**Rearranging the equation**

A force acting on an object can make it accelerate.

Doubling the resultant force doubles the acceleration.

If the mass of the object is doubled, acceleration is halved.

This relationship is usually written as:

force, F, in newton (N)

mass, m, in kilogram (kg)

acceleration, a, in metres per second squared (m/s2)

Force = mass x acceleration

F = m x a

***One newton*** *is the force needed to accelerate a mass of 1 kg at a rate of 1 m/s2.*

Which of these equations have been re-arranged correctly?

Choose ***all*** that are correct.

**A**

**B**

**C**

**D**

acceleration

=

force

mass

mass

=

force

acceleration

mass

=

acceleration

force

Force x mass = acceleration

*Physics > Big idea PFM: Forces and motion > Topic PFM6: Forces make things change > Key concept PFM6.2: Force, mass and acceleration*

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| **Diagnostic question** |
| **Rearranging the equation** |

**Overview**

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| Learning focus: | The acceleration of an object is proportional to the resultant force acting on it and inversely proportional to its mass. An object accelerates in the direction of the resultant force acting on it. |
| Observable learning outcome: | Explain the equation F = m x a and use it to make calculations. |
| Question type: | Simple multiple choice |
| Key words: | Force, mass, acceleration |

**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**

A and B are correct; C and D are wrong.

**How to respond - what next?**

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Each step that Boohan (2016) describes should explicitly be worked through at first, and later support can be gradually withdrawn as students work through further examples on their own.

For example, in order to find the expression for the acceleration, the following steps should be worked through.

Begin with the original equation:

Swap sides so that , the variable we wish to find, is on the left:

Divide both sides by m:

Cancel the factors of on the left hand side, because

This may seem laborious, but by carefully working through all the steps in detail, students will learn how to rearrange equations correctly without taking shortcuts that can lead to errors.

It is important that students think about the meaning of these equations. For students who may study physics beyond age 16, thinking about units, and checking that these are the same on both sides of the equation is a useful extension activity.

Students should have the opportunity to practise solving numerical problems that require them both to substitute values into these equations, and to rearrange them.

**Acknowledgments**

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**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 epistemology. *Science and Education,* 24**,** 561-590.