2024

AP® Physics 1: Algebra-Based

Sample Student Responses and Scoring Commentary

Inside:

Free-Response Question 5

- ☑ **Scoring Guidelines**
- ☑ **Student Samples**
- ☑ **Scoring Commentary**

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.

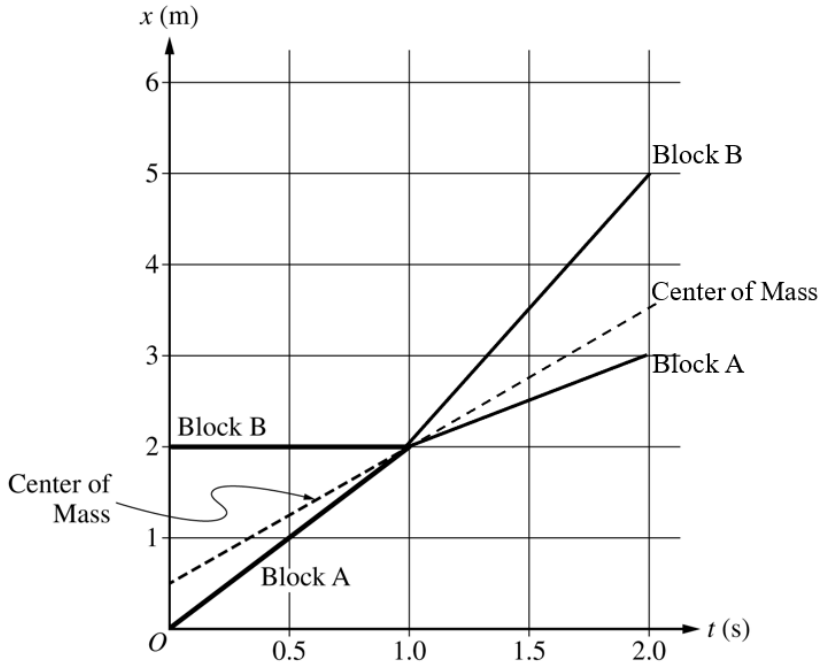
For drawing and labeling a straight line for the position of Block B with a positive, nonvertical slope — **1 point**

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**

Question 5

Begin your response to **QUESTION 5** on this page.

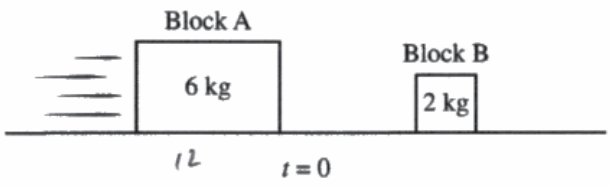


Figure 1

5. (7 points, suggested time 13 minutes)

At time $t = 0$, Block A slides along a horizontal surface toward Block B, which is initially at rest, as shown in Figure 1. The masses of blocks A and B are 6 kg and 2 kg, respectively. The blocks collide elastically at $t = 1.0$ s, and as a result, the magnitude of the change in kinetic energy of Block B is 9 J. All frictional forces are negligible.

(a) **Determine** the speed of Block B immediately after the collision.

Elastic = KE is conserved. P is conserved.

$P_i = P_f$

$m_A v_i = m_A v_{f_1} + m_B v_{f_2}$

$KE_i = KE_f$

$\frac{1}{2} m_A v_i^2 = \frac{1}{2} m_A v_{f_1}^2 + \frac{1}{2} m_B v_{f_2}^2 \rightarrow \frac{1}{2} m_B v_{f_2}^2 = 9$

ΔKE of block B = 9

$\frac{1}{2}(2) v_{f_2}^2 = 9$

$\frac{1}{2} m_B v_{f_2}^2 = \Delta KE$

$v_{f_2} = \sqrt{\frac{2\Delta KE}{m_B}} = \sqrt{\frac{2 \cdot 9}{2}} = 3 \text{ m/s}$

$v_{f_2} = 3$ m/s (can't go left)

Block B is moving at 3 m/s

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Question 5

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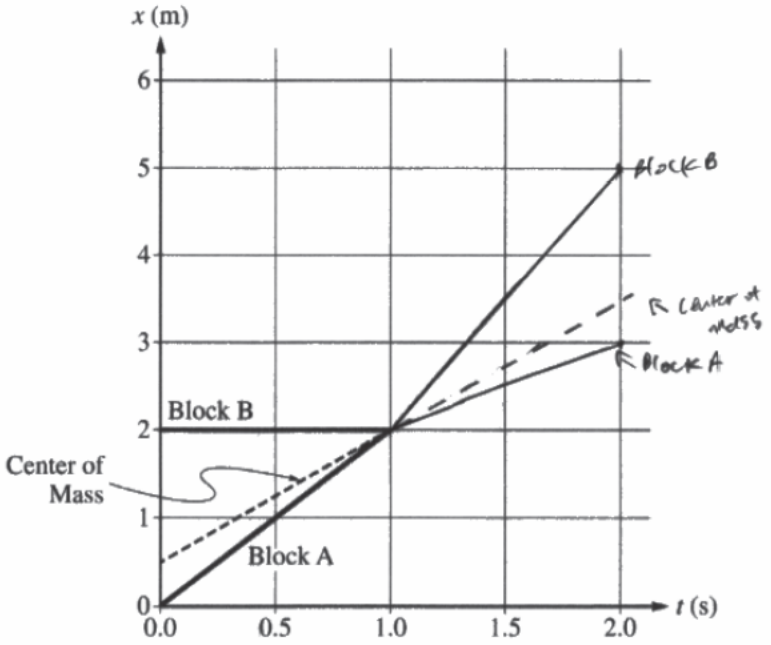

Figure 2

The graph shown in Figure 2 represents the positions x of Block A, Block B, and the center of mass of the two-block system as functions of t between $t = 0$ and $t = 1.0$ s.

(b) On the graph in Figure 2, **draw** and **label** three lines to represent the positions of Block A, Block B, and the center of mass of the two-block system as functions of t between $t = 1.0$ s and $t = 2.0$ s. Each line should be distinctly labeled.

(c) Consider if in the original scenario, instead of colliding elastically, the blocks collided and stuck together. **Describe** how the line drawn for the center of mass in part (b) would change, if at all. Briefly **justify** your response.

It would not change as momentum is still conserved, so as there are no external forces acting on the system, the systems velocity, v_{cm}, must change after the collision.

$F_{ext}=0 \rightarrow a_{cm}=0$ (v_{cm} is constant

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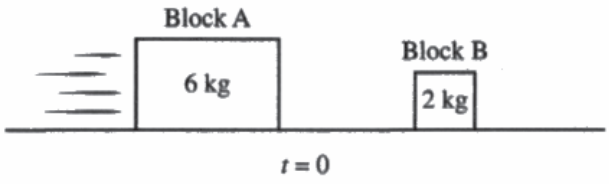

Figure 1

5. **(7 points, suggested time 13 minutes)**

At time $t = 0$, Block A slides along a horizontal surface toward Block B, which is initially at rest, as shown in Figure 1. The masses of blocks A and B are 6 kg and 2 kg, respectively. The blocks collide elastically at $t = 1.0$ s, and as a result, the magnitude of the change in kinetic energy of Block B is 9 J. All frictional forces are negligible.

(a) **Determine** the speed of Block B immediately after the collision.

$KE_{fB} = 9J$

$9 = \frac{1}{2} m v_B^2$

$\sqrt{\frac{18}{m}} = v_B$

$\sqrt{\frac{18}{2}} = v_B$

$v_B = 3 m/s$

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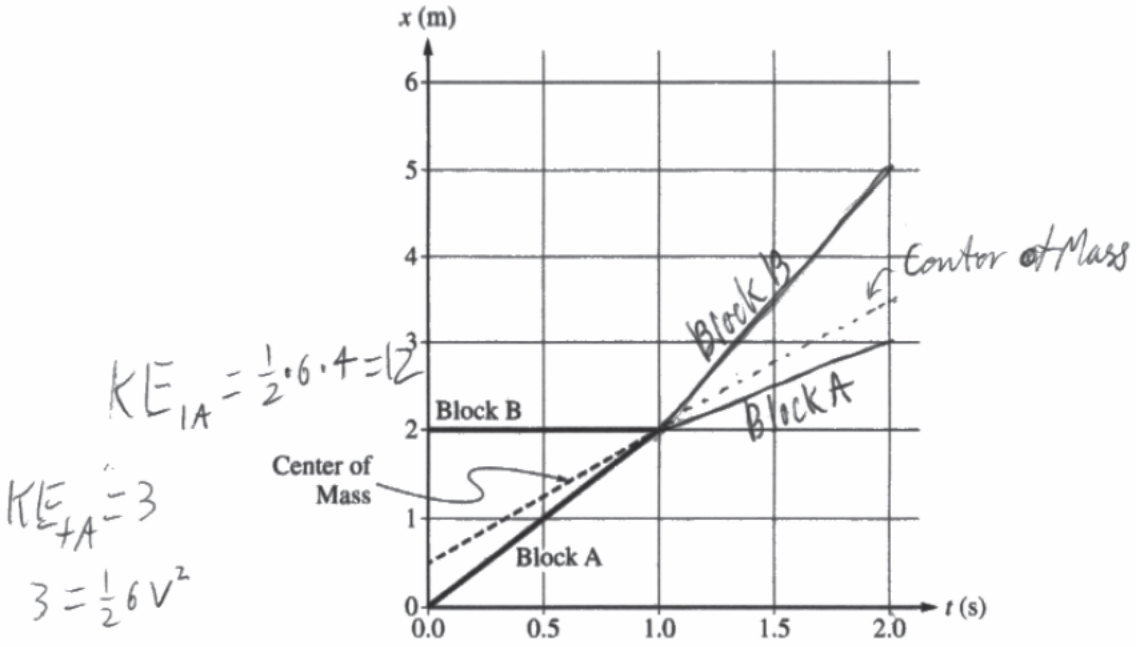

$KE_{1A} = \frac{1}{2} \cdot 6 \cdot 4 = 12$

$KE_{+A} = 3$

$3 = \frac{1}{2} 6 v^2$

Figure 2

The graph shown in Figure 2 represents the positions x of Block A, Block B, and the center of mass of the two-block system as functions of t between $t = 0$ and $t = 1.0$ s.

(b) On the graph in Figure 2, **draw** and **label** three lines to represent the positions of Block A, Block B, and the center of mass of the two-block system as functions of t between $t = 1.0$ s and $t = 2.0$ s. Each line should be distinctly labeled.

(c) Consider if in the original scenario, instead of colliding elastically, the blocks collided and stuck together. **Describe** how the line drawn for the center of mass in part (b) would change, if at all. Briefly **justify** your response.

If the Blocks stuck together, KE would not be conserved. ∴ the ~~speed~~ velocity (slope of line) would be less, leading to a less steep line.

Question 5

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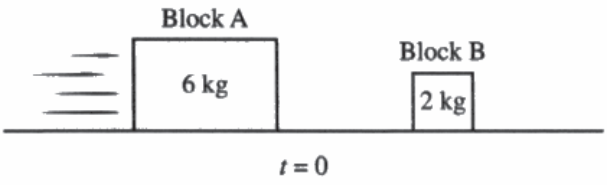

Figure 1

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At time $t = 0$, Block A slides along a horizontal surface toward Block B, which is initially at rest, as shown in Figure 1. The masses of blocks A and B are 6 kg and 2 kg, respectively. The blocks collide elastically at $t = 1.0$ s, and as a result, the magnitude of the change in kinetic energy of Block B is 9 J. All frictional forces are negligible.

(a) **Determine** the speed of Block B immediately after the collision.

$m_1v_1 + m_2v_2 = m_2'v_2'$

$6v_1 = 2v_2'$

$6\frac{\Delta x}{t} = 2v_2'$

$6\left(\frac{3}{1}\right) = 2v_2'$

$12 = 2v_2'$

$v_2' = 6\ m/s$

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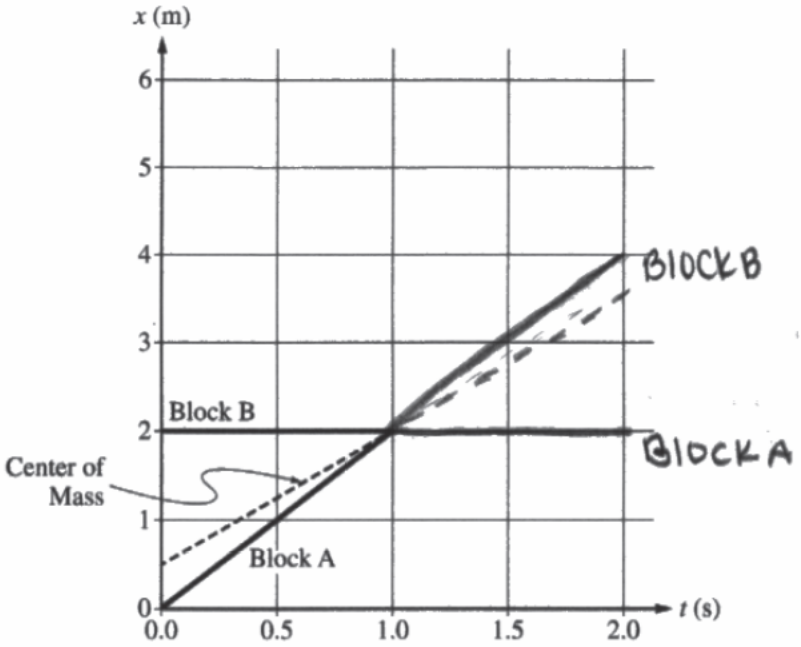

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(c) Consider if in the original scenario, instead of colliding elastically, the blocks collided and stuck together. **Describe** how the line drawn for the center of mass in part (b) would change, if at all. Briefly **justify** your response.

The mass would become larger so the velocity would became less, and the center of mass would be placed evenly between the positions of Block A and B.

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Question 5

Note: Student samples are quoted verbatim and may contain spelling and grammatical errors.

Overview

The responses were expected to demonstrate the ability to:

- Relate the change in kinetic energy of a stationary object to the final speed of the object.
- Recognize and apply the principle of conservation of momentum to both elastic and inelastic collisions.
- Relate the speed of an object with a position versus time graph.
- Recognize the behavior of the center of mass for a two-body system before and after collisions, and properly represent the center of mass speed on a position versus time graph after a collision.

Sample: 5A
Score: 7

Part (a) earned 1 point for correctly indicating the speed of Block B is $3\ \text{m/s}$ after the collision. Part (b) earned 4 points. The first point was earned for correctly drawing and labeling a straight line for the position of Block A with a less positive slope than the slope of its pre-collision line. The second point was earned for correctly drawing and labeling a straight line for the position of Block B with a positive, non-vertical slope. The third point was earned for correctly drawing a straight line for the center of mass of the two-block system position with the same slope as the pre-collision line. The slope is easily indicated by where the line reaches at $t = 2.0\ \text{s}$. The center of mass line should reach the point $(2\ \text{s}, 3.5\ \text{m})$. The fourth point was earned for correctly drawing lines for Block A and Block B with correct slopes, $1\ \text{m/s}$ and $3\ \text{m/s}$, respectively, that begin at $t = 1\ \text{s}$ and $x = 2\ \text{m}$. These slopes are easily indicated by where the lines reach at $t = 2.0\ \text{s}$. Block A should reach the point $(2\ \text{s}, 3\ \text{m})$ and Block B should reach the point $(2\ \text{s}, 5\ \text{m})$. Part (c) earned 2 points. The first point was earned for indicating that the lines drawn for the center of mass of both two-block systems are the same with, "It would not change … ." The second point was earned for correctly indicating "momentum is still conserved" and "there are no external forces."

Sample: 5B
Score: 5

Part (a) earned 1 point for correctly indicating the speed of Block B is $3\ \text{m/s}$ after the collision. Part (b) earned 4 points. The first point was earned for correctly drawing and labeling a straight line for the position of Block A with a less positive slope than the slope of its pre-collision line. The second point was earned for correctly drawing and labeling a straight line for the position of Block B with a positive, non-vertical slope. The third point was earned for correctly drawing a straight line for the center of mass of the two-block system position with the same slope as the pre-collision line. The slope is easily indicated by where the line reaches at $t = 2.0\ \text{s}$. The fourth point was earned for correctly drawing lines for Block A and Block B with correct slopes, $1\ \text{m/s}$ and $3\ \text{m/s}$, respectively, that begin at $t = 1\ \text{s}$ and $x = 2\ \text{m}$. These slopes are easily indicated by where the lines reach at $t = 2.0\ \text{s}$. Part (c) did not earn any points. The first point was not earned because the response incorrectly indicates that the line drawn for the center of mass of the two-block system would be different as it would be "less steep." The second point was not earned because the response does not give an appropriate explanation.

Question 5 (continued)

Sample: 5C
Score: 2

Part (a) did not earn any points because the response does not correctly indicate the speed of Block B is $3\ \text{m/s}$ after the collision. Part (b) earned 2 points. The first point was not earned because the response incorrectly draws and labels a straight line for the position of Block A with a horizontal line with no slope. The second point was earned for correctly drawing and labeling a straight line for the position of Block B with a positive, non-vertical slope. The third point was earned for correctly drawing a straight line for the center of mass of the two-block system position with the same slope as the pre-collision line. The slope is easily indicated by where the line reaches $t = 2.0\ \text{s}$. The fourth point was not earned because the response draws lines for Block A and Block B that do not have the correct slopes. These slopes are easily indicated by where the lines reach at $t = 2.0\ \text{s}$. Block A should reach the point $(2\ \text{s}, 3\ \text{m})$ and Block B should reach the point $(2\ \text{s}, 5\ \text{m})$. Part (c) did not earn any points. The first point was not earned because the response does not correctly address the lines drawn for the center of mass of both the two-block systems. The second point was not earned because the response does not give an appropriate explanation.