Question 1: Short Answer — 7 points

(a) For using conservation of energy to find the speed v of the bicycle as it leaves the ramp — **1 point**

For using kinematics, vertical components, attempting to find the time the bicycle is in the air — **1 point**

For a correct expression for X_0 in terms of given quantities — **1 point**

Example response for part (a)

$E_{top} = E_{bottom}$
$m_0 g H_0 = \frac{1}{2} m_0 v^2$
$v = \sqrt{2gH_0}$
$v_{fy} = v_{iy} + at$
$-v\sin\theta = v\sin\theta - gt$
$-2v\sin\theta = -gt$

$2\sin\theta_0\sqrt{2gH_0} = gt$
$t = \dfrac{2\sin\theta_0\sqrt{2gH_0}}{g}$
$X_0 = v_x t$
$X_0 = \cos\theta_0\sqrt{2gH_0}\,\dfrac{2\sin\theta_0\sqrt{2gH_0}}{g}$
$X_0 = 4H_0\cos\theta_0\sin\theta_0$

Scoring Note:
Using the range equation to get $X_0 = 2H_0\sin 2\theta_0$ is sufficient to earn the second and third points.

Total for part (a) — **3 points**

(b) Correct answer: 12 cars

For an answer and justification that attempts to use the functional dependence of the horizontal distance on the initial height — **1 point**

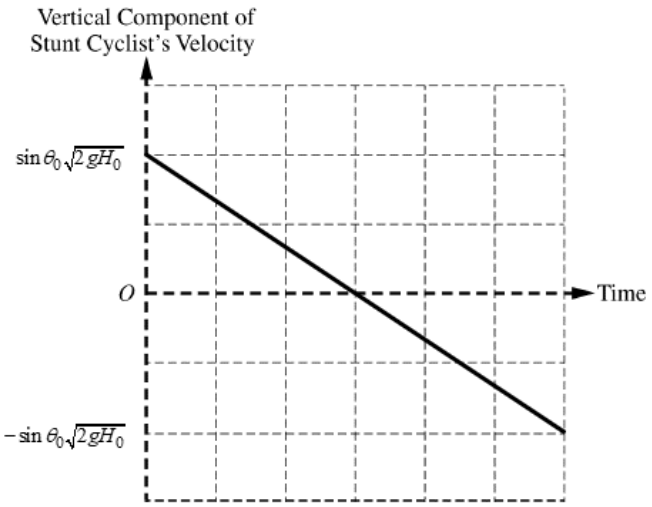
For an answer consistent with the expression derived in part (a) — **1 point**

Total for part (b) — **2 points**

(c) For a linear graph with a constant negative slope — **1 point**

For a graph that starts at v_y and ends at $-v_y$, using only allowed variables — **1 point**

Example response for part (c)



Total for part (c) — **2 points**

Total for Question 1 — **7 points**

2017

AP CollegeBoard

AP Physics 1: Algebra-Based

Scoring Guidelines

AP® PHYSICS
2017 SCORING GUIDELINES

General Notes About 2017 AP Physics Scoring Guidelines

1. The solutions contain the most common method of solving the free-response questions and the allocation of points for this solution. Some also contain a common alternate solution. Other methods of solution also receive appropriate credit for correct work.

2. The requirements that have been established for the paragraph length response in Physics 1 and Physics 2 can be found on AP Central at https://secure-media.collegeboard.org/digitalServices/pdf/ap/paragraph-length-response.pdf.

3. Generally, double penalty for errors is avoided. For example, if an incorrect answer to part (a) is correctly substituted into an otherwise correct solution to part (b), full credit will usually be awarded. One exception to this may be cases when the numerical answer to a later part should be easily recognized as wrong, e.g., a speed faster than the speed of light in vacuum.

4. Implicit statements of concepts normally receive credit. For example, if use of the equation expressing a particular concept is worth one point, and a student's solution embeds the application of that equation to the problem in other work, the point is still awarded. However, when students are asked to derive an expression it is normally expected that they will begin by writing one or more fundamental equations, such as those given on the exam equation sheet. For a description of the use of such terms as "derive" and "calculate" on the exams, and what is expected for each, see "The Free-Response Sections—Student Presentation" in the *AP Physics; Physics C: Mechanics, Physics C: Electricity and Magnetism Course Description* or "Terms Defined" in the *AP Physics 1: Algebra-Based and AP Physics 2: Algebra-Based Course and Exam Description*.

5. The scoring guidelines typically show numerical results using the value $g = 9.8\ \text{m/s}^2$, but use of $10\ \text{m/s}^2$ is of course also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

6. Strict rules regarding significant digits are usually not applied to numerical answers. However, in some cases answers containing too many digits may be penalized. In general, two to four significant digits are acceptable. Numerical answers that differ from the published answer due to differences in rounding throughout the question typically receive full credit. Exceptions to these guidelines usually occur when rounding makes a difference in obtaining a reasonable answer. For example, suppose a solution requires subtracting two numbers that should have five significant figures and that differ starting with the fourth digit (e.g., 20.295 and 20.278). Rounding to three digits will lose the accuracy required to determine the difference in the numbers, and some credit may be lost.

2017 SCORING GUIDELINES

Question 1

7 points total **Distribution of points**

(a) 2 points

Correct ranking: $(A = D = E) > (B = C)$ OR $A = D = E,\ B = C$

Note: A ranking must be given for any points to be earned for the explanation.

Note: The ranking must be correct to earn the full 2 points for the explanation.

For indicating $A = D = E$ in the ranking, with a valid explanation 1 point

Example: "*A*, *D*, and *E* are all connected across the battery, so they must have the same ΔV as the battery."

For indicating $B = C$ in the ranking, with a valid explanation 1 point

Example: "The same current flows through both bulbs *B* and *C*, so they have the same voltage drop across them. By Kirchhoff's voltage rule, the sum of the voltages in this circuit must add to zero, so each bulb has half the battery voltage."

Example 1: For each of bulbs *A*, *D*, and *E*, current can go around the circuit passing through only that bulb and the battery, and hence the potential drop across all three bulbs equals the voltage of the battery (because $\Delta V = 0$ for a complete loop). In circuit 2, *B* and *C* are in series so the overall potential drop (equal to the battery's voltage) is "shared" equally between the two bulbs (because they are identical) and the potential difference across each is half is the battery's voltage.

Example 2: *A*, *D*, and *E* are all connected directly across the battery terminals and therefore "get" the full battery potential difference. By contrast, the potential drop across the *BC* part of the circuit is "split" between *B* and *C*, and split equally.

2017 SCORING GUIDELINES

Question 1 (continued)

Distribution of points

(b) 5 points

Correct answers: Circuit 3 runs out first, circuit 2 runs out last

Note: In the paragraph response, "energy dissipation" or "current" are acceptable substitutes for "power."
For indicating that all three circuits draw different amounts of power — 1 point
Note: This point may be earned by addressing only two circuits in the response.
For explaining that the battery in circuit 2 delivers the least power using correct physical reasoning by addressing potential difference OR resistance — 1 point
For explaining that the battery in circuit 3 delivers the most power using correct physical reasoning by addressing potential difference OR resistance — 1 point
For an implicit or explicit statement that greater power results in shorter battery life — 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

Example: The battery in circuit 3 runs out first, then the battery in circuit 1, and finally the battery in circuit 2. The power (rate of energy loss) of a battery is $P = I\Delta V$, and all three batteries have the same potential difference. So the rate of energy loss, and hence the order in which the batteries "die," is given by the ranking of the currents through the batteries. Circuit 3 has the most current because the availability of two paths (loops) makes the overall resistance of this circuit the lowest. Circuit 2 has the least current because there is only one loop, and it contains two bulbs, making the overall resistance greater than that of circuit 1.

2017 SCORING GUIDELINES

Question 2

12 points total

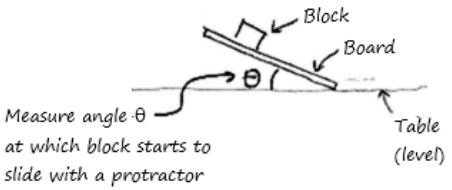
Distribution of points

(a)

i. 3 points

For drawing a diagram of an experimental setup to measure the coefficient of friction that is feasible in a school physics lab — 1 point
For indicating the measurements necessary for calculating the coefficient of friction — 1 point
For indicating equipment necessary for measuring the quantities required to calculate the coefficient of friction — 1 point

Example:



ii. 3 points

For a description that is consistent with the diagram in part (a)(i), in enough detail that another student could replicate the experiment — 1 point
For a description that is a conceptually valid method to find quantities that would allow a calculation of a friction coefficient — 1 point
For including a valid method for reducing experimental error — 1 point

Example:
With the block at rest on the board, slowly lift one end of board until the block just begins to slide. Measure the angle between board and table and repeat several times with block at different locations on the board (with multiple trials at each location).

(b) 3 points

Note: In order to earn full credit for part (b), all terms (variables) must be indicated in the diagram and/or procedure of part (a).
For using Newton's second law (or reasoning in terms of zero net force) in one dimension, parallel to the board's surface, either explicitly or implicitly — 1 point
For using Newton's second law (or reasoning in terms of zero net force) in one dimension, perpendicular to the board's surface, either explicitly or implicitly — 1 point
Note: Replacing the normal force with *mg* is "implicit" use of Newton's second law in the perpendicular direction for a horizontal surface. For a tilted surface, the appropriate trigonometric term should be included.
For a correct derived expression of the coefficient of static friction in terms of quantities indicated in part (a) — 1 point

2017 SCORING GUIDELINES

Question 2 (continued)

Distribution of points

(c) 2 points

Correct answer: "The static and kinetic coefficients are not equal."
Reasoning cannot earn credit if the incorrect selection is made.

For identifying group 5's results as outliers, or indicating the presence of an outlier — 1 point
For a conclusion that coefficients are not the same, justified by either removing the outlier or noting the coefficients are different for each group — 1 point

(d) 1 point

For a valid argument that indicates the coefficient of static friction is a property of the two surfaces, and is consistent with the selected answer — 1 point

Example 1: Selects "Remain the same"
Referring to the equation in part (b), coefficient does not depend on mass.
Example 2: Selects "Remain the same"
The coefficient depends on the nature of the surfaces involved, not the masses or normal force of the objects involved.
Example 3: Selects "Decrease"
The increased normal force will cause smoothing of the surfaces, decreasing the coefficient of friction.
Example 4: Selects "Increase"
The increased normal force will cause the surfaces to become gouged, increasing the coefficient of friction.

2017 SCORING GUIDELINES

Question 3

12 points total

Distribution of points

(a) 1 point

Correct answer: "To the right of *C*"
Reasoning cannot earn credit if the incorrect selection is made.

For an explanation that the torque exerted by the disk or the angular momentum of the disk is greater when farther from the pivot — 1 point

Example 1: The disk exerts a greater torque on the rod when it pushes the rod farther from the pivot.
Example 2: The disk has greater angular momentum when it's farther from the pivot. The disk loses almost all its speed during the collision and hence gives the rod almost all its angular momentum. So the rod ends up with more angular momentum when the disk hits it farther from the pivot.

(b) 2 points

Correct answer: "Yes"
If "No" is selected, the explanation may still earn full credit if an incorrect selection was made in part (a).

For a selection consistent with the selection from part (a) — 1 point
For indicating that the equation shows that ω increases with increasing x — 1 point

Example: According to the equation, ω increases with x; a bigger x produces a bigger angular speed. This agrees with my reasoning from part (a), where I said a bigger x creates a bigger angular speed after the collision.

(c) 3 points

For focusing on functional dependence (instead of, for example, considering units/dimensions) — 1 point
For addressing m_{disk}, I, or both — 1 point
For correctly concluding that the equation is wrong because of the dependence on m_{disk}, I, or both — 1 point

Example: If m_{disk} is large, then more angular momentum will be transferred during the collision. But the equation shows the angular speed decreasing with increasing m_{disk}, because it is in the denominator.

2017 SCORING GUIDELINES

Question 3 (continued)

Distribution of points

(d) 4 points

For using an expression of conservation of angular momentum for the disk and rod — 1 point
Note: This point is not awarded for equating angular and linear momentum.
For indicating that the initial angular momentum of the system is equal to $m_{\text{disk}} v_0 x$ — 1 point
For a dimensionally correct expression for the post-collision angular momentum that includes $I\omega$ — 1 point
For indicating the correct rotational inertia of the system after the collision: $I + m_{\text{disk}} x^2$ — 1 point

(e) 2 points

Correct answer: "Greater than"

For indicating, either directly or by analogy to the linear case, that the disk's angular momentum with respect to the pivot changes more in the bouncy scenario than in the original scenario OR for using a similar argument in terms of impulse — 1 point
Note: This point is for describing what happens to the disk.
For using conservation of angular momentum or momentum-impulse reasoning to conclude that the rod gains more angular momentum, and hence more angular speed, in the bouncy scenario — 1 point
Note: This point is for describing what happens to the rod.

Example: After the bouncy collision, the disk has angular momentum in the clockwise direction. To keep the system angular momentum constant, the magnitude of the rod's counterclockwise angular momentum must be greater than before.

2017 SCORING GUIDELINES

Question 4

7 points total

Distribution of points

(a) 3 points

Correct answer: "No"
Note: If the wrong answer is selected, partial credit can be earned for the justification.

For attempting to use conservation of energy to compare the two blocks — 1 point
For explicitly or implicitly indicating that the launch velocities are different — 1 point
For stating or implying that the time to reach the ground is the same for both blocks — 1 point

Example: The amount of potential energy converted to kinetic energy is different for the two blocks. The potential energy is proportional to the change in height, which is smaller for block 2. Therefore, at the edge of the table, block 1 will have more kinetic energy than block 2, and hence a larger speed. The launches are both horizontal and from the same height, so the blocks will spend the same amount of time in the air. Because $d = vt$, the distances will be different for the two blocks (as the speeds are different).

(b)

i. 2 points

Correct answer: "The two blocks land the same distance from their respective tables."

For indicating that the change in potential energy from release to launch is the same for the two cases — 1 point
For an indication (explicit or implicit) that the launch velocities are the same — 1 point

ii. 2 points

Correct answer: "Block 1"

For indicating that the average speed or velocity on the slide is higher for Team 1, OR that block 1 reaches its maximum speed in less time — 1 point
For a valid explanation of why the average speed or velocity is higher for team 1, OR why block 1 reaches its maximum speed in less time — 1 point

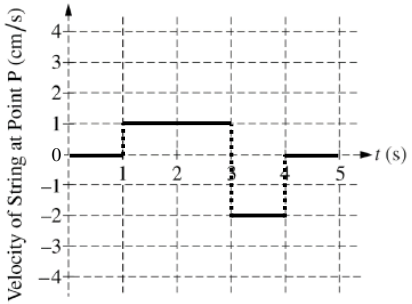
Example: Because the ramp on Table 1 is initially steeper, block 1 has a higher average speed while it's on the ramp so it launches off the table before block 2.

2017 SCORING GUIDELINES

Question 5

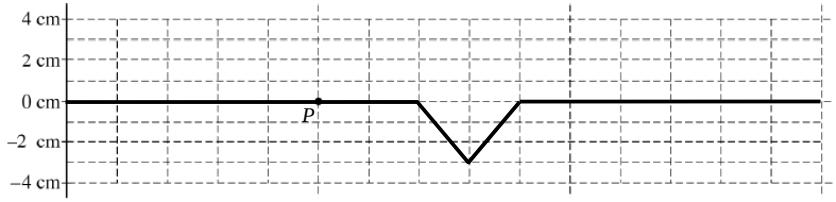
7 points total **Distribution of points**

(a) 3 points



For indicating zero velocity for $0 < t < 1$ s and 4 s $< t < 5$ s — 1 point
For indicating two different non-zero constant velocities, one at the interval 1 s $< t < 3$ s and the other at the interval 3 s $< t < 4$ s — 1 point
For indicating a maximum velocity of $+1$ cm/s and a minimum velocity of -2 cm/s — 1 point

(b) 4 points



For drawing a single pulse and zero elsewhere — 1 point
For drawing a single pulse that is triangular (need not be isosceles or of two-unit extent) — 1 point
For drawing a single pulse with the correct maximum displacement from equilibrium of -3 cm — 1 point
For drawing a single pulse at the correct location that is two units wide between the 7th and 9th grid lines (i.e., 2 grid lines to the right of P to 4 grid lines to the right of P) and zero elsewhere — 1 point

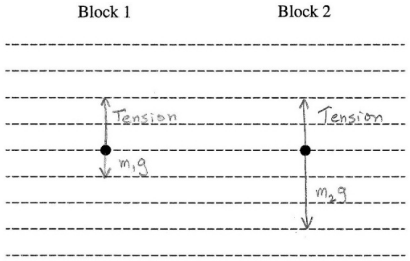
AP® Physics 1
2015 Scoring Guidelines

2015 SCORING GUIDELINES

Question 1

7 points total **Distribution of points**

(a) 2 points



For drawing two vectors starting on the dots that point upward, have the same length and are labeled as the tension force — 1 point

For drawing two vectors starting on the dots that point downward, where the vector for block 1 is smaller than the vector for block 2 and both are labeled as the gravitational force — 1 point

One earned point is deducted for drawing any extraneous vectors.

One earned point is deducted for vector lengths that do not allow the system to accelerate in the proper direction.

(b) 3 points

For writing an equation for Newton's second law for block 1 — 1 point

$m_1a = T - m_1g$

For writing an equation for Newton's second law for block 2 — 1 point

$m_2a = m_2g - T$

For eliminating T to obtain an equation that can be solved for the acceleration — 1 point

$T = m_1a + m_1g$

$m_2a = m_2g - m_1a - m_1g$

$(m_2 + m_1)a = (m_2 - m_1)g$

$a = (m_2 - m_1)g/(m_2 + m_1)$

2015 SCORING GUIDELINES

Question 1 (continued)

Distribution of points

(b) (continued)

Alternate solution — *Alternate points*

The system of two blocks must move as a unit, so the acceleration of the system is the acceleration of block 2.

For writing an equation showing that the net force acting on the system is the difference in masses times the acceleration of gravity — *1 point*

$F_{net} = (m_2 - m_1)g$

For writing an equation that relates the net force to the sum of the masses and the acceleration of the system — *1 point*

$F_{net} = (m_2 + m_1)a$

For writing an equation that can be solved for the acceleration in terms of the variables used in the summation of forces equations — *1 point*

$(m_2 + m_1)a = (m_2 - m_1)g$

$a = (m_2 - m_1)g/(m_2 + m_1)$

(c) 2 points

The acceleration of the new system, and thus of block 2, is smaller.

For indicating that the mass of the system is larger — 1 point

For a clear indication that the tension on block 2 is greater — 1 point

Alternate solution — *Alternate points*

For indicating that the mass of the system is larger — *1 point*

For indicating that the net force exerted on the system stays the same — *1 point*

Notes:

No points are earned for a correct prediction without a reasonable attempt at an explanation.

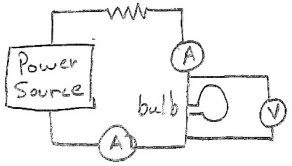
No points are earned for an incorrect prediction, regardless of the explanation.

2015 SCORING GUIDELINES

Question 2

12 points total **Distribution of points**

(a) 5 points



For drawing a circuit in which the power source, resistor, and bulb are wired in series — 1 point
For connecting at least one ammeter in series with the bulb — 1 point
For connecting the voltmeter across the bulb in parallel — 1 point
For describing measurements that can plausibly be used to answer question 1 — 1 point
Example: Measure the current entering and leaving the bulb with ammeters connected in series on either side of the bulb.
For describing measurements that can plausibly be used to answer question 2 — 1 point
Example: Measure the potential difference across the bulb with a voltmeter connected in parallel with the bulb.
The response does not need to mention multiple measurements.

(b)

(i) 1 point

For describing an analytical method of using the data, and explaining how that analytical method can be used to answer question 1 — 1 point
Example: If the current is the same on both sides of the bulb, then the number of electrons per second entering and leaving the bulb is the same.

(ii) 1 point

For describing an analytical method of using the data, and explaining how that analytical approach can be used to answer question 2 — 1 point
Example: If the potential difference across the bulb is not zero, then electrons that leave the bulb have different electric potential energy than electrons that enter it.

2015 SCORING GUIDELINES

Question 2 (continued)

Distribution of points

(c)

(i) 1 point

For any of the following: — 1 point
Describing any changes to the circuit needed to have a setup that can plausibly be used to determine whether the bulb's resistance is constant as a function of current.
Describing changes to a circuit that are not needed but do not impair the ability to determine whether the bulb's resistance is constant as a function of current.
Correctly indicating that no changes are needed.
Example based on circuit diagram in part (a): Remove one of the ammeters.

(ii) 1 point

For describing any additional measurements needed to determine whether current varies linearly as a function of voltage, or indicating that none are needed if the appropriate multiple measurements are mentioned in part (a) or (c)(i) — 1 point
Example: Measure the current through the bulb and the potential difference across the bulb for multiple settings of the power source.

(d) 3 points

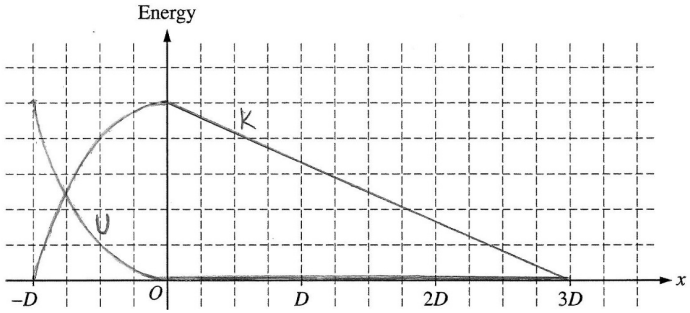
For describing an analytical method in which data are represented or manipulated in some way that can plausibly be used to determine whether current varies linearly as a function of potential difference — 1 point
Examples:
Graphing measurements of current as a function of potential difference
Calculating the ratio of current to potential difference for multiple settings of the power source
For identifying that linearity is the relevant feature for determining whether the bulb is ohmic — 1 point
Examples:
Evaluating whether a plot of current as a function of voltage is linear
Evaluating whether the ratio of current to potential difference is constant
For describing a strategy for evaluating whether the conclusion of linearity is valid for a given data set taking into account the meter uncertainties — 1 point
Examples:
Drawing error boxes that represent the uncertainties of the meters around each point and evaluating whether a straight line can be drawn that goes through all the error boxes.
Indicating that small differences in the ratios could be due to uncertainty in the meters and would not discount the conclusion that the bulb is ohmic

2015 SCORING GUIDELINES

Question 3

12 points total **Distribution of points**

(a) 4 points



For sketching either energy curve with a reasonably correct shape between $x = -D$ and $x = 0$, with zero and maximum values at the correct locations — 1 point

For sketching two curves from $x = -D$ to $x = 0$ with shapes and values such that the total energy is constant (even if the curves are incorrect) — 1 point

For sketching potential energy equal to zero from $x = 0$ to $x = 3D$ — 1 point

For sketching kinetic energy as a linear function from its maximum value at $x = 0$ to zero at $x = 3D$ — 1 point

(b)

(i) 1 point

For identifying that the student is correct that the block will have more energy when it leaves the spring — 1 point

(ii) 1 point

For identifying that the student is incorrect about the new final position of the block because the spring's energy does not scale linearly with its compression — 1 point

2015 SCORING GUIDELINES

Question 3 (continued)

Distribution of points

(c) 3 points

For indicating that the final energy in the spring (which becomes the mechanical energy of the block as it reaches the rough track) is four times the original energy in the spring — 1 point

For indicating that the frictional force remains the same — 1 point

For equating the initial energy in the spring to an expression that shows that the energy dissipated by friction is proportional to the distance the block slides down the rough track — 1 point

Example:

$U_1 = \frac{1}{2}kD^2$ and $U_2 = \frac{1}{2}k(2D)^2$ so $U_2 = 4U_1$

$W_1 = \mu mg(3D)$ and $W_2 = \mu mg\Delta x_2$

$W_1 = U_1$ and $W_2 = U_2 = 4U_1 = 4W_1$

$\mu mg\Delta x_2 = 4(\mu mg(3D))$

$\Delta x_2 = 4(3D) = 12D$

(d) 3 points

For indicating that the student's correct reasoning that the block has more energy in the second situation is expressed by the calculations comparing the initial energy in the spring — 1 point

For indicating that the student's correct reasoning that the block will slide farther is expressed by an equation that indicates that the work done by friction to stop the block in the second situation is some factor greater than the work done in the first situation — 1 point

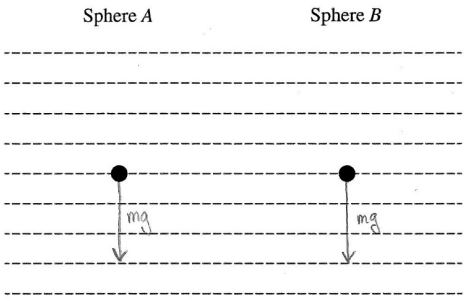
For indicating that the student's incorrect reasoning that energy scales linearly with the spring's compression is corrected by the expression for the initial energy of the spring — 1 point

2015 SCORING GUIDELINES

Question 4

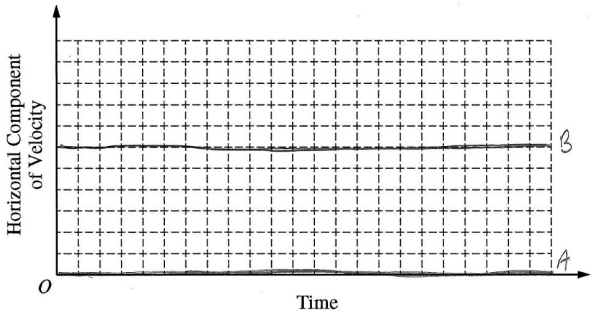
7 points total **Distribution of points**

(a) 1 point



For sketching only one force pointing straight down from each sphere and indicating that this force represents the force of gravity — 1 point

(b) 1 point



For sketching a horizontal line at zero velocity for sphere *A,* and sketching a horizontal line at some non-zero velocity for sphere *B* — 1 point

(c) 5 points

For indicating that the difference in horizontal motion does not affect the vertical motion of the spheres — 1 point
For indicating that both spheres start with the same vertical velocity — 1 point
For indicating that both spheres have the same vertical acceleration — 1 point
For indicating that falling the same height would take the same time — 1 point
For no incorrect or irrelevant statements — 1 point

2015 SCORING GUIDELINES

Question 5

7 points total **Distribution of points**

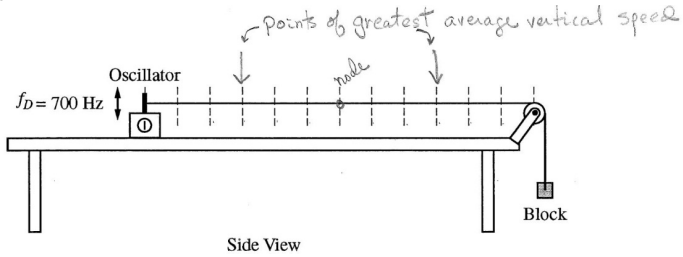
(a) 3 points

For reasoning that since the strings all have the same length, and since the wavelength of the fundamental depends on the length, all four waves have the same wavelength (e.g., $\lambda_1 = 2L$) — 1 point
For reasoning that since the wavelengths are all the same, different frequencies correspond to different velocities of the waves on the strings — 1 point
For reasoning that all the string tensions are the same due to the same mass M of each block, and therefore the linear mass densities must be different for different velocities since $v = \sqrt{F_T/(m/L)}$ (or since the vertical component of the tension will result in different vertical accelerations for strings with different masses) — 1 point
Note: Responses may refer to the physical differences between the strings in a variety of ways, e.g., different linear mass density, different total mass, different thicknesses of the same material

(b) 2 points

For combining $v = f\lambda$ with $v = \sqrt{F_T/(m/L)}$ (or referring to such an equation written in part (a)) — 1 point
For indicating how the equation leads to the conclusion that frequency would not be proportional to the inverse of the linear mass density — 1 point

(c) 2 points



For any indication of the second harmonic on the string, or a wave drawn such that $\lambda_2 = L$. — 1 point
For points which are at the antinodes of the second harmonic, or at the antinodes of any standing wave drawn on the string — 1 point
Notes:
Full credit is earned for having two points that are located one fourth the length of the string and three fourths the length of the string from the oscillator.
One earned point is deducted for each incorrect point marked on the figure