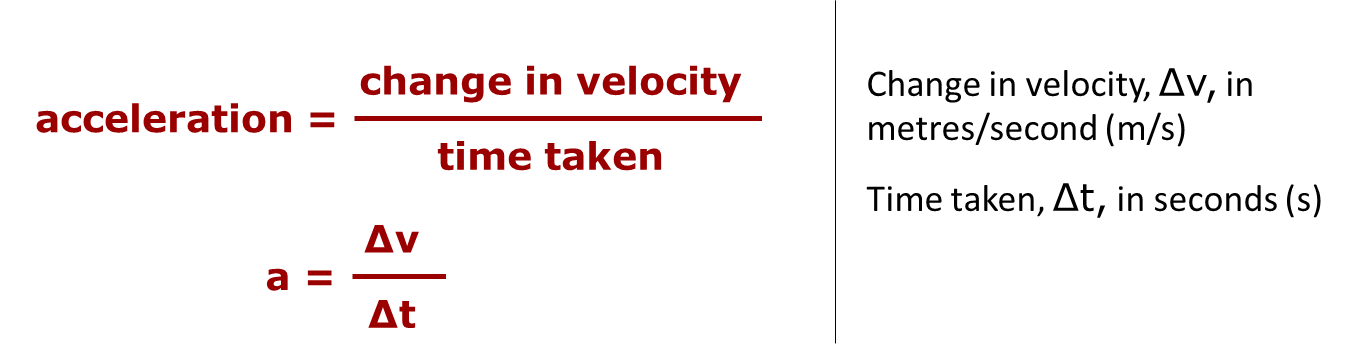
**Calculating acceleration**

Acceleration is calculated as the change in velocity divided by the time taken for the change:



The units of acceleration can be worked out from this equation.

They are metres per second (for the velocity)per second (m/s/s).

This is usually shortened to m/s2.

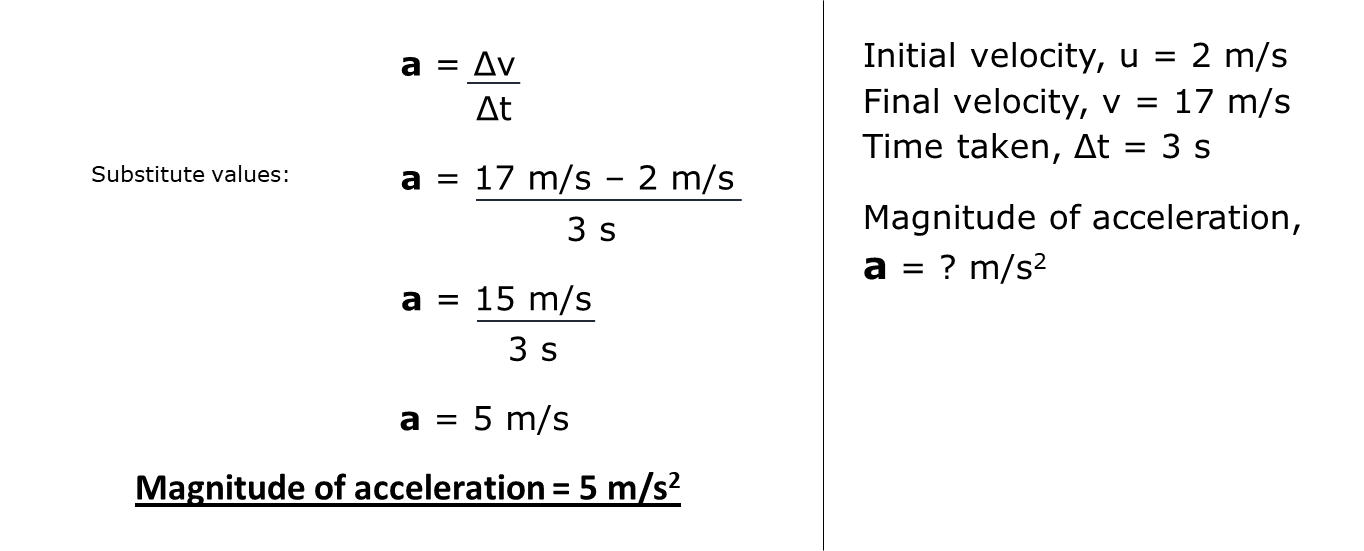
Acceleration is measured in **metres per second squared**.

**Example:** At the top of a slope, a rollercoaster is travelling at 2 m/s.

It speeds up as it moves down a straight slope. After 3 seconds, it is travelling at 17 m/s.

What is the magnitude of the acceleration of the rollercoaster?

**Model answer**

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**To answer**

1. A cheetah accelerates from rest to 27 m/s in 3 s.

What is the magnitude of its acceleration?

2. During take-off, it takes the space shuttle 10 s to reach 200 m/s. What is the magnitude of its acceleration?

3. A bullet is fired from a rifle. It takes 0.003 seconds to travel along the barrel and leaves it at 600 m/s.

What is the magnitude of its acceleration?

4. A car slows down from 30 m/s to 20 m/s in 5 s.

What is the magnitude of its acceleration?

5. A lift is travelling downwards at 1.4 m/s. As it reaches a floor, it slows and stops in 0.7 s.

What is the magnitude of its acceleration?

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

|  |
| --- |
| **Response activity** |
| **Calculating with 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: | Calculate acceleration in one dimension from the equation: |
| 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: Thinking about acceleration

**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**

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. 9 m/s2

2. 20 m/s2

3. 200 000 m/s2

4. 2 m/s2

5. 2 m/s2

**Acknowledgments**

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