2024

AP® Physics 1: Algebra-Based

Scoring Guidelines

Question 1: Short Answer — 7 points

(a) For drawing bars whose total heights add up to 6 units — **1 point**

Scoring Note: This point may be earned if only one bar is drawn.

For drawing a bar for U_g that has a height of 2 units — **1 point**

Example Response

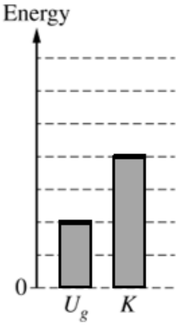


Diagram B

Total for part (a) — 2 points

(b) For a multi-step derivation that begins with conservation of energy — **1 point**

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

- The correct answer for the speed at Point B $v = \sqrt{8gR}$
- The correct substitutions for the initial and final heights
- Substitutions for initial and final heights consistent with part (a)

Example Response

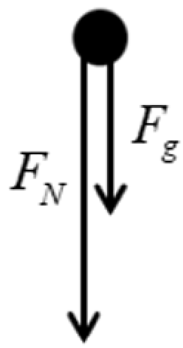
$$E_i = E_f$$
$$U_{gA} = U_{gB} + K_B$$
$$mgy_A = mgy_B + \frac{1}{2}mv^2$$
$$Mg(6R) = Mg(2R) + \frac{1}{2}Mv^2$$
$$g(6R) = g(2R) + \frac{1}{2}v^2$$
$$\frac{1}{2}v^2 = 4gR$$
$$v = \sqrt{8gR}$$

Total for part (b) — 2 points

(c)(i) For drawing a downward arrow labeled as the gravitational force **1 point**

For drawing a downward arrow labeled as the normal force **1 point**

Example Response



Scoring Note: Examples of appropriate labels for the gravitational force include F_G, F_g, F_{grav}, W, mg, Mg, "grav force," "F Earth on block," "F on block by Earth," $F_{\text{Earth on Block}}$, $F_{\text{E,Block}}$, or $F_{\text{Block,E}}$. The labels G or g are not appropriate labels for the gravitational force.

Scoring Note: Examples of appropriate labels for the normal force include F_n, F_N, N, "normal force," or "track force."

Scoring Note: Arrows of any nonzero magnitude can earn these points.

(c)(ii) For indicating **one** of the following: **1 point**

- The block must be moving at the top of the loop to remain in contact with the loop
- If the block has zero speed at Point C the block will lose contact with the loop
- The block does not have enough kinetic energy and will lose contact with the loop
- The block does not have enough momentum and will lose contact with the loop

Scoring Note: Responses that use relevant derivations may earn this point.

Example Response

If the block were released from a height $4R$ above the ground, then based on energy conservation, the block will have a speed equal to zero at Point C. If the speed is zero, the block will lose contact with the track.

Total for part (c) 3 points

Total for question 1 7 points

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. $4\pi^2 m$
- $\frac{T^2}{4\pi^2}$ vs. m
- m vs. $\frac{T^2}{4\pi^2}$
- T vs. $\sqrt{m}$
- $\sqrt{m}$ vs. T
- $\frac{T}{2\pi}$ vs. $\sqrt{m}$
- $\sqrt{m}$ vs. $\frac{T}{2\pi}$
- 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 $\frac{1}{f}$ 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: • 0.25 kg as the mass • 0.3 m/s as the initial velocity	**1 point**
	For an answer that approximates the change in kinetic energy to be $\Delta K \approx -0.0113$ J **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.	**1 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

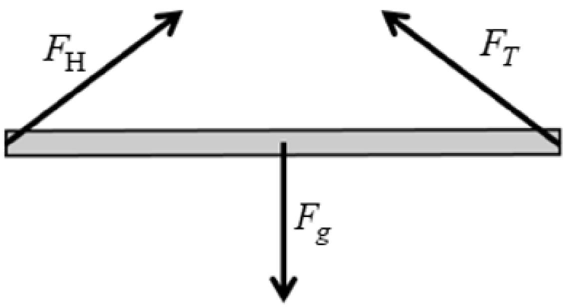
Question 3: Qualitative/Quantitative Translation — 12 points

(a) For drawing the gravitational force at the center of the beam that is directed downward — **1 point**

For drawing the tension force at the right end of the beam that is directed upward and leftward — **1 point**

For a diagram with three force vectors that represent a system in equilibrium — **1 point**

Example Response



Scoring Note: Examples of appropriate labels for the gravitational force include F_G, F_g, F_{grav}, W, mg, Mg, "grav force," F Earth on beam," "F on beam by Earth," $F_{\text{Earth on Beam}}$, $F_{\text{E,Beam}}$, or $F_{\text{Beam,E}}$. The labels G or g are not appropriate labels for the gravitational force.

Scoring Note: Examples of appropriate labels for the normal force include F_n, F_N, N, "normal force," or "wall force."

Scoring Note: Examples of appropriate labels for the tension force include F_{string}, F_s, F_T, F_{Tension}, "string force," or "tension force."

Total for part (a) — 3 points

(b) For selecting "$F_{T2} > F_{T1}$" with an attempt at a relevant justification — **1 point**

For a justification that includes **one** of the following: — **1 point**

- For relating the vertical component of the tension in the string to the weight of the bar
- For relating the force needed to exert the same torque to the angle of the string

Example Response

In order for the beam to remain horizontal and at equilibrium, the torque exerted by the string must remain the same for all angles. When the angle decreases, the perpendicular component of the tension remains the same. Therefore, the tension in the string is greater for a smaller angle.

Total for part (b) — 2 points

(c)	For a multi-step derivation that begins with Newton's second law for rotation, $\Sigma\tau = I\alpha$ or $\Sigma\tau = 0$	**1 point**
	For indicating **one** of the following: • The net torque is zero • The net force is zero	**1 point**
	For indicating **one** of the following: • The magnitude of the torque from the string is $(F_T \sin\theta)L$ • The magnitude of the torque from the weight of the beam is $Mg\frac{L}{2}$ • The correct answer, $F_T = \frac{Mg}{2\sin\theta}$	**1 point**

Example Response

$\Sigma\tau = I\alpha$

$\tau_{\text{gravity}} + \tau_{\text{string}} = 0$

$\left(F_g\right)\frac{L}{2}\left(\sin 90^\circ\right) - F_T(L)\sin\theta = 0$

$Mg\frac{L}{2} = (F_T \sin\theta)L$

$F_T = \frac{Mg}{2\sin\theta}$

Total for part (c) 3 points

(d)	For an attempt to use functional dependance to relate the derivation in part (c) to the reasoning used in part (b) **Scoring Note:** The functional dependance does not need to be used correctly to earn this point.	**1 point**
	For an explanation that correctly relates the derivation in part (c) to the reasoning used in part (b)	**1 point**

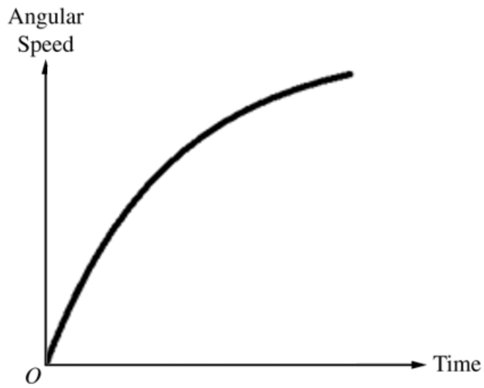
Example Response

The equation agrees with my explanation because my equation shows that the tension is inversely proportional to $\sin\theta$ *and for* $\theta < 90^\circ$, $\sin\theta$ *decreases as* θ *decreases, so the tension would be greater for smaller angles.*

Total for part (d) 2 points

(e)	For drawing a graph that is monotonically increasing	**1 point**
	For drawing a concave down curve	**1 point**

Example Response



Total for part (e) 2 points

Total for question 3 12 points

Question 4: Paragraph — 7 points

(a) For indicating **one** of the following: **1 point**

- That the gravitational force would be smaller for a greater radius
- That the gravitational field strength would be smaller for a greater radius
- That the acceleration due to gravity would be smaller for a greater radius

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

- The sphere travels the same vertical distance in both scenarios
- The amount of work done on the sphere is dependent on the magnitude of the gravitational force
- The change in gravitational potential energy is less on Planet X

Example Response

The mass is the same and the radius is larger, so the force of gravity is less. The work done depends on the force times distance. Because the distance is the same, the work is less.

Total for part (a) 2 points

(b)	For relating a larger planetary mass to a **one** of the following: • A larger weight of the sphere • A larger acceleration due to gravity g • A larger gravitational field strength	**1 point**
	For indicating that the period is inversely related to **one** of the following: • The acceleration due to gravity g • The gravitational field strength	**1 point**
	For indicating that the amount of stretch is dependent on **one** of the following: • The weight of the sphere • The acceleration due to gravity g • The gravitational field strength	**1 point**
	For relating the length of the string to the period of the pendulum	**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

$T = 2\pi\sqrt{\frac{\ell}{g}}$. On Planet Y the gravitational force on the sphere is larger than when on Earth. Therefore, the sphere will experience a larger acceleration due to gravity on Planet Y. Because "g" is in the denominator of the equation, a larger acceleration due to gravity leads to a potentially smaller period. However, the increased gravitational force exerted on the sphere by Planet Y could result in the string stretching. This could result in the length of the pendulum increasing. Because T increases with the length of the pendulum, a longer string could potentially lead to a larger period.

Total for part (b) 5 points

Total for question 4 7 points

Question 5: Short Answer — 7 points

(a) For determining the speed of Block B to be 3 m/s — **1 point**

Example Response

$$\frac{1}{2}(2\text{ kg})v_f^{\,2} = 9\text{ J}$$
$$v_f = 3\text{ m/s}$$

Total for part (a) — 1 point

(b) For drawing and labeling a straight line for the position of Block A with a lesser positive slope than the slope of its pre-collision line — **1 point**

Scoring Note: The correct slope is not required to earn this point.

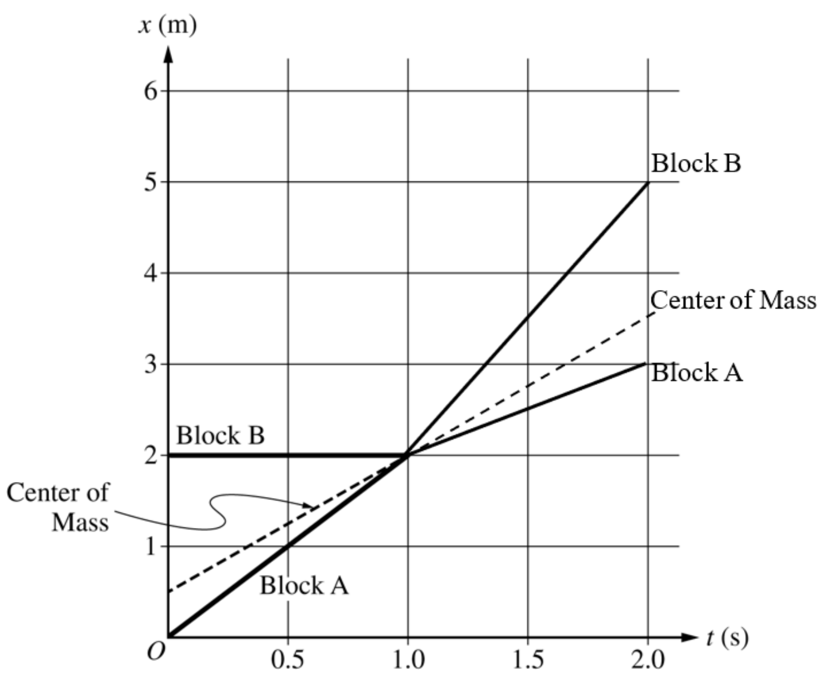
For drawing and labeling a straight line for the position of Block B with a positive, nonvertical slope — **1 point**

Scoring Note: The correct slope is not required to earn this point.

For drawing a straight line for the center of mass of the two-block system position with the same slope as the pre-collision line — **1 point**

For drawing lines for Block A and Block B with the correct slopes, 1 m/s and 3 m/s, respectively, that begin at $t = 1.0$ s and $x = 2$ m — **1 point**

Example Response



Total for part (b) — 4 points

(c)	For indicating the line drawn for the center of mass of both two-block systems is the same	**1 point**
	For an explanation that indicates **one** of the following: • Momentum is conserved in an inelastic collision • No external forces exerted on the two-block system	**1 point**
	Example Response *The slope of the line drawn for the center of mass would remain the same as the that of the elastic collision because momentum is conserved. The lines for Block* A *and Block* B *would lie along the center of mass line because the blocks slide together.*	
	Total for part (c)	**2 points**
	Total for question 5	**7 points**