**Rearranging specific heat capacity**

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**

The equation can be rearranged to calculate:

* change in temperature, ΔΘ,
* mass, m,
* or specific heat capacity, c.

In which of these has the equation been rearranged wrongly?

**A**

**B**

**C**

**D**

m

=

ΔE

c

x

ΔΘ

c

=

ΔΘ

m

x

ΔE

m

=

ΔE

c

x

ΔΘ

x

ΔΘ

=

ΔE

m

x

c

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

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| --- |
| **Diagnostic question** |
| **Rearranging specific heat capacity** |

**Overview**

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| --- | --- |
| 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: | Make calculations using the equation ΔE = mcΔΘ. |
| Question type: | Simple multiple choice |
| Key words: | Energy change, temperature change, mass, specific heat capacity |

**What does the research say?**

Rearranging formulae is something that students can often find challenging (Boohan, 2016). The difficulty in students being able to use maths in physics may be that they can’t do the maths, but it could also be to do with students struggling with the way symbols in equations are used to make meaning differently in maths and physics (Redish and Kuo, 2015).

In physics each symbol in an equation is connected to a physical variable. Students are required to perform mathematical operations with the equation and then connect the mathematical operations and the results of calculations to their implications in the physical world (Redish and Kuo, 2015). To show mastery in physics students should be able to explain their equations in words, however at age 14-16 students often hide an incomplete understanding as they can calculate correct answers by treating equations just as mathematical operations without a good understanding of the physics that may be necessary for their future studies.

Redish and Kuo (2015) suggest for many students, the first step in physics calculations needs to be highlighting the physical meaning, which can later be tied to the formal mathematical laws. This can help students by giving meaning to equations, so analysis of problems is no longer a ‘brittle rote procedure’. It can also lead to conceptual short cuts that enable students to access more challenging problems. For many experienced physicists, physical meaning is gained by beginning with the mathematical relations that come easily to them, but their strategy is less effective for many learners.

Boohan (2016) describes four steps to rearranging formulae involving multiplication and division: first swap sides if necessary, so the variable to be made the subject of the formula is on the left; then multiply or divide both sides by the same variable(s) to leave the subject of the equation on its own; the third step is to cancel out these variables on the left hand side. Finally students should always check that the meaning of the new equation makes sense. Through this process, confident students might take shortcuts, but Boohan recommends that teaching always emphasises an understanding of the principles by carrying out all the steps.

**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**

Answer B has been rearranged wrongly as c ≠ ΔΘ / (m x ΔE).

**How to respond - what next?**

To work out whether each answer is correct or not, students need to be able to rearrange the original equation correctly.

Some students might think that answer C has been rearranged wrongly if they are answering as if it were a ‘spot the difference’ question, because the variables on the right hand side have been written in a less familiar order.

If students have misunderstandings about rearranging equations in order to carry out calculations using the equation ΔE = mcΔΘ, a useful strategy is to guide them through several examples of rearranging equations. Each step, that Boohan (2016) describes, should be explicitly worked through at first, and later support can be gradually withdrawn as students work through further examples on their own.

This example shows how Boohan (2016) suggests rearranging this equation should be taught:

Rearranging to make specific heat capacity the subject of the equation.

The original equation: ΔE = m x c x ΔΘ

So that ‘specific heat capacity’ is on the left, swap sides:

m x c x ΔΘ = ΔE

To remove mass and change of temperature from the left side, divide each side by ‘mass’ and ‘change of temperature’:

m x c x ΔΘ ΔE

m x ΔΘ m x ΔΘ

=

On the left side, ‘mass’ and ‘change of temperature’ cancel out (since mass ÷ mass = 1), and so the rearranged equation becomes:

ΔE

m x ΔΘ

c =

Giving students opportunity to work in pairs or in small groups to describe the physical meaning of each correctly rearranged equation, can help develop a better scientific understanding by encouraging the social construction of new ideas through dialogue. It can also help guide students towards a more formal understanding of specific heat capacity. This task can be extended by asking students to explain the units of specific heat capacity.

Students understanding of this equation could be further consolidated by giving them sets of problems to practise.

**Acknowledgments**

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Images: Peter Fairhurst (UYSEG).

**References**

Boohan, R. (2016). *The Language of Mathematics in Science: A guide for teachers of 11-16 science*Hartfield, Herts: Association for Science Education.

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