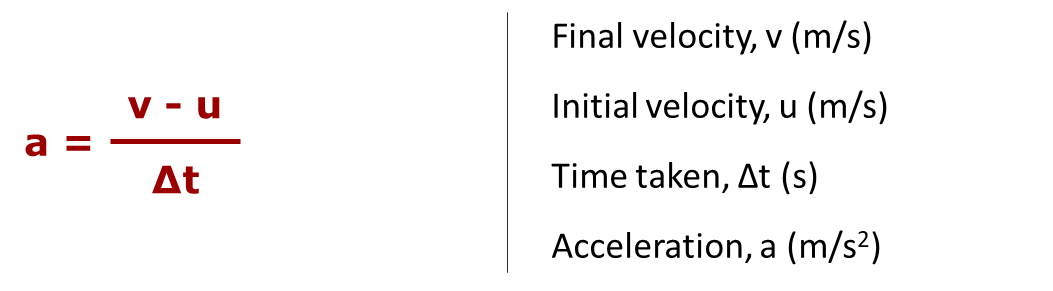
**New arrangements**

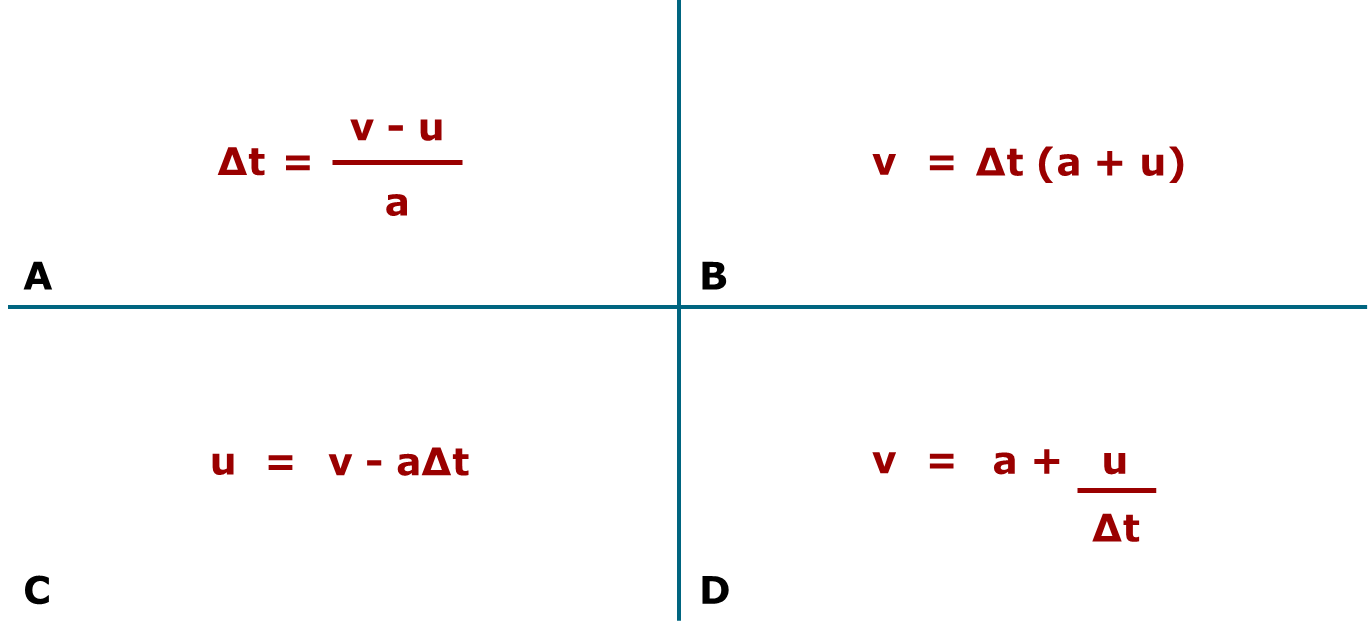
Acceleration is the rate of change of velocity.

It can be calculated using the equation:



The equation can be rearranged to find a velocity or a time.

Which **two** of these equations are correct?



*Physics > Big idea PFM: Forces and Motion > Topic PFM4: Measuring and calculating motion > Key concept PFM4.2: Acceleration*

|  |
| --- |
| **Diagnostic question** |
| **New arrangements** |

**Overview**

|  |  |
| --- | --- |
| Learning focus: | Acceleration, like displacement and velocity, is a vector quantity. Acceleration measures by how much velocity changes in a given time interval. |
| Observable learning outcome: | Rearrange the equation a=(v-u)/Δt to calculate a velocity or a time. |
| Question type: | Simple multiple choice |
| Key words: | Acceleration, velocity, time |

**What does the research say?**

Students sometimes do not understand the scientists use of the word ‘over’ to mean ‘divided by’, and interpret it as meaning ‘during’. This can lead to their failing to take time into account correctly in calculations (using a moment in time rather than a time interval in the denominator), or when comparing accelerations (Trowbridge and McDermott, 1981). They may use average velocities in calculating accelerations, rather than instantaneous velocities (Marshall and Carrejo, 2008). Correct and careful use of language and symbols can help students to avoid misunderstandings.

Rearranging formulae is something that students can often find challenging (Boohan, 2016). The difficulty in students being able to use mathematics 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).

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; multiply or divide both sides by the same variable(s) to leave the subject of the equation on its own; 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.

Units in equations should be treated explicitly and with care. It is good practice always to include units in calculations, not least because this may help students to appreciate that symbols refer to physical quantities. Keeping track of units can also help in checking that calculations make sense physically, and prepares the way for dimensional analysis post-16 (Boohan, 2016). The units of acceleration may be particularly problematic as acceleration is a rate of change of a rate of change, and is measured in metres/second2, a unit that is unfamiliar to students.

Whilst carrying out calculations is an important part of students’ learning, success in using equations is not the same thing as developing conceptual understanding in mechanics (Kim and Pak, 2002), and misconceptions may remain. To expert physicists, symbols stand for physical quantities, and the results of the mathematical manipulations must be interpreted in terms of their meaning for a given physical system. Experts draw on their experience and (often tacit) knowledge of physical systems in order to make meaning from the mathematics (Carson, 1999; Redish and Kuo, 2015). To novices, the manipulation of the symbols, and the substitution of numbers into formulae may be ends in themselves, devoid of physical meaning. Even after having been taught mechanics, students may lack the ability to reason about the vectors that represent kinematical quantities and forces (Flores, Kanim and Kautz, 2004). This is why asking students to think qualitatively as well as quantitatively, about kinematical quantities, is important.

A complication here lies in dealing with vectors. Students need to be clear about the vector nature of quantities such as displacement, velocity, change in velocity and acceleration; despite being taught about vectors at school, very many students on undergraduate introductory physics courses in the USA have no *useful* knowledge of vectors (Aguirre, 1988; Knight, 1995).

**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 C are both right

**How to respond - what next?**

It is common for students at this level to struggle to rearrange equations correctly. Often this is because they do not take time to include every step, or because they make assumptions that are not valid.

B Students who think this option is right have added u to the left-hand side, then multiplied both sides by Δt. Their error is that in adding u to the left side they think they have cancelled out the u on the right-hand side. On the right-hand side, the u is above the denominator Δt.

D Students who think this option is right have added u/Δt to both sides and have misunderstood that this leaves v/Δt and not v.

If students have misunderstandings about rearranging the equation to calculate a velocity or a time interval, it can help to spend time guiding them through the rearrangement of equations, and to give them opportunity to practice on their own. The following BEST ‘response activity’ could be used to do this, in follow-up to this diagnostic question:

* Response activity: Calculating with steady acceleration

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG), research by Simon Carson (UYSEG).

Images: Peter Fairhurst (UYSEG).

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