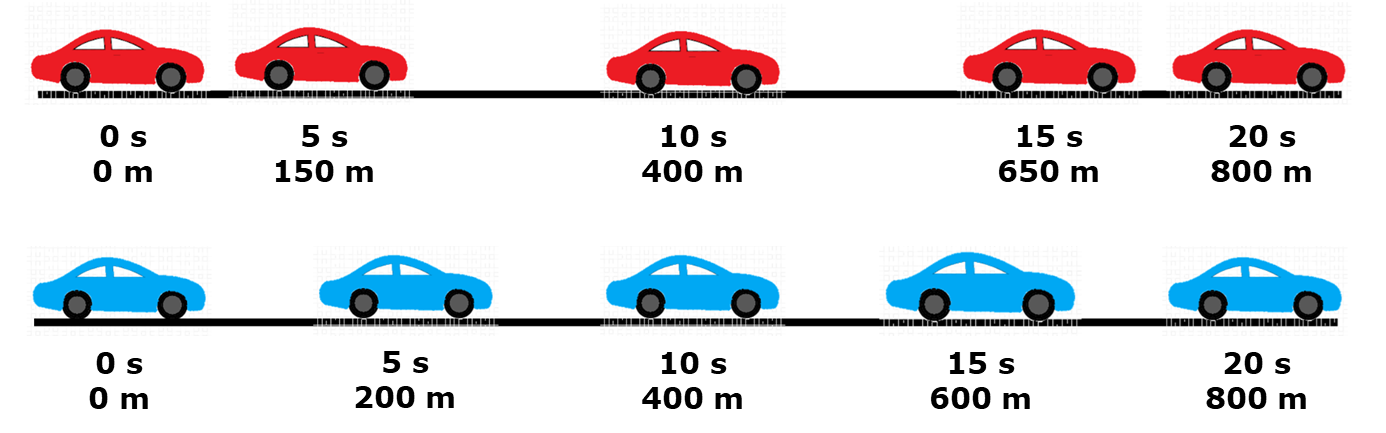
**Who’s going fastest?**

Two cars move along a road.

The pictures show how far each car has travelled at different times.



**1.** Which car has the highest average velocity during the first 5 seconds?

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

|  |  |  |
| --- | --- | --- |
| **A** | The red car. |  |
|  |  |  |
| **B** | The blue car. |  |
|  |  |  |
| **C** | Neither – they have the same speed. |  |
|  |  |  |
| **D** | You can’t tell from this picture. |  |

1. Which car has the highest average velocity for the first half of the journey?

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

|  |  |  |
| --- | --- | --- |
| **A** | The red car. |  |
|  |  |  |
| **B** | The blue car. |  |
|  |  |  |
| **C** | Neither – they have the same average velocity. |  |
|  |  |  |
| **D** | You can’t tell from this picture. |  |

**3.** Which car has the highest average velocity for the second half of the journey?

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

|  |  |  |
| --- | --- | --- |
| **A** | The red car. |  |
|  |  |  |
| **B** | The blue car. |  |
|  |  |  |
| **C** | Neither – they have the same average velocity. |  |
|  |  |  |
| **D** | You can’t tell from this picture. |  |

**4.** Which car has the highest average velocity for the whole journey?

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

|  |  |  |
| --- | --- | --- |
| **A** | The red car. |  |
|  |  |  |
| **B** | The blue car. |  |
|  |  |  |
| **C** | Neither – they have the same average velocity. |  |
|  |  |  |
| **D** | You can’t tell from this picture. |  |

**5.** Which car has the highest instantaneous velocity at the half-way point, after 10 seconds?

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

|  |  |  |
| --- | --- | --- |
| **A** | The red car. |  |
|  |  |  |
| **B** | The blue car. |  |
|  |  |  |
| **C** | Neither – they have the same instantaneous velocity. |  |
|  |  |  |
| **D** | You can’t tell from this picture. |  |

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

|  |
| --- |
| **Diagnostic question** |
| **Who’s going fastest?** |

**Overview**

|  |  |
| --- | --- |
| Learning focus: | Velocity and displacement are vector quantities. Velocity measures by how much displacement changes in a given time interval. |
| Observable learning outcome: | Calculate average velocity and instantaneous velocity for one-dimensional motion. |
| Question type: | Simple multiple choice |
| Key words: | Velocity, average, instantaneous |

**What does the research say?**

Students have developed their understanding of motion, both kinematics (the mathematical description of motion) and dynamics (the study of the causes of motion), through a lifetime of experience, and have built up an understanding that has been termed ‘gut dynamics’, or ‘lay dynamics’ (Driver *et al.*, 1994). These ideas are persistent and resistant to change, are systematic, and may be ‘theory-like’; they have been found among different groups of students and at different academic levels (Saltiel and Malgrange, 1980; Lemmer, 2013).

Students have a somewhat undifferentiated understanding of the kinematical terms speed, velocity and acceleration, merging them together into a general idea of ‘motion’. Sometimes they conflate words that have related meanings, such as distance and displacement, or speed and velocity, not always realising the important differences between them (de Winter and Hardman, 2021). Although these terms are connected, the differences matter, and teachers should use terms carefully, taking care to be precise in their use of language.

Speed is a scalar quantity and is often defined as:

This can lead to misunderstandings when students are not clear that the time referred to is the *time interval* during which the distance is travelled. This can lead to confusion when students study graphs of motion, and do not differentiate between the slope of a graph, and the division of coordinates at a point (McDermott, Rosenquist and van Zee, 1987), especially as students do not always take time into their thinking about motion appropriately (Trowbridge and McDermott, 1980; Driver *et al.*, 1994). It is better, therefore, to define speed as:

‘’ (the Greek letter delta) is the symbol used by physicists to denote a change in a quantity.

Similarly, velocity is the rate of change of displacement, so that the average velocity is the change in the (vector) displacement divided by the time interval over which the change occurs:

The bold typeface for **s** and **v** is used to show that they are vector quantities.

The idea of an instantaneous velocity should be carefully developed and made clear that it is different to instantaneous speed.

Everyday experience is of moving at speeds or velocities for finite periods of time. Instantaneous speed or instantaneous velocity is the speed or velocity at one moment of time, when the time interval is unimaginably small. For this reason, it is better to use ‘change in time’ in the definitions of these quantities and in calculations, not just ‘time’.

**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**

1. B 2. C 3. C 4. C 5. A

**How to respond - what next?**

1. To answer question 1 correctly requires only that students divide the displacement and time after 5 seconds. Both cars move in the same direction so the direction of their velocities is the same and only the magnitudes in that direction need be compared – this is a point that should be discussed with students in order to emphasise the vector nature of velocity. As the time interval is the same for both cars, no calculations need to be done and displacements can be compared directly.

Students who answer this question incorrectly may have no understanding of the term ‘velocity’.

2. Question 2 requires students to compare the average velocities over the whole of the first 10 seconds. The red car is clearly accelerating during this time. Students who confuse acceleration with speed or velocity may decide that the red car is going fastest, on average, during the first half of the journey, or may struggle to decide which is going the fastest, on average.

3. Similarly, in question 3, the red car is decelerating, but both cars have the same average velocity. Students who answer this incorrectly may not be discriminating clearly between velocity and acceleration.

4. Question 4, like question 1, should be reasonably straightforward as it only requires use of the numbers at the end of the journey.

A few students may think that the red car has a higher average speed because it is moving faster in the middle (misunderstood as average) part of the journey. Others may think the blue car, because it is moving faster at the end of the journey, which is the point at which data needs to be taken to work out the average speed.

5. Question 5 requires students to think about an instantaneous velocity, which is the speed at one moment of time. From the picture, it should be clear to students that the red car travels further than the blue car during the middle part of the journey and therefore has a greater velocity at the mid-point.

However students who confuse position with speed (and hence in this case with velocity) may think the cars are going at the same speed at the midpoint because they are at the same position (Jones, 1983).

If students have misunderstandings about the difference between average and instantaneous velocity, it is useful to discuss the idea of an average velocity calculated over smaller and smaller time intervals.

Thinking about what a car speedometer shows and comparing this with the variation of speed over a typical journey may help students to distinguish between instantaneous and average velocity. Asking students to work in pairs or small groups to write a definition of instantaneous velocity in their own words can help them to consolidate their learning.

The following BEST response activity could be used as a follow up to this question:

* Response activity: Calculating average velocity and instantaneous velocity

**Acknowledgments**

Developed by Simon Carson (UYSEG).

Images: Simon Carson (UYSEG).

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