KNOWLEDGE

3.A.1

An observer in a reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration.

a. Displacement, velocity, and acceleration are all vector quantities.

b. Displacement is change in position. Velocity is the rate of change of position with time. Acceleration is the rate of change of velocity with time. Changes in each property are expressed by subtracting initial values from final values.

Relevant Equations:

$$\vec{v}_{avg} = \frac{\Delta \vec{x}}{\Delta t}$$

$$\vec{a}_{avg} = \frac{\Delta \vec{v}}{\Delta t}$$

c. A choice of reference frame determines the direction and the magnitude of each of these quantities.

d. There are three fundamental interactions or forces in nature: the gravitational force, the electroweak force, and the strong force. The fundamental forces determine both the structure of objects and the motion of objects.

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LEARNING OBJECTIVE

3.A.1.1

Express the motion of an object using narrative, mathematical, and graphical representations. **[SP 1.5, 2.1, 2.2]**

3.A.1.2

Design an experimental investigation of the motion of an object. **[SP 4.2]**

3.A.1.3

Analyze experimental data describing the motion of an object and be able to express the results of the analysis using narrative, mathematical, and graphical representations. **[SP 5.1]**

ESSENTIAL KNOWLEDGE

e. In inertial reference frames, forces are detected by their influence on the motion (specifically the velocity) of an object. So force, like velocity, is a vector quantity. A force vector has magnitude and direction. When multiple forces are exerted on an object, the vector sum of these forces, referred to as the net force, causes a change in the motion of the object. The acceleration of the object is proportional to the net force.

f. The kinematic equations only apply to constant acceleration situations. Circular motion and projectile motion are both included. Circular motion is further covered in Unit 3. The three kinematic equations describing linear motion with constant acceleration in one and two dimensions are

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

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

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

g. For rotational motion, there are analogous quantities such as angular position, angular velocity, and angular acceleration. The kinematic equations describing angular motion with constant angular acceleration are

$$\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$$

$$\omega = \omega_0 + \alpha t$$

$$\omega^2 = \omega_0^2 + 2\alpha_x (\theta - \theta_0)$$

h. This also includes situations where there is both a radial and tangential acceleration for an object moving in a circular path.

Relevant Equation:

$$a_c = \frac{v^2}{r}$$

For uniform circular motion of radius *r*, *v* is proportional to omega, *ω* (for a given *r*), and proportional to *r* (for a given omega, *ω*). Given a radius *r* and a period of rotation *T*, students derive and apply *v* = (2*πr*)/*T*.

BOUNDARY STATEMENT:

AP Physics 2 has learning objectives under Enduring Understanding 3.A that focus on electric and magnetic forces and other forces arising in the context of interactions introduced in Physics 2, rather than the mechanical systems introduced in Physics 1.

SCIENCE PRACTICES

Modeling

1.2

The student can describe representations and models of natural or man-made phenomena and systems in the domain.

1.4

The student can use representations and models to analyze situations or solve problems qualitatively and quantitatively.

Mathematical Routines

2.2

The student can apply mathematical routines to quantities that describe natural phenomena.

2.3

The student can estimate quantities that describe natural phenomena.

Argumentation

6.4

The student can make claims and predictions about natural phenomena based on scientific theories and models.

TOPIC 1.2

Representations of Motion

Required Course Content

ENDURING UNDERSTANDING

4.A

The acceleration of the center of mass of a system is related to the net force exerted on the system, where $\vec{a} = \frac{\sum \vec{F}}{m}$.

LEARNING OBJECTIVE

4.A.1.1

Use representations of the center of mass of an isolated two-object system to analyze the motion of the system qualitatively and semi-quantitatively. **[SP 1.2, 1.4, 2.3, 6.4]**

ESSENTIAL KNOWLEDGE

4.A.1

The linear motion of a system can be described by the displacement, velocity, and acceleration of its center of mass.

a. The variables *x*, *v*, and *a* all refer to the center-of-mass quantities.

Relevant Equations:

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

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

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

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LEARNING OBJECTIVE

4.A.2.1

Make predictions about the motion of a system based on the fact that acceleration is equal to the change in velocity per unit time, and velocity is equal to the change in position per unit time. **[SP 6.4]**

4.A.2.3

Create mathematical models and analyze graphical relationships for acceleration, velocity, and position of the center of mass of a system and use them to calculate properties of the motion of the center of mass of a system. **[SP 1.4, 2.2]**

ESSENTIAL KNOWLEDGE

4.A.2

The acceleration is equal to the rate of change of velocity with time, and velocity is equal to the rate of change of position with time.

a. The acceleration of the center of mass of a system is directly proportional to the net force exerted on it by all objects interacting with the system and inversely proportional to the mass of the system.
b. Force and acceleration are both vectors, with acceleration in the same direction as the net force.
c. The acceleration of the center of mass of a system is equal to the rate of change of the center of mass velocity with time, and the center of mass velocity is equal to the rate of change of position of the center of mass with time.
d. The variables *x*, *v*, and *a* all refer to the center-of-mass quantities.

Relevant Equations:

$$\vec{a} = \frac{\sum \vec{F}}{m_{system}}$$

$$\vec{v}_{avg} = \frac{\Delta \vec{x}}{\Delta t}$$

$$\vec{a}_{avg} = \frac{\Delta \vec{v}}{\Delta t}$$

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