**Energy in a thermal store**

The *change* of energy in a thermal store can be calculated:

**Change in energy**

**Mass**

**Specific heat capacity**

**Change in temperature**

**=**

**x**

**x**

**ΔE** = **m** x **c** x **ΔΘ**

*Out loud this says: delta E equals m times c times delta theta.*

*Delta (Δ) is a Greek letter that is used as shorthand for writing: a change in.*

|  |  |
| --- | --- |
| ΔE is measured in Joules | J |
| m is measured in kilograms | kg |
| c is measured in Joules per kilogram per degree C | J/kg/oC |
| ΔΘ is measured in degrees C | oC |

**Energy in a thermal store**

**1.** What does this calculation tell us about energy in the thermal store of the gold block?

Mass of block is 2 kg.

It is heated to increase its temperature from 20oC to 40 oC.

Specific heat capacity of gold is 130 J/kg/ oC.

ΔE = m x c x ΔΘ

ΔE = 2 x 130 x 20

ΔE = 5200 Joules

|  |  |  |
| --- | --- | --- |
| **A** | It has 5200 J of energy in its thermal store. |  |
|  |  |  |
| **B** | It has 10 400 J of energy in its thermal store. |  |
|  |  |  |
| **C** | It has an extra 5200 J of energy in its thermal store. |  |

**2.** What does this calculation tell us about energy in the thermal store of the gold block?

Mass of block is 3 kg.

It is cooled to reduce its temperature from 40oC to 0 oC.

Specific heat capacity of gold is 130 J/kg/ oC.

ΔE = m x c x ΔΘ

ΔE = 3 x 130 x (-40)

ΔE = -15 600 Joules

|  |  |  |
| --- | --- | --- |
| **A** | It has 15 600 J less energy in its thermal store. |  |
|  |  |  |
| **B** | It has 15 600 J of energy in its thermal store. |  |
|  |  |  |
| **C** | It has no energy in its thermal store. |  |

*Physics > Big idea PMA: Matter> Topic PMA3: Energy of moving particles > Key concept PMA3.2: Specific heat capacity*

|  |
| --- |
| **Diagnostic question** |
| **Energy in a thermal store** |

**Overview**

|  |  |
| --- | --- |
| Learning focus: | Specific heat capacity is the amount of energy added to the thermal store of a material in order to increase the temperature of 1kg of that material by 1oC. |
| Observable learning outcome: | Predict how one quantity in the equation ΔE = mcΔΘ is affected by changes to other quantities. |
| Question type: | Simple multiple choice |
| Key words: | Energy change, temperature change, mass, specific heat capacity, thermal store |

**What does the research say?**

Herrington (2011) suggests the traditional method of teaching specific heat capacity, which involves learning the related definitions and equations and using equations to determine the specific heat capacity in a laboratory setting contributes to confusion about specific heat capacity. Although students are often able to calculate values with the equation, they often do not often understand what specific heat capacity tells us about a material. Instead it can be more effective to introduce students to the concept of heat capacity and to guide them to make connections to their own personal experiences before introducing definitions and equations.

One way to think about specific heat capacity is as a measure of how hard it is to change the temperature of a material. For two objects of the same mass, the one with the bigger specific heat capacity will be harder to warm up as it requires more energy to increase its temperature by 1oC.

In this progression toolkit an understanding of the physical meaning of specific heat capacity is developed before introducing its formal definition and the mathematical equation from which it can be calculated. This allows explicit links to be made between students’ physical understanding and the mathematical operations, and this helps students to understand the equation in terms of its implications in the real world (Redish and Kuo, 2015).

This diagnostic question can be used to check whether students have made some of these necessary links.

**Ways to use this question**

Students should complete the question individually. This could be a pencil and paper exercise, or you could use an electronic ‘voting system’ or mini white boards and the PowerPoint presentation.

The answers to the question will show you whether students understood the concept sufficiently well to apply it correctly.

If there is a range of answers, you may choose to respond through structured class discussion. Ask one student to explain why they gave the answer they did; ask another student to explain why they agree with them; ask another to explain why they disagree, and so on. This sort of discussion gives students the opportunity to explore their thinking and for you to really understand their learning needs.

*Differentiation*

You may choose to read the questions to the class, so that everyone can focus on the science. In some situations it may be more appropriate for a teaching assistant to read for one or two students.

**Expected answers**

1. C, an extra 5200J.

2. A, 15 600J less.

**How to respond - what next?**

It is not straight forward to measure the total energy in the thermal store of a material, but using physical measurements of mass, temperature change and specific heat capacity the ***change*** of energy in the thermal store can be calculated.

*Question 1*

A common misunderstanding is that the energy calculated is the total energy in the thermal store (answer A).

A few students may select answer B if they have the preconception that the block has no energy in its thermal store at 0oC. This is only the case at absolute zero, which is approximately -273oC (and because matter behaves differently at very low temperatures we cannot use ΔE = mcΔΘ to calculate total energy in a thermal store by adding an extra 273 to the temperature).

*Question 2*

In this question students are introduced to the idea that when the temperature decreases the value of ΔΘ is negative. A significant minority of students at age 14-16 may not be confident in calculating with negative values.

A negative value for the energy change shows that energy has been transferred out of the block to its surroundings. The quantity quantifies how much energy has been transferred.

Students who think wrongly that they are calculating the total energy are likely to select answer B (ignoring the negative sign). Some may think the block has no energy because it is at 0oC and choose answer C.

If students have misunderstandings about what the results of this calculation describe about the energy in the thermal store of the block, it can help to guide them through the same calculations in reverse. To do this, perhaps start by asking what would happen to the temperature if energy is transferred to the block by heating (or from the block by cooling). Careful questioning should elicit the understanding that the temperature will increase (or decrease) no matter what the temperature of the block is at the start.

The BEST diagnostic question: Temperature change can be used to check students’ understanding of how the temperature of a material is affected by the amount of energy transferred into or out of its thermal store. It can also be used to check understanding of what happens when more than one variable in the equation changes at one time.

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Images: Peter Fairhurst (UYSEG).

**References**

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Redish, E. F. and Kuo, E. (2015). Language of physics, language of math: Disciplinary culture and dynamic epistemol. *Science and Education,* 24**,** 561-590.