

2023 MCAS Sample Student Work and Scoring Guide

High School Introductory Physics Question 21: Constructed-Response

Reporting Category: Energy

Practice Category: Mathematics and Data

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: Determine the direction of heat flow between marbles and water in an investigation, calculate the amount of thermal energy transferred and the specific heat of the marbles, and describe whether changing the number of marbles would affect their specific heat.

[View item in MCAS Digital Item Library](#)

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 specific heats of substances. The response correctly identifies the direction of heat flow and clearly explains why. The response correctly calculates the amount of thermal energy gained by the water and correctly calculates the specific heat of glass. The response also correctly compares the specific heat of five glass marbles to ten glass marbles and clearly explains why.
4B	
3	The response demonstrates a general understanding of thermal energy transfer and specific heats of substances.
2	The response demonstrates a limited understanding of thermal energy transfer and specific heats of substances.
1	The response demonstrates a minimal understanding thermal energy transfer and specific heats of substances.
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 student conducted an investigation to determine the specific heat of glass. The student placed five glass marbles with a total mass of 27.3 g into a beaker of boiling water. After the marbles reached 100°C, the student placed them in an insulated cup containing 75 g of water at 20°C. The water and the glass marbles in the cup eventually reached a temperature of 25.5°C.

Part A

In the insulated cup with water, did heat flow from the water to the marbles or from the marbles to the water? Explain your answer.

B <i>I</i> <u>U</u>	1344
In the insulated cup, heat flowed from the marbles to the water because the marbles were at a greater temperature and cooled down while the water heated up.	

Part B

The specific heat of water is 4.19 J/g • °C.

Calculate the amount of thermal energy gained by the water in the cup. Show your calculations and include units in your answer.

$Q = mc\Delta T \quad 25.5 - 20 = 5.5 = \Delta T$ $Q = 75 \cdot 4.19 \cdot 5.5$ $Q = 1728.375 \text{ J}$	<p>▼ Symbols</p> <table border="1"><tr><td>+</td><td>-</td><td>×</td><td>÷</td></tr><tr><td>±</td><td>-</td><td>·</td><td>/</td></tr><tr><td>=</td><td>≠</td><td>$\frac{\square}{\square}$</td><td>$\frac{\square\square}{\square\square}$</td></tr><tr><td>$y^x$</td><td>$\sqrt{\quad}$</td><td>$\sqrt[3]{\quad}$</td><td>$\sqrt[n]{\quad}$</td></tr><tr><td>$x_i$</td><td>$\pi$</td><td>$\infty$</td><td>(</td></tr><tr><td>)</td><td>λ</td><td>Δ</td><td>Ω</td></tr><tr><td>°</td><td></td><td></td><td></td></tr></table>	+	-	×	÷	±	-	·	/	=	≠	$\frac{\square}{\square}$	$\frac{\square\square}{\square\square}$	y^x	$\sqrt{\quad}$	$\sqrt[3]{\quad}$	$\sqrt[n]{\quad}$	x_i	π	∞	()	λ	Δ	Ω	°			
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x_i	π	∞	(
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Part C

Calculate the specific heat of the glass. Show your calculations and include units in your answer.



$$c = \frac{Q}{m\Delta T} \quad 100 - 25.5 = 74.5 = \Delta T$$

$$c = \frac{1728.375}{27.3 \cdot 74.5}$$

$$c = \frac{1728.375}{2033.85} \quad c = 0.85 \cdot \frac{J}{g \cdot ^\circ C}$$

▼ Symbols

+	-	×	÷
±	-	·	/
=	≠	□	□
y^x	$\sqrt{\quad}$	$\sqrt[3]{\quad}$	$\sqrt[n]{\quad}$
x_i	π	∞	(
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Part D

The investigation is repeated with ten glass marbles having a total mass of 54.6 g.

Compare the specific heat of the five glass marbles to the specific heat of the ten glass marbles. Explain your answer.

B *I* U 1299

The specific heat of a substance is always constant, so it doesn't matter whether you use 10 or 5 marbles, the experiment will yield the same results. The specific heat of the glass is always the same.

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Score Point 4B

This question has four parts.

A student conducted an investigation to determine the specific heat of glass. The student placed five glass marbles with a total mass of 27.3 g into a beaker of boiling water. After the marbles reached 100°C, the student placed them in an insulated cup containing 75 g of water at 20°C. The water and the glass marbles in the cup eventually reached a temperature of 25.5°C.

Part A

In the insulated cup with water, did heat flow from the water to the marbles or from the marbles to the water? Explain your answer.




B *I* U      1374

The heat flowed from the marbles to the water. The marbles were hotter than the water, and heat always flows from hot to cold.

Part B

The specific heat of water is 4.19 J/g • °C.

Calculate the amount of thermal energy gained by the water in the cup. Show your calculations and include units in your answer.

$$Q = mc\Delta T$$
$$Q = 75 \cdot 4.19 \cdot 5.5$$
$$Q = 1,728.375 \text{ J}$$

Symbols

+	-	×	÷
±	-	·	/
=	≠	≡	≡
y^x	$\sqrt{\quad}$	$\sqrt[3]{\quad}$	$\sqrt[n]{\quad}$
x_i	π	∞	(
)	λ	Δ	Ω
°			

Part C

Calculate the specific heat of the glass. Show your calculations and include units in your answer.



$$Q = mc\Delta T$$
$$1,728.37 = 27.3 \cdot c \cdot 74.5$$
$$c = 0.85 \frac{J}{g \cdot ^\circ C}$$

▼ Symbols

+	-	×	÷
±	-	·	/
=	≠	≡	≡
y^x	$\sqrt{\quad}$	$\sqrt[3]{\quad}$	$\sqrt[n]{\quad}$
x_i	π	∞	(
)	λ	Δ	Ω
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Part D

The investigation is repeated with ten glass marbles having a total mass of 54.6 g.

Compare the specific heat of the five glass marbles to the specific heat of the ten glass marbles. Explain your answer.

B *I* U 1387

They are equal. Specific heat does not change when mass changes. Each material always only has one specific heat.

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Score Point 3

This question has four parts.

A student conducted an investigation to determine the specific heat of glass. The student placed five glass marbles with a total mass of 27.3 g into a beaker of boiling water. After the marbles reached 100°C, the student placed them in an insulated cup containing 75 g of water at 20°C. The water and the glass marbles in the cup eventually reached a temperature of 25.5°C.

Part A

In the insulated cup with water, did heat flow from the water to the marbles or from the marbles to the water? Explain your answer.




B *I* U      1397

The heat flow was from the 100 C marbles to the 20 C water, because heat always flows from hot to cold.

Part B

The specific heat of water is 4.19 J/g • °C.

Calculate the amount of thermal energy gained by the water in the cup. Show your calculations and include units in your answer.

$$Q = mc\Delta T = 75 \times 4.19 \times 5.5 = 1728.375 J$$

- [Symbols](#)
- [Relations](#)
- [Geometry](#)
- [Groups](#)

Part C

Calculate the specific heat of the glass. Show your calculations and include units in your answer.


$$Q = mc\Delta T$$
$$c = \frac{Q}{m\Delta T} = \frac{100}{27.3 \times 74.5} = 0.049 \frac{J}{g \cdot ^\circ C}$$

▼ Symbols

+	-	×	÷
±	-	·	/
=	≠	≡	≡
y^x	$\sqrt{\quad}$	$\sqrt[3]{\quad}$	$\sqrt[n]{\quad}$
x_i	π	∞	(
)	λ	Δ	Ω
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Part D

The investigation is repeated with ten glass marbles having a total mass of 54.6 g.

Compare the specific heat of the five glass marbles to the specific heat of the ten glass marbles. Explain your answer.

B *I* U 1388

The specific heat will stay the same, because you have the same material, so its specific heat will not change.

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Score Point 2

This question has four parts.

A student conducted an investigation to determine the specific heat of glass. The student placed five glass marbles with a total mass of 27.3 g into a beaker of boiling water. After the marbles reached 100°C, the student placed them in an insulated cup containing 75 g of water at 20°C. The water and the glass marbles in the cup eventually reached a temperature of 25.5°C.

Part A

In the insulated cup with water, did heat flow from the water to the marbles or from the marbles to the water? Explain your answer.

B <i>I</i> <u>U</u>	1389
The heat flowed from the marbles to the water because heat always flows from the warmest object to the coolest.	

Part B

The specific heat of water is 4.19 J/g • °C.

Calculate the amount of thermal energy gained by the water in the cup. Show your calculations and include units in your answer.

$Q = mc\Delta T$ $(75\text{g}) \left(4.19 \cdot \frac{\text{J}}{\text{g}^\circ\text{C}} \right) (5.5^\circ\text{C}) = 1728.375\text{J}$	<p>▼ Symbols</p> <table border="1"><tr><td>+</td><td>-</td><td>×</td><td>÷</td></tr><tr><td>±</td><td>-</td><td>·</td><td>/</td></tr><tr><td>=</td><td>≠</td><td>$\frac{\square}{\square}$</td><td>$\frac{\square}{\square}$</td></tr><tr><td>x^x</td><td>$\sqrt{\quad}$</td><td>$\sqrt[3]{\quad}$</td><td>$\sqrt[n]{\quad}$</td></tr><tr><td>x_i</td><td>π</td><td>∞</td><td>(</td></tr><tr><td>)</td><td>λ</td><td>Δ</td><td>Ω</td></tr><tr><td>°</td><td></td><td></td><td></td></tr></table>	+	-	×	÷	±	-	·	/	=	≠	$\frac{\square}{\square}$	$\frac{\square}{\square}$	x^x	$\sqrt{\quad}$	$\sqrt[3]{\quad}$	$\sqrt[n]{\quad}$	x_i	π	∞	()	λ	Δ	Ω	°			
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x_i	π	∞	(
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Part C

Calculate the specific heat of the glass. Show your calculations and include units in your answer.



$$100 = (5.46g) (c) (74.5)$$

$$13.404 = (c) (74.5)$$

$$c = 0.179 \cdot \frac{J}{g^{\circ}C}$$

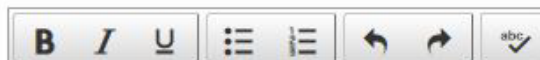
▼ Symbols

+	-	×	÷
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y^x	$\sqrt{\quad}$	$\sqrt[3]{\quad}$	$\sqrt[n]{\quad}$
x_i	π	∞	(
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Part D

The investigation is repeated with ten glass marbles having a total mass of 54.6 g.

Compare the specific heat of the five glass marbles to the specific heat of the ten glass marbles. Explain your answer.



1327

The specific heat of the ten glass marbles is lower than the 5 glass marbles because they have a large mass to be heated or cooled to the same temperature as the 5 marbles.

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Score Point 1

This question has four parts.

A student conducted an investigation to determine the specific heat of glass. The student placed five glass marbles with a total mass of 27.3 g into a beaker of boiling water. After the marbles reached 100°C, the student placed them in an insulated cup containing 75 g of water at 20°C. The water and the glass marbles in the cup eventually reached a temperature of 25.5°C.

Part A




In the insulated cup with water, did heat flow from the water to the marbles or from the marbles to the water? Explain your answer.

B <i>I</i> <u>U</u>     	1395
heat flowed from the marbles to the water because the marbles were at a higher temperature than the water	

Part B

The specific heat of water is 4.19 J/g • °C.

Calculate the amount of thermal energy gained by the water in the cup. Show your calculations and include units in your answer.

  																													
$Q = mc\Delta T$ $Q = 75 (4.19) (49.5) = 15555.375 \text{ J}$	<p>▼ Symbols</p> <table border="1"><tr><td>+</td><td>-</td><td>×</td><td>÷</td></tr><tr><td>±</td><td>-</td><td>·</td><td>/</td></tr><tr><td>=</td><td>≠</td><td>≡</td><td>≡</td></tr><tr><td>y^x</td><td>$\sqrt{\quad}$</td><td>$\sqrt[3]{\quad}$</td><td>$\sqrt[n]{\quad}$</td></tr><tr><td>x_i</td><td>π</td><td>∞</td><td>(</td></tr><tr><td>)</td><td>λ</td><td>Δ</td><td>Ω</td></tr><tr><td>°</td><td></td><td></td><td></td></tr></table>	+	-	×	÷	±	-	·	/	=	≠	≡	≡	y^x	$\sqrt{\quad}$	$\sqrt[3]{\quad}$	$\sqrt[n]{\quad}$	x_i	π	∞	()	λ	Δ	Ω	°			
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Part C

Calculate the specific heat of the glass. Show your calculations and include units in your answer.



$$c = m\Delta T$$

$$c = 27.3 (74.5) = 2033.85 \text{ five marbles}$$

▼ Symbols

+	-	×	÷
±	-	·	/
=	≠	≡	≡
y^x	$\sqrt{\quad}$	$\sqrt[3]{\quad}$	$\sqrt[n]{\quad}$
x_i	π	∞	(
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Part D

The investigation is repeated with ten glass marbles having a total mass of 54.6 g.

Compare the specific heat of the five glass marbles to the specific heat of the ten glass marbles. Explain your answer.

B *I* U

1332

$c = 54.6(4067.7) = 222096.42$ 10 marbles
 2033.85 times 2 because it's twice as much
 the specific heat of 10 marbles is greater than the specific heat of 5 marbles because $10 > 5$

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Score Point 0

This question has four parts.

A student conducted an investigation to determine the specific heat of glass. The student placed five glass marbles with a total mass of 27.3 g into a beaker of boiling water. After the marbles reached 100°C, the student placed them in an insulated cup containing 75 g of water at 20°C. The water and the glass marbles in the cup eventually reached a temperature of 25.5°C.

Part A

In the insulated cup with water, did heat flow from the water to the marbles or from the marbles to the water? Explain your answer.

B <i>I</i> <u>U</u>	1431
The heat flow went from the water because heat transfers cold to hot.	

Part B

The specific heat of water is 4.19 J/g • °C.

Calculate the amount of thermal energy gained by the water in the cup. Show your calculations and include units in your answer.

$\frac{4.19 \cdot \frac{J}{g \cdot C}}{100 \cdot C}$ <p>thermal energy gained by water was $0.0419 \frac{J}{g \cdot C}$</p>	Symbols <table border="1"><tr><td>+</td><td>-</td><td>×</td><td>÷</td></tr><tr><td>±</td><td>-</td><td>·</td><td>/</td></tr><tr><td>=</td><td>≠</td><td>$\frac{\square}{\square}$</td><td>$\frac{\square\square}{\square\square}$</td></tr><tr><td>$x^x$</td><td>$\sqrt{\quad}$</td><td>$\sqrt[3]{\quad}$</td><td>$\sqrt[n]{\quad}$</td></tr><tr><td>$x_i$</td><td>$\pi$</td><td>$\infty$</td><td>(</td></tr><tr><td>)</td><td>λ</td><td>Δ</td><td>Ω</td></tr><tr><td>°</td><td></td><td></td><td></td></tr></table>	+	-	×	÷	±	-	·	/	=	≠	$\frac{\square}{\square}$	$\frac{\square\square}{\square\square}$	x^x	$\sqrt{\quad}$	$\sqrt[3]{\quad}$	$\sqrt[n]{\quad}$	x_i	π	∞	()	λ	Δ	Ω	°			
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x_i	π	∞	(
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Part C

Calculate the specific heat of the glass. Show your calculations and include units in your answer.



$$Q = mc\Delta T$$

$$100 = 27.3c \cdot 74.5$$

$$\frac{100}{2033.85} = \frac{2033.85c}{2033.85}$$

$$\text{specific heat of glass} = 0.04917 \cdot \frac{J}{g^{\circ}C}$$

▼ Symbols

+	-	×	÷
±	-	·	/
=	≠	$\frac{\square}{\square}$	$\frac{\square}{\square}$
y^x	$\sqrt{\quad}$	$\sqrt[3]{\quad}$	$\sqrt[n]{\quad}$
x_i	π	∞	(
)	λ	Δ	Ω
°			

Part D

The investigation is repeated with ten glass marbles having a total mass of 54.6 g.

Compare the specific heat of the five glass marbles to the specific heat of the ten glass marbles. Explain your answer.

B	<i>I</i>	<u>U</u>	$\frac{\square}{\square}$	$\frac{\square}{\square}$	↶	↷	abc ✓	1419
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100=54.6c74.5
 100/4067.7c = 4067.7c/4067.7c
 Specific heat = 0.02458J/gC

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