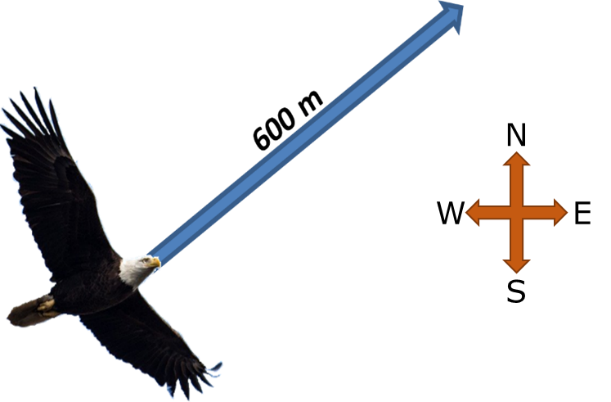
**Setting it out**

An eagle flies north-east from its nest.

It flies 600 metres in 50 seconds.

**a.** Which of these calculations *best* shows how to find the

**velocity** of the eagle?

*Put a tick (✓) in the box next to the best answer.*

|  |  |  |
| --- | --- | --- |
| **A** |  |  |
|  |  |  |
| **B** |  |  |
|  |  |  |
| **C** |  |  |
|  |  |  |
| **D** |  |  |

**b.** What is the *best* reason for your last answer?

*Put a tick (✓) in the box next to the best answer.*

|  |  |  |
| --- | --- | --- |
| **A** | Speed and velocity both have the same units |  |
|  |  |  |
| **B** | Velocity and speed both have a direction |  |
|  |  |  |
| **C** | Speed has a direction, but velocity doesn’t |  |
|  |  |  |
| **D** | Velocity has a direction, but speed doesn’t |  |

*Physics > Big idea PFM: Forces and motion > Topic PFM4: Measuring and calculating motion > Key concept PFM4.1 Velocity*

|  |
| --- |
| **Diagnostic question** |
| **Setting it out** |

**Overview**

|  |  |
| --- | --- |
| Learning focus: | Velocity and displacement are vector quantities. Velocity measures by how much displacement changes in a given time interval. |
| Observable learning outcome: | Explain the difference between distance and displacement, and between speed and velocity. |
| Question type: | Two tier multiple choice |
| Key words: | Displacement, velocity, scalar, vector |

**What does the research say?**

Students need to be clear about the vector nature of quantities such as displacement, 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). Understanding two dimensional motion, such as the orbits of planets and circular motion, requires an understanding of vectors, both mathematically and intuitively, and has been a subject of research for school students (Mihas and Gemousakakis, 2007; Tairab *et al.*, 2020), and at university level, where both undergraduates and expert physicists struggled with some aspects of the vector nature of acceleration when asked to reason qualitatively (Reif and Allen, 1992).

Students’ misunderstandings of vector ideas may be compounded by the different approaches taken in school mathematics and physics teaching: although students may be able to add and subtract column vectors in mathematics, graphical addition and subtraction of vectors of the sort more likely to be encountered in physics proved more problematic (Tairab *et al.*, 2020). It is important, therefore, to establish a good understanding of displacement and velocity as vectors before studying accelerations and forces.

Velocity is not the same as speed, though students are prone to conflate these ideas. Here is a case where the use of language matters: if teachers speak of velocity, and calculate a scalar speed by dividing distance by time, making no reference to displacement or to direction, the equivalence of speed and velocity in students’ minds will be reinforced. If new concepts – such as velocity – are introduced by appeal to familiar concepts – such as speed – without being clearly and explicitly defined and differentiated, students are left with the confusing task of discriminating between them and their everyday ideas (Reif and Allen, 1992). As motion is often studied in one dimension with students aged 14-16, the direction of velocity is sometimes indicated with a + or – sign, but this on its own is not enough unless the direction with respect to which the sign is defined is given. Experts will assume an implicit definition of the direction, but novices may not.

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).

**Ways to use this question**

Students should complete the questions 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 follow-on question will give you insights into how they are thinking and highlight specific misunderstandings that some may hold.

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. C b. D

**How to respond - what next?**

Asking students to set out calculations fully and clearly can help them to understand the physical meaning of their calculations. The equals sign implies not just equality of numbers, but also of the units, and of the type of quantity (here, scalar or vector). An equation that begins ‘velocity =’ must have a magnitude and a direction, alongside units, because velocity is a vector quantity with dimensions.

Experts may neglect to include units and directions at mid-points in calculations, understanding them implicitly until required to state them explicitly. Novices, on the other hand, may neglect units and directions because they are not aware that they should be included, or even of what they are. Expert teachers can help students to develop their understanding by being explicit about these factors in their calculations, and encouraging good habits, which can in turn help to develop good physical understanding, in their students.

If students have misunderstandings about the use of units and directions in calculations, practice in setting out calculations correctly will help. It may be useful for students to set out calculations, and to receive feedback from their peers, using a mark scheme in order to avoid reinforcing errors and misconceptions.

The following BEST ‘response activity’ could be used in follow-up to this diagnostic question:

* Response activity: How fast are they going

**Acknowledgments**

Developed by Simon Carson (UYSEG)

Images: Simon Carson (UYSEG)

**References**

Aguirre, J. M. (1988) Student preconceptions about vector kinematics, *The Physics Teacher*, 26(4), pp. 212–216. doi: 10.1119/1.2342490.

Boohan, R. (2016) *The language of mathematics in science: a guide for teachers of 11-16 science*. Hatfield: Association for Science Education.

Knight, R. D. (1995) The vector knowledge of beginning physics students, p. 6.

Mihas, P. and Gemousakakis, T. (2007) Difficulties that students face with two-dimensional motion, *Physics Education*, 42(2), pp. 163–169. doi: 10.1088/0031-9120/42/2/005.

Reif, F. and Allen, S. (1992) Cognition for Interpreting Scientific Concepts: A Study of Acceleration, *Cognition and Instruction*, 9(1), pp. 1–44. doi: 10.1207/s1532690xci0901\_1.

Tairab, H. *et al.* (2020) Examining Grade 11 science students’ difficulties in learning about vector operations, *Physics Education*, 55(5), p. 055029. doi: 10.1088/1361-6552/aba107.