AP PHYSICS 1

UNIT 7

Oscillations

5–8%
AP EXAM WEIGHTING

~5–10
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 7

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

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

UNIT 7

5–8% AP EXAM WEIGHTING | **~5–10** CLASS PERIODS

Oscillations

ESSENTIAL QUESTIONS

- How can oscillations be used to make our lives easier and more comfortable?
- How can an astronaut be "weighed" in space?
- How could you measure the length of a long string with a stopwatch?
- What do a child on a swing, a beating heart, and a metronome have in common?

Developing Understanding

In Unit 7, students will apply previously-encountered models and methods of analysis to simple harmonic motion. They will also be reminded that, even in new situations, the fundamental laws of physics remain the same. Because this unit is the first in which students possess all the tools of force, energy, and momentum conservation—such as energy bar charts, free-body diagrams, and momentum diagrams—scaffolding lessons will enhance student understanding of fundamental physics principles and their limitations, as they relate to oscillating systems. Students will also use the skills and knowledge they have gained to make and justify claims, as well as connect new concepts with those learned in previous topics.

Building the Science Practices

1.A 1.C 2.A 3.C

Throughout this unit, there are many opportunities for students to create graphs (**1.C**) that may include force, energy, or momentum as either a function of position or time for a single scenario and to make connections between physics concepts based on these graphs. In Unit 7, as in other units in AP Physics 1, practice creating and using models to represent physical scenarios (**1.A**) and then translating the information presented in these models into other representations—such as symbolic expressions (**2.A**)—can help students justify or support claims about oscillating systems (**3.C**).

Preparing for the AP Exam

The second free-response question on the AP Physics 1 Exam—the Translation Between Representations question (TBR)—requires students to create graphical and verbal models of scenarios, as well as compare these models to mathematical representations of the same situation. Similar in nature to the Qualitative/Quantitative Translation question (QQT), the TBR involves creating multiple representations and describing the relationships between those representations; however, the types of representations being compared in the TBR differ from those in the QQT. In the TBR, a student might be asked to sketch free-body diagrams of a block oscillating on a spring at the maximum displacement and at equilibrium. The student might then be asked to create energy bar charts for the block–spring system at maximum displacement and at equilibrium. Lastly, the student might be asked to make connections between the two representations, explaining how the representations are consistent with each other. While Unit 7 content provides especially good practice for the TBR, content from any unit may be included in this free-response question on the AP Exam.

UNIT AT A GLANCE

Topic	Suggested Skills
7.1 Defining Simple Harmonic Motion (SHM)	**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. **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.
7.2 Frequency and Period of SHM	**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.
7.3 Representing and Analyzing SHM	**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.D** Predict new values or factors of change of physical quantities using functional dependence between variables. **3.C** Justify or support a claim using evidence from experimental data, physical representations, or physical principles or laws.
7.4 Energy of Simple Harmonic Oscillators	**1.A** Create diagrams, tables, charts, or schematics to represent physical situations. **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.B** Apply an appropriate law, definition, theoretical relationship, or model to make a claim.

Go to **AP Classroom** to assign the **Progress Check** for Unit 7.
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	7.2	**Desktop Experiment Task** Have students determine the spring constant of a spring using (1) known masses and a meterstick only and then (2) known masses and a stopwatch only.
2	7.2	**Desktop Experiment Task** Have students use a pendulum to determine the acceleration due to gravity. Ask them to refine the experiment from a single-trial calculation, to taking an average, to making a graph of linearized data.
3	7.2	**Predict and Explain** Have students make a pendulum bob oscillate with the other end of the string “clamped” between your fingers. While the bob oscillates, pull the string through your fingers so that the string length is shortened. Before doing this, ask students what will happen to the period of the oscillation and amplitude (measured in degrees), and then explain why the period decreases and the amplitude angle increases.
4	7.2	**Create a Plan** Have students choose a song and find its tempo (in beats per minute). Then, have them build a pendulum so that it swings back and forth on each beat. Next, give students a spring. Have them first find the spring’s constant and then find the amount of mass necessary to make the spring-mass oscillate on each beat.
5	7.4	**Construct an Argument** A cart wiggles on a horizontal spring. A blob of clay is dropped on the cart and sticks (could be when the cart is at the center or at one end). Ask students to explain what happened to the period, total energy, amplitude of motion, and maximum speed.

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.B

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

TOPIC 7.1
Defining Simple Harmonic Motion (SHM)

Required Course Content

LEARNING OBJECTIVE

7.1.A

Describe simple harmonic motion.

ESSENTIAL KNOWLEDGE

7.1.A.1

Simple harmonic motion is a special case of periodic motion.

7.1.A.2

SHM results when the magnitude of the restoring force exerted on an object is proportional to that object's displacement from its equilibrium position.

Derived equation:

$$ma_x = -k\Delta x$$

7.1.A.2.i

A restoring force is a force that is exerted in a direction opposite to the object's displacement from an equilibrium position.

7.1.A.2.ii

An equilibrium position is a location at which the net force exerted on an object or system is zero.

7.1.A.2.iii

The motion of a pendulum with a small angular displacement can be modeled as simple harmonic motion because the restoring torque is proportional to the angular displacement.

TOPIC 7.2

Frequency and Period of SHM

Required Course Content

LEARNING OBJECTIVE

7.2.A

Describe the frequency and period of an object exhibiting SHM.

ESSENTIAL KNOWLEDGE

7.2.A.1

The period of SHM is related to the frequency f of the object's motion by the following equation:

$$T = \frac{1}{f}$$

7.2.A.1.i

The period of an object–ideal-spring oscillator is given by the equation

$$T_s = 2\pi\sqrt{\frac{m}{k}}.$$

7.2.A.1.ii

The period of a simple pendulum displaced by a small angle is given by the equation

$$T_p = 2\pi\sqrt{\frac{\ell}{g}}.$$

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.

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

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

TOPIC 7.3
Representing and Analyzing SHM

Required Course Content

LEARNING OBJECTIVE

7.3.A
Describe the displacement, velocity, and acceleration of an object exhibiting SHM.

ESSENTIAL KNOWLEDGE

7.3.A.1
For an object exhibiting SHM, the displacement of that object measured from its equilibrium position can be represented by the equations $x = A\cos(2\pi ft)$ or $x = A\sin(2\pi ft)$.

7.3.A.1.i
Minima, maxima, and zeros of displacement, velocity, and acceleration are features of harmonic motion.

7.3.A.1.ii
Recognizing the positions or times at which the displacement, velocity, and acceleration for SHM have extrema or zeros can help in qualitatively describing the behavior of the motion.

7.3.A.2
Changing the amplitude of a system exhibiting SHM will not change the period of that system.

7.3.A.3
Properties of SHM can be determined and analyzed using graphical representations.

TOPIC 7.4

Energy of Simple Harmonic Oscillators

Required Course Content

LEARNING OBJECTIVE

7.4.A

Describe the mechanical energy of a system exhibiting SHM.

ESSENTIAL KNOWLEDGE

7.4.A.1

The total energy of a system exhibiting SHM is the sum of the system's kinetic and potential energies.

Relevant equation:

$$E_{total} = U + K$$

7.4.A.2

Conservation of energy indicates that the total energy of a system exhibiting SHM is constant.

7.4.A.3

The kinetic energy of a system exhibiting SHM is at a maximum when the system's potential energy is at a minimum.

7.4.A.4

The potential energy of a system exhibiting SHM is at a maximum when the system's kinetic energy is at a minimum.

7.4.A.4.i

The minimum kinetic energy of a system exhibiting SHM is zero.

7.4.A.4.ii

Changing the amplitude of a system exhibiting SHM will change the maximum potential energy of the system and, therefore, the total energy of the system.

Relevant equation for a spring–object system:

$$E_{total} = \frac{1}{2}kA^2$$

SUGGESTED SKILLS

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

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