Question 1: Short Answer — 7 points

(a) For an explanation that indicates that the maximum kinetic energy and maximum potential energy are the same due to energy conservation — **1 point**

Scoring Note: This point may be earned for only stating "conservation of energy."

Example Response

The maximum kinetic energy and maximum potential energy of the car-spring system are both 4 J, because energy is conserved in this system.

Total for part (a) — 1 point

(b) For using the equation for frequency or period in a ratio — **1 point**

Example Responses

$$\frac{\frac{1}{2\pi}\sqrt{\frac{k}{m_2}}}{\frac{1}{2\pi}\sqrt{\frac{k}{m_1}}} \quad OR \quad \frac{\frac{1}{2\pi}\sqrt{\frac{k}{m_1}}}{\frac{1}{2\pi}\sqrt{\frac{k}{m_2}}} \quad OR \quad \frac{2\pi\sqrt{\frac{m_2}{k}}}{2\pi\sqrt{\frac{m_1}{k}}} \quad OR \quad \frac{2\pi\sqrt{\frac{m_1}{k}}}{2\pi\sqrt{\frac{m_2}{k}}}$$

Scoring Note: Simplified versions of the above ratios also earn this point.

For substituting the total mass $4m_0$ into the correct ratio: $\frac{f_2}{f_1}$ or $\frac{T_1}{T_2}$ — **1 point**

Example Response

$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$

$$\frac{f_2}{f_1} = \frac{\frac{1}{2\pi}\sqrt{\frac{k}{4m_0}}}{\frac{1}{2\pi}\sqrt{\frac{k}{m_0}}}$$

$$\frac{f_2}{f_1} = \frac{1}{2}$$

Total for part (b) — 2 points

(c)(i) For a valid explanation in terms of work or energy for why the systems' energies should be the same — **1 point**

Accept **one** of the following:

- No work is done on the system
- The maximum spring potential energy is the same
- The force exerted on the system is perpendicular to the direction of motion

Example Response

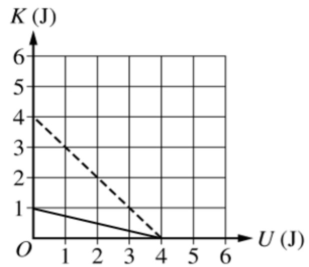
The maximum potential energy of the system does not depend upon the mass of the system, therefore there will be no change when the block is added.

(c)(ii) For drawing a single straight line with a horizontal intercept that is the same as the horizontal intercept of the original graph of 4 J — **1 point**

For drawing a line with a vertical intercept that is less than the vertical intercept in the original graph — **1 point**

For drawing a line with the correct vertical intercept of 1 J — **1 point**

Example Response



Total for part (c) — 4 points

Total for question 1 — 7 points

Question 5: Short Answer — 7 points

(a) For obtaining a period from the graph of 1.25 seconds — **1 point**

For substituting the values of period and mass into a valid equation for the spring constant — **1 point**

Example Response

$T = 1.25\text{ s}$

$T = 2\pi\sqrt{\frac{m}{k}}$

$k_0 = \frac{m}{\left(\frac{T}{2\pi}\right)^2} = \frac{0.50\text{ kg}}{\left(\frac{1.25\text{ s}}{2\pi}\right)^2} = 12.6\text{ N/m}$

Alternate Solution

For stating that the spring is stretched 0.40 m *to its equilibrium position (because the equilibrium height is* 60 cm *and the original height was* 100 cm*)* — 1 point

For substituting the amount of spring stretch and mass into a valid equation for the spring constant — 1 point

Alternate Example Response

The string is stretched 0.40 m *under a force of* $mg = 5\text{ N}$. *Because* $F = -kx$, *we have*

$k = \frac{mg}{x} = \frac{5}{0.4}\text{ N/m} = 12.5\text{ N/m}$

Total for part (a) 2 points

(b)(i) For a valid reason why the kinetic energy is the same at both times — **1 point**

Example Responses

The magnitude of the slope of the graph is the same at both times, this means the speed and, therefore, the kinetic energy is the same at both times.

OR

The object is the same distance from equilibrium at both times, so the kinetic energy must be the same.

(b)(ii) For a valid reason why the total potential energy is the same at both times — **1 point**

Example Responses

The total energy of the system is constant, so if K *is the same at both times,* U *must be also.*

OR

The total energy of the system is constant, and equal energy is transferred from gravitational potential to spring potential.

Total for part (b) 2 points

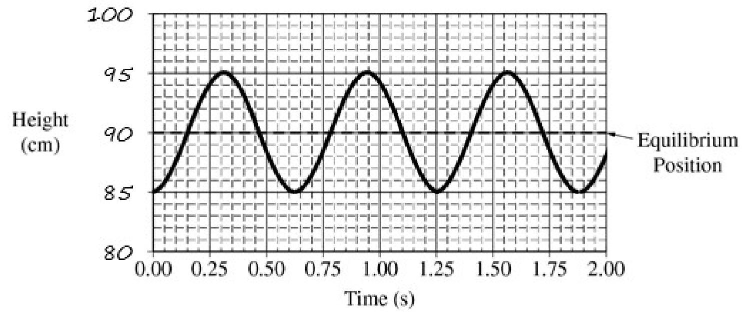
(c)(i) For writing 90 cm or 0.90 m — **1 point**

(c)(ii) For **both** of the following: — **1 point**

- a graph that has the same amplitude as the original graph
- a graph that is centered on the new equilibrium value consistent with (c)(i)

For a graph with half the period as the original graph — **1 point**

Example Response



Total for part (c) 3 points

Total for question 5 7 points

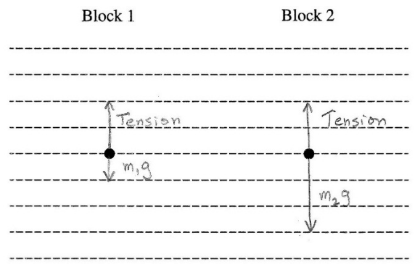
AP® Physics 1
2015 Scoring Guidelines

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.

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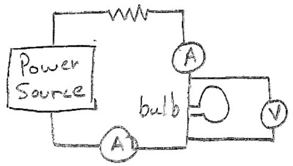
Question 2

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.

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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

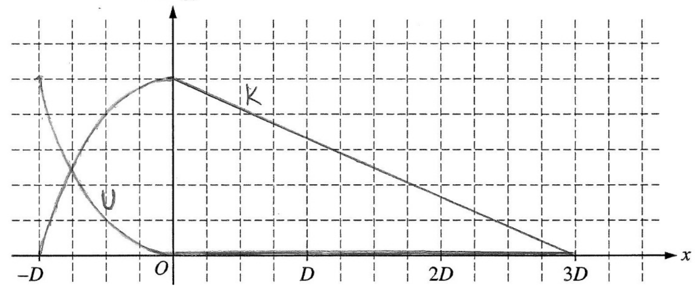
2015 SCORING GUIDELINES

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

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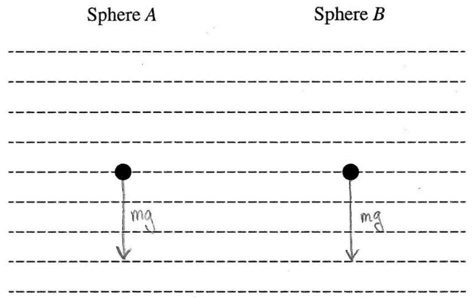
Question 4

7 points total

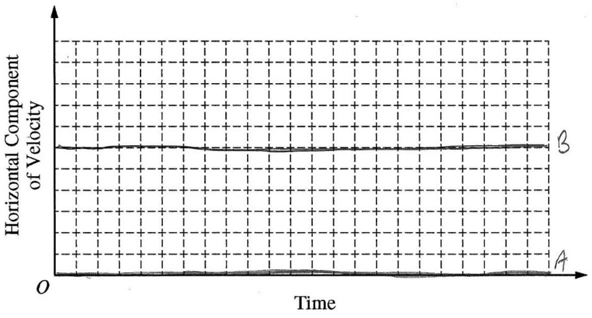
Distribution of points

(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

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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

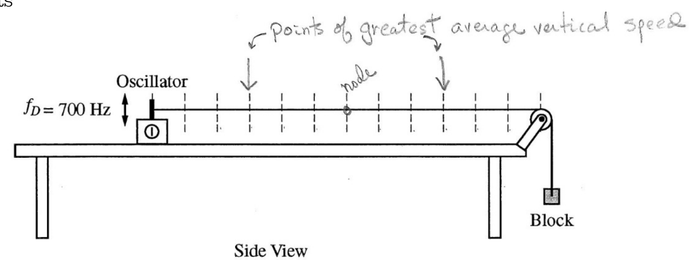
Note: Responses may refer to the physical differences between the strings in a variety of ways, e.g., different linear mass density, different total mass, different thicknesses of the same material

(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