2025

AP® Physics 1: Algebra-Based

Sample Student Responses and Scoring Commentary

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Free-Response Question 1

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Question 1: Mathematical Routines (MR) — 10 points

A **(i)** For sketching **one** of the following: **Point A1**

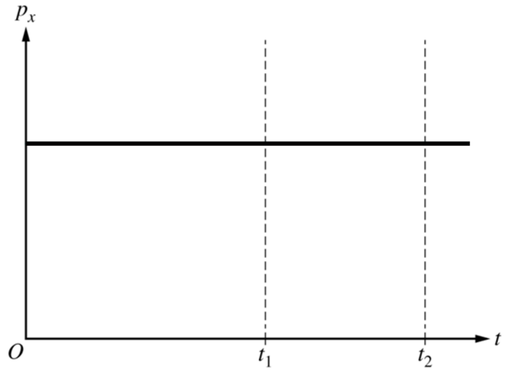
- A constant p_x for $t < t_1$
- A constant p_x for $t > t_1$

For sketching a line that demonstrates momentum is constant **Point A2**

Accept **one** of the following:

- A continuous, nonzero, horizontal line from $t = 0$ to $t = t_2$
- A continuous, nonzero, horizontal line from $t = 0$ to $t > t_2$

Example Response



(ii) For including a conservation of momentum equation **Point A3**

Scoring Note: Part A (ii) and part A (iii) may be scored together, if necessary.

For setting $m_c v_c$ equal to the momentum of the block-cart system after the collision **Point A4**

Scoring Note: A correct, isolated, final expression of $v_f = \frac{5}{6}v_c$ earns points A3 and A4.

Example Response

$$p_i = p_f$$

$$m_c v_c = (m_c + m_b)v_f = \left(m_c + \frac{1}{5}m_c\right)v_f$$

$$v_f = \frac{5}{6}v_c$$

(iii)	For a multistep derivation that includes the correct relationship between kinetic energy, mass, and speed (i.e., $K = \frac{1}{2}mv^2$) **Scoring Note:** The minimum requirement to earn this point is to show an expression of kinetic energy or change in energy that goes beyond the given equation on the reference information. For example, substituting quantities from the problem into $K = \frac{1}{2}mv^2$ or indicating the change in kinetic energy is $\Delta K = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$ earns the point.	**Point A5**
	For an indication that m_c and $\frac{6}{5}m_c$ are the initial and final masses, respectively, of the objects moving horizontally	**Point A6**
	For including an expression for v_f consistent with part A (ii) **Scoring Note:** A correct, isolated, final expression of $\Delta K = -\frac{1}{12}m_c{v_c}^2$ earns points A3, A4, A6, and A7.	**Point A7**

Example Response

$$\Delta K = K_f - K_0$$

$$K_0 = \frac{1}{2}m_c{v_c}^2$$

$$K_f = \frac{1}{2}\left(\frac{6}{5}m_c\right)\left(\frac{5}{6}v_c\right)^2 = \frac{5}{12}m_c{v_c}^2$$

$$\Delta K = -\frac{1}{12}m_c{v_c}^2$$

B

For indicating “Remains constant”

Point B1

Scoring Note: This point is scored independently from the graph drawn in Figure 2 in part A (i).

For indicating **one** of the following:

Point B2

- The frictional force exerted on the new block by the cart is equal in magnitude and opposite in direction to the frictional force exerted on the cart by the new block.
- The frictional force is internal to the new block-cart system.
- The net external force is still zero.
- The frictional force does not cause a net external force.

For indicating **one** of the following:

Point B3

- The change in momentum of the new block is equal in magnitude and opposite in direction to the change in momentum of the cart.
- The impulse exerted on the cart and the impulse exerted on the new block are equal in magnitude and opposite in direction.
- The correct relationship between the change in the momentum of the block-cart system and the net external force.

Example Response

The momentum of the new block-cart system will remain constant because the frictional force exerted on the new block by the cart is internal to the system and only a net external force will cause a change in momentum of the system.

Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Question 1: Version J

PART A

ii. $p_i = p_f$

$m_c v_c + \overset{0}{\cancel{\frac{1}{5} m_c v_i}} = (m_c + \frac{1}{5} m_c) v_f$

$\frac{\cancel{m_c} v_c}{(\frac{6}{5} \cancel{m_c})} = v_f$

$v_f = \frac{5}{6} v_c$

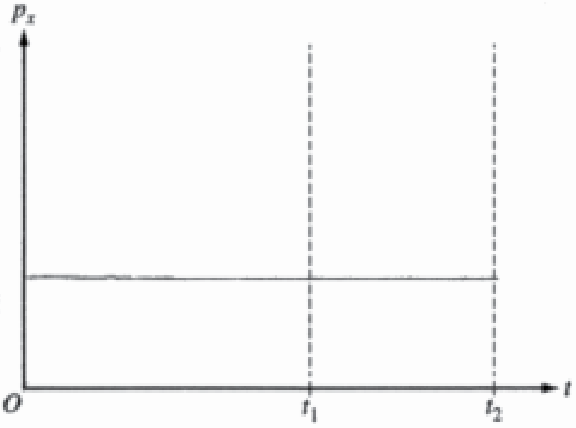


Figure 2

iii.

$\Delta K = K_f - K_i$

$K_f = \frac{1}{2} m v^2 = \frac{1}{2} (\frac{6}{5} m_c)(\frac{5}{6} v_c)^2 = \frac{6}{10} m_c (\frac{25}{36} v_c^2) = \frac{5}{12} m_c v_c^2$

$K_i = \frac{1}{2} m v_i^2 = \frac{1}{2} m v_c^2$

$\Delta K = \frac{5}{12} m_c v_c^2 - \frac{1}{2} m_c v_c^2 = \frac{5}{12} m_c v_c^2 - \frac{6}{12} m_c v_c^2 = -\frac{m_c v_c^2}{12}$

The system lost $\frac{m_c v_c^2}{12}$ in Kinetic Energy

PART B

____ Increases ____ Decreases ✓ Remains constant

The block is being dropped from above the cart so the initial impact will not have any effect on the momentum in the x direction. Additionally, the frictional force between the block and the cart is internal to the system, so it doesn't cause a change in momentum, as only external forces change ~~in~~ a system's momentum.

Go to Question 2 in Bluebook when you're done with this question.

Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Question 1: Version J

PART A

(ii) $P_1 = P_f$

$mv_0 = mv$

$m_c V_c = (\frac{1}{5} m_c + m_c) V_f$

$V_f = \frac{m_c V_c}{(\frac{6}{5} m_c)}$

$V_f = \frac{5 \cancel{m_c} V_c}{6 \cancel{m_c}}$

$V_f = \frac{5V_c}{6}$ m/s

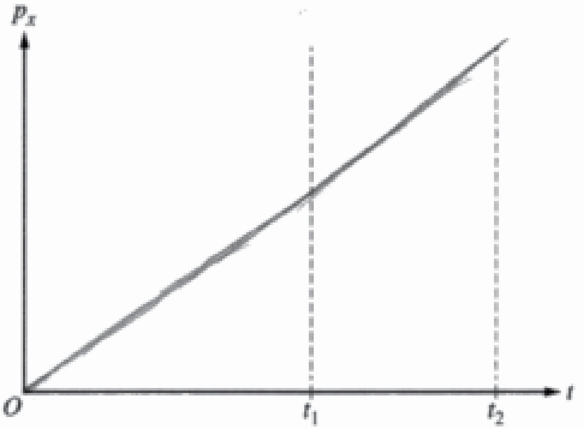


Figure 2

$\Sigma F = 0$ Constant speed

(iii) $E_1 = E_f$

$K_0 = K$

$\Delta K = K - K_0$

$\Delta K = \frac{1}{2}mv^2 - \frac{1}{2}mv_0^2$

$\Delta K = \frac{1}{2}(\frac{6}{5}m_c)(\frac{5V_c}{6})^2 - \frac{1}{2}m_c V_c$

PART B

_____ Increases ✓ Decreases _____ Remains constant

Because there is work other, which is friction. Based on the law of conservation of momentum: $P_1 = P_f$

$mv - W_{other} = mv_0$

The friction will decrease the momentum.

Go to Question 2 in Bluebook when you're done with this question.

Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Question 1: Version J

PART A

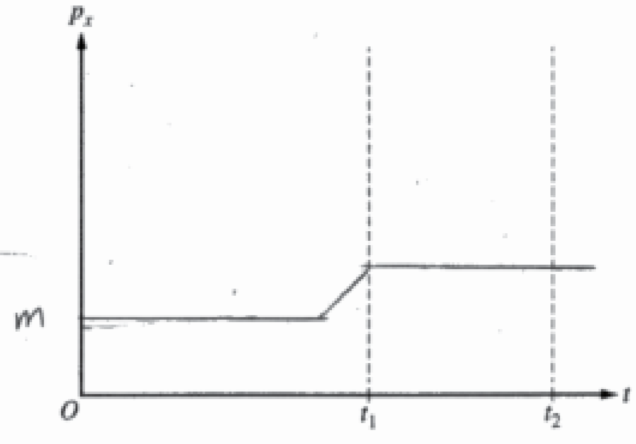


Figure 2

$p = mv$

$t = 0$ $t = t_1$

$m = m$ $m = m + \frac{1}{5}m$

$v = +$ $v = v_c + 9.8$

2. $v \overset{?}{=} \overset{\uparrow v}{v_0} + at$ $F = ma$

☆ $v_f =$ $v_c = m_c + \frac{1}{5}m_c \cdot a$

$a = 0$

$v = \text{constant}$

$K = \frac{1}{2}mv^2$

3. $K = \frac{1}{2}(m_c + \frac{1}{5}m_c) \times V_c^2$

PART B

✓ Increases ____ Decreases ____ Remains constant

$\Sigma p = \Sigma mv$

to get the total p of the block cart system you have to combine them. the p of the cart doesn't change but the block does. it is moving back + forth, causing it's v to change, so I know it can't be constant. I know the block can't go below the carts p or it will fall off. so it must be a higher p then the cart, causing an net increase of p

Go to Question 2 in Bluebook when you're done with this question.

Question 1

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

Overview

NEW for 2025: The question overviews can be found in the *Chief Reader Report on Student Responses* on AP Central.

Sample: 1A
Score: 10

Part A (i) earned both points. The first point (A1) was earned because the response includes a horizontal line from 0 to t_1 and the second point (A2) was earned because the line is drawn as continuous and horizontal with a nonzero value for the complete time interval $t = 0$ to $t = t_2$. Part A (ii) earned both points. The response correctly indicates conservation of momentum by including $p_i = p_f$, earning the first point (A3). The second point (A4) was earned as the response appropriately substitutes the combined mass of the block-cart system into the conservation of momentum equation. Part A (iii) earned all three points. The multistep derivation including the correct expression relating mass, velocity, and kinetic energy earned the first point (A5), and correctly substituting the final mass as $\frac{6}{5}m_{\text{c}}$ and the initial mass as m_{c} into the expression earned the second point (A6). The third point (A7) was earned by the correct substitution of the final velocity value derived in part A (ii) into the energy expression.

Part B earned all three points. The first point (B1) was earned because the response makes the correct claim that the total momentum of the system remains constant by checking the correct statement. The response indicates that the frictional forces between the block and the cart are internal to the system even with addition of the block to the cart and change in frictional forces, earning the second point (B2). The third point (B3) was earned by stating that the changed frictional force is internal; thus, there is no net external force, concluding that the system's total momentum is conserved.

Question 1 (continued)

Sample: 1B
Score: 5

Part A (i) did not earn either point. The sketch for part A (i) shows a line with a nonzero slope, so the first point (A1) was not earned as neither the interval for $t < t_1$ or for $t > t_1$ shows a horizontal line showing constant momentum. While the line is continuous, the second point (A2) was not earned because the line is never horizontal. Part A (ii) earned both points. The first point (A3) was earned because the response includes an equation that correctly represents the conservation of momentum. From conservation, the second point (A4) was earned because the response sets the initial momentum of the system equal to the total momentum after the collision, including a correct expression for the total mass of the system. Part A (iii) earned all three points. The response correctly states the relationship between mass, velocity, and kinetic energy and uses that relationship in a multistep derivation; thus, the first point (A5) was earned. The second point (A6) was earned for correctly substituting both the total mass of the block-cart system and the initial mass of the cart into the kinetic energy expression. The final velocity from part A (ii) is correctly substituted into the kinetic energy expression earning the response the third point (A7). This expression need not be simplified to earn the last two points of part A (iii).

Part B did not earn any of the three points. The first point (B1) was not earned because the response makes an incorrect claim about the behavior of the system's momentum, choosing the checkbox for decreases instead of remains constant. The second point (B2) was not earned. Although the response mentions the frictional force, claiming the force does work on the system does not identify friction as an internal force or account for the equal and opposite force between the cart and the block. The third point (B3) was not earned because there is no discussion of a net or external force acting to change the system's momentum. Stating that "friction will decrease the momentum" is not sufficient evidence to earn this point.

Sample: 1C
Score: 2

Part A (i) earned one out of two points. The first point (A1) was earned because the response shows a horizontal line from t_1 to t_2 and continues the horizontal trend beyond t_2. However, the second point (A2) was not earned, as the line is not continuously horizontal for the entire time interval demonstrating momentum conservation. Part A (ii) did not earn either point. The first point (A3) was not earned because, although an equation for momentum is provided, the response does not include an equation that explicitly demonstrates conservation of momentum. The second point (A4) was not earned because there is no substitution indicating that the initial mass multiplied by the initial velocity is equal to the final momentum. Part A (iii) earned one out of three points. The response does include the correct expression for kinetic energy in terms of mass and velocity and an attempt at a substitution. This shows multistep use of kinetic energy, earning the first point (A5). The second point (A6) was not earned because, although the final mass was correctly substituted, the initial mass was omitted. Both are necessary to earn this point. The third point (A7) was not earned as the final velocity derived in part A (ii) was not substituted into the kinetic energy expression.

Part B did not earn any of the three points. The first point (B1) was not earned because the response makes an incorrect claim regarding the conservation of momentum, checking that momentum increases. The second point (B2) was not earned because the response does not correctly discuss the relationship between the frictional force and the system. Finally, the response does not correctly relate external forces to the change in momentum, failing to earn the third point (B3).