2026 MCAS Sample Student Work and Scoring Guide

High School Introductory Physics
Question 16: Constructed-Response

Reporting Category: Motion, Forces, and Interactions
Practice Category: Mathematics and Data

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 momentum of an object just before a collision, the change in momentum of the object as a result of the collision, and the average force applied to the object during the collision.

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 **3B**	The response demonstrates a thorough understanding of momentum and forces during a collision. The response correctly calculates the momentum of glider X before the collision in trial 1 and the change in momentum of glider X as a result of that collision. The response also correctly calculates the average force on glider X during the collision in trial 1.
2	The response demonstrates a partial understanding of momentum and forces during a collision.
1	The response demonstrates a minimal understanding of momentum and forces during a collision.
0	The response is incorrect or contains some correct work that is irrelevant to the skill or concept being measured.

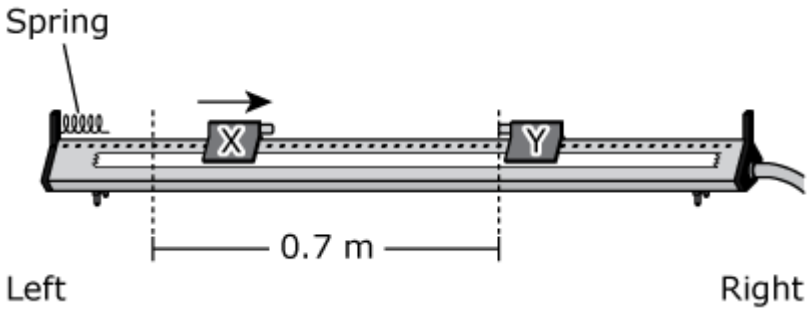
*Letters are used to distinguish between sample student responses that earned the same score (e.g., 3A and 3B).

Module Introduction

A group of students conducted an investigation to learn about collisions. The students used an air track and two gliders, X and Y. Friction was negligible on the air track. The investigation had the following steps:

- The spring pushed glider X.
- Glider X moved a distance of 0.7 m to the right at a constant velocity.
- Glider X collided with glider Y.

The diagram shows glider X moving toward glider Y after glider X was pushed by the spring.



The students recorded the data from three trials of the investigation. A negative velocity indicates that the glider moved to the left, and a positive velocity indicates that the glider moved to the right. The data are shown in the table. No velocity data were recorded for glider Y after the collisions.

Trial	Mass of Gliders (kg)		Velocity before Collision (m/s)		Velocity after Collision (m/s)	
	X	Y	X	Y	X	Y
1	0.2	0.4	0.60	0	–0.20	?
2	0.8	0.2	0.30	0	0.18	?
3	0.8	0.8	0.30	0	0.00	?

Score Point 3A

This question has three parts.

During trial 1, glider X was moving to the right before the collision with glider Y, and then moved to the left after the collision with glider Y.

Part A

Based on the data table, calculate the momentum of glider X before the collision in trial 1. Show your calculations and include units in your answer.

$$p = mv$$

$$p = 0.2\,\text{kg} \times 0.6 \cdot \frac{m}{s}$$

$$p = 0.12 \cdot \frac{\text{kg} \times m}{s}$$

Part B

Calculate the change in momentum of glider X that resulted from the collision in trial 1. Show your calculations and include units in your answer.

$$\Delta p = m\Delta v$$

$$\Delta p = 0.2\,\text{kg} \times \left(-0.2 \cdot \frac{m}{s} - 0.6 \cdot \frac{m}{s}\right)$$

$$\Delta p = 0.2\,\text{kg} \times \left(-0.8 \cdot \frac{m}{s}\right)$$

$$\Delta p = -0.16 \cdot \frac{\text{kg} \times m}{s}$$

Part C

In trial 1, the collision between glider X and glider Y occurred over 0.01 s.

Calculate the average force applied to glider X during the collision. Show your calculations and include units in your answer.

$$\Delta p = F\Delta t$$

$$-0.16 \cdot \frac{\text{kg} \times m}{s} = F \times 0.01s$$

$$F = -16N$$

(16N to the left)

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Score Point 3B

This question has three parts.

During trial 1, glider X was moving to the right before the collision with glider Y, and then moved to the left after the collision with glider Y.

Part A

Based on the data table, calculate the momentum of glider X before the collision in trial 1. Show your calculations and include units in your answer.

$$p_{before} = mv_{before} = (0.2)\ (0.6) = 0.12\,\text{kg} \cdot \frac{m}{s}$$

Part B

Calculate the change in momentum of glider X that resulted from the collision in trial 1. Show your calculations and include units in your answer.

$$p_{after} = mv_{after} = (0.2)\ (-0.20) = -0.04\,\text{kg} \cdot \frac{m}{s}$$

$$p_{before} = mv_{before} = (0.2)\ (0.6) = 0.12\,\text{kg} \cdot \frac{m}{s}$$

$$\Delta p = p_{after} - p_{before} = -0.04 - 0.12 = -0.16\,\text{kg} \cdot \frac{m}{s}$$

Part C

In trial 1, the collision between glider X and glider Y occurred over 0.01 s.

Calculate the average force applied to glider X during the collision. Show your calculations and include units in your answer.

$$V_f = V_i + a\Delta t$$

$$-0.20 = 0.60 + a\,(0.01)$$

$$a = -80\ \frac{m}{s^2}$$

$$F_{net} = ma = (0.2)\ (80) = 16N$$

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Score Point 2

This question has three parts.

During trial 1, glider X was moving to the right before the collision with glider Y, and then moved to the left after the collision with glider Y.

Part A

Based on the data table, calculate the momentum of glider X before the collision in trial 1. Show your calculations and include units in your answer.

$p = ?$

$m = 0.2\,\text{kg}$

$v = 0.6 \cdot \frac{m}{s}$

$p = mv$

$p = 0.2\,(0.6)$

$p = 0\,.12\,\text{kg} \cdot \frac{m}{s}$

Part B

Calculate the change in momentum of glider X that resulted from the collision in trial 1. Show your calculations and include units in your answer.

$p = ?$

$m = 0.2\,\text{kg}$

$v = -0.2 \cdot \frac{m}{s}$

$p = mv$

$p = 0.2\,(-0.2)$

$p = -.04\,\text{kg} \cdot \frac{m}{s}$

Part C

In trial 1, the collision between glider X and glider Y occurred over 0.01 s.

Calculate the average force applied to glider X during the collision. Show your calculations and include units in your answer.

$a = \frac{v}{t}$

$v = -.8 \cdot \frac{m}{s}$

$t = .01s$

$a = -\frac{.8}{.01}$

$a = -80\text{m}/\,s^2$

$m = .2\,\text{kg}$

$F = .2 \cdot (-80)$

$F = -16N$

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Score Point 1

This question has three parts.

During trial 1, glider X was moving to the right before the collision with glider Y, and then moved to the left after the collision with glider Y.

Part A

Based on the data table, calculate the momentum of glider X before the collision in trial 1. Show your calculations and include units in your answer.

$p = mv$

$p = .2 \times .6$

$p = .12$

Part B

Calculate the change in momentum of glider X that resulted from the collision in trial 1. Show your calculations and include units in your answer.

$p = mv$

$p = .2 \times {}^{-}.20$

-0.04

Part C

In trial 1, the collision between glider X and glider Y occurred over 0.01 s.

Calculate the average force applied to glider X during the collision. Show your calculations and include units in your answer.

$f = \mathrm{mg}$

$f = .2 \times 10$

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Score Point 0

This question has three parts.

During trial 1, glider X was moving to the right before the collision with glider Y, and then moved to the left after the collision with glider Y.

Part A

Based on the data table, calculate the momentum of glider X before the collision in trial 1. Show your calculations and include units in your answer.

$.60ms \div .20 = .3$

Part B

Calculate the change in momentum of glider X that resulted from the collision in trial 1. Show your calculations and include units in your answer.

$.4 - .2 = .2$

Part C

In trial 1, the collision between glider X and glider Y occurred over 0.01 s.

Calculate the average force applied to glider X during the collision. Show your calculations and include units in your answer.

$.60 \div .7 = .85$

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