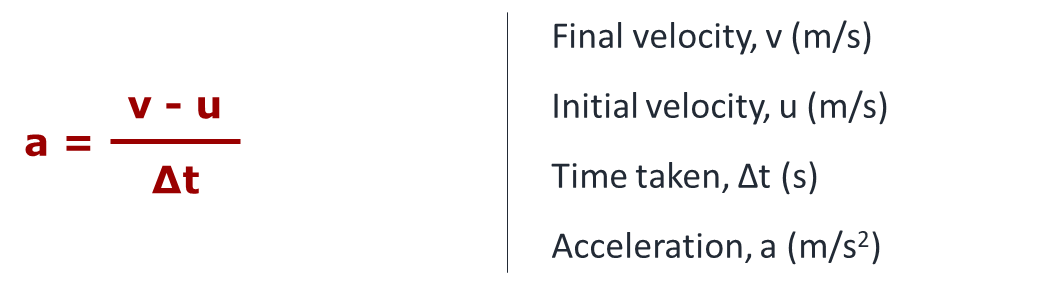
**Calculating with steady acceleration**

Acceleration is the rate of change of velocity.

It can be calculated using the equation:

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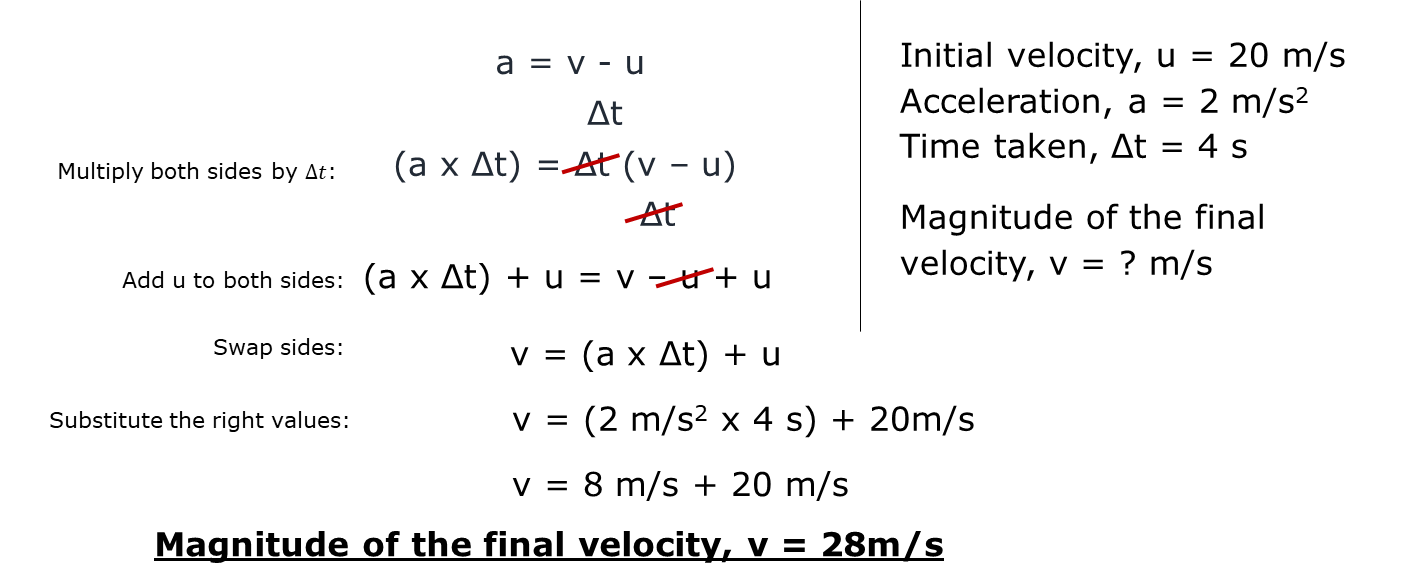
The equation can be rearranged to find a velocity or a time.

**Finding a velocity**

**Example:** A car is travelling at 20 m/s. It accelerates at 2 m/s2 for 4 s.

What is the magnitude of the final velocity of the car?

**Model answer:**

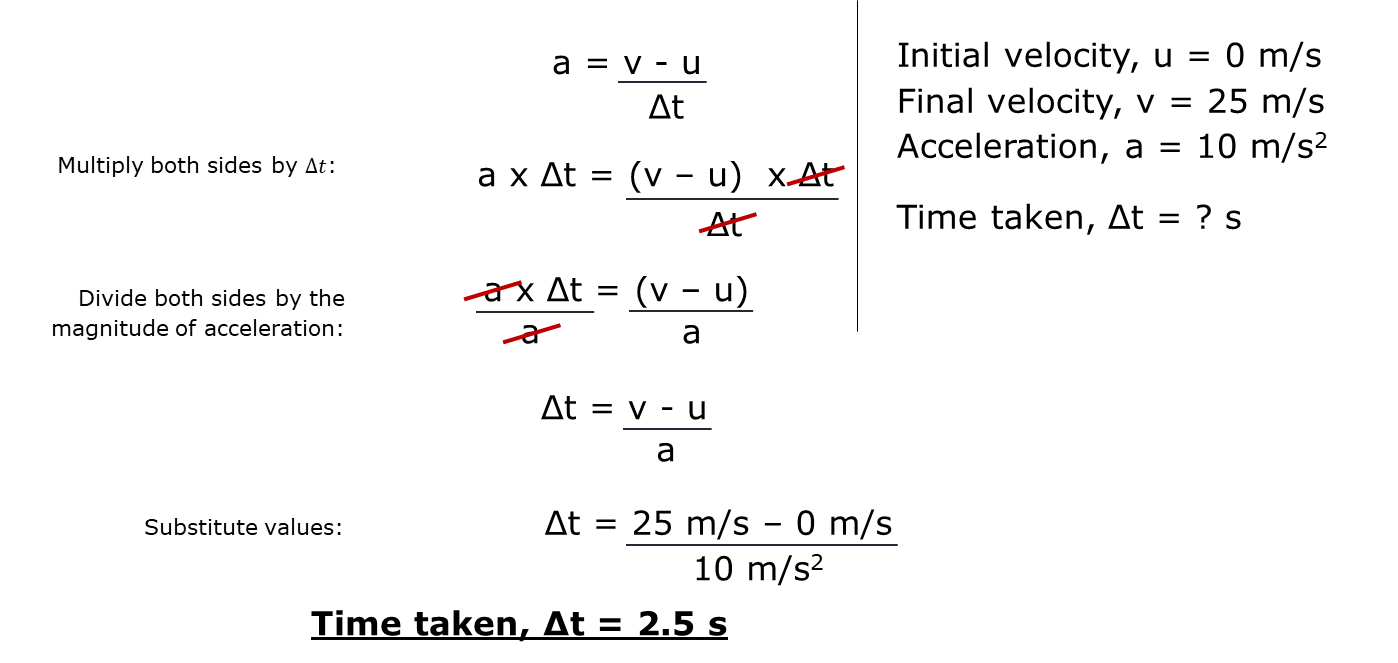


**Finding the time taken**

**Example:** A stone falls from a cliff and hits the ground at 25 m/s.

Its acceleration is 10 m/s2 downwards, how long did it take to fall?

**Model answer:**



**Finding a velocity - to answer**

**1.** A rocket is travelling at 50 m/s.

It accelerates at 25 m/s2 for 6 seconds.

What is the magnitude of the final velocity of the rocket?

**2.** A car is travelling at 25 m/s.

The driver uses its brakes to slow it down.

The magnitude of its acceleration is 2 m/s2.

How fast is the car travelling after 10 seconds?

**3.** A lift is slowing and the magnitude of its acceleration is 1.5 m/s2. It takes 2 s to come to rest.

How fast was the lift travelling before it began to slow down?

**Finding the time taken – to answer**

**4.** On the surface of Mars, an object falls with an acceleration that has a magnitude of about 3.7 m/s2.

If an object is dropped and hits the ground at 4.5 m/s, how long did it take to fall?

**5.** A driver increases the speed of a car from 20 m/s to 30 m/s.

If the magnitude of the car’s acceleration is 1.5 m/s2, how long does it take the car to speed up?

**6.** A rocket travels through space at 10 000 m/s.

Its forward thrusters are used to give it an acceleration of 5 m/s2 in the opposite direction to its velocity.

How long does it take before the rocket is travelling in the opposite direction at the same speed?

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

|  |
| --- |
| **Response activity** |
| **Calculating with steady acceleration** |

**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: | Application and practice - calculations |
| Key words: | Acceleration, velocity, time |

This activity can help develop students’ understanding by addressing the sticking-points revealed by the following diagnostic questions:

* Diagnostic question: New arrangements

**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 activity**

The model answer pays explicit attention to the vector nature of the quantities even though this can make the solutions seem clumsy. Expert physicists know when it is appropriate to deal with the magnitudes of vectors, and when directions need to be considered. This is not necessarily the case for novices, and paying explicit attention to this may help students to avoid errors associated with ignoring the vector nature of acceleration, velocity and change in velocity, and help to prepare them for future work.

Whenever a numerical value is given without a direction, students should be made aware, explicitly, that only the magnitude of a vector is being considered. The questions are written in a way that makes this explicit.

This activity gives students the opportunity to practise applying their understanding and to clarify their thinking through discussion. To support this, students should answer the question in pairs or small groups. Listening to individual groups as they work often highlights any difficulties they might have. These can often be overcome, through a whole class clarification or redirection part way through the activity.

Allowing only one student in each pair or small group to write down the answer on behalf of the group encourages discussion of both the science and of the presentation of the answer. Mini-white boards allow groups to show you their answers for immediate feedback.

*Differentiation*

If some students are working with a teaching assistant, then a list of prompt questions for the TA could help to make this activity more purposeful.

**Expected answers**

**1.** 200 m/s **4.** 1.22 s

**2.** 5 m/s **5.** 6.67 s

**3.** 3 m/s **6.** 4 000 s (66.7 minutes)

**Acknowledgments**

Developed by Simon Carson (UYSEG)

Images: Simon Carson (UYSEG)

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