2025 MCAS Sample Student Work and Scoring Guide

High School Introductory Physics
Question 21: Constructed-Response

Reporting Category: Energy
Practice Category: Evidence, Reasoning, and Modeling
Standard: HS.PHY.3.4 - Provide evidence that when two objects of different temperature are in thermal contact within a closed system, the transfer of thermal energy from higher-temperature objects to lower-temperature objects results in thermal equilibrium, or a more uniform energy distribution among the objects and that temperature changes necessary to achieve thermal equilibrium depend on the specific heat values of the two substances.
Item Description: Interpret a temperature vs. time graph of two objects in water to identify and explain the initial temperature of the water, describe when the objects will stop cooling, explain how more thermal energy was lost by one of the objects, and describe how the total heat transfer would be different if an object had a higher specific heat.

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.

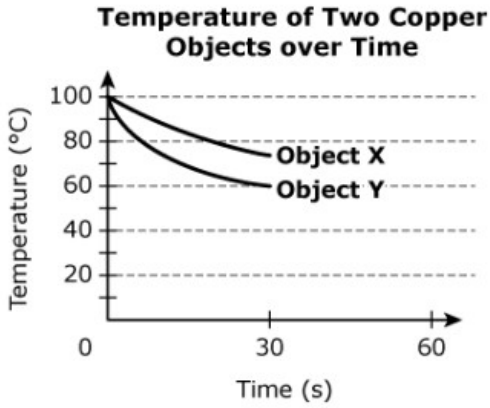
Score*	Description
4A	The response demonstrates a thorough understanding of thermal energy transfer and thermal equilibrium. The response correctly identifies that the initial temperature of the water is lower than 60°C and clearly explains the reasoning. The response clearly describes when the objects will stop cooling. The response correctly compares the thermal energy lost by the two objects and clearly explains the reasoning. The response also clearly describes how using an object with a higher specific heat would affect the total heat transfer.
4B	
3	The response demonstrates a general understanding of thermal energy transfer and thermal equilibrium.
2	The response demonstrates a limited understanding of thermal energy transfer and thermal equilibrium.
1	The response demonstrates a minimal understanding of thermal energy transfer and thermal equilibrium.
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.

Two copper objects, X and Y, have different shapes. Each object is heated to 100°C and then placed in its own jar. Each jar contains the same amount of water that is at the same temperature. Object Y cools at a faster rate than object X because object Y has a greater surface area. The graph shows the temperature of each object over time.



Part A

Was the initial water temperature higher than 100°C, between 100°C and 60°C, or lower than 60°C? Explain your reasoning.

MATH

The initial water temperature was lower than $60°C$. This is because as the copper objects cooled, they transfered their heat to the water. Since Object Y cools to $60°$, the initial water temperature must have been lower than that in order to heat up while object Y cools.

Maximum number of characters: 1500 || Characters remaining: 1287

Part B

Describe when the copper objects will stop cooling.

The copper objects will stop cooling when they have reached thermal equilibrium, or an equal temperature with the water. There will be no temperture difference, and therefore no heat transfer.

Maximum number of characters: 1500 || Characters remaining: 1337

Part C

The mass of each copper object is 10 g.

Compare the thermal energy lost by the two objects from 0 s to 30 s. Explain your reasoning.

$Q = mc\Delta T$ We know that Object X lost about $30°C$, and Objet Y lost about $40°C$. The masses of both objects is 10 g, and they are both made of copper, so the specific heat would be the same. Therefore, Object Y lost $\frac{4}{3}$ times as much heat as Object X. This is because it has a greater surface area so it will give off more heat in 30 s.

Maximum number of characters: 1500 || Characters remaining: 1257

Part D

Describe how the total heat transfer between a 10 g object and the water would be different if the object were made of a metal with a higher specific heat.

If the objects were made of a metal with a higher specific heat, more heat would be transferred, because it takes more heat to change the temperature of an object with a higher specific heat.

Maximum number of characters: 1500 || Characters remaining: 1343

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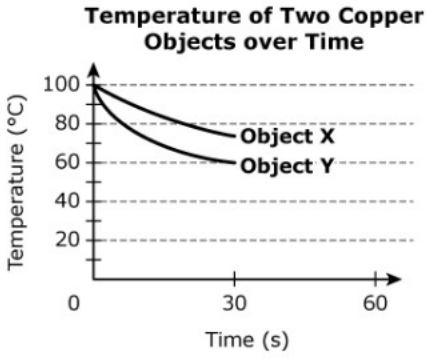
Score Point 4B

This question has four parts.

Two copper objects, X and Y, have different shapes. Each object is heated to 100°C and then placed in its own jar. Each jar contains the same amount of water that is at the same temperature. Object Y cools at a faster rate than object X because object Y has a greater surface area. The graph shows the temperature of each object over time.



Part A

Was the initial water temperature higher than 100°C, between 100°C and 60°C, or lower than 60°C? Explain your reasoning.

The initial temperature of the water was lower than $60°C$. I know because of thermal equilibrium. That means the temperatures will get closer to each other until both water and object reach the same temperature, in between both of their initial temperatures. The initial temperature must be less than $60°C$ for object Y to end on $60°C$ because $60°C$ is the final temperature (in between the initial temperature of the water and object).

Maximum number of characters: 1500 || Characters remaining: 1157

Part B

Describe when the copper objects will stop cooling.

The copper objects will stop cooling when they reach the same temperature as the water. Again, thermal equilibrium. Heat won't be transferred between two objects that are the same temperature.

Maximum number of characters: 1500 || Characters remaining: 1337

Part C

The mass of each copper object is 10 g.

Compare the thermal energy lost by the two objects from 0 s to 30 s. Explain your reasoning.

Object Y lost more thermal energy than Object X. $Q = mc\Delta T$. We can discount c (specific heat capacity) and m (mass) because they are the same for both. The ΔT (change in temperature) for Obj. X is $-25°C$; for Obj. Y it is $-40°C$. Since everything else about the two copper objects is the same, the object that saw the greatest change in temperature is the object that lost more thermal energy; Object Y.

Maximum number of characters: 1500 || Characters remaining: 1194

Part D

Describe how the total heat transfer between a 10 g object and the water would be different if the object were made of a metal with a higher specific heat.

The total heat transfer would be different with a metal with a higher specific heat capacity (still under the same situation). Objects with a high specific heat capacity need more energy to raise its temperature one degree, so it would lose more energy (than an object with a lower specific heat capacity) when its temperature drops. Therefore, the total amount of heat energy transferred would be higher because there is more heat energy.

Maximum number of characters: 1500 || Characters remaining: 1133

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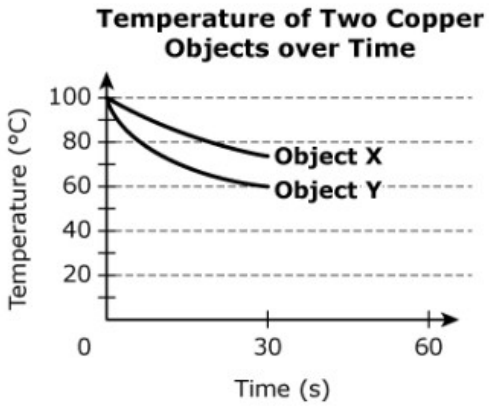
Score Point 3

This question has four parts.

Two copper objects, X and Y, have different shapes. Each object is heated to 100°C and then placed in its own jar. Each jar contains the same amount of water that is at the same temperature. Object Y cools at a faster rate than object X because object Y has a greater surface area. The graph shows the temperature of each object over time.



Part A

Was the initial water temperature higher than 100°C, between 100°C and 60°C, or lower than 60°C? Explain your reasoning.

The water had to be lower than $60°C$ because over time the objects cooled and at 30 seconds object Y was at $60°C$ and if the water was above $60°C$ then there is no possible way that the object could have cooled down to $60°$.

Maximum number of characters: 1500 || Characters remaining: 1340

Part B

Describe when the copper objects will stop cooling.

The copper objects will stop cooling when they reach the thermal equilbrum. This is when all of the objects reach the same temperature, and once they all reach the same temperature then heat is not being transfered which means that the objects will stop cooling.

Maximum number of characters: 1500 || Characters remaining: 1282

Part C

The mass of each copper object is 10 g.

Compare the thermal energy lost by the two objects from 0 s to 30 s. Explain your reasoning.

After 30 seconds object Y lost more thermal energy than object X. At 30 seconds object Y temperature was $60°C$ and object X temperature was $70°C$. As you can see object Y lost more thermal energy than object X because it's temperature was lower.

Maximum number of characters: 1500 || Characters remaining: 1308

Part D

Describe how the total heat transfer between a 10 g object and the water would be different if the object were made of a metal with a higher specific heat.

The total heat transfer would be different because if the objects had a higher specific heat then they would cool slower and have a different thermal equilbrum temperature.

Maximum number of characters: 1500 || Characters remaining: 1355

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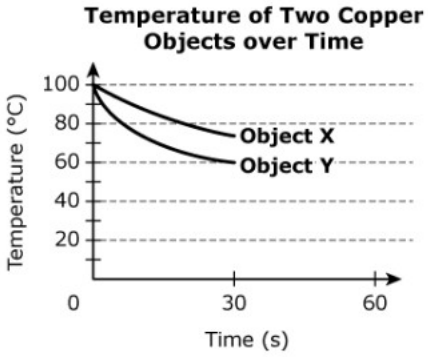
Score Point 2

This question has four parts.

Two copper objects, X and Y, have different shapes. Each object is heated to 100°C and then placed in its own jar. Each jar contains the same amount of water that is at the same temperature. Object Y cools at a faster rate than object X because object Y has a greater surface area. The graph shows the temperature of each object over time.



Part A

Was the initial water temperature higher than 100°C, between 100°C and 60°C, or lower than 60°C? Explain your reasoning.

MATH

100 because it started in 100

Maximum number of characters: 1500 | | Characters remaining: 1476

Part B

Describe when the copper objects will stop cooling.

It will stop when the water and cooper are in the same temperature.

Maximum number of characters: 1500 | | Characters remaining: 1445

Part C

The mass of each copper object is 10 g.

Compare the thermal energy lost by the two objects from 0 s to 30 s. Explain your reasoning.

Y lost more energy because the temperature decrease the most.

Maximum number of characters: 1500 | | Characters remaining: 1448

Part D

Describe how the total heat transfer between a 10 g object and the water would be different if the object were made of a metal with a higher specific heat.

The temperature of the water will increase.

Maximum number of characters: 1500 | | Characters remaining: 1463

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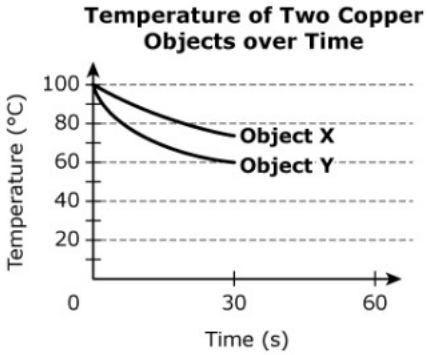
Score Point 1

This question has four parts.

Two copper objects, X and Y, have different shapes. Each object is heated to 100°C and then placed in its own jar. Each jar contains the same amount of water that is at the same temperature. Object Y cools at a faster rate than object X because object Y has a greater surface area. The graph shows the temperature of each object over time.



Part A

Was the initial water temperature higher than 100°C, between 100°C and 60°C, or lower than 60°C? Explain your reasoning.

Between $100°C$ and $60°C$ because on the graph, it shows both lines ending at $60°C$ and about $75°C$.

Maximum number of characters: 1500 || Characters remaining: 1439

Part B

Describe when the copper objects will stop cooling.

MATH

The copper objects will stop cooling when the temperature of the copper and the water is the same. Heat always travels from hot to cold.

Maximum number of characters: 1500 || Characters remaining: 1388

Part C

The mass of each copper object is 10 g.

Compare the thermal energy lost by the two objects from 0 s to 30 s. Explain your reasoning.

MATH

Since both copper are 10g, they lost thermal energy at the same rate.

Maximum number of characters: 1500 || Characters remaining: 1443

Part D

Describe how the total heat transfer between a 10 g object and the water would be different if the object were made of a metal with a higher specific heat.

MATH

The total heat transfer would be different if metal were used because it has a different heat capacity, so it would take longer or shorter to cool down.

Maximum number of characters: 1500 || Characters remaining: 1375

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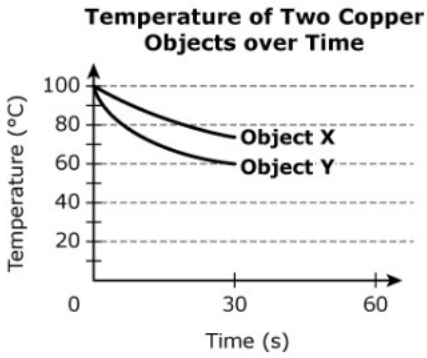
Score Point 0

This question has four parts.

Two copper objects, X and Y, have different shapes. Each object is heated to 100°C and then placed in its own jar. Each jar contains the same amount of water that is at the same temperature. Object Y cools at a faster rate than object X because object Y has a greater surface area. The graph shows the temperature of each object over time.



Part A

Was the initial water temperature higher than 100°C, between 100°C and 60°C, or lower than 60°C? Explain your reasoning.

The initial water temperature is between 100° C and 60° C

Maximum number of characters: 1500 || Characters remaining: 1455

Part B

Describe when the copper objects will stop cooling.

The two copper objects will stop cooling at 60° C.

Maximum number of characters: 1500 || Characters remaining: 1460

Part C

The mass of each copper object is 10 g.

Compare the thermal energy lost by the two objects from 0 s to 30 s. Explain your reasoning.

Object Y's temperature will fall while object X's temperature will also fall but not as swifly.

Maximum number of characters: 1500 || Characters remaining: 1420

Part D

Describe how the total heat transfer between a 10 g object and the water would be different if the object were made of a metal with a higher specific heat.

The object will take much longer to heat up.

Maximum number of characters: 1500 || Characters remaining: 1464

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