AP

AP® Physics 1 and AP® Physics 2 Exams

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AP Physics 1: Algebra-Based and
AP Physics 2: Algebra-Based Curriculum Framework

CollegeBoard

The College Board

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The College Board strongly encourages educators to make equitable access a guiding principle for their AP programs by giving all willing and academically prepared students the opportunity to participate in AP. We encourage the elimination of barriers that restrict access to AP for students from ethnic, racial, and socioeconomic groups that have been traditionally underserved. Schools should make every effort to ensure their AP classes reflect the diversity of their student population. The College Board also believes that all students should have access to academically challenging course work before they enroll in AP classes, which can prepare them for AP success. It is only through a commitment to equitable preparation and access that true equity and excellence can be achieved.

Contents

Introduction

These sample exam questions were originally included in the *AP Physics 1: Algebra-Based and AP Physics 2: Algebra-Based Curriculum Framework,* published in fall 2012. The *AP Physics 1 and 2 Course and Exam Description,* which is out now, includes that curriculum framework, along with a new, unique set of exam questions. Because we want teachers to have access to all available questions that support the new exam, we are making those from the fall 2012 curriculum framework available in this supplementary document.

The sample exam questions illustrate the relationship between the curriculum framework and the redesigned AP Physics 1 and 2 Exam, and they serve as examples of the types of questions that appear on the exam.

Each question is followed by the targeted learning objective(s) from the curriculum framework. These sample questions help illustrate how the learning objectives for both courses are assessed. For multiple-choice questions, the correct answer is provided.

AP Physics 1: Algebra-Based Sample Exam Questions

Sample Multiple-Choice Questions
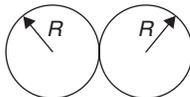
1. Two solid spheres of radius R made of the same type of steel are placed in contact, as shown in the figures above. The magnitude of the gravitational force that they exert on each other is F_1. When two other solid spheres of radius $3R$ made of this steel are placed in contact, what is the magnitude of the gravitational force that they exert on each other?

    (A) F_1

    (B) $3F_1$

    (C) $9F_1$

    (D) $81F_1$

    Answer: D

    > **Targeted Learning Objective:**
    >
    > **Learning Objective (3.C.1.1):** The student is able to use Newton's law of gravitation to calculate the gravitational force the two objects exert on each other and use that force in contexts other than orbital motion. [See Science Practice 2.2]
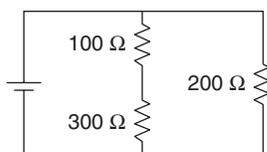
2. The figure above shows three resistors connected in a circuit with a battery. Which of the following correctly ranks the energy E dissipated in the three resistors during a given time interval?

(A) $E_{300\Omega} > E_{200\Omega} > E_{100\Omega}$

(B) $E_{300\Omega} > E_{100\Omega} > E_{200\Omega}$

(C) $E_{200\Omega} > E_{300\Omega} > E_{100\Omega}$

(D) $E_{200\Omega} > E_{100\Omega} > E_{300\Omega}$

Answer: C

> **Targeted Learning Objectives:**
>
> **Learning Objective (5.B.9.3):** The student is able to apply conservation of energy (Kirchhoff's loop rule) in calculations involving the total electric potential difference for complete circuit loops with only a single battery and resistors in series and/or in, at most, one parallel branch. [See Science Practices 2.2, 6.4, and 7.2]
>
> **Learning Objective (5.C.3.1):** The student is able to apply conservation of electric charge (Kirchhoff's junction rule) to the comparison of electric current in various segments of an electrical circuit with a single battery and resistors in series and in, at most, one parallel branch and predict how those values would change if configurations of the circuit are changed. [See Science Practices 6.4 and 7.2]

3. A person driving a car suddenly applies the brakes. The car takes 4 s to come to rest while traveling 20 m at constant acceleration. Can the speed of the car immediately before the brakes were applied be determined without first determining the car's acceleration?

(A) Yes, by dividing the distance (20 m) by the time (4 s).

(B) Yes, by determining the average speed while braking and doubling it.

(C) No, because the acceleration is needed to use standard equations such as $\Delta x = v_o t + \frac{1}{2} at^2$.

(D) No, because the fundamental relationship that defines velocity contains acceleration.

Answer: B

> **Targeted Learning Objectives:**
>
> **Learning Objective (3.A.1.1):** The student is able to express the motion of an object using narrative, mathematical, and graphical representations. [See Science Practices 1.5, 2.1, and 2.2]
>
> **Learning Objective (4.A.2.1):** The student is able to 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. [See Science Practice 6.4]

4. While traveling in its elliptical orbit around the Sun, Mars gains speed during the part of the orbit where it is getting closer to the Sun. Which of the following can be used to explain this gain in speed?

   (A) As Mars gets closer to the Sun, the Mars–Sun system loses potential energy and Mars gains kinetic energy.

   (B) A component of the gravitational force exerted on Mars is perpendicular to the direction of motion, causing an acceleration and hence a gain in speed along that direction.

   (C) The torque exerted on Mars by the Sun during this segment of the orbit increases the Mars–Sun system's angular momentum.

   (D) The centripetal force exerted on Mars is greater than the gravitational force during this segment of the orbit, causing Mars to gain speed as it gets closer to the Sun.

   Answer: A

   **Targeted Learning Objectives:**

   Learning Objective (3.B.1.1): The student is able to predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations with acceleration in one dimension. [See Science Practices 6.4 and 7.2]

   Learning Objective (3.E.1.1): The student is able to make predictions about the changes in kinetic energy of an object based on considerations of the direction of the net force on the object as the object moves. [See Science Practices 6.4 and 7.2]

   Learning Objective (4.C.2.1): The student is able to make predictions about the changes in the mechanical energy of a system when a component of an external force acts parallel or antiparallel to the direction of the displacement of the center of mass. [See Science Practice 6.4]

   Learning Objective (5.B.4.1): The student is able to describe and make predictions about the internal energy of systems. [See Science Practices 6.4 and 7.2]

   Learning Objective (5.E.2.1): The student is able to describe or calculate the angular momentum and rotational inertia of a system in terms of the locations and velocities of objects that make up the system. Students are expected to do qualitative reasoning with compound objects. Students are expected to do calculations with a fixed set of extended objects and point masses. [See Science Practice 2.2]
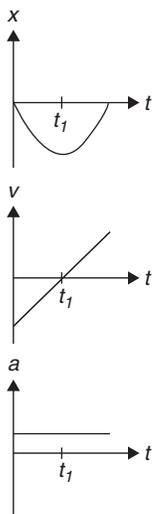
5. The graphs above represent the position *x*, velocity *v*, and acceleration *a* as a function of time *t* for a marble moving in one dimension. Which of the following could describe the motion of the marble?

    (A) Rolling along the floor and then bouncing off a wall

    (B) Rolling down one side of a bowl and then rolling up the other side

    (C) Rolling up a ramp and then rolling back down

    (D) Falling and then bouncing elastically off a hard floor

    Answer: C

    > **Targeted Learning Objective:**
    >
    > **Learning Objective (3.A.1.1):** The student is able to express the motion of an object using narrative, mathematical, and graphical representations. [See Science Practices 1.5, 2.1, and 2.2]

Multi-Correct: Students need to select all the correct answers to the question below in order to earn credit.

6. A race car going around a flat, unbanked circular track gradually increases speed as it completes one full trip around the track. Which of the following can explain why the car gains speed?

(A) Energy stored in the fuel is converted to mechanical energy.

(B) A component of the frictional force exerted by the ground on the tires is directed toward the center of the circle.

(C) A component of the frictional force exerted by the ground on the tires is in the direction of motion.

(D) The car's velocity and acceleration are perpendicular.

Answer: A and C

> **Targeted Learning Objectives:**
>
> **Learning Objective (3.E.1.1):** The student is able to make predictions about the changes in kinetic energy of an object based on considerations of the direction of the net force on the object as the object moves. [See Science Practices 6.4 and 7.2]
>
> **Learning Objective (3.E.1.2):** The student is able to use net force and velocity vectors to determine qualitatively whether kinetic energy of an object would increase, decrease, or remain unchanged. [See Science Practice 1.4]
>
> **Learning Objective (4.C.2.1):** The student is able to make predictions about the changes in the mechanical energy of a system when a component of an external force acts parallel or antiparallel to the direction of the displacement of the center of mass. [See Science Practice 6.4]

Sample Free-Response Questions

Experimental Design
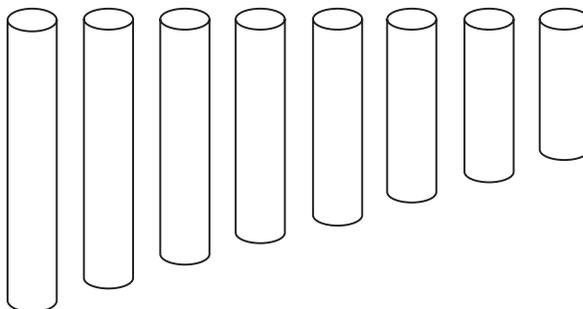
1. You are given a set of chimes that consists of eight hollow metal tubes open at both ends, as shown above. The chimes are played by striking them with a small hammer to produce musical sounds. Your task is to use the chimes to determine the speed of sound in air at room temperature. You have available a set of tuning forks and other common laboratory equipment but are not allowed to use electronic equipment, such as a sound sensor. (A tuning fork vibrates when struck and produces sound at a particular frequency, which is printed on the tuning fork.)

   (a) Describe your experimental procedure in enough detail so that another student could perform your experiment. Include what measurements you will take and how you will take them.

   (b) Describe how you will use your measurements to determine the speed of sound, in enough detail that another student could duplicate your process.

   (c) Describe one assumption you made about the design of your experiment, and explain how it might affect the value obtained for the speed of sound.

   (d) A student doing a different experiment to determine the speed of sound in air obtained wavelength and period measurements and created the following plot of the data. Use the graph to calculate the speed of sound and include an explanation of your method.
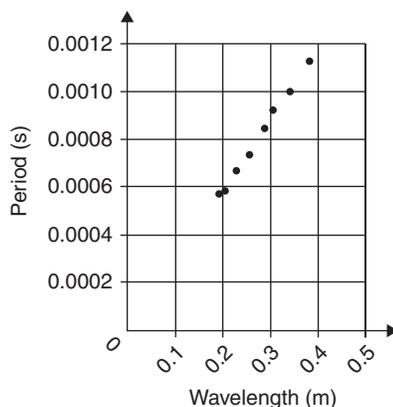
Targeted Learning Objectives:

Learning Objective (6.B.4.1): The student is able to design an experiment to determine the relationship between periodic wave speed, wavelength, and frequency and relate these concepts to everyday examples. [See Science Practices 4.2, 5.1, and 7.2]

Learning Objective (6.D.3.3): The student is able to plan data collection strategies, predict the outcome based on the relationship under test, perform data analysis, evaluate evidence compared to the prediction, explain any discrepancy and, if necessary, revise the relationship among variables responsible for establishing standing waves on a string or in a column of air. [See Science Practices 3.2, 4.1, 5.1, 5.2, and 5.3]

Short Answer
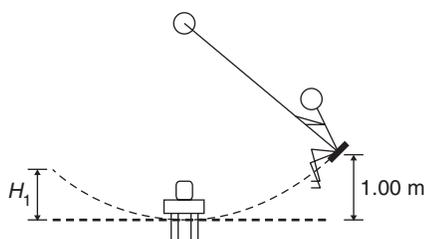
Note: Figure not drawn to scale.

2. A student of mass 50.0 kg swings on a playground swing, which is very light compared to the student. A friend releases the seat of the swing from rest at a height of 1.00 m above the lowest point of the motion. The student swings down and, at the lowest point of the motion, grabs a jug of water of mass 4.00 kg. The jug is initially at rest on a small table right next to the swing, so it does not move vertically as the student grabs it. The student keeps swinging forward while holding the jug, and the seat reaches a maximum height H_1 above the lowest point. Air resistance and friction are negligible.

   (a) Indicate whether H_1 is greater than, less than, or equal to 1.00 m.

   _____ Greater than 1.00 m

   _____ Less than 1.00 m

   _____ Equal to 1.00 m

   Justify your answer qualitatively, with no equations or calculations.

   (b) Explain how H_1 can be calculated. You need not actually do the calculations, but provide complete instructions so that another student could use them to calculate H_1.

   (c) The student now swings backward toward the starting point. At the lowest point of the motion, the student drops the water jug. Indicate whether the new maximum height that the seat reaches is greater than, less than, or equal to H_1.

   _____ Greater than H_1

   _____ Less than H_1

   _____ Equal to H_1

   Justify your answer.

Targeted Learning Objectives:

Learning Objective (5.B.4.2): The student is able to calculate changes in kinetic energy and potential energy of a system, using information from representations of that system. [See Science Practices 1.4, 2.1, and 2.2]

Learning Objective (5.D.1.3): The student is able to apply mathematical routines appropriately to problems involving elastic collisions in one dimension and justify the selection of those mathematical routines based on conservation of momentum and restoration of kinetic energy. [See Science Practices 2.1 and 2.2]

Learning Objective (5.D.2.1): The student is able to qualitatively predict, in terms of linear momentum and kinetic energy, how the outcome of a collision between two objects changes depending on whether the collision is elastic or inelastic. [See Science Practices 6.4 and 7.2]

Learning Objective (5.D.2.3): The student is able to apply the conservation of linear momentum to a closed system of objects involved in an inelastic collision to predict the change in kinetic energy. [See Science Practices 6.4 and 7.2]

Learning Objective (5.D.2.5): The student is able to classify a given collision situation as elastic or inelastic, justify the selection of conservation of linear momentum as the appropriate solution method for an inelastic collision, recognize that there is a common final velocity for the colliding objects in the totally inelastic case, solve for missing variables, and calculate their values. [See Science Practices 2.1 and 2.2]

AP Physics 2: Algebra-Based Sample Exam Questions

Sample Multiple-Choice Questions
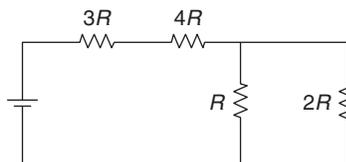
1. The figure above shows four resistors connected in a circuit with a battery. Which of the following correctly ranks the potential difference, ΔV, across the four resistors?

   (A) $\Delta V_{4R} > \Delta V_{3R} > \Delta V_{2R} > \Delta V_R$

   (B) $\Delta V_{4R} > \Delta V_{3R} > \Delta V_{2R} = \Delta V_R$

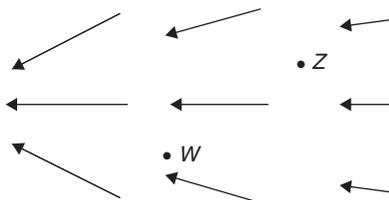   (C) $\Delta V_{4R} = \Delta V_{3R} > \Delta V_R > \Delta V_{2R}$

   (D) $\Delta V_{2R} = \Delta V_R > \Delta V_{3R} > \Delta V_{4R}$

   Answer: B

   > **Targeted Learning Objective:**
   >
   > **Learning Objective (5.B.9.5):** The student is able to use conservation of energy principles (Kirchhoff's loop rule) to describe and make predictions regarding electrical potential difference, charge, and current in steady-state circuits composed of various combinations of resistors and capacitors. [See Science Practice 6.4]

Refer to the diagram below for questions 2–3.

The figure above represents an electric field created by charged objects that are not shown. The field vectors and the locations w and z are in the plane of the page.

2. At which location is the electric potential greater?

   (A) W

   (B) Z

   (C) Neither; the potential is the same at both locations.

   (D) It cannot be determined without knowing the values of the charges on the objects creating the electric field.

   Answer: B

   Targeted Learning Objectives:

   Learning Objective (1.A.5.2): The student is able to construct representations of how the properties of a system are determined by the interactions of its constituent substructures. [See Science Practices 1.1, 1.4, and 7.1]

   Learning Objective (2.E.2.1): The student is able to determine the structure of isolines of electric potential by constructing them in a given electric field. [See Science Practices 6.4 and 7.2]

3. A small charged bead held inside the electric field has an electric force exerted upon it. At which location does the electric force have a greater magnitude?

   (A) W

   (B) Z

   (C) Neither; the magnitude of the force is the same at both locations.

   (D) It cannot be determined without knowing the sign of the charge on the bead.

   Answer: A

   Targeted Learning Objective:

   Learning Objective (2.C.1.1): The student is able to predict the direction and the magnitude of the force exerted on an object with an electric charge q placed in an electric field E using the mathematical model of the relation between an electric force and an electric field: $\vec{F} = q\vec{E}$; a vector relation. [See Science Practices 6.4 and 7.2]

4. A student writes the following information for a process that involves a fixed quantity of ideal gas.

$W = -P\Delta V$

$\Delta U = Q + W$

$P = 2.0x10^5 \, Pa$

$\Delta V = -2.0x10^{-3} \, m^3$

$\Delta U = -600J$

Which of the following descriptions best represents the process?

(A) The gas expands at a constant pressure of 200 kPa.

(B) The gas is cooled at constant volume until its pressure falls to 200 kPa.

(C) The gas is compressed at a constant pressure of 200 kPa.

(D) The gas is heated and its pressure increases at constant volume.

Answer: C

> **Targeted Learning Objective:**
>
> **Learning Objective (5.B.7.1):** The student is able to predict qualitative changes in the internal energy of a thermodynamic system involving transfer of energy due to heat or work done and justify those predictions in terms of conservation of energy principles. [See Science Practices 6.4 and 7.2]

Multi-Correct: Students need to select all the correct answers to the questions below in order to earn credit.
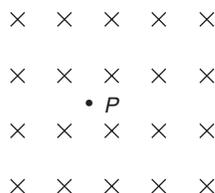

5. An electron is at point *P* in a uniform magnetic field directed into the page, as depicted above. For which of the following states of motion of the electron is the magnetic force exerted on the electron equal to zero?

(A) The electron is not moving.

(B) The electron is moving perpendicularly into the page.

(C) The electron is moving perpendicularly out of the page.

(D) The electron is moving.

Answer: A, B, C

> **Targeted Learning Objective:**
>
> **Learning Objective (2.D.1.1):** The student is able to apply mathematical routines to express the force exerted on a moving charged object by a magnetic field. [See Science Practice 2.2]

H_P

H_T
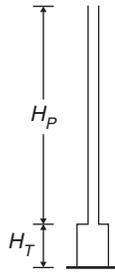
6. The figure above shows a pipe of height H_P and cross-sectional area A_P attached to the top of a tank of height H_T and cross-sectional area A_T. The pipe and tank are completely filled with water. The force exerted by the water on the bottom of the tank depends on which of the given quantities?

    (A) A_P

    (B) A_T
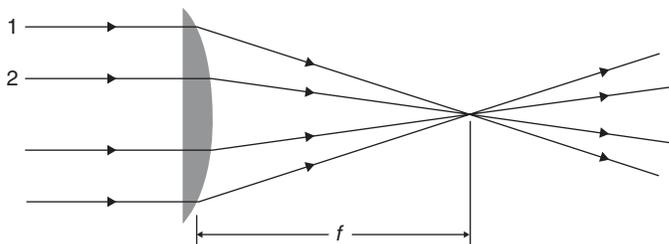
    (C) H_P

    (D) H_T

    Answer: B, C, D

    Targeted Learning Objective:

    Learning Objective (5.B.10.2): The student is able to use Bernoulli's equation and the relationship between force and/or pressure to make calculations related to a moving fluid. [See Science Practice 2.2]

Sample Free-Response Questions

Quantitative/Qualitative Translation

1. The figure above represents a glass lens that has one flat surface and one curved surface. After incoming parallel rays pass through the lens, the rays pass through a focal point. The focal length *f* is the distance from the center of the lens to the focal point.

    (a) The rays undergo refraction and change direction at the right surface of the lens, as shown. Explain why the angle of refraction of ray 1 is greater than that of ray 2.

    (b) The index of refraction of the glass is n_{glass}, and the radius of curvature of the lens's right edge is *R*. (The radius of curvature is the radius of the sphere of which that edge is a part. A smaller *R* corresponds to a lens that curves more.) A teacher who wants to test a class's understanding about lenses asks the students if the equation $f = n_{glass}R$ makes sense for the focal length of the lens in air. Is the teacher's equation reasonable for determination of the focal length? Qualitatively explain your reasoning, making sure you address the dependence of the focal length on both *R* and n_{glass}.

    (c) An object is placed a distance *f* / 2 (half of the focal length) to the left of the lens. On which side of the lens does the image form, and what is its distance from the lens in terms of *f*? Justify your answer. (Assume this is a thin lens.)

    (d) The lens is now placed in water, which has an index of refraction that is greater than air but less than the glass. Indicate below whether the new focal length is greater than, less than, or equal to the focal length *f* in air.

    _____ Greater than in air

    _____ Less than in air

    _____ The same as in air

    Justify your answer qualitatively, with no equations or calculations.


Targeted Learning Objectives:

Learning Objective (6.E.3.1): The student is able to describe models of light traveling across a boundary from one transparent material to another when the speed of propagation changes, causing a change in the path of the light ray at the boundary of the two media. [See Science Practices 1.1 and 1.4]

Learning Objective (6.E.3.3): The student is able to make claims and predictions about path changes for light traveling across a boundary from one transparent material to another at non-normal angles resulting from changes in the speed of propagation. [See Science Practices 6.4 and 7.2]

Learning Objective (6.E.5.1): The student is able to use quantitative and qualitative representations and models to analyze situations and solve problems about image formation occurring due to the refraction of light through thin lenses. [See Science Practices 1.4 and 2.2]

Short Answer

Metal Beam

Dry Silk Filament

Wet Silk Filament

1

2

Positively Charged Rod
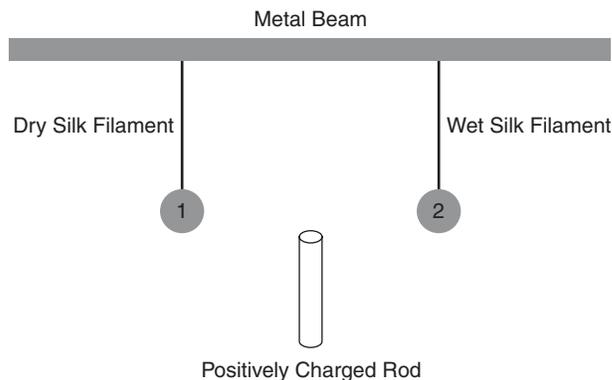
2. Two small conducting spheres attached to very thin silk filaments hang from a very large metal beam. The silk attached to sphere 1 is dry and therefore nonconducting, while the silk attached to sphere 2 is wet, making it a conductor. Initially the spheres are uncharged. A student takes a positively charged plastic rod and moves it close to both spheres, holding the rod the same distance from each sphere as shown above. Throughout the experiment, the rod never touches the spheres, and the spheres never touch each other.

   (a) Which of the spheres moves toward the rod? If they both do, which one moves closer to the rod? Explain your reasoning, using words and diagrams.

   The wet silk filament attached to sphere 2 gradually dries out. After the silk is completely dry, the rod is moved far away from both spheres.

   (b) Indicate below how the two spheres are now positioned, relative to their original vertical positions.

   _____ Closer to each other

   _____ Farther from each other

   _____ In their original vertical positions

   Explain your reasoning.

   (c) Which of the following describes how the forces exerted by the spheres on each other now compare?

   _____ Sphere 1 exerts a greater force on sphere 2 than sphere 2 exerts on sphere 1.

   _____ Sphere 2 exerts a greater force on sphere 1 than sphere 1 exerts on sphere 2.

   _____ Sphere 1 exerts the same force on sphere 2 that sphere 2 exerts on sphere 1.

   Briefly explain your reasoning.

Targeted Learning Objectives:

Learning Objective (3.A.3.4): The student is able to make claims about the force on an object due to the presence of other objects with the same property: mass, electric charge. [See Science Practices 6.1 and 6.4]

Learning Objective (3.A.4.2): The student is able to use Newton's third law to make claims and predictions about the action–reaction pairs of forces when two objects interact. [See Science Practices 6.4 and 7.2]

Learning Objective (4.E.3.2): The student is able to make predictions about the redistribution of charge caused by the electric field due to other systems, resulting in charged or polarized objects. [See Science Practices 6.4 and 7.2]

Learning Objective (4.E.3.4): The student is able to construct a representation of the distribution of fixed and mobile charge in insulators and conductors that predicts charge distribution in processes involving induction or conduction. [See Science Practices 1.1, 1.4, and 6.4]

Science Practices for AP Physics 1 and 2

Science Practice 1: The student can use representations and models to communicate scientific phenomena and solve scientific problems.

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

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

1.3   The student can *refine 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.

1.5   The student can *reexpress key elements of natural phenomena across multiple representations* in the domain.

Science Practice 2: The student can use mathematics appropriately.

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.

2.3   The student can *estimate numerically quantities that describe* natural phenomena.

Science Practice 3: The student can engage in scientific questioning to extend thinking or to guide investigations within the context of the AP course.

3.1   The student can *pose scientific questions*.

3.2   The student can *refine scientific questions*.

3.3   The student can *evaluate scientific questions*.

Science Practice 4: The student can plan and implement data collection strategies in relation to a particular scientific question.

[Note: Data can be collected from many different sources, e.g., investigations, scientific observations, the findings of others, historic reconstruction, and/or archived data.]

4.1 The student can *justify the selection of the kind of data* needed to answer a particular scientific question.

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

4.3 The student can *collect data* to answer a particular scientific question.

4.4 The student can *evaluate sources of data* to answer a particular scientific question.

Science Practice 5: The student can perform data analysis and evaluation of evidence.

5.1 The student can *analyze data* to identify patterns or relationships.

5.2 The student can *refine observations and measurements* based on data analysis.

5.3 The student can *evaluate the evidence provided by data sets* in relation to a particular scientific question.

Science Practice 6: The student can work with scientific explanations and theories.

6.1 The student can *justify claims with evidence*.

6.2 The student can *construct explanations of phenomena based on evidence* produced through scientific practices.

6.3 The student can *articulate the reasons that scientific explanations and theories are refined or replaced*.

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

6.5 The student can *evaluate alternative scientific explanations*.

Science Practice 7: The student is able to connect and relate knowledge across various scales, concepts, and representations in and across domains.

7.1 The student can *connect phenomena and models* across spatial and temporal scales.

7.2 The student can *connect concepts* in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.