2025 MCAS Sample Student Work and Scoring Guide

High School Introductory Physics
Question 17: Constructed-Response

Reporting Category: Motion, Forces, and Interactions
Practice Category: Investigations and Questioning
Standard: HS.PHY.2.3 - Apply scientific principles of motion and momentum to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.
Item Description: Calculate the change in momentum of an object, calculate the average net force on the object, and explain why an identified change to the setup of the investigation would reduce the average net force on the object.

This item can be found in the released item sets on the MCAS Resource Center.

Scoring Guide

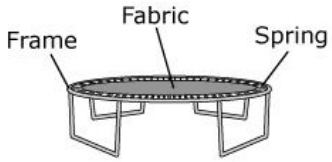
Select a score point in the table below to view the sample student response.

Score*	Description
3A	The response demonstrates a thorough understanding of momentum and force during a collision. The response correctly calculates the change in momentum of a ball and the average net force on the ball. The response also correctly identifies one change to the setup that would reduce the average net force on the ball and clearly explains the reasoning.
3B	
2	The response demonstrates a partial understanding of momentum and force during a collision.
1	The response demonstrates a minimal understanding of momentum and force during a collision.
0	The response is incorrect or contains some correct work that is irrelevant to the skill or concept being measured.

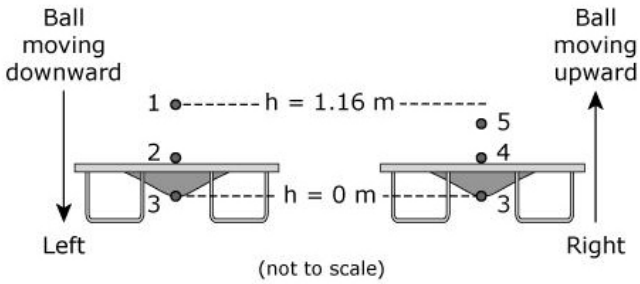
*Letters are used to distinguish between sample student responses that earned the same score (e.g., 3A and 3B).

Score Point 3A

Students used a trampoline and a ball to investigate energy conversions. The trampoline is shown in the diagram.



The students dropped a 5 kg metal ball onto the trampoline. The diagram below shows the positions of the ball during the investigation.



The ball was dropped from position 1 and was just above the trampoline at position 2. When the ball collided with the trampoline, both the fabric and springs stretched as the ball continued to move downward. The ball momentarily stopped at position 3, and then began moving upward as the fabric and springs returned to their original position. The ball was just above the trampoline at position 4 and continued to move upward to position 5.

The students recorded the ball's speed, height, and direction of motion at each position. The data are shown in the table.

Position	Speed (m/s)	Height (m)	Direction of Motion
1	0	1.16	no motion
2	3.2	0.65	downward
3	0	0	no motion
4	2.8	0.65	upward
5	0	1.04	no motion

This question has three parts.

The collision time between the 5 kg ball and the trampoline was 0.175 s as the ball moved from position 2 to position 3.

Part A

Calculate the change in momentum of the ball as it moved from position 2 to position 3. Show your calculations and include units in your answer.

$p = mv$

$\Delta p = m\,|(v_2 - v_1)|$

$m = 5$ kg

$v_1 = 3.2\ m\ /\ s$

$v_2 = 0\ m\ /\ s$

$\Delta p = 5\,|(0 - 3.2)|$

$\Delta p = 16\ \text{kg}\, m\ /\ s$

The change in momentum is 16 $kgm\ /\ s$.

Part B

Calculate the average net force on the ball as it moved from position 2 to position 3. Show your calculations and include units in your answer.

$F\Delta t = \Delta p$

$\Delta p = 16kgm\ /\ s$

$\Delta t = 0.175s$

$F\,(0.175) = 16$

$\square \div 0.175 \quad \square \div 0.175$

$F = 91.4kgm\ /\ s^2 = 91.4N$

The average net force on the ball is 91.4 N.

Part C

Identify one change to the setup of the investigation that would reduce the average net force on the ball as it moved from position 2 to position 3. Explain your reasoning.

Lowering the beginning height of the ball would reduce the net force on the ball between positions 2 and 3. In lowering the height, the total mechanical energy of the ball would lower and, in that, lower the velocity of the ball at point 2, making the change of velocity between 2 and 3 also lower, and, thus requiring less force to reduce the speed at 3 to zero.

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Score Point 3B

This question has three parts.

The collision time between the 5 kg ball and the trampoline was 0.175 s as the ball moved from position 2 to position 3.

Part A

Calculate the change in momentum of the ball as it moved from position 2 to position 3. Show your calculations and include units in your answer.

momentum = mass*velocity

momentum at position 2 = 5kg * $3.2 \cdot \frac{m}{s} = 16$ kgm/s

momentum at position 3 = 5kg * $0 \cdot \frac{m}{s} = 0$ kgm/s

change in momentum = $0 - 16$ kgm/s = -16kgm/s

Part B

Calculate the average net force on the ball as it moved from position 2 to position 3. Show your calculations and include units in your answer.

change in momentum = impulse = force * time of impact

force = change in momentum / time

$\square = -\frac{16kg\frac{m}{s}}{0.175s}$

$\square = 91.4N$

Part C

Identify one change to the setup of the investigation that would reduce the average net force on the ball as it moved from position 2 to position 3. Explain your reasoning.

The trampoline could be made of a more stretchable material, so when the ball goes down on the trampoline, it has longer time to slow down.

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Score Point 2

This question has three parts.

The collision time between the 5 kg ball and the trampoline was 0.175 s as the ball moved from position 2 to position 3.

Part A

Calculate the change in momentum of the ball as it moved from position 2 to position 3. Show your calculations and include units in your answer.

$p_2 = mv$

$p_2 = 5 \times 3.2$

$p_2 = 16J$

$p_3 = mv$

$p_3 = 5 \times 0$

$p_3 = 0J$

$\Delta p = p_2 - p_3$

$\Delta p = 16 - 0$

$\Delta p = 16J$

Part B

Calculate the average net force on the ball as it moved from position 2 to position 3. Show your calculations and include units in your answer.

$F_{net} = ma$

$F_{net} = 5 \times 3.2$

$F_{net} = 16N$

Part C

Identify one change to the setup of the investigation that would reduce the average net force on the ball as it moved from position 2 to position 3. Explain your reasoning.

Changing the mass of the ball to something lighter would reduce the average net force on the ball. The mass of the ball and the net force of the ball are directly proportional, meaning that if one reduces then the other does, and if one increases then the other will as well. This means that when you replace the ball with a lighter ball, the average net force will be reduced.

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Score Point 1

This question has three parts.

The collision time between the 5 kg ball and the trampoline was 0.175 s as the ball moved from position 2 to position 3.

Part A

Calculate the change in momentum of the ball as it moved from position 2 to position 3. Show your calculations and include units in your answer.

$p = mv$

$p = 5\,\text{kg} \times 0.175$

$p = 0.875$

Part B

Calculate the average net force on the ball as it moved from position 2 to position 3. Show your calculations and include units in your answer.

$a = \Delta v \,/\, \Delta t$

$a = \frac{3.2}{0.175}$

$a = 18.3\ m \,/\, s \,/\, s$

fnet=ma

fnet= $5 \times 18.3 = 91.5N$

Part C

Identify one change to the setup of the investigation that would reduce the average net force on the ball as it moved from position 2 to position 3. Explain your reasoning.

Change the PE of where the ball started from where it got dropped from because if you make changes to that, the ball will either increase or decrease at protions 3 and 5 because of how much force is being put on the trampoline.

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Score Point 0

This question has three parts.

The collision time between the 5 kg ball and the trampoline was 0.175 s as the ball moved from position 2 to position 3.

Part A

Calculate the change in momentum of the ball as it moved from position 2 to position 3. Show your calculations and include units in your answer.

$p = 5\,\text{kg} \times .175$

$p = .875$

Part B

Calculate the average net force on the ball as it moved from position 2 to position 3. Show your calculations and include units in your answer.

$f = 3.2 \times .65$

$f = 2.08$

Part C

Identify one change to the setup of the investigation that would reduce the average net force on the ball as it moved from position 2 to position 3. Explain your reasoning.

If they added more mass to the ball it would change the average net froce as it moved from position 2 to postion 3.

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