2022

AP® CollegeBoard

AP® Physics 1: Algebra-Based

Scoring Guidelines

Question 1: Short Answer — 7 points

(a)(i) For relating the net force to acceleration or change in velocity — **1 point**

For a correct description of the relative magnitudes of the tension and gravitational forces during Block 2's motion — for both $T > W$ and $T < W$ — **1 point**

Scoring Notes: This point is not earned if the spring force is explicitly stated to be a force directly exerted on Block 2. If the spring force is mentioned, it must be connected to the string tension.

Example Response

The direction of the acceleration and the direction of the net force are the same. The block speeds up when the gravitational force is greater than the tension and then slows down because the tension becomes larger than the gravitational force.

(a)(ii) For an equation of conservation of energy that includes a gravitational potential energy term and a spring potential energy term — **1 point**

For a correct expression for Δy that depends only on M_2, k_0, and g — **1 point**

$$\Delta y = \frac{2M_2 g}{k_0}$$

Example Response

$$U_i = U_f \quad (K_i = K_f = 0)$$

$$U_{g\text{-}M_1} + M_2 g\Delta y = U_{g\text{-}M_1} + \frac{1}{2}k_0\Delta y^2$$

$$M_2 g\Delta y = \frac{1}{2}k_0\Delta y^2$$

$$M_2 g = \frac{1}{2}k_0\Delta y$$

$$\Delta y = \frac{2M_2 g}{k_0}$$

Total for part (a) — 4 points

(b) For selecting "Does not change" with a correct explanation — **1 point**

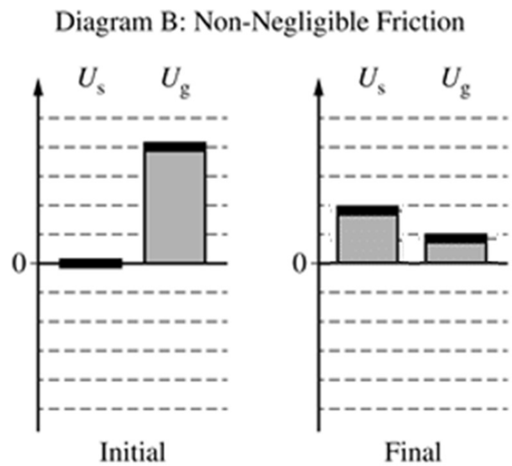
Example Response

There are no external forces on the system and no energy is dissipated by friction, so the total mechanical energy stays the same.

Total for part (b) — 1 point

(c)	For a final bar chart where both U_s and U_g are positive	**1 point**
	For a final bar chart where the sum of U_s and U_g is less than four units	**1 point**

Example Response



Total for part (c) 2 points

Total for question 1 7 points

Question 2: Qualitative/Quantitative Translation — 12 points

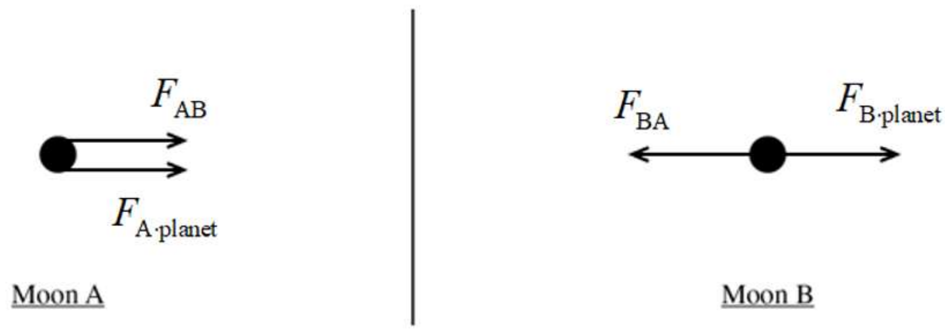
(a) For two forces directed to the right on Moon A, correctly labeled, with no extraneous forces — **1 point**

For two horizontal forces in opposite directions on Moon B. The labels on the forces must be correct and distinguishable from each other, with no extraneous forces. — **1 point**

Scoring Notes:

- Acceptable labels for forces include: F_{AB}, $F_{\text{A on B}}$, F_{planet}, F_{moon}, F_0, F_p, F_{gA}, etc.
- Maximum 1 point can be earned if the arrows do not start on the dot.

Example Response



Total for part (a) — **2 points**

(b)(i) For indicating the force vectors on Moon A point in the same direction and therefore, the magnitudes add, while the force vectors on Moon B point in opposite directions and the magnitudes are to be subtracted — **1 point**

Example Response

The force vectors on Moon A point in the same direction and therefore add, while the force vectors on Moon B point in opposite directions and will subtract.

(b)(ii) For a justification based on the inverse relation between gravitational force and distance — **1 point**

Scoring Note: This point may be earned in either part (b)(i) or (b)(ii).

For indicating Moon B is closer to the planet than Moon A, and therefore, the gravitational force exerted by the planet is larger for Moon B than for Moon A — **1 point**

Example Response

The gravitational force is greater for objects that are closer together, and Moon B is closer to the planet than Moon A, so the gravitational force from the planet is greater for Moon B than for Moon A.

Total for part (b) — **3 points**

(c)	For using the law of gravitation at least once	**1 point**
	For substituting in correct distances in all expressions	**1 point**
	For substituting in correct masses in all expressions	**1 point**
	For correctly adding terms for ΣF_A and subtracting terms for ΣF_B	**1 point**

Scoring Note: An overall negative sign on either force is acceptable.

Example Response

Moon A

$$F_g = G\frac{m_1 m_2}{r^2}$$

$$\Sigma F_A = F_{A\text{-planet}} + F_{AB}$$

$$\Sigma F_A = G\frac{m_0 m_p}{R_A^{\ 2}} + G\frac{m_0^{\ 2}}{(R_A - R_B)^2}$$

$$\Sigma F_A = Gm_0\left(\frac{m_p}{R_A^{\ 2}} + \frac{m_0}{(R_A - R_B)^2}\right)$$

Moon B

$$F_g = G\frac{m_1 m_2}{r^2}$$

$$\Sigma F_B = F_{B\text{-planet}} - F_{BA}$$

$$\Sigma F_B = G\frac{m_0 m_p}{R_B^{\ 2}} - G\frac{m_0^{\ 2}}{(R_A - R_B)^2}$$

$$\Sigma F_B = Gm_0\left(\frac{m_p}{R_B^{\ 2}} - \frac{m_0}{(R_A - R_B)^2}\right)$$

Total for part (c) 4 points

(d)(i)	For addressing the functional dependence expressed in the equations from part (c)	**1 point**

Scoring Notes:

- It is not necessary to use the functional dependence correctly to earn this point.
- This point may be earned in either part (d)(i) or (d)(ii).

	For a correct explanation for why the expressions in part (c) either support or do not support the reasoning consistent with response in part (b)(i)	**1 point**

Example Response

Yes. For the net force on Moon A, both force terms have the same sign, so they add, while for the net force on Moon B, the two terms have opposite signs, so they have a canceling effect.

(d)(ii)	For a correct explanation for why the expressions in part (c) either support or do not support the reasoning consistent with response in part (b)(ii)	**1 point**

Example Response

The gravitational force has an inverse relationship with distance. If Moon A is very far away, ΣF_A from part (c) will be small. If Moon B is close to the planet while Moon A is far away, the force toward the planet would be big while the force toward the moon would be small such that ΣF_B could be larger than ΣF_A.

Total for part (d) 3 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 — **1 point**

Scoring Note: This need not be the final velocity.

For a valid explanation of how the final kinetic energy could be determined — **1 point**

Scoring Note: This needs to be the FINAL kinetic energy.

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*

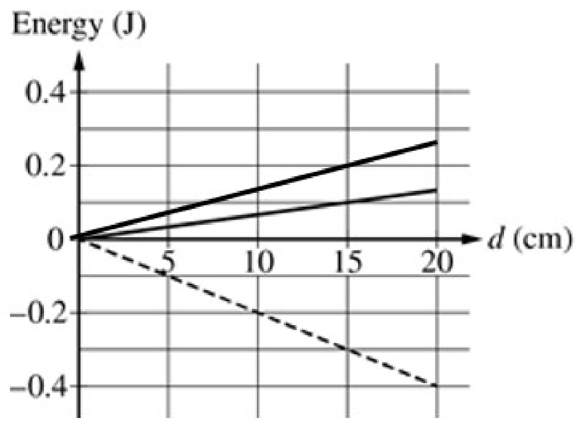
$$K = \frac{1}{2} m_B (v_F)^2 .$$

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).

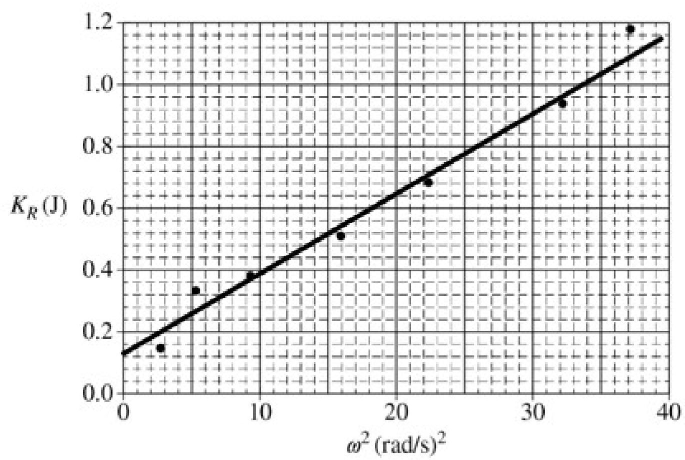
Example Response



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 $I = 2 \times \text{slope} = 0.0517\ \text{kg} \cdot \text{m}^2$

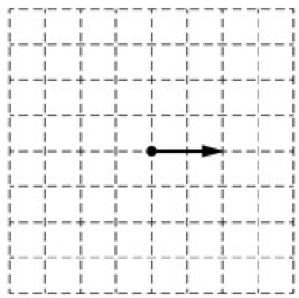
Total for part (d) 3 points

Total for question 3 12 points

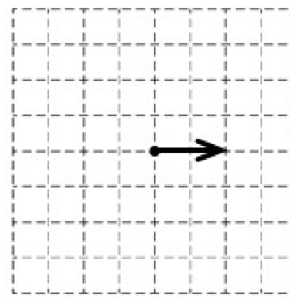
Question 4: Short Answer Paragraph Argument — 7 points

(a) For drawing an arrow representing the sphere-block momentum, two grid units in length and pointing to the right — **1 point**

Example Response



Case A: Momentum of Clay-Block System, Immediately After Collision



Case B: Momentum of Sphere-Block System, Immediately After Collision

Total for part (a) — 1 point

(b) For indicating that momentum is conserved — **1 point**

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

- why a greater amount of momentum is transferred by the rubber sphere
- why the block in Case B has greater momentum than in Case A

For indicating that a larger momentum leads to a greater speed — **1 point**

For indicating the blocks fall for the same amount of time — **1 point**

For indicating that a block moving at a faster speed lands at a greater horizontal distance — **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 Response

The momentum of the clay-block and sphere-block systems before the collision is the same for both cases and because momentum does not change in the collision; it is the same after the collision also. The sphere in Case B bounces off the block, so it has less (or negative) momentum after the collision than the clay in Case A. In order for the systems in both cases to have the same momentum after the collision, Block B must have greater momentum, and therefore greater speed, than Block A. The blocks take the same amount of time to fall, so the horizontal distance traveled by Block B (launch speed x time to fall) is greater than d_A.

Total for part (b) — 6 points

Total for question 4 — 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

$T = 1.25\ \text{s}$

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

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

Alternate Solution

For stating that the spring is stretched $0.40\ \text{m}$ *to its equilibrium position (because the equilibrium height is* $60\ \text{cm}$ *and the original height was* $100\ \text{cm}$*)* — 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 $0.40\ \text{m}$ *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.*

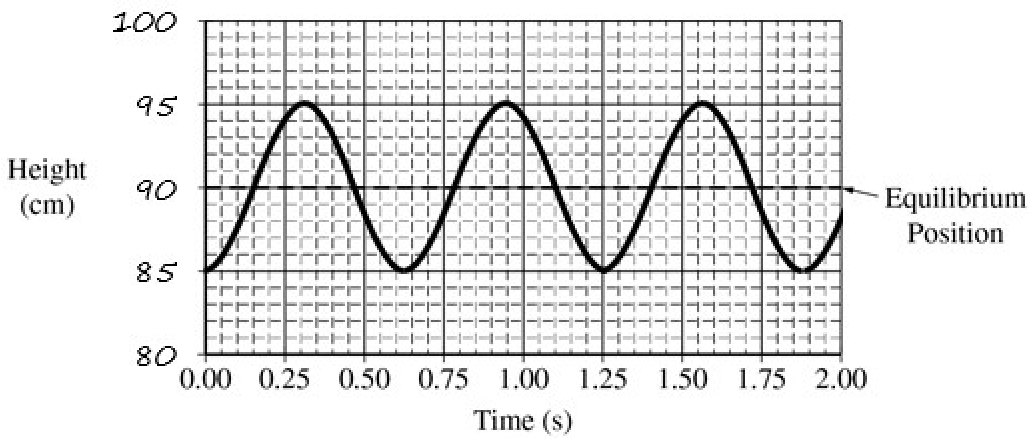
OR

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: • 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)	**1 point**
	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