

AP[®] Physics C: Mechanics Scoring Guidelines

Question 1: Mathematical Routines (MR)

10 points

A (i) For drawing only one arrow for the momentum of Block 2 before the collision that points leftward and is 6 units long **Point A1**

For drawing only identical arrows for the momentum of the two-block system before and after the collision that are equal to the sum of the momentums drawn for blocks 1 and 2 before the collision **Point A2**

Example Response

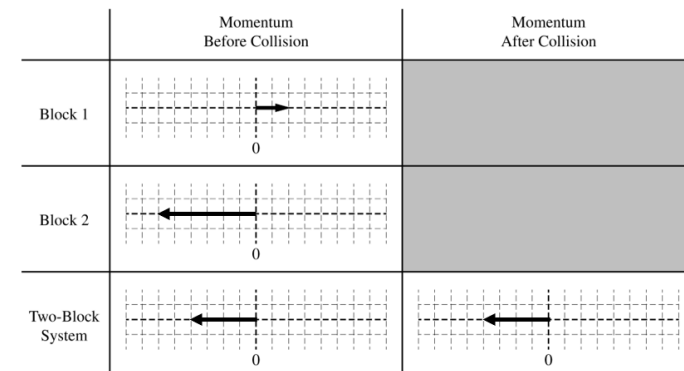


Figure 2

(ii) For a multistep derivation that includes the integral form of impulse or the differential form of Newton's second law **Point A3**

For indicating **one** of the following: **Point A4**

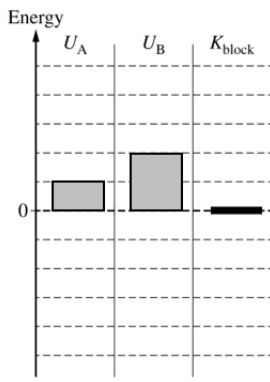
- The final speed of Block 1 or Block 2 is $\frac{4}{7}v_0$.
- The change in the momentum of Block 2 is $+\frac{18}{7}mv_0$.
- The change in the momentum of Block 1 is $-\frac{18}{7}mv_0$.
- The change in the velocity of Block 2 is $+\frac{3}{7}v_0$.
- The change in the velocity of Block 1 is $-\frac{18}{7}v_0$.

For substituting the given expression for $F(t)$ into an expression for the impulse exerted on either block or the differential form of Newton's second law **Point A5**

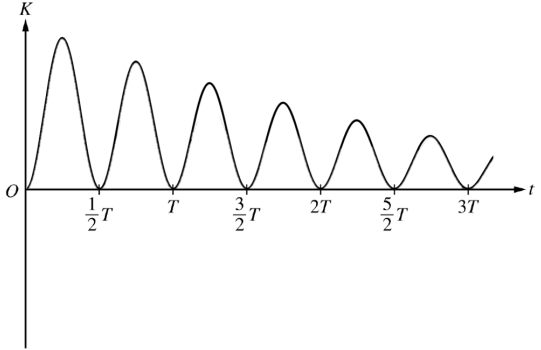
For an integral with appropriate limits or a constant of integration **Point A6**

For a correct expression for F_{max} in terms of given quantities **Point A7**

Example Responses		
$\vec{J} = \int_{t_1}^{t_2} \vec{F}_{\text{net}}(t) dt = \Delta \vec{p} \quad \text{OR} \quad \vec{F}_{\text{net}} = \frac{d\vec{p}}{dt} \quad \int \vec{F}_{\text{net}} dt = \Delta \vec{p}$		
$\sum \vec{p}_0 = \sum \vec{p}_f$ $(m)(2v_0) + (6m)(-v_0) = (m + 6m)(v_f)$ $v_f = -\frac{4}{7}v_0$		
$\Delta p_{\text{Block 2}} = -\Delta p_{\text{Block 1}} = 6m\left(-\frac{4}{7}v_0 - (-v_0)\right)$		
$\Delta p_{\text{Block 2}} = \int_0^{t_c} F_{\text{max}} \sin(At) dt$		
$\frac{18}{7}mv_0 = \frac{F_{\text{max}}}{A} [-\cos(At)]_0^{t_c}$ $\frac{18}{7}mv_0 = \frac{F_{\text{max}}}{A} [1 - \cos(At_c)]$		
$F_{\text{max}} = \frac{18}{7} \left(\frac{Amv_0}{1 - \cos(At_c)} \right)$		
B	For a multistep derivation that includes conservation of momentum	Point B1
	For indicating that the magnitude of the final momentum of the two-block system is $7mv_0$	Point B2
	For a correct expression for v_1 in terms of v_0	Point B3
Example Response		
$\sum \vec{p}_0 = \sum \vec{p}_f$ $mv_1 + 6m(-v_0) = 7m(v_0)$ $mv_1 = 13mv_0$ $v_1 = 13v_0$		

Question 2: Translation Between Representations (TBR)		12 points
A	For indicating that K_{block} is zero	Point A1
	For drawing bars with positive heights for U_A and U_B	Point A2
	For drawing a bar for U_B with a height that is twice the height of the bar drawn for U_A	Point A3
Scoring Note: This point may be earned regardless of the signs of either bar.		
Example Response		
		
Figure 3		
B	For a multistep derivation that includes energy conservation or simple harmonic motion	Point B1
	For relating the presence of both springs to the behavior of the system	Point B2
	For relating positions $x = x_1$ and $x = \frac{1}{2}x_1$ to the oscillation of the block	Point B3
	For a correct expression for v in terms of given quantities	Point B4

Example Responses		
$E_{\text{tot},0} = U_A(x_1) + U_B(x_1) + K_{\text{block}}(x_1)$		$x = x_{\text{max}} \cos(\omega t + \phi)$
$E_{\text{tot},f} = U_A\left(\frac{1}{2}x_1\right) + U_B\left(\frac{1}{2}x_1\right) + K_{\text{block}}\left(\frac{1}{2}x_1\right)$		$x(t) = x_1 \cos \omega t$
		$v(t) = -x_1 \omega \sin \omega t$
$E_{\text{tot},0} = \frac{1}{2}(k)(x_1)^2 + \frac{1}{2}(2k)(x_1)^2 + 0$	OR	$k_{\text{eff}} = k + 2k = 3k$
$E_{\text{tot},f} = \frac{1}{2}(k)\left(\frac{1}{2}x_1\right)^2 + \frac{1}{2}(2k)\left(\frac{1}{2}x_1\right)^2 + K_{\text{block}, \frac{1}{2}x_1}$		$\omega = \sqrt{\frac{3k}{m}}$
$E_{\text{tot},0} = E_{\text{tot},f}$		$\frac{x_1}{2} = x_1 \cos \omega t_{\frac{1}{2}x_1}$
$\frac{1}{2}kx_1^2 + kx_1^2 = \frac{1}{8}kx_1^2 + \frac{1}{4}kx_1^2 + K_{\text{block}, \frac{1}{2}x_1}$		$\cos \omega t_{\frac{1}{2}x_1} = \frac{1}{2}$
$\frac{3}{2}kx_1^2 = \frac{3}{8}kx_1^2 + K_{\text{block}, \frac{1}{2}x_1}$		$t_{\frac{1}{2}x_1} = \frac{\pi}{3\omega}$
$K_{\text{block}, \frac{1}{2}x_1} = \frac{9}{8}kx_1^2$		$v_{\frac{1}{2}x_1} = -x_1 \omega \sin \omega t_{\frac{1}{2}x_1}$
$\frac{1}{2}mv^2 = \frac{9}{8}kx_1^2$		$v_{\frac{1}{2}x_1} = -x_1 \sqrt{\frac{3k}{m}} \sin \frac{\pi}{3}$
$v = \frac{3}{2}x_1 \sqrt{\frac{k}{m}}$		$v = \left v_{\frac{1}{2}x_1}\right = \frac{3}{2}x_1 \sqrt{\frac{k}{m}}$

C	For sketching a curve that starts at zero and is always positive or zero	Point C1
	For sketching a periodic curve with zeros that have a period of $\frac{1}{2}T$	Point C2
	For sketching a periodic curve with a decreasing amplitude	Point C3
Example Response		
		
Scenario 2		
Figure 5		
D	For indicating one of the following: - The period increases. - The rate at which the graph approaches zero increases. - The maximum value of K over each period is less than the graph drawn.	Point D1
	For a correct justification relevant to the feature indicated	Point D2
Example Responses		
<i>The period of the graph increases. The period of a simple harmonic oscillator increases with increasing mass.</i>		
OR		
<i>The rate at which the graph approaches zero amplitude increases. Because the mass of the block is larger, the force of friction is greater, which causes the block to lose energy at a greater rate.</i>		

Question 3: Experimental Design and Analysis (LAB) 10 points

A

For describing a procedure that includes measuring h and the speed of the block as the block moves across the surface

For a procedure that indicates a reasonable method of reducing experimental uncertainty

Examples of acceptable responses may include the following:

- Repeating the experiment multiple times for the same value of h
- Repeating the experiment for multiple values of h

Example Response

Measure the height h at which the block-box system is released. Measure the speed of the block as the block slides across the horizontal surface. Repeat the measurement of the speed of the block for varying release heights.

Point A1

Point A2

B

For describing a graph that has linear trend that can be used to find g

Examples of acceptable responses include the following:

- v^2 vs. $2h$
- $\frac{1}{2}v^2$ vs. h
- v^2 vs. h
- v vs. $\sqrt{h}$

Scoring Notes:

- Responses that include the reciprocals of the preceding examples, in addition to other equivalent graphs, also earn this point.
- This point may be earned independently of the response in part A.

For correctly relating the slope of the best-fit line to g

Examples of acceptable responses include the following:

Graph	Analysis
v^2 vs. $2h$	slope = g
$\frac{1}{2}v^2$ vs. h	slope = g
v^2 vs. h	slope = $2g$
v vs. $\sqrt{h}$	slope = $\sqrt{2g}$

Example Response

Plot v^2 on the vertical axis and $2h$ on the horizontal axis. The slope of the best-fit line is equal to g .

Point B1

Point B2

C

(i) For indicating appropriate quantities that could be plotted to produce a linear graph that can be used to determine μ , such as h vs. x_{max}

Scoring Note: Responses that include the reciprocal of the preceding example, in addition to other equivalent graphs, also earn this point.

(ii) For labeling the axes (including units) with a linear scale

For plotting data points consistent with **one** of the following:

- The quantities indicated in part C (i)
- The quantities provided in Table 2
- The axes indicated on the grid

(iii) For drawing a line or curve that approximates the trend of the plotted data

Point C1

Point C2

Point C3

Point C4

Example Response

D	For correctly relating the slope of the best-fit line to the value of μ Examples of acceptable responses includes the following:	Point D1				
	<table> <tr> <th>Graph</th><th>Analysis</th></tr> <tr> <td>h vs. x_{max}</td><td>slope = μ</td></tr> </table>	Graph	Analysis	h vs. x_{max}	slope = μ	
Graph	Analysis					
h vs. x_{max}	slope = μ					
	For a value of μ within a range of 0.30 to 0.50	Point D2				
Example Response						
$E_0 + W = E_f$						
$mgh - F_f x_{\text{max}} = 0$						
$mgh = \mu mg x_{\text{max}}$						
$h = \mu x_{\text{max}}$						
$y = mx + b$						
$h = \mu x_{\text{max}}$						
slope = μ						
slope = $\frac{0.95 \text{ m} - 0.30 \text{ m}}{2.4 \text{ m} - 0.70 \text{ m}}$						
slope = 0.38						
$\mu = \text{slope} = 0.38$						

Question 4: Qualitative Quantitative Translation (QQT)		8 points
A	For indicating $f_D < f_R$	Point A1
	For a justification that compares one of the following: - The motions of the disk and the ring using translational kinematics - The motions of the disk and the ring using rotational kinematics - The rotational inertias of the disk and the ring	Point A2
	For a justification that includes one of the following: - Reasoning that attempts Newton’s second law in translational form - Reasoning that attempts Newton’s second law in rotational form - Reasoning that attempts conservation of energy	Point A3
Example Response		
<i>The ring has a greater rotational inertia because it has more mass distributed towards the edge. So the ring travels farther and has less acceleration down the ramp. Because the ring and the disk have the same mass, the gravitational forces exerted on the shapes are the same. From Newton’s second law, the ring must have less net force down the ramp and more friction up the ramp.</i>		
B	For a multistep derivation that includes Newton’s second law in both translational and rotational forms	Point B1
	For indicating opposite signs for the gravitational force and frictional force in an expression for Newton’s second law	Point B2
	For using the relationship $a = r\alpha$ in an attempt to solve a system of equations	Point B3
Scoring Note: Responses that include conservation of energy may earn full credit.		
Example Response		
$\alpha_{\text{sys}} = \frac{\sum \tau}{I_{\text{sys}}}$ $\left(\frac{a}{R}\right) = \frac{fR}{I}$ $a = \frac{fR^2}{I}$ $\tilde{a}_{\text{sys}} = \frac{\sum \tilde{F}}{m_{\text{sys}}}$ $f - Mg \sin \theta = -Ma$ $f - Mg \sin \theta = -M \frac{fR^2}{I}$ $f + M \frac{fR^2}{I} = Mg \sin \theta$ $f \left(1 + \frac{MR^2}{I}\right) = Mg \sin \theta$ $f = \frac{Mg \sin \theta}{1 + \frac{MR^2}{I}}$		

C	For indicating “Equal to”	Point C1
	For a justification that includes that kinetic friction is only dependent on the surfaces (or equivalently, the coefficient of kinetic friction between those surfaces) and normal force	Point C2
	Example Response <i>The forces of kinetic friction are equal. If slipping, the friction is kinetic, and the force of kinetic friction on the hoop and the disk are the same because the coefficient of kinetic friction is only dependent on the surfaces, and the normal forces on both are the same.</i>	