2022

AP CollegeBoard

AP® Physics 1: Algebra-Based

Sample Student Responses and Scoring Commentary

Inside:

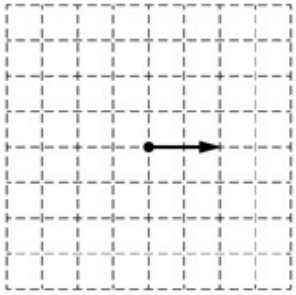
Free-Response Question 4

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

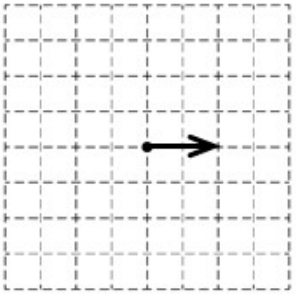
Question 4: Short Answer Paragraph Argument — 7 points

(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**

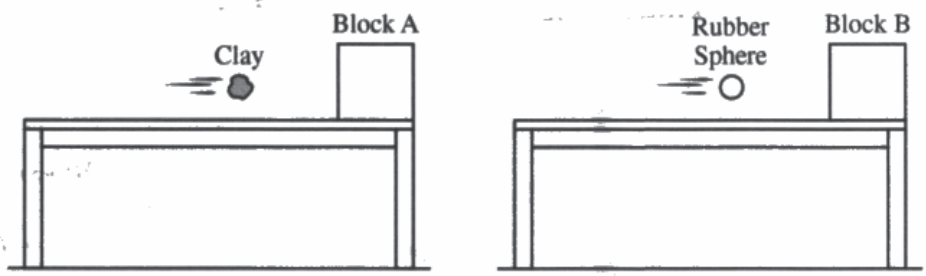
Question 4

Begin your response to **QUESTION 4** on this page.

4. (7 points, suggested time 13 minutes)

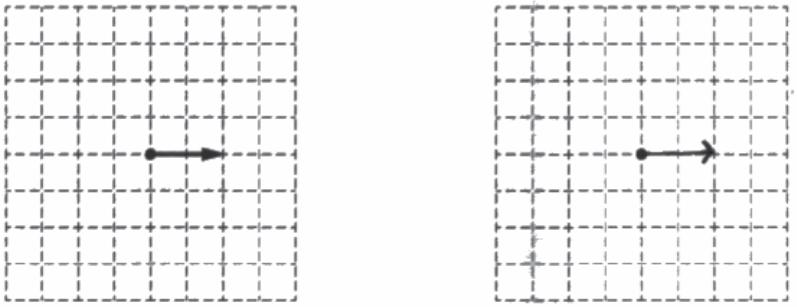
A student has a piece of clay and a rubber sphere, both of the same mass. Both objects are thrown horizontally at the same speed at identical blocks that are at rest at the edge of identical tables, as shown, where friction between the blocks and the table is negligible. After the collisions, both blocks fall to the floor.

In Case A, the clay sticks to Block A after the collision. In Case B, the rubber sphere bounces off of Block B after the collision.



Case A: Clay and Block A Before Collision

Case B: Rubber Sphere and Block B Before Collision



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

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

(a) In the figure at left above, the arrow represents the momentum immediately after the collision for the clay-block system in Case A. In the figure at right above, draw an arrow starting on the dot to represent the momentum of the sphere-block system immediately after the collision in Case B. If the momentum is zero, write "zero" next to the dot. The momentum, if it is not zero, must be represented by an arrow starting on, and pointing away from, the dot. The length of the vector, if not zero, should reflect the magnitude of the momentum relative to Case A.

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Question 4

Continue your response to **QUESTION 4** on this page.

(b) After the clay and Block A collide, Block A lands a horizontal distance d_A from the edge of the table. Does Block B land on the floor at a horizontal distance from the edge of the table that is greater than, less than, or equal to d_A ? In a clear, coherent, paragraph-length response that may also contain equations and/or drawings, explain your reasoning. Neglect any frictional effects due to the table or air resistance.

Greater than due to the fact that momentum is conserved. The clay ball hits the block and stops, causing all of the momentum in the system to be in the positive direction. However, the rubber spere bounces off, sending it's momentum in the negative direction, and since both systems had the same initial momentum, the rubber balls negative momentum must be counter acted by a greater positive momentum in Block B. And this momentum in solely the blocks part of the system of Block B is greater than the momentum in the whole system of Block A, and the mass of block B is less because there is no clay stuck to it, so the velocity must be greater because momentum = mass • velocity, so the mass being less means velocity is greater, so it travels further.

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Question 4

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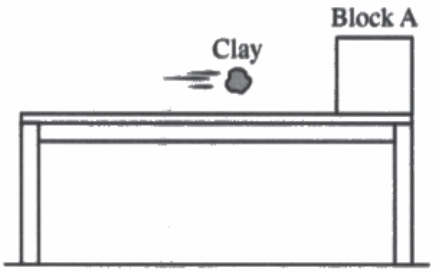
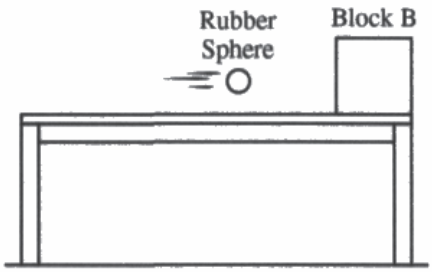
4. (7 points, suggested time 13 minutes)

A student has a piece of clay and a rubber sphere, both of the same mass. Both objects are thrown horizontally at the same speed at identical blocks that are at rest at the edge of identical tables, as shown, where friction between the blocks and the table is negligible. After the collisions, both blocks fall to the floor.

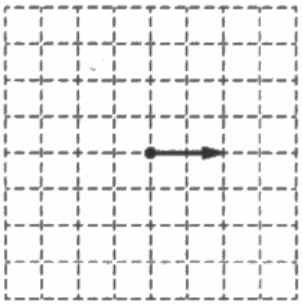
In Case A, the clay sticks to Block A after the collision. In Case B, the rubber sphere bounces off of Block B after the collision.



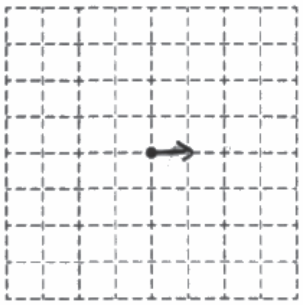
Case A: Clay and Block A Before Collision



Case B: Rubber Sphere and Block B Before Collision



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



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

(a) In the figure at left above, the arrow represents the momentum immediately after the collision for the clay-block system in Case A. In the figure at right above, draw an arrow starting on the dot to represent the momentum of the sphere-block system immediately after the collision in Case B. If the momentum is zero, write "zero" next to the dot. The momentum, if it is not zero, must be represented by an arrow starting on, and pointing away from, the dot. The length of the vector, if not zero, should reflect the magnitude of the momentum relative to Case A.

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Question 4

Continue your response to **QUESTION 4** on this page.

(b) After the clay and Block A collide, Block A lands a horizontal distance d_A from the edge of the table. Does Block B land on the floor at a horizontal distance from the edge of the table that is greater than, less than, or equal to d_A ? In a clear, coherent, paragraph-length response that may also contain equations and/or drawings, explain your reasoning. Neglect any frictional effects due to the table or air resistance.

Block B lands a distance greater than d_A because of conserved momentum in both cases.

A: $m_A(0) + m_{clay}v_0 = m_{A+clay}v_f$, B: $m_B(0) + m_{sphere}v_0 = m_B v_f + m_{sphere}v_f$

In case A, the final velocity will be less than the initial velocity of the clay because the mass increased while momentum was conserved meaning velocity decreases proportionately. In projectile motion, v_0 in the horizontal direction is constant. So, the object with a higher v_0 will travel faster & therefore further. Block B has a greater v_0 when it leaves the table because its mass is less than that of the block A-sphere system, but the same impulse. So, because it is faster it will travel further.

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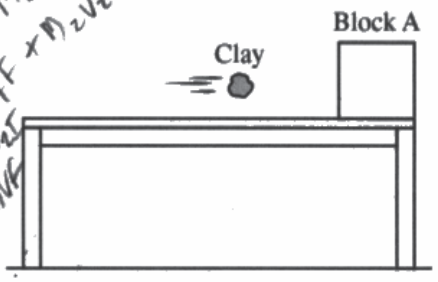
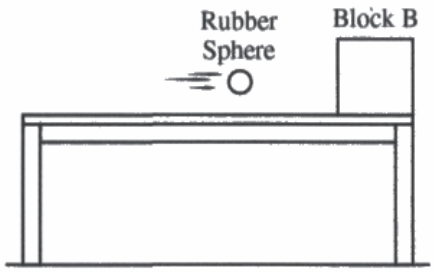
A student has a piece of clay and a rubber sphere, both of the same mass. Both objects are thrown horizontally at the same speed at identical blocks that are at rest at the edge of identical tables, as shown, where friction between the blocks and the table is negligible. After the collisions, both blocks fall to the floor.

In Case A, the clay sticks to Block A after the collision. In Case B, the rubber sphere bounces off of Block B after the collision.

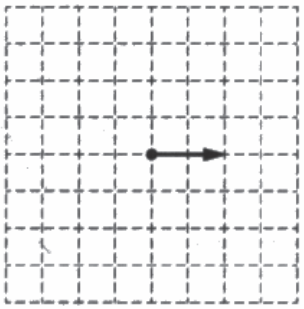
$p_I = m_1 v_{1I} + m_2 v_{2I}$
$= m_1 v_{1F} + m_2 v_{2F}$
$I = m_1 v_{1I} + m_2 v_{2I}$
$= (m_1 + m_2) v_F$



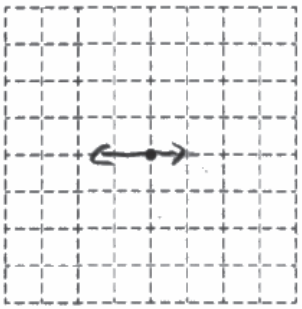
Case A: Clay and Block A Before Collision



Case B: Rubber Sphere and Block B Before Collision



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



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

(a) In the figure at left above, the arrow represents the momentum immediately after the collision for the clay-block system in Case A. In the figure at right above, draw an arrow starting on the dot to represent the momentum of the sphere-block system immediately after the collision in Case B. If the momentum is zero, write "zero" next to the dot. The momentum, if it is not zero, must be represented by an arrow starting on, and pointing away from, the dot. The length of the vector, if not zero, should reflect the magnitude of the momentum relative to Case A.

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Question 4

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(b) After the clay and Block A collide, Block A lands a horizontal distance d_A from the edge of the table. Does Block B land on the floor at a horizontal distance from the edge of the table that is greater than, less than, or equal to d_A ? In a clear, coherent, paragraph-length response that may also contain equations and/or drawings, explain your reasoning. Neglect any frictional effects due to the table or air resistance.

N. Block B lands on the floor a horizontal distance greater than d_A. This is because Case A experiences an inelastic collision., which is shown as $m_1 V_{1I} + m_2 V_{2I} = (m_1 + m_2) V_F$. Whereas Case B experiences an elastic, which is shown as $m_1 V_{1I} + m_2 V_{2I} = m_1 V_{1F} + m_2 V_{2F}$. With this, it is shown how energy is conserved. However, with an inelastic collision (case A) the 2 objects stick together after. So, although the bodies are the same everything, along with the objects, Block B will travel further because it is less mass than Case A after the collision, but with equal force acted on it. Same force, less mass = greater distance.

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Question 4

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

Overview

The responses were expected to demonstrate the ability to:

- Draw a vector arrow for momentum that indicates conservation of momentum in a collision.
- Apply knowledge of conservation of momentum in a collision in two different situations.
- Compare the final velocities of blocks after an elastic or inelastic collision.
- Identify the relationship between momentum and velocity.
- Indicate that the time of flight in projectile motion is independent of mass and depends only upon vertical height, which is identical for both cases.
- Indicate that in horizontal projectile motion, the initial horizontal velocity and time in the air determine the range. More generally, identify the relationship between velocity and displacement in the horizontal direction, including the fact that there is zero acceleration in the horizontal direction.

Sample: 4A
Score: 6

Part (a) earned 1 point for a response that correctly draws an arrow pointing to the right with a magnitude of two grid units. Part (b) earned 5 points. The first point was earned for stating that momentum is conserved. The second point was earned for correctly indicating that Block B has a greater momentum than Block A: "However, the rubber sp[h]ere bounces off, sending it's momentum in the negative direction, and since both systems had the same initial momentum, the rubber balls negative momentum must be counter acted by a greater positive momentum in Block B." The third point was earned for correctly making the connection that a greater momentum leads to a greater velocity. The fourth point was not earned because the response does not indicate that the fall time for the blocks is the same. The fifth point was earned for correctly recognizing that a higher horizontal velocity will cause a higher horizontal displacement. The response states, "velocity is greater, so it travels farther." The sixth point was earned for meeting the requirements for a paragraph-length response.

Sample: 4B
Score: 4

Part (a) earned 0 points because although the arrow does point to the right, the arrow does not have a magnitude of two grid units. Part (b) earned 4 points. The first point was earned for a response that states, "because of conserved momentum in both cases." The second point was not earned because the response does not correctly explain why the momentum in Case B is greater than the momentum in Case A. The third point was earned for a response that correctly indicates that a greater momentum leads to a greater velocity. The response indicates proportionality between momentum and velocity. The fourth point was not earned because the response does not indicate that the blocks have the same fall time. The fifth point was earned for a response that states, "the object with a higher v_0 will travel faster & therefore further." The sixth point was earned for meeting the requirements for a paragraph-length response.

Question 4 (continued)

Sample: 4C
Score: 2

Part (a) earned 0 points because two arrows are drawn in the response with only one arrow pointing to the right and this arrow does not have a magnitude of two grid units. Part (b) earned 2 points. The first point was earned for a response that makes a conservation of momentum statement using the expression "$m_1 v_{1i} + m_2 v_{2i} = (m_1 + m_2) v_f$." The second point was not earned because the response does not explain why Block B has more momentum after the collision than Block A. The third point was not earned because the response does not state that a greater momentum leads to a greater velocity after the collision. The fourth point was not earned because the response does not state that both blocks have the same fall time. The fifth point was not earned because the response does not indicate that a greater velocity will lead to a greater distance. The sixth point was earned for meeting the requirements for a paragraph-length response.