Multiple-Choice Answer Key

The following contains the answers to
the multiple-choice questions in this exam.

Answer Key for AP Physics 1
Practice Exam, Section I

Question 1: C
Question 2: B
Question 3: B
Question 4: D
Question 5: D
Question 6: C
Question 7: A
Question 8: C
Question 9: B
Question 10: C
Question 11: B
Question 12: C
Question 13: C
Question 14: D
Question 15: C
Question 16: D
Question 17: C
Question 18: A
Question 19: D
Question 20: A
Question 21: A
Question 22: C
Question 23: C
Question 24: A
Question 25: D
Question 26: A
Question 27: C
Question 28: D
Question 29: A
Question 30: C
Question 31: B
Question 32: C
Question 33: B
Question 34: D
Question 35: B
Question 36: C
Question 132: A,C
Question 133: B,D
Question 134: A,D
Question 135: B,D

Free-Response Scoring Guidelines

The following contains the scoring guidelines
for the free-response questions in this exam.

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Question 1

7 points total **Distribution of points**

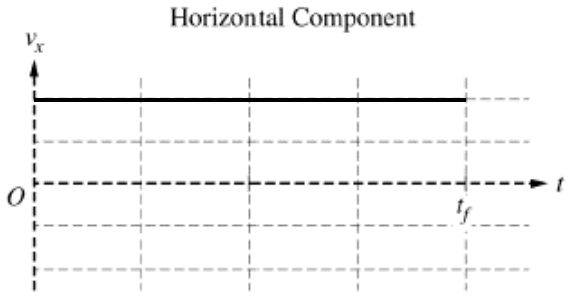


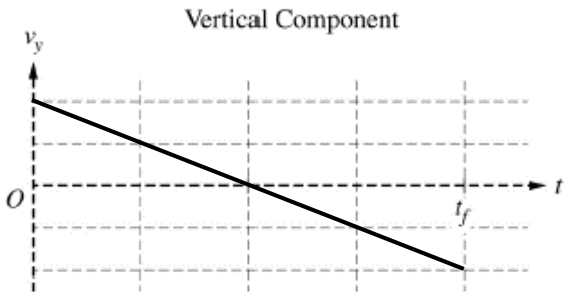
A toy consists of two identical solid spheres connected by a string with negligible mass. The toy is thrown at an angle above the horizontal (not straight up) such that the string remains taut and both spheres are revolving counterclockwise in a vertical plane around the center of the string, as shown above.

(a) LO / SP: 4.A.2.1 / 6.4; 4.A.2.3 / 1.4, 2.2
2 points

Sketch graphs of the horizontal and vertical components of the velocity of the center of the string as a function of time, from the instant the spheres are released at time $t = 0$ until the instant the system returns to its initial height at time t_f. Take the positive direction to be toward the right for the horizontal component and the positive direction to be upward for the vertical component.

Example graphs:





Horizontal component: For a non-zero horizontal line		1 point
Vertical component: For a non-vertical line with a negative slope that crosses the horizontal axis near $t_f/2$ and reaches t_f		1 point
Note: Any part of the sketched graph beyond t_f is ignored.		

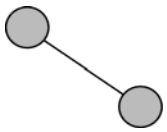
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Question 1 (continued)

Distribution of points

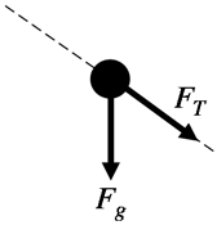
(b) LO / SP: 3.A.4.3 / 1.4; 3.B.2.1 / 1.1; 4.A.2.1 / 6.4; 4.A.2.3 / 1.4, 2.2; 4.A.3.2 / 1.4
5 points



The figure above shows the toy at the instant the center of the string reaches the top of its trajectory. This is a side view: the sphere on the left is higher than the sphere on the right.

i 2 points

On the dot below, which represents the left sphere only, draw and label the forces (not components) exerted on the left sphere at this instant. Represent each force by a distinct arrow starting on, and pointing away from, the dot. The dashed line is drawn at the same angle as the string.

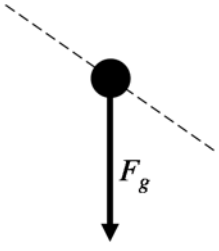


Left Sphere

For a gravitational force with correct direction and label		1 point
For a tension force with correct direction and label		1 point
Note: A maximum of one point may be earned if there are any extraneous forces.		

ii 1 point

On the dot below, which represents the whole toy (the spheres-string system), draw and label the forces (not components) that act on the system at this instant. Represent each force by a distinct arrow starting on, and pointing away from, the dot. The dashed line is drawn at the same angle as the string.



Whole Toy

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Question 1 (continued)

Distribution of points

(b)(ii) continued

For a vector pointing downward representing the gravitational force with no extraneous forces		1 point
Note: A label is not required, since the use of labels is assessed in part (b)(i).		

iii 2 points

When the toy was released, the center of the string was moving with an initial speed of 15 m/s at a 60° angle above the horizontal. Calculate the speed of the center of the string at the instant shown above, when the center of the string reaches the top of its trajectory.

For attempting to find the horizontal component of velocity Note: See examples below. This point is earned for the wrong use of trig functions if it is clear it is being used to find the horizontal component, but not awarded if it's not clear which component the trig function is referring to, or for stating that the vertical component is zero.		1 point
For a correct numerical answer for horizontal velocity with correct units		1 point
Examples: 0 points: $v\sin\theta = 13$ m/s (No clear indication of an attempt to find the horizontal component) 1 point: $v_x = v\sin\theta = 13$ m/s (An attempt to find the horizontal component is implied by the v_x term) 1 point: $v\cos\theta$ (An attempt to find the horizontal component is implied by the $\cos\theta$ term) 1 point: $v\cos\theta = 7.5$ (Correct numerical answer with no units) 1 point: 7.5 m/s (Correct answer with units, but no work shown) 2 points: $15\cos 60 = 7.5$ m/s (Correct answer with units) 2 points: $15\cos 60$ m/s (Correct answer with units)		

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Question 1 (continued)

Learning Objectives (LO)

LO 3.A.4.3: The student is able to analyze situations involving interactions among several objects by using free-body diagrams that include the application of Newton's third law to identify forces. [See Science Practice 1.4]

LO 3.B.2.1: The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. [See Science Practices 1.1, 1.4, 2.2]

LO 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]

LO 4.A.2.3: The student is able to 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. [See Science Practices 1.4, 2.2]

LO 4.A.3.2: The student is able to use visual or mathematical representations of the forces between objects in a system to predict whether or not there will be a change in the center-of-mass velocity of that system. [See Science Practice 1.4]

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Question 2

12 points total **Distribution of points**

A heavy lab cart moves with kinetic energy K_{init} on a track and collides with a lighter lab cart that is initially at rest. The carts bounce off each other but the collision is not perfectly elastic, causing the two-cart system to lose kinetic energy K_{lost}. A student wonders if the fraction of kinetic energy lost from the two-cart system during the collision $\left(\frac{K_{\text{lost}}}{K_{\text{init}}}\right)$ depends on the speed of the first cart before the collision and plans to perform an experiment.

(a) LO / SP: 5.D.1.4 / 4.2, 6.4
1 point

The student hypothesizes that a greater fraction of kinetic energy is lost from the system during the collision when the speed of the first cart is greater.

Briefly state one reason the hypothesis might be correct.

For a valid statement relating the speed of cart and dissipation of mechanical energy Note for pre-reading: Response does not have to address the fractional loss of kinetic energy (points are earned for this distinction in later parts).		1 point
Examples of valid statements: More damage when going faster Slower collision means compression and decompression during collision happen without permanent deformation Examples of invalid statements: Higher fraction of *K* is lost at higher speeds Because more kinetic energy is lost		

(b) LO / SP: 3.A.1.2 / 4.2; 5.D.1.4 / 4.2
5 points

Design an experimental procedure that could be used to test the student's hypothesis. Assume equipment usually found in a school physics laboratory is available.

In the table below, list the quantities that would be measured and the equipment that would be used to measure each quantity. Also, define a symbol to represent each quantity. You do not need to use every row and may add additional rows as needed.

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Question 2 (continued)

Distribution of points

Quantity to be Measured	Symbol	Equipment for Measurement

Describe the overall procedure to be used, referring to the table above. Provide enough detail so that another student could replicate the experiment. As needed, use the symbols defined in the table and/or include a simple diagram of the setup. Be sure to address how experimental uncertainty could be reduced.

For measuring the speed of both carts before and after collision Note: It is not necessary to measure the initial speed of the cart that is at rest.		1 point
For measuring the mass of the carts (or calculating mass ratio using conservation of momentum, which may be stated later)		1 point
For equipment and measurements consistent with procedure as described or drawn in diagram (e.g., motion detectors in the right places to measure speed of both carts)		1 point
For varying the speed (making speed the independent variable) of the first cart in a feasible experiment that could be done in a school lab. Note: "Varying the speed" means at least 2 trials (to test hypothesis), and "feasible" means that equipment is used appropriately for each measurement.		1 point
For attempting to reduce uncertainty, e.g., multiple trials for a given initial speed of cart 1, or trials involving at least three different initial speeds		1 point

Example:

Quantity to be Measured	Symbol	Equipment for Measurement
Initial speed of heavy cart (H)	v_{iH}	Motion sensor (MS1)
Final speed of heavy cart	v_{fH}	Motion sensor (MS1)
Mass of heavy cart	m_H	Triple beam balance
Final speed of light cart (L)	v_{fL}	Motion sensor (MS2)
Mass of light cart	m_L	Triple beam balance



Measure the mass of each cart with the triple beam balance. Set the carts and motion sensors on the track. With the motion sensors recording, push the heavy cart toward the light cart so that they collide. Record the motion sensors readings for the speeds of the heavy cart immediatly before the collision, and the speeds of both carts immediately after the collision. Repeat 8 times, varying the force with which the heavy cart is pushed so that a wide range of initial velocities for the heavy cart are used.

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Question 2 (continued)

Distribution of points

(c) LO / SP: 4.C.1.1 / 1.4, 2.2; 5.B.4.2 / 1.4, 2.2; 5.D.1.4 / 5.1
3 points

Describe how the experimental data could be analyzed to confirm or disconfirm the hypothesis that a greater fraction of kinetic energy is lost from the system during the collision when the speed of the first cart is greater. Include a description or example of any equations, data tables, graphs, or other representations that could be used.

For a correct indication of how initial and final total kinetic energy would be calculated from the raw data		1 point
For using the difference between initial and final total kinetic energy to determine the kinetic energy lost		1 point
For a description of how the calculated <u>fractional</u> energy losses would be used to confirm or disconfirm the hypothesis		1 point
Example: For each trial, calculate the initial kinetic energy of the heavy cart using $K_{\text{init}} = \frac{1}{2} m_{\text{H}} v_{\text{iH}}^2$. Also calculate the final kinetic energy $K_f = \frac{1}{2} m_{\text{H}} v_{\text{f H}}^2 + \frac{1}{2} m_{\text{L}} v_{\text{f L}}^2$. Make a graph of $K_{\text{lost}} / K_{\text{init}} = \left(K_{\text{init}} - K_f\right) / K_{\text{init}}$ as a function of v_{iH}. If a positive trend is seen in the data, the hypothesis is confirmed.		

(d) LO / SP: 4.C.1.1 / 1.4, 2.2; 5.B.4.2 / 1.4, 2.2; 5.D.2.5 / 2.2
3 points

Consider a different scenario in which the carts stick together after the collision. The masses of the heavier and lighter cart are m_1 and m_2, respectively. Derive an expression for the fraction of kinetic energy lost $\left(\frac{K_{\text{lost}}}{K_{\text{init}}}\right)$ during the collision. Express your answer in terms of m_1 and m_2.

For using momentum conservation to find v_f in terms of v_i, or the ratio of post-collision to pre-collision speed		1 point
For a correct expression for final kinetic energy (or consistent with v_f found from conservation of momentum) OR a correct expression for the fractional energy loss in terms of m_1, m_2, the initial speed of the heavy cart, and the final speed of the two-cart system		1 point
A correct expression for fraction of kinetic energy lost: $\frac{m_2}{m_1 + m_2}$ or $1 - \frac{m_1}{m_1 + m_2}$ <u>Note</u>: The above point is not earned if the answer includes any variables other than m_1 and m_2		1 point

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Question 2 (continued)

Learning Objectives (LO)

LO 3.A.1.2: The student is able to design an experimental investigation of the motion of an object. [See Science Practice 4.2]

LO 4.C.1.1: The student is able to calculate the total energy of a system and justify the mathematical routines used in the calculation of component types of energy within the system whose sum is the total energy. [See Science Practices 1.4, 2.1, and 2.2]

LO 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]

LO 5.D.1.4: The student is able to design an experimental test of an application of the principle of the conservation of linear momentum, predict an outcome of the experiment using the principle, analyze data generated by that experiment whose uncertainties are expressed numerically, and evaluate the match between the prediction and the outcome. [See Science Practices 4.2, 5.1, 5.3, and 6.4]

LO 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]

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Question 3

12 points total **Distribution of points**



Note: Figure not drawn to scale.

As shown above, the left end of a horizontal string is attached to an oscillator and the right end is attached to a wall. The string's midpoint is labeled C, and a dot has been painted on the left half of the string. The left half of the string is uniformly thick, with diameter D_0, while the right half of the string gradually increases in thickness from the midpoint C to the wall. The string is made of a material with uniform density (mass per unit volume).

(a) LO / SP: 3.A.1.1 / 1.5, 2.1, 2.2; 3.B.3.1 / 6.4, 7.2; 3.B.3.4 / 2.2, 6.2; 6.B.4.1 / 5.1, 7.2
5 points

The oscillator shakes the left end of the string up and down, creating waves traveling to the right with speed v_0. A student observes that every wave crest approaching the midpoint C passes through C but gradually slows down on the right half of the string.

i 2 points

On which half of the string, if either, do the waves have a longer wavelength?

____ Left half ____ Right half ____ Same wavelength on both halves

Briefly explain your reasoning.

Correct answer: "Left half" Note: A maximum of 1 point may be earned if the wrong selection is made.		
For stating that the frequency stays the same		1 point
For stating that, since the speed of the wave decreases as it moves to the right, the wavelength must decrease as well, or for using $\lambda \propto v$ or $v = f\lambda$		1 point

Alternate solution		
For using reasoning that applies to a pulse (the leading edge is slower than trailing edge, so the trailing edge "catches up to" the leading edge and wavelength decreases)		2 points

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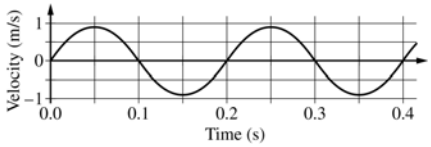
Question 3 (continued)

Distribution of points

(a) continued

ii 3 points

The graph below represents the vertical <u>velocity</u> of the dot on the left half of the string as a function of time.



Describe how you could use the graph to estimate the amplitude of the waves at the dot's location. You do NOT have to actually calculate the amplitude.

For using the area under the velocity vs. time curve.		1 point
For correctly or incorrectly relating the area under the curve to the amplitude OR identifying a specific area (in terms of range of times, "humps", cycles, etc.)		1 point
For correctly identifying a quarter cycle, or "half a hump", as the area or displacement corresponding to the amplitude (or any correct relationship between cycles and amplitude)		1 point
Examples: 1 point: Unspecified area: "Use the area under the curve." 2 points: Any area specified: "Use the area under the curve from t = 0 to t = 0.4 s" "Area under a full hump because that's a full period." "Area under a the curve for 1/4 period" (only 2 points because didn't specify what period corresponds to on the graph) 3 points: Correct area (quarter cycle, OR half cycle with statement that it's twice the amplitude): "The area under half a hump"		

Alternate solution based on $v_{max} = \omega A$		
For using $v_{max} = \omega A$		1 point
For indicating how ω *can be determined from the graph (e.g.,* $\omega = \frac{2\pi}{T}$*, where* T *corresponds to a complete cycle)*		1 point
For a correct algebraic expression for amplitude (e.g., $\frac{v_{max}T}{2\pi}$*)*		1 point

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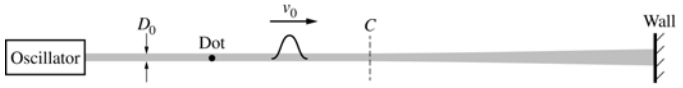
Question 3 (continued)

Distribution of points

(b) LO / SP: 3.A.1.1 / 1.5, 2.1, 2.2; 6.B.4.1 / 5.1
3 points

In a different experiment, the oscillator shakes the left end of the string up and down at a rate of 50 cycles per second. The leading edge of the wave reaches the midpoint *C*, which is 0.75 m from the left end of the string, 0.030 second after the oscillator starts shaking the string. Calculate the wavelength of the wave on the left half of the string.

For calculating wave speed $(v = d/t)$		1 point
For implicitly or explicitly using $f = 50$ Hz		1 point
For calculating wavelength using $\lambda = v/f$		1 point
Example: $v = \frac{0.75 \text{ m}}{0.030 \text{ s}} = 25 \text{ m/s}$ $\lambda = \frac{v}{f} = \frac{25 \text{ m/s}}{50 \text{ s}^{-1}} = 0.5 \text{ m}$		



Note: Figure not drawn to scale.

Later, the student uses the oscillator to create a single pulse with initial speed v_0 at the left end of the string, as shown above. The student wants to quantify the observation that the pulse slows down on the right half of the string. The student comes up with the following equation relating the string's diameter D at a given point on the string to the speed *v* of the pulse at that point: $v = v_0\left(\frac{D_0}{D}\right)$.

(c) LO / SP: 3.A.1.1 / 1.5, 2.2
1 point

Is the equation consistent with the observation that the pulse slows down on the right half of the string?
____ Yes ____ No
Briefly explain your reasoning.

Correct answer: "Yes"
Note: If the wrong selection is made, the explanation is not graded.

For stating that as *D* increases, *v* decreases		1 point

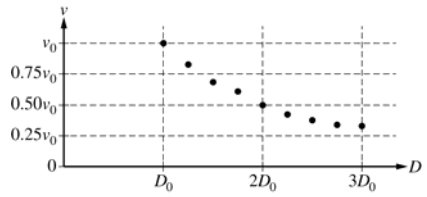
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Question 3 (continued)

Distribution of points

(d) LO / SP: 3.A.1.1 / 1.5, 2.2
1 point

Using frame-by-frame analysis of video of the pulse, the student plots the speed v of the pulse as a function of the string diameter D, as shown below.



Are the data in the graph consistent with the student's equation above?
____ Yes ____ No
Briefly explain your answer.

Correct answer: "Yes"		
Note: If the wrong selection is made, no credit can be earned.		
For stating that the data agree with the equation because of the downward trend in the data, or for stating that v decreases as D increases (inverse relationship), or for comparing calculated values from the equation with the data in the graph		1 point

(e) LO / SP: 6.A.1.2 / 1.2
2 points



Note: Figure not drawn to scale.

The figure above shows only the right half of the string. The solid line represents the shape of the wave pulse when its peak reaches point X, which is to the right of the midpoint C. Draw the pulse when it reaches point Y. Your drawing should clearly indicate whether the width of the pulse at point Y is greater than, equal to, or less than the width of the pulse at point X.

Example:



Note: Figure not drawn to scale.

For a pulse with similar overall shape as the original		1 point
For a pulse that is narrower Note: The height is not considered for earning this point.		1 point

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Question 3 (continued)

Learning Objectives (LO)

LO 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]

LO 3.B.3.1: The student is able to predict which properties determine the motion of a simple harmonic oscillator and what the dependence of the motion is on those properties. [See Science Practices 6.4 and 7.2]

LO 3.B.3.4: The student is able to construct a qualitative and/or a quantitative explanation of oscillatory behavior given evidence of a restoring force. [See Science Practices 2.2 and 6.2]

LO 6.A.1.2: The student is able to describe representations of transverse and longitudinal waves. [See Science Practice 1.2]

LO 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]

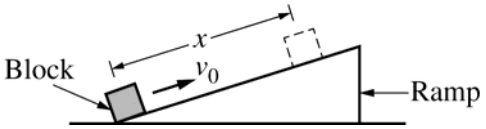
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Question 4

7 points total **Distribution of points**

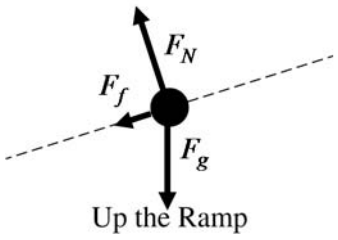
A student strikes a block at the bottom of a ramp, giving it an initial speed v_0 up the ramp, as shown at right. There is friction between the ramp and the block as it slides a distance x up the ramp and then slides back down.

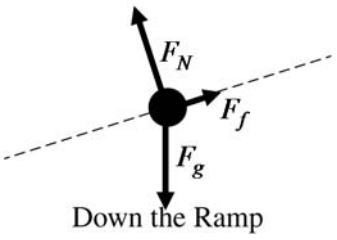


(a) LO / SP: 3.A.2.1 / 1.1; 3.B.2.1 / 1.1, 1.4
2 points

On the dots below, which represent the block as it is sliding up the ramp and down the ramp, draw and label the forces (not components) exerted on the block. Represent each force by a distinct arrow starting on, and pointing away from, the dot. The dashed lines are drawn at the same angle as the surface of the ramp.

Example:





For a labeled friction force vector in the correct direction in both diagrams		1 point
For labeled gravitational and normal forces in the correct directions in both diagrams, with no extraneous forces		1 point

(b) LO / SP: 2.B.1.1 / 2.2; 3.A.1.1 / 1.5, 2.2; 3.B.1.1 / 6.4, 7.2; 3.B.1.3 / 1.5, 2.2; 3.B.2.1 / 1.1, 1.4, 2.2
5 points

The block takes time t_{up} to slide up the ramp a distance x. The block then takes time t_{down} to slide back down to the bottom of the ramp, where it has speed v_f. Is t_{down} greater than, equal to, or less than t_{up}?

____ $t_{\text{down}} > t_{\text{up}}$ ____ $t_{\text{down}} = t_{\text{up}}$ ____ $t_{\text{down}} < t_{\text{up}}$

In a clear, coherent paragraph-length response that may also contain figures and/or equations, explain your reasoning. If you need to draw anything other than what you have shown in part (a) to assist in your response, use the space below. Do NOT add anything to the figures in part (a).

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Question 4 (continued)

Distribution of points

Correct Answer: $t_{down} > t_{up}$

Note: The response is graded even if an incorrect selection is made.

For stating that the magnitude of the net force on the block is greater when it is sliding up the ramp than when it is sliding down the ramp because the direction of the frictional force changes while the direction of the component of the gravitational force along the ramp does not (this can be implied) OR a description of the net force consistent with the free-body diagrams (FBDs) in part (a)		1 point
For stating that the magnitude of acceleration of the block while sliding up the ramp is greater than that when sliding down, OR a description of acceleration consistent with the FBDs in part (a)		1 point
For a justification that v_f is less than v_0, OR average *v* up is greater than average *v* down (e.g., speed changes more on way up than on way down because acceleration is greater on the way up and the same distance covered and final/initial speed on way up/down is zero), OR a description of final and initial speeds consistent with the FBDs in part (a)		1 point
For a correct *argument* that, if v_f is less than v_0 or the average speed up is greater than the average speed down, then t_{down} is greater than t_{up}. (This argument could include a kinematic equation.) Note: Student cannot earn this point even if justification is consistent with an incorrect FBD in part (a)		1 point
For a logical, relevant, and internally consistent argument that addresses the required argument or question asked, and follows the guidelines described in the published requirements for the paragraph-length response		1 point
Note: A maximum of 4 of 5 points (first 3 points plus 5th point) can be earned if the FBDs in part (a) are incorrect (e.g., friction force is in the same direction in both FBDs)		

Alternate solution using work/energy reasoning for 1st two points of part (b)		
For correctly applying work-energy to up/down ramp (or, indicating block-Earth system has the same potential energy at the beginning and end)		1 point
For correct treatment of energy loss to friction		1 point

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Question 4 (continued)

Learning Objectives (LO)

LO 2.B.1.1: The student is able to apply $F = mg$ to calculate the gravitational force on an object with mass m in a gravitational field of strength g in the context of the effects of a net force on objects and systems. [See Science Practices 2.2 and 7.2]

LO 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]

LO 3.A.2.1: The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation. [See Science Practice 1.1]

LO 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]

LO 3.B.1.3: The student is able to reexpress a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object. [See Science Practices 1.5 and 2.2]

LO 3.B.2.1: The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively. [See Science Practices 1.1, 1.4, and 2.2]

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AP® PHYSICS 1
2018 SCORING GUIDELINES

Question 5

7 points total **Distribution of points**

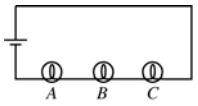


Figure 1

Students in a physics lab use a battery and three identical lightbulbs to construct the circuit shown in Figure 1 above. The brightness of each bulb increases when the current through the bulb increases.

(a) LO / SP: 5.C.3.1 / 6.4
1 point

Which bulb, if any, is the brightest?
____ *A* ____ *B* ____ *C* ____ All bulbs have the same brightness.
Briefly explain your reasoning in terms of current and/or potential difference.

Correct answer: "All bulbs have the same brightness"		
Note: The response does not earn credit if an incorrect selection is made.		
For correct checkbox and assertion that current (rate of charge flow) is the same throughout the circuit. Note: For this point to be earned, statement must include current and/or potential difference (i.e., "because they are in series" is not sufficient).		1 point
Examples: The current through the light bulbs is the same everywhere within a series circuit regardless of their proximity to the battery. Because the potential difference across each bulb is the same.		

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Question 5 (continued)

Distribution of points

(b) LO / SP: 5.B.9.3 / 2.2, 6.4; 5.C.3.1 / 6.4; 5.C.3.3 / 1.4, 2.2
3 points

The students observe the brightness of bulbs *A*, *B*, and *C*. The students then add a fourth lightbulb *D,* with a larger resistance than bulbs *A*, *B*, and *C*, as shown in Figure 2 below.

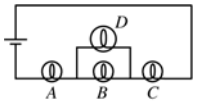


Figure 2

i 2 points

Is bulb *A* now brighter than, dimmer than, or the same brightness as it was in the circuit in Figure 1 ?
____ Brighter ____ Dimmer ____ Same brightness
Briefly explain your reasoning.

Correct answer: "Brighter"		
Note: The response is graded even if an incorrect selection is made.		
For recognizing that the addition of lightbulb *D* reduces the equivalent resistance of the circuit		1 point
For correctly stating that the overall current (i.e., current through battery) is greater in the modified circuit		1 point

ii 1 point

Is bulb *B* now brighter than, dimmer than, or the same brightness as it was in the circuit in Figure 1 ?
____ Brighter ____ Dimmer ____ Same brightness
Briefly explain your reasoning.

Correct answer: "Dimmer"
Note: The response does not earn credit if an incorrect selection is made.

For an argument that the current is now split between bulb *B* and bulb *D*, which tends to lower the current through bulb *B* Note: It is not necessary to address change in current through the battery.		1 point
Alternate Solution		
For an argument that the potential difference across both bulb A and bulb C increases and the potential difference of the battery remains constant, which causes the potential difference across bulb B to decrease due to conservation of energy (Kirchhoff's Loop Rule)		*1 point*

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Question 5 (continued)

Distribution of points

(c) LO / SP: 5.B.9.3 / 2.2, 6.4; 5.C.3.1 / 6.4; 5.C.3.3 / 1.4, 2.2
3 points

Bulbs *A*, *B*, and *C* each have resistance $10\ \Omega$, while bulb *D* has a resistance of $30\ \Omega$. In the circuit shown in Figure 2, the current through bulb *D* is measured to be 0.20 A. Calculate the potential difference across bulb *A*.

Reasoning using current:		
For correctly calculating the current through bulb *B* (0.6 A)		1 point
For an implicit or explicit calculation of the total current consistent with previous step (0.8 A)		1 point
For a potential difference across bulb *A* consistent with previous steps and with correct units: 8 V		1 point

Reasoning using potential difference:		
For correctly calculating the potential difference across bulb *D* and recognizing (explicitly or implicitly) that it is equal to the potential difference across bulb *B* (6 V)		1 point
For explicitly or implicitly determining the ratio R_A/R_{BD} (4/3)		1 point
For a potential difference across bulb *A* consistent with previous steps and with correct units: 8 V		1 point

Learning Objectives (LO)

LO 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, 7.2]

LO 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, 7.2]

LO 5.C.3.3: The student is able to use a description or schematic diagram of an electrical circuit to calculate unknown values of current in various segments or branches of the circuit. [See Science Practices 1.4, 2.2]

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Scoring Worksheet

The following provides a scoring worksheet and conversion table used for calculating a composite score of the exam.

2018 AP Physics 1 Scoring Worksheet

Section I: Multiple Choice

_____	× 1.0000 =	_____
Number Correct (out of 40)		Weighted Section I Score (Do not round)

Section II: Free Response

Question 1	_____ (out of 7)	× 0.8888 =	_____ (Do not round)
Question 2	_____ (out of 12)	× 0.8888 =	_____ (Do not round)
Question 3	_____ (out of 12)	× 0.8888 =	_____ (Do not round)
Question 4	_____ (out of 7)	× 0.8888 =	_____ (Do not round)
Question 5	_____ (out of 7)	× 0.8888 =	_____ (Do not round)

Sum = _____
Weighted Section II Score (Do not round)

Composite Score

_____	+ _____	= _____
Weighted Section I Score	Weighted Section II Score	Composite Score (Round to nearest whole number)

AP Score Conversion Chart
Physics 1

Composite Score Range	AP Score
61-80	5
48-60	4
36-47	3
24-35	2
0-23	1

Question Descriptors and Performance Data

The following contains tables showing the content assessed,
the correct answer, and how AP students performed on each question.

Multiple-Choice Questions

Question	Learning Objectives	Essential Knowledge	Science Practices	Key	% Correct
1	3.A.3.1; 3.B.2.1	3.A.3; 3.B.2	6.4; 1.4	C	89
2	5.D.2.5	5.D.2	2.2	B	52
3	3.A.1.1; 3.A.1.3	3.A.1; 3.A.1	1.5; 2.2; 5.1	B	90
4	3.A.1.1; 3.A.1.3; 3.B.3.3	3.A.1; 3.A.1; 3.B.3	1.5; 2.2; 5.1; 2.2; 5.1	D	67
5	3.B.3.3	3.B.3	2.2; 5.1	D	54
6	6.B.2.1; 6.B.4.1	6.B.2; 6.B.4	1.4; 5.1	C	62
7	6.D.3.1	6.D.3	4.2	A	47
8	3.B.2.1; 4.C.1.1; 4.C.2.2; 5.B.4.2; 5.B.5.5	3.B.2; 4.C.1; 4.C.2; 5.B.4; 5.B.5	2.2; 2.2; 2.2; 2.2; 2.2; 6.4	C	68
9	4.B.2.2	4.B.2	5.1	B	36
10	5.B.9.3; 5.C.3.1; 5.C.3.3	5.B.9; 5.C.3; 5.C.3	6.4; 7.2; 6.4; 7.2; 1.4	C	64
11	3.E.1.1; 3.E.1.2; 5.B.3.1; 5.B.4.1	3.E.1; 3.E.1; 5.B.3; 5.B.4	6.4; 7.2; 1.4; 2.2; 6.4; 7.2; 6.4; 7.2	B	51
12	5.B.4.1; 5.B.4.2; 5.B.5.4	5.B.4; 5.B.4; 5.B.5	6.4; 1.4; 6.4	C	83
13	3.E.1.1; 4.C.1.2	3.E.1; 4.C.1	6.4; 6.4	C	48
14	5.A.2.1; 5.B.4.2	5.A.2; 5.B.4	6.4; 1.4; 2.1; 2.2	D	37
15	1.B.1.1; 1.B.1.2; 5.A.2.1	1.B.1; 1.B.1; 5.A.2	6.4; 6.4; 6.4	C	63
16	3.A.1.1; 3.B.1.3; 3.B.2.1	3.A.1; 3.B.1; 3.B.2	1.5; 2.2; 1.5; 2.2; 1.1; 1.4; 2.2	D	43
17	5.B.4.2	5.B.4	1.4; 2.1	C	49
18	3.E.1.1; 4.C.2.1; 5.B.5.4	3.E.1; 4.C.2; 5.B.5	6.4; 7.2; 6.4; 6.4; 7.2	A	44
19	4.C.1.1; 4.C.1.2; 5.B.3.2; 5.B.5.5	4.C.1; 4.C.1; 5.B.3; 5.B.5	1.4; 2.1; 2.2; 6.4; 1.4; 2.2; 2.2; 6.4	D	32
20	3.A.1.1	3.A.1	1.5; 2.2	A	37
21	3.E.1.1; 3.E.1.4; 4.C.1.1; 4.C.2.2; 5.B.4.2	3.E.1; 3.E.1; 4.C.1; 4.C.2; 5.B.4	6.4; 2.2; 1.4; 2.2; 1.4; 2.2; 1.4; 2.2	A	36
22	3.A.1.1; 5.B.5.5	3.A.1; 5.B.5	2.2; 2.2	C	39
23	3.B.1.1; 3.B.2.1; 4.A.2.1	3.B.1; 3.B.2; 4.A.2	6.4; 1.1; 1.4; 6.4	C	41
24	6.A.1.1	6.A.1	6.2	A	47
25	1.B.1.1; 5.B.9.3; 5.C.3.3	1.B.1; 5.B.9; 5.C.3	6.4; 2.2; 6.4; 7.2; 1.4; 2.2	D	47
26	5.C.3.1; 5.C.3.3	5.C.3; 5.C.3	6.4; 1.4; 2.2	A	36
27	3.F.1.2; 4.D.1.1	3.F.1; 4.D.1	1.4; 1.4	C	58
28	3.F.2.1; 4.D.3.1	3.F.2; 4.D.3	6.4; 2.2	D	43
29	3.F.2.1	3.F.2	6.4	A	32
30	3.B.3.1	3.B.3	6.4; 7.2	C	32
31	6.A.3.1; 6.B.1.1	6.A.3; 6.B.1	1.4; 1.4	B	69
32	6.D.4.2	6.D.4	2.2	C	29
33	3.A.1.1; 3.A.3.1	3.A.1; 3.A.3	1.5; 2.2; 6.4; 7.2	B	33
34	4.A.1.1; 4.A.2.1; 4.A.3.2; 5.D.2.5; 5.D.3.1	4.A.1; 4.A.2; 4.A.3; 5.D.2; 5.D.3	1.4; 6.4; 6.4; 1.4; 2.2; 6.4	D	25
35	3.C.2.1	3.C.2	6.4	B	31
36	5.B.5.3	5.B.5	1.4; 2.2; 6.4	C	42

Question	Learning Objectives	Essential Knowledge	Science Practices	Key	% Correct
131	3.A.4.3; 3.B.2.1	3.A.4; 3.B.2	1.4; 1.1; 1.4	A, C	66
132	3.D.2.2; 3.D.2.3	3.D.2; 3.D.2	6.4; 5.1	B, D	40
133	3.A.1.1	3.A.1	1.5; 2.2	A, D	36
134	2.B.1.1; 2.B.2.1	2.B.1; 2.B.2	2.2; 7.2; 2.2	B, D	42

Free-Response Questions

Question	Learning objectives	Essential Knowledge	Science Practices	Mean Score
1	3.A.4.3; 3.B.2.1; 4.A.2.1; 4.A.2.3; 4.A.3.2	3.A.4; 3.B.2; 4.A.2; 4.A.2; 4.A.3	1.4; 1.1; 6.4; 1.4; 2.2; 1.4	3.61
2	3.A.1.2; 4.C.1.1; 5.B.4.2; 5.D.1.4; 5.D.2.5	3.A.1; 4.C.1; 5.B.4; 5.D.1; 5.D.2	4.2; 1.4; 2.2; 1.4; 2.2; 4.2; 5.1; 6.4; 2.2	3.06
3	3.A.1.1; 3.B.3.1; 3.B.3.4; 6.A.1.2; 6.B.4.1	3.A.1; 3.B.3; 3.B.3; 6.A.1; 6.B.4	1.5; 2.1; 2.2; 6.4; 7.2; 2.2; 6.2; 1.2; 5.1; 7.2	5.24
4	2.B.1.1; 3.A.1.1; 3.A.2.1; 3.B.1.1; 3.B.1.3; 3.B.2.1	2.B.1; 3.A.1; 3.A.2; 3.B.1; 3.B.1; 3.B.2	2.2; 1.5; 2.2; 1.1; 6.4; 7.2; 1.5; 2.2; 1.1; 1.4; 2.2	1.62
5	5.B.9.3; 5.C.3.1; 5.C.3.3	5.B.9; 5.C.3; 5.C.3	2.2; 6.4; 6.4; 1.4; 2.2	2.65

AP Physics 1: Algebra-Based

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