Question 2: Translation Between Representations (TBR) — 12 points

A

For drawing one bar in Figure 2 that shows only gravitational potential energy (U_g) — **Point A1**

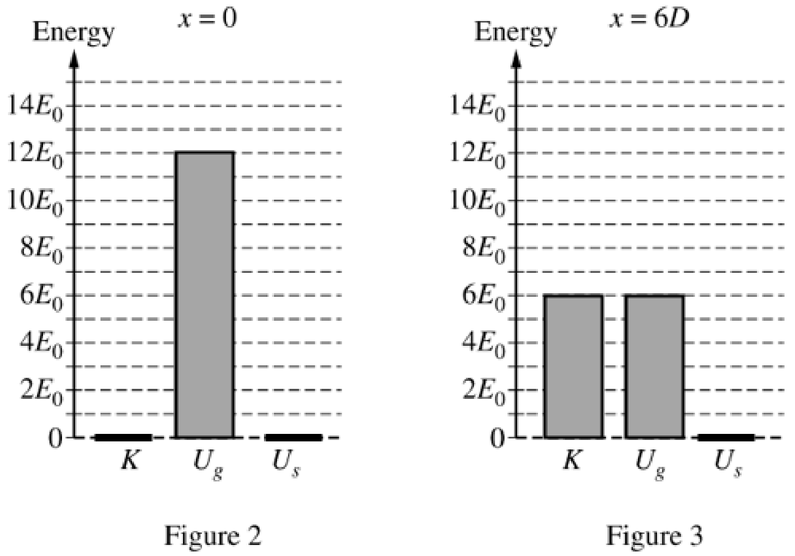
Scoring Note: The correct height of the bar is not required to earn this point.

For including only K and U_g in Figure 3 — **Point A2**

Scoring Note: The correct heights of the bars are not required to earn this point.

For drawing bars in figures 2 and 3 whose total height, respectively, equals $12E_0$ — **Point A3**

Example Response



B	For a multistep derivation that includes conservation of energy	**Point B1**
	For equating the gravitational potential energy to the spring potential energy	**Point B2**
	For **one** of the following: • Substituting $12D\sin\theta$ for Δy in a gravitational potential energy expression • Substituting $4D$ in for Δx in a spring potential energy expression	**Point B3**
	For a correct expression for k Accept any algebraic equivalent of **one** of the following: • $k = \frac{3}{2}\frac{Mg\sin\theta}{D}$ • $\frac{3}{2}\frac{Mg\sin\theta}{D}$ **Scoring Note:** A correct, isolated, final expression of $k = \frac{3}{2}\frac{Mg\sin\theta}{D}$ earns points B2, B3, and B4.	**Point B4**

Example Response

$E_0 = E_f$

$U_g = U_s$

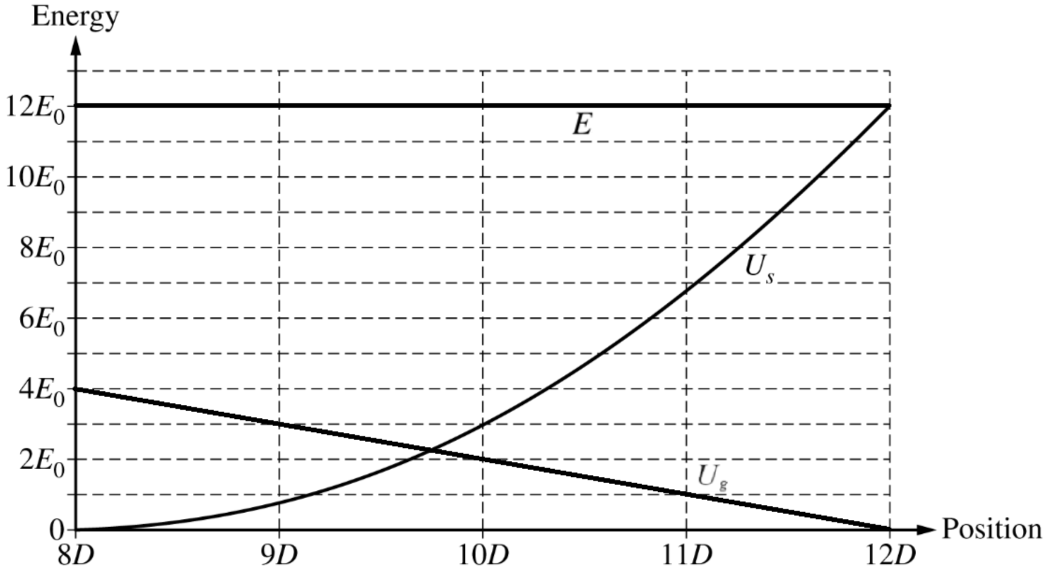
$mg\Delta y = \frac{1}{2}k(\Delta x)^2$

$Mg(12D\sin\theta) = \frac{1}{2}k(4D)^2$

$k = \frac{3}{2}\frac{Mg\sin\theta}{D}$

C	**(i)**	For sketching a horizontal line at $12E_0$, continuous from $8D$ to $12D$, with a label that indicates total mechanical energy	**Point C1**
	(ii)	For sketching a straight line that is decreasing with a label that indicates gravitational potential energy	**Point C2**
		For starting the line that represents gravitational potential energy at the point $(8D, 4E_0)$	**Point C3**

Example Response



D For **one** of the following: **Point D1**

- Indicating $v_{9D} > v_{8D}$ if the graph in part C shows $U_g + U_s$ at $x = 8D$ is **greater than** $U_g + U_s$ at $x = 9D$
- Indicating $v_{9D} < v_{8D}$ if the graph in part C shows $U_g + U_s$ at $x = 8D$ is **less than** $U_g + U_s$ at $x = 9D$
- Indicating $v_{9D} = v_{8D}$ if the graph in part C shows $U_g + U_s$ at $x = 8D$ is **equal to** $U_g + U_s$ at $x = 9D$

For a justification consistent with the graph that correctly relates the speed to the gravitational potential energy, spring potential energy, and either kinetic energy or total energy **Point D2**

Example Response

The speed at $x = 9D$ is greater than the speed at $x = 8D$. From the graph, the kinetic energy at $x = 8D$ must be $8E_0$. At $x = 9D$, the spring potential energy is $< E_0$ and the gravitational potential energy is $3E_0$, leaving $> 8E_0$ of the energy as kinetic. Therefore, the speed must be greater at $x = 9D$ than at $x = 8D$.

Question 2: Experimental Design — 12 points

(a)	For measuring the mass of at least one cylinder with the digital scale	**1 point**
	For measuring the period of oscillation of the cylinder-spring system with the stopwatch	**1 point**
	For a procedure that indicates that the cylinder hung on the spring should be set into oscillatory motion	**1 point**
	For a procedure that indicates a method to reduce experimental uncertainty	**1 point**

Accept **one** of the following:

- For using multiple masses
- For doing multiple trials with a single mass
- For measuring multiple oscillations and dividing by the number of oscillations

Example Response

Place a cylinder on the digital scale and record the mass. Hang the cylinder from the spring and pull the cylinder down a small distance so that the spring is stretched. Release the cylinder. Use the stopwatch to measure the amount of time necessary for the cylinder to complete ten full cycles (from maximum stretch length back to maximum stretch length). Repeat the procedure for cylinders of different masses.

Total for part (a) **4 points**

(b)(i) For listing quantities that can be measured with a stopwatch and a digital scale and could be plotted to produce a linear graph whose slope can be used to determine k **1 point**

Accept **one** of the following:

- m vs. T^2
- T^2 vs. m
- $4\pi^2 m$ vs. T^2
- T^2 vs. $4\pi^2 m$
- $\dfrac{T^2}{4\pi^2}$ vs. m
- m vs. $\dfrac{T^2}{4\pi^2}$
- T vs. $\sqrt{m}$
- $\sqrt{m}$ vs. T
- $\dfrac{T}{2\pi}$ vs. $\sqrt{m}$
- $\sqrt{m}$ vs. $\dfrac{T}{2\pi}$
- T vs. $2\pi\sqrt{m}$
- $2\pi\sqrt{m}$ vs. T

Scoring Note: This point may be earned for any of the bullets above substituting $\dfrac{1}{f}$ for T.

Example Response

Vertical axis: m Horizontal axis: T^2

(b)(ii) For correctly relating the slope of the best-fit line to the value of k **1 point**

Example Response

Plotting the mass as a function of the period-squared would result in a graph whose slope could be used to find k by using the equation for the period of an oscillating cylinder-spring system.

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

$$\text{slope} = \frac{k}{4\pi^2}$$

$$k = (\text{slope})4\pi^2$$

Graph	**Slope**	k
m vs. T^2	$\text{slope} = \frac{k}{4\pi^2}$	$k = (\text{slope})4\pi^2$
T^2 vs. m	$\text{slope} = \frac{4\pi^2}{k}$	$k = \frac{4\pi^2}{\text{slope}}$
$4\pi^2 m$ vs. T^2	$\text{slope} = k$	$k = \text{slope}$
T^2 vs. $4\pi^2 m$	$\text{slope} = \frac{1}{k}$	$k = \frac{1}{\text{slope}}$
$\frac{T^2}{4\pi^2}$ vs. m	$\text{slope} = \frac{1}{k}$	$k = \frac{1}{\text{slope}}$
m vs. $\frac{T^2}{4\pi^2}$	$\text{slope} = k$	$k = \text{slope}$
T vs. $\sqrt{m}$	$\text{slope} = \sqrt{\frac{4\pi^2}{k}}$	$k = \frac{4\pi^2}{\text{slope}^2}$
$\sqrt{m}$ vs. T	$\text{slope} = \sqrt{\frac{k}{4\pi^2}}$	$k = \text{slope}^2 \times 4\pi^2$
$\frac{T}{2\pi}$ vs. $\sqrt{m}$	$\text{slope} = \sqrt{\frac{1}{k}}$	$k = \frac{1}{\text{slope}^2}$
$\sqrt{m}$ vs. $\frac{T}{2\pi}$	$\text{slope} = \sqrt{k}$	$k = \text{slope}^2$
T vs. $2\pi\sqrt{m}$	$\text{slope} = \sqrt{\frac{1}{k}}$	$k = \frac{1}{\text{slope}^2}$
$2\pi\sqrt{m}$ vs. T	$\text{slope} = \sqrt{k}$	$k = \text{slope}^2$

Total for part (b) **2 points**

(c)(i) For using the kinetic energy equation $K = \frac{1}{2}mv^2$ — **1 point**

For substituting **one** of the following: — **1 point**

- 0.25 kg as the mass
- 0.3 m/s as the initial velocity

For an answer that approximates the change in kinetic energy to be $\Delta K \approx -0.0113 \text{ J}$ — **1 point**

Scoring Note: A correct response with no supporting work earns this point only.

Scoring Note: The unit and the negative sign are not required to earn this point.

Example Response

$$\Delta K = K_f - K_i$$
$$\Delta K = \frac{1}{2}mv_f^{\,2} - \frac{1}{2}mv_i^{\,2}$$
$$\Delta K = \frac{1}{2}0.25(0)^2 - \frac{1}{2}0.25(0.3)^2$$
$$\Delta K = -0.0113 \text{ J}$$

(c)(ii) For indicating the magnitude of the change in momentum is zero — **1 point**

For indicating the area under the force-time graph represents the value of the change in momentum — **1 point**

Example Response

The area under the curve for a force vs time graph represents the impulse or change in momentum. The area under the curve for 0.5 s *to* 2.5 s *is zero.*

(c)(iii) For an explanation that compares the estimated value of the change in momentum from (c)(ii) to the data from the velocity-time graph — **1 point**

Example Response

The velocity-time graph shows that velocity is 0.3 m/s *at both* 0.5 s *and* 2.5 s*, and momentum is mass times velocity, so the momentum is the same at both times. This agrees with my estimation from part (c)(ii) that the change in momentum is zero.*

Total for part (c) — 6 points

Total for question 2 — 12 points

Question 3: Experimental Design — 12 points

(a)	For listing relevant equipment that matches the measured quantities	**1 point**
	For listing measurements of quantities sufficient to determine the kinetic energy of the block	**1 point**
	For listing measurements of quantities sufficient to determine the gravitational potential energy of the block-Earth system	**1 point**
	For a plausible procedure (i.e., can be done in a typical school physics lab)	**1 point**
	For attempting to reduce uncertainty	**1 point**

Example Response

Quantity to Be Measured	Symbol for Quantity	Equipment for Measurement
Mass of block	m_B	Mass balance
Distance that block falls (initial height above floor)	d	Meterstick
Time for block to fall	t_B	Stopwatch

1. *Measure the mass of the block with the mass balance.*
2. *Hold the block in place with the string taut and measure the distance d with the meterstick.*
3. *Release the block and start the stopwatch.*
4. *Stop the stopwatch when the block hits the floor.*
5. *Record* d *and* t_B.
6. *Repeat steps* 3-5 *to get three separate trials at the same starting distance* d .
7. *Repeat steps* 2-6 *for several different starting distances* d .

Total for part (a) — 5 points

(b)	For indicating that mass and velocity are needed **Scoring Note:** This need not be the final velocity.	**1 point**
	For a valid explanation of how the final kinetic energy could be determined **Scoring Note:** This needs to be the FINAL kinetic energy.	**1 point**

Example Response

You can calculate the block's average speed by dividing $\frac{d}{t_B}$. *The block's final speed* v_F *is twice the average,* $\frac{2d}{t_B}$. *The kinetic energy* K *can then be calculated from*

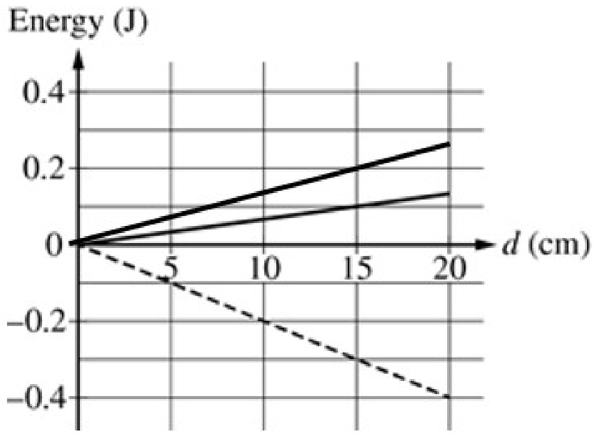
$$K = \frac{1}{2} m_B (v_F)^2 .$$

Total for part (b) — 2 points

(c)	For drawing a straight line that passes through the origin and has a positive slope	**1 point**
	For drawing a line that yields a total energy sum of zero at all values of d	**1 point**

Scoring Note: The correct line passes through the origin and (15 cm, 0.2 J).

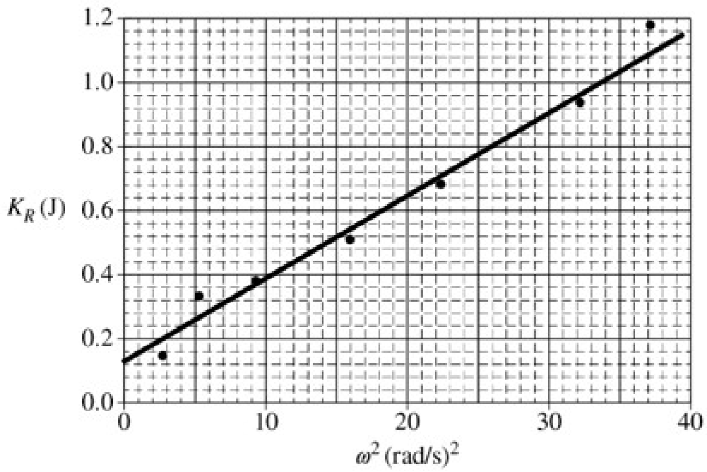
Example Response



Total for part (c) 2 points

(d)(i)	For drawing a reasonable best-fit line	**1 point**

Example Response



(d)(ii)	For correctly calculating a value for the slope using points on the line drawn, or a statement that a calculator was used to do a linear regression	**1 point**
	For **both** of the following: • correctly relating the slope of the graph to the rotational inertia • a value of the rotational inertia I consistent with the calculated slope with correct units	**1 point**

Example Response

$$\text{slope} = \frac{1.04 - 0.20}{35 - 2.5} = 0.0258 \text{ kg} \cdot \text{m}^2$$

From $K = \frac{1}{2}I\omega^2$ *, we have* $\text{slope} = \frac{1}{2}I$

The rotational inertia is $I = 2 \times \text{slope} = 0.0517 \text{ kg} \cdot \text{m}^2$

Total for part (d) 3 points

Total for question 3 12 points

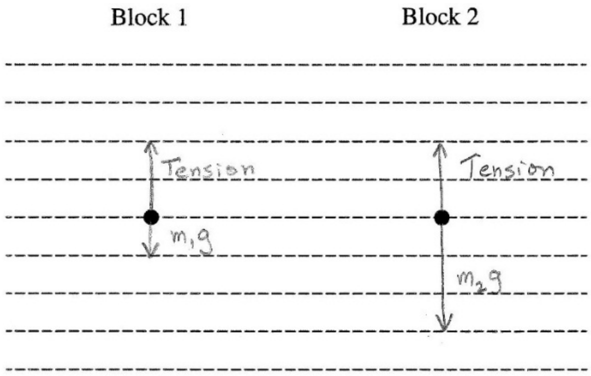
AP® Physics 1
2015 Scoring Guidelines

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

$m_1 a = T - m_1 g$

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

$m_2 a = m_2 g - T$

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

$T = m_1 a + m_1 g$

$m_2 a = m_2 g - m_1 a - m_1 g$

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

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

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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.

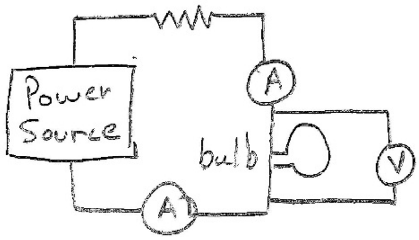
No points are earned for an incorrect prediction, regardless of the explanation.

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.	

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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

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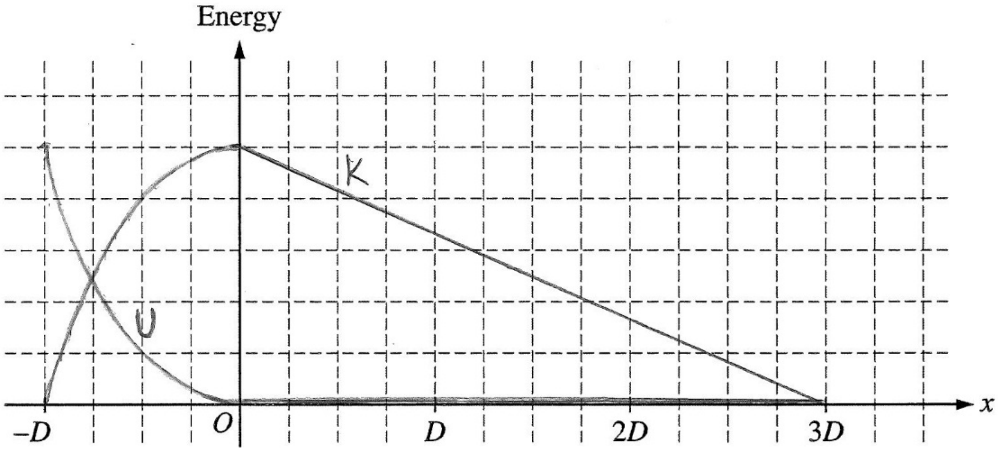
Question 3

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

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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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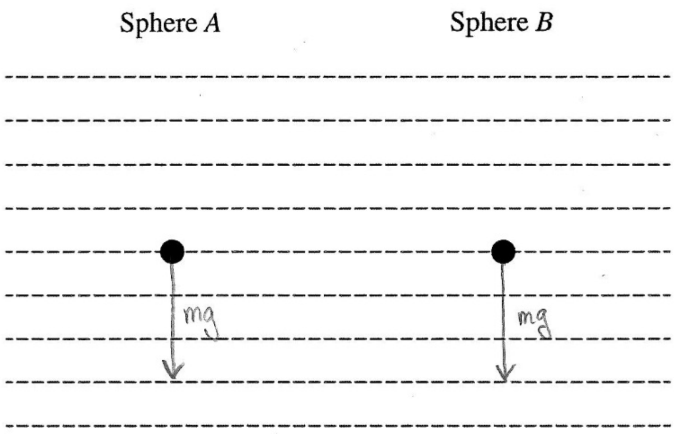
Question 4

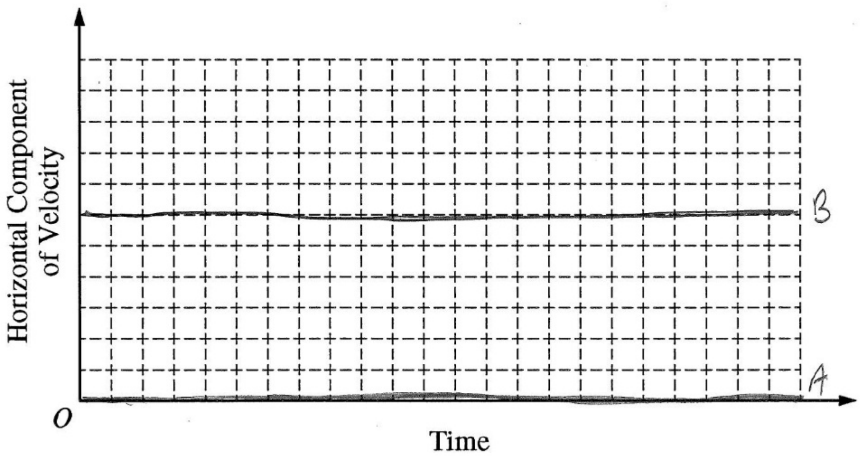
7 points total **Distribution of points**

(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

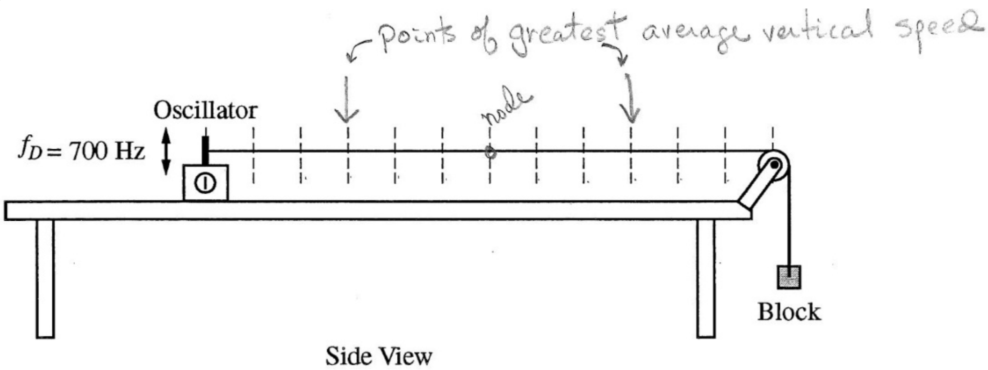
Note: Responses may refer to the physical differences between the strings in a variety of ways, e.g., different linear mass density, different total mass, different thicknesses of the same material

(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