# 2022 MCAS Sample Student Work and Scoring Guide

## High School Introductory Physics
## Question 20: Constructed-Response

**Reporting Category:** Energy
**Practice Category:** Mathematics and Data
**Standard:** HS.PHY.3.1 - Use algebraic expressions and the principle of energy conservation to calculate the change in energy of one component of a system when the change in energy of the other component(s) of the system, as well as the total energy of the system including any energy entering or leaving the system, is known. Identify any transformations from one form of energy to another, including thermal, kinetic, gravitational, magnetic, or electrical energy, in the system.
**Item Description:** Interpret a diagram to determine where an object has its greatest amount of gravitational potential energy (GPE), calculate the object's GPE, compare the object's kinetic energy (KE) at two positions, and determine the object's position when its KE and GPE are equal.

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### Scoring Guide

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

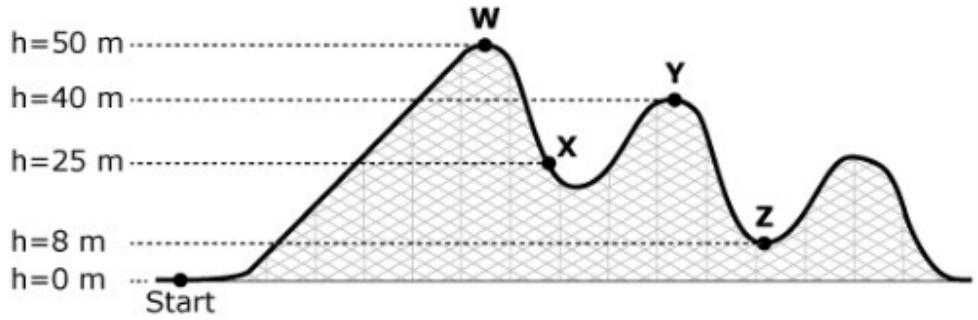
| Score* | Description |
|---|---|
| **4A** | The response demonstrates a thorough understanding of energy conservation, including the transformation of gravitational potential energy to kinetic energy. The response correctly identifies the point where the car had the greatest gravitational potential energy and correctly calculates the car's gravitational potential energy at that point. The response correctly compares the car's kinetic energy at point Y to the car's kinetic energy at point Z and clearly explains the reasoning. The response also correctly identifies the height at which the kinetic energy of the car was equal to the gravitational potential energy of the car and clearly explains the reasoning. |
| **4B** | |
| **3** | The response demonstrates a general understanding of energy conservation, including the transformation of gravitational potential energy to kinetic energy. |
| **2** | The response demonstrates a limited understanding of energy conservation, including the transformation of gravitational potential energy to kinetic energy. |
| **1** | The response demonstrates a minimal understanding of energy conservation, including the transformation of gravitational potential energy to kinetic energy. |
| **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., 4A and 4B).

## Score Point 4A

### This question has four parts.

A diagram of a roller coaster track at an amusement park is shown. The location where passengers get into a car to ride along the track is labeled "Start." Four additional points along the track are labeled W, X, Y, and Z.




For one ride, a car and its passengers had a total mass of 4500 kg. The car was pulled with a motor from the starting point to point W. The car was held at rest at point W until it was released. The car then moved along the track to point Z with negligible friction.

### Part A

Identify the point on the roller coaster track where the car and its passengers had the greatest amount of gravitational potential energy.

The car and its passengers had the most gravitational potential energy at Point W, the highest point above the ground (50m)

### Part B

Calculate the amount of gravitational potential energy the car and its passengers had at the point you identified in Part A. Show your calculations and include units in your answer.

$$U_g = mgh$$
$$\square = 4500 \cdot 10 \cdot 50$$
$$\square = 2{,}250{,}000 \text{ J}$$

### Part C

Compare the amount of kinetic energy of the car and its passengers at point Y to the amount of kinetic energy of the car and its passengers at point Z. Explain your reasoning.

The car and its passengers have more kinetic energy at point Z than point Y, because energy has to be conserved. There is more potential energy at point Y than point Z because point Y is higher off the ground, but the total mechanical energy at both points must be the same, meaning there is more kinetic energy at point Z and less at point Y.

### Part D

Identify the height at which the kinetic energy of the car and its passengers was equal to the gravitational potential energy of the car and its passengers. Explain your reasoning.

The kinetic and potential energy for the car and its passengers are equal at 25m (point X), because the car has moved downwards halfway from its original point, meaning its potential energy is also half as much. The other half has been converted into kinetic energy, meaning the kinetic and potential energy is the same.

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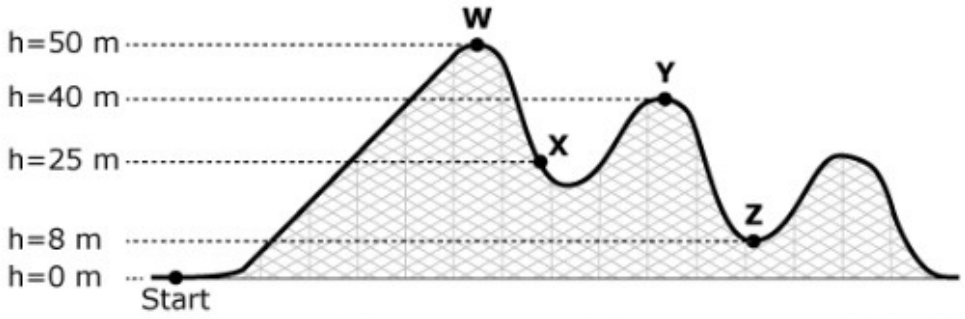
## Score Point 4B

### This question has four parts.

A diagram of a roller coaster track at an amusement park is shown. The location where passengers get into a car to ride along the track is labeled "Start." Four additional points along the track are labeled W, X, Y, and Z.




For one ride, a car and its passengers had a total mass of 4500 kg. The car was pulled with a motor from the starting point to point W. The car was held at rest at point W until it was released. The car then moved along the track to point Z with negligible friction.

### Part A

Identify the point on the roller coaster track where the car and its passengers had the greatest amount of gravitational potential energy.

The roller caoster had the most gravitational potential energy at point W because that is where the car and passengers were furthest up.

### Part B

Calculate the amount of gravitational potential energy the car and its passengers had at the point you identified in Part A. Show your calculations and include units in your answer.

$$GPE = ?$$
$$m = 4500\,\text{kg}$$
$$h = 50\,m$$
$$GPE = mgh$$
$$GPE = 4500\,(10)\,\,(50)$$
$$GPE = 2{,}250{,}000\,\text{J}$$

### Part C

Compare the amount of kinetic energy of the car and its passengers at point Y to the amount of kinetic energy of the car and its passengers at point Z. Explain your reasoning.

At point Z, the car and its passengers have more kinetic energy than potential energy because they are closer to the ground, which means less potential energy. At point Y, the car has more potential energy than kinetic because it is higher off the ground.

### Part D

Identify the height at which the kinetic energy of the car and its passengers was equal to the gravitational potential energy of the car and its passengers. Explain your reasoning.

Point X is the height at which the kinetic and gravitational potential energy is the same. This is because point X is halfway between the start point, 0m, and the highest point, 50m at 25m, causing it to have an equal amount of kinetic and gravitational potential energy.

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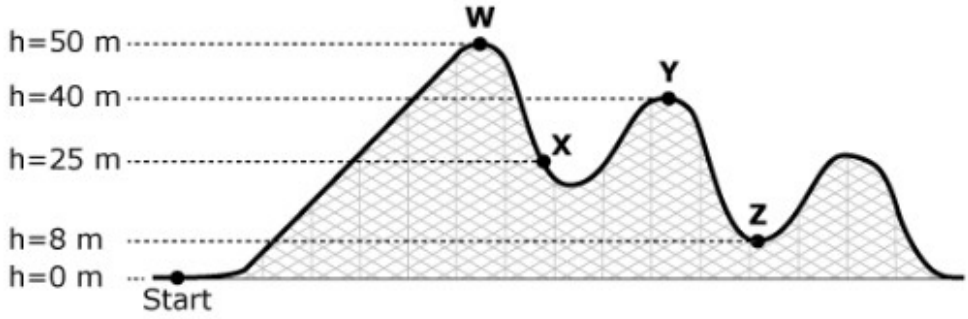
## Score Point 3

### This question has four parts.

A diagram of a roller coaster track at an amusement park is shown. The location where passengers get into a car to ride along the track is labeled "Start." Four additional points along the track are labeled W, X, Y, and Z.




For one ride, a car and its passengers had a total mass of 4500 kg. The car was pulled with a motor from the starting point to point W. The car was held at rest at point W until it was released. The car then moved along the track to point Z with negligible friction.

### Part A

Identify the point on the roller coaster track where the car and its passengers had the greatest amount of gravitational potential energy.

The passangers had the most potential energy on point W because its the highest point.

### Part B

Calculate the amount of gravitational potential energy the car and its passengers had at the point you identified in Part A. Show your calculations and include units in your answer.

$$PE = mgh$$
$$PE = 4500 \cdot 10 \cdot 50$$
$$PE = 2{,}250{,}000 \text{ J}$$

### Part C

Compare the amount of kinetic energy of the car and its passengers at point Y to the amount of kinetic energy of the car and its passengers at point Z. Explain your reasoning.

Point Y has less kinetic energy than pont Z because it it is at a higher point. In other words, Point Z has greater KE because it is at a lower point.

### Part D

Identify the height at which the kinetic energy of the car and its passengers was equal to the gravitational potential energy of the car and its passengers. Explain your reasoning.

The highest and lowest heights would be equal because PE is converted to KE has it moves downward.

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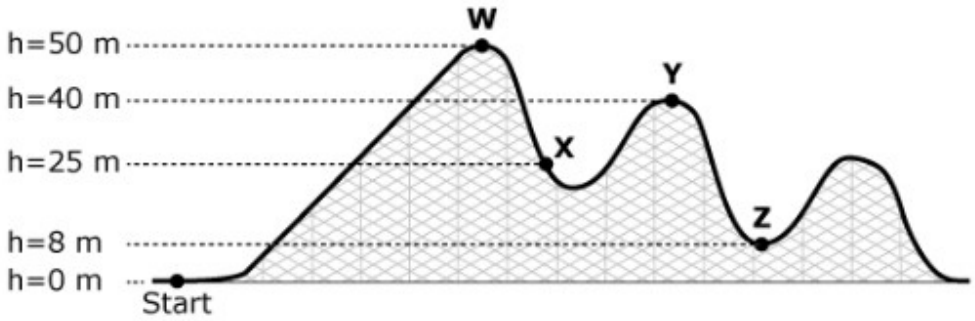
## Score Point 2

### This question has four parts.

A diagram of a roller coaster track at an amusement park is shown. The location where passengers get into a car to ride along the track is labeled "Start." Four additional points along the track are labeled W, X, Y, and Z.




For one ride, a car and its passengers had a total mass of 4500 kg. The car was pulled with a motor from the starting point to point W. The car was held at rest at point W until it was released. The car then moved along the track to point Z with negligible friction.

### Part A

Identify the point on the roller coaster track where the car and its passengers had the greatest amount of gravitational potential energy.

W

### Part B

Calculate the amount of gravitational potential energy the car and its passengers had at the point you identified in Part A. Show your calculations and include units in your answer.

$$\Delta PE = myg\Delta h$$
$$\Delta PE = 4500\,(10)\,\,(50)$$
$$\Delta PE = 2250000\ \text{J}$$

### Part C

Compare the amount of kinetic energy of the car and its passengers at point Y to the amount of kinetic energy of the car and its passengers at point Z. Explain your reasoning.

y
KE=1/2mv^2
KE=1/2 4500 10^2
KE=225000

z
KE=1/2mv^2
KE=1/2 4500 10^2
KE=225000

The amount of kinetic energy is the same at point Y and point Z

### Part D

Identify the height at which the kinetic energy of the car and its passengers was equal to the gravitational potential energy of the car and its passengers. Explain your reasoning.

W the kinetic energy and potential energy are the same.

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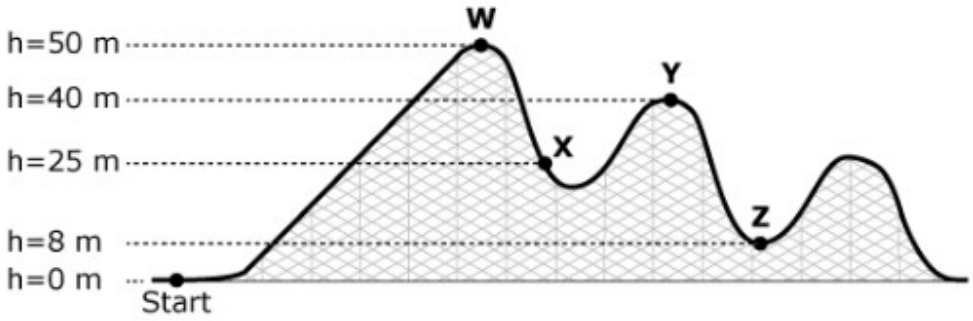
## Score Point 1

### This question has four parts.

A diagram of a roller coaster track at an amusement park is shown. The location where passengers get into a car to ride along the track is labeled "Start." Four additional points along the track are labeled W, X, Y, and Z.




For one ride, a car and its passengers had a total mass of 4500 kg. The car was pulled with a motor from the starting point to point W. The car was held at rest at point W until it was released. The car then moved along the track to point Z with negligible friction.

### Part A

Identify the point on the roller coaster track where the car and its passengers had the greatest amount of gravitational potential energy.

The roller coaster track had the most gravitational potential energy at point W.

### Part B

Calculate the amount of gravitational potential energy the car and its passengers had at the point you identified in Part A. Show your calculations and include units in your answer.

$4500\ \text{kg} \div 50 = 90\ \text{m}$

### Part C

Compare the amount of kinetic energy of the car and its passengers at point Y to the amount of kinetic energy of the car and its passengers at point Z. Explain your reasoning.

There was more kinetic energy at point Y because it's 40 m and point Z only has 8 m

### Part D

Identify the height at which the kinetic energy of the car and its passengers was equal to the gravitational potential energy of the car and its passengers. Explain your reasoning.

Point Y is closer to point W which has the most gravitational potential energy.

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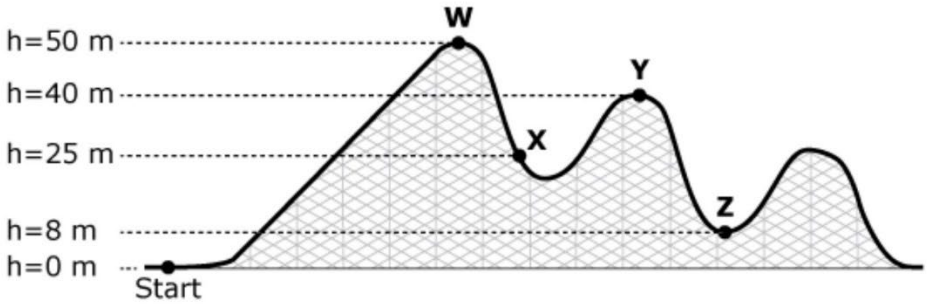
## Score Point 0

### This question has four parts.

A diagram of a roller coaster track at an amusement park is shown. The location where passengers get into a car to ride along the track is labeled “Start.” Four additional points along the track are labeled W, X, Y, and Z.




For one ride, a car and its passengers had a total mass of 4500 kg. The car was pulled with a motor from the starting point to point W. The car was held at rest at point W until it was released. The car then moved along the track to point Z with negligible friction.

### Part A

Identify the point on the roller coaster track where the car and its passengers had the greatest amount of gravitational potential energy.

the point where the car and the passengers had the greatest amount of gravitational potential energy is at point Y.

### Part B

Calculate the amount of gravitational potential energy the car and its passengers had at the point you identified in Part A. Show your calculations and include units in your answer.

the calculation would be 5x8 which would equal 40 m

### Part C

Compare the amount of kinetic energy of the car and its passengers at point Y to the amount of kinetic energy of the car and its passengers at point Z. Explain your reasoning.

the amount of kinetic energy is 5m because when you divid 40 and 8 it equals to 5m

### Part D

Identify the height at which the kinetic energy of the car and its passengers was equal to the gravitational potential energy of the car and its passengers. Explain your reasoning.

The height that its equal to gravitational potential energy is at point W because 4500/50 would be the height whitch would be 90m

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