2024 MCAS Sample Student Work and Scoring Guide

High School Introductory Physics
Question 38: Constructed-Response

Reporting Category: Motion, Forces, and Interactions
Practice Category: Mathematics and Data
Standard: HS.PHY.2.10 - Use free-body force diagrams, algebraic expressions, and Newton's laws of motion to predict changes to velocity and acceleration for an object moving in one dimension in various situations.
Item Description: Analyze a velocity vs. time graph to explain when an object has the greatest acceleration during a time interval, calculate the average acceleration of the object over a given amount of time, and compare the net forces on the object for two different time intervals and explain the reasoning.

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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 force and acceleration. The response correctly identifies the interval when the athlete had the greatest acceleration and clearly explains the reasoning. The response correctly calculates the athlete's average acceleration for the entire race. The response also correctly compares the net force on the athlete for two intervals and clearly explains the reasoning.
3B	
2	The response demonstrates a partial understanding force and acceleration.
1	The response demonstrates a minimal understanding of force and acceleration.
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

Track and field is a sport that consists of many different events, including the 100 m sprint and the high jump.

100 m Sprint

The 100 m sprint is a short running race. Athlete K completed a 100 m sprint in 10.9 s. The table shows athlete K's average velocity for each 10 m segment of the running race.

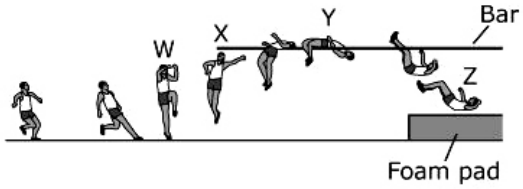
Average Velocity of Athlete K

Running Race Segment (m)	Average Velocity (m/s)
0 – 10	4.8
10 – 20	8.7
20 – 30	9.8
30 – 40	10.6
40 – 50	10.8
50 – 60	10.8
60 – 70	10.6
70 – 80	10.4
80 – 90	10.4
90 – 100	10.4

High Jump

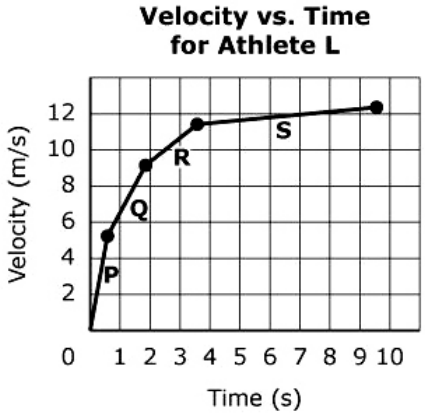
The high jump is an event in which an athlete runs toward a bar and then jumps over it. Athlete M completed a high jump and then safely collided with a foam pad. Athlete M's mass was 80 kg. The diagram shows several positions of athlete M during the high jump, with four positions labeled W, X, Y, and Z.

Athlete M
Completing a High Jump



This question has three parts.

Another athlete, athlete L, completed a 100 m sprint in 9.6 s. The graph shows athlete L's velocity over time. Four time intervals are labeled P, Q, R, and S.



Part A

Identify the interval of the race when athlete L had the greatest acceleration. Explain your reasoning.

Interval P had the greatest acceleration because it is the steepest incline on the graph provided.

Part B

Calculate athlete L's average acceleration for the entire race. Show your calculations and include units in your answer.

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

$\Delta v = 12.1 \cdot \frac{m}{s}$

$\Delta t = 9.6s$

$\frac{12.1}{9.6} = 1.260416667 \cdot \frac{m}{s^2}$

Part C

Compare the net force on athlete L during interval Q with the net force on athlete L during interval S. Explain your reasoning.

The force on the athlete is greater in interval Q then interval S because interval Q has more acceleration because the line is steeper so because the mass doesnt change in this instance more acceleration equals more force on the athlete.

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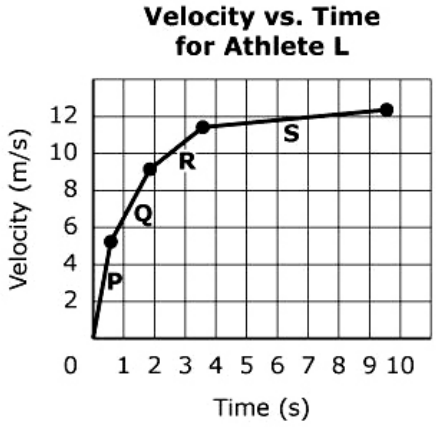
Score Point 3B

This question is part of a module with an introduction. The introduction can be seen in score point 3A.

This question has three parts.

Another athlete, athlete L, completed a 100 m sprint in 9.6 s. The graph shows athlete L's velocity over time. Four time intervals are labeled P, Q, R, and S.



Part A

Identify the interval of the race when athlete L had the greatest acceleration. Explain your reasoning.

The interval of the race when Athlete L had the greatest acceleration is P because it had the greatest slope out of all the intervals. If it had the greatest slope, then the velocity increased the fastest which means the acceleration is the greatest.

Part B

Calculate athlete L's average acceleration for the entire race. Show your calculations and include units in your answer.

$$a_{average} = \frac{\Delta V}{\Delta T}$$

$$a = \frac{12.3}{9.6}$$

$$a = 1.28 \ \frac{m}{s^2}$$

Part C

Compare the net force on athlete L during interval Q with the net force on athlete L during interval S. Explain your reasoning.

The net force on athlete L during interval Q is greater than the net force on athlete L during interval S. The slope of interval Q is greater than the slope of interval S, so the acceleration is greater. Therefore, the net force also increases as the acceleration increases.

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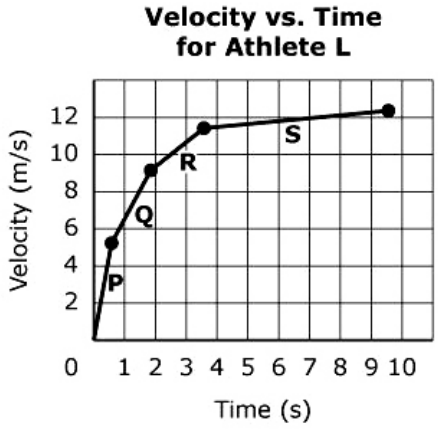
Score Point 2

This question is part of a module with an introduction. The introduction can be seen in score point 3A.

This question has three parts.

Another athlete, athlete L, completed a 100 m sprint in 9.6 s. The graph shows athlete L's velocity over time. Four time intervals are labeled P, Q, R, and S.



Part A

Identify the interval of the race when athlete L had the greatest acceleration. Explain your reasoning.

Interval P was the interval where athlete L had the greatest acceleration because that is where the line is the steepest on the graph.

Part B

Calculate athlete L's average acceleration for the entire race. Show your calculations and include units in your answer.

$$v = \frac{100}{9.6}$$

$$v = 10.4$$

$$a = \frac{10.4}{9.6}$$

$$a = 1$$

Part C

Compare the net force on athlete L during interval Q with the net force on athlete L during interval S. Explain your reasoning.

The netforce on athlete L during interval Q would be greater than the netforce on athlete L during interval S because the acceleration during interval Q is greater.

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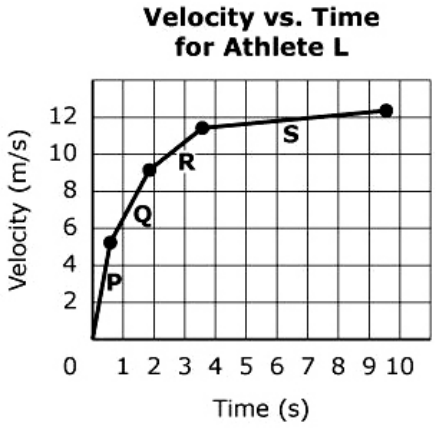
Score Point 1

This question is part of a module with an introduction. The introduction can be seen in score point 3A.

This question has three parts.

Another athlete, athlete L, completed a 100 m sprint in 9.6 s. The graph shows athlete L's velocity over time. Four time intervals are labeled P, Q, R, and S.



Part A

Identify the interval of the race when athlete L had the greatest acceleration. Explain your reasoning.

Athlete L had the most acceleration at interval P because it is the steepest point on the graph, meaning they gained the most velocity in the shortest amount of time.

Part B

Calculate athlete L's average acceleration for the entire race. Show your calculations and include units in your answer.

I used the graph to estimate the average velocity of the four points shown, $(5 + 9 + 12 + 12)$ I got 38, then divided it by 4 to get the average, 9.5 $\frac{m}{s}$, which I divided by 9.6 to get approximately $0.99\, m\ /\ s^2$ for the average acceleration of athlete L

Part C

Compare the net force on athlete L during interval Q with the net force on athlete L during interval S. Explain your reasoning.

There is no net force at point Q and S because they are staying at a constant velocity during the intervals. Athlete L only accelerates during the points on the graph when they change velocity.

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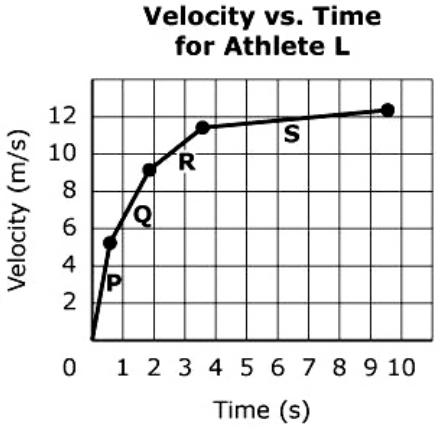
Score Point 0

This question is part of a module with an introduction. The introduction can be seen in score point 3A.

This question has three parts.

Another athlete, athlete L, completed a 100 m sprint in 9.6 s. The graph shows athlete L's velocity over time. Four time intervals are labeled P, Q, R, and S.



Part A

Identify the interval of the race when athlete L had the greatest acceleration. Explain your reasoning.

Interval S is athlete L's greatest acceleratio because it looks like thast when she went the fastest during that long period of time.

Part B

Calculate athlete L's average acceleration for the entire race. Show your calculations and include units in your answer.

$100m \div 9.6s = 10.4m \,/\, s$

Part C

Compare the net force on athlete L during interval Q with the net force on athlete L during interval S. Explain your reasoning.

The net force of interval Q is less then the net force of Interval S because at interval Q athlete L was slowly catching up speed but once she got to interval S she sped up faster then how she was in interval Q.

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