**Spaghetti junction**

Two cars are travelling on different parts of a motorway junction.

The picture shows the cars at three different times.

Diagram

Description automatically generated

Both cars are moving along the road at a constant 15 m/s.

1. What do you think about the **speed** of the two cars?

*For each statement, tick (✓)* ***one*** *column to show what you think.*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Statements about the speed of the two cars | I am **sure** this is right | I think this is right | I think this is wrong | I am **sure** this is wrong |
| At time 1, they both have the same speed. |  |  |  |  |
| At time 2, they both have the same speed. |  |  |  |  |
| At time 2, the blue car has a higher speed. |  |  |  |  |
| At time 3, they both have the same speed. |  |  |  |  |

**2.** What do you think about the **velocity** of the two cars?

*For each statement, tick (✓)* ***one*** *column to show what you think.*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Statements about the velocity of the two cars | I am **sure** this is right | I think this is right | I think this is wrong | I am **sure** this is wrong |
| At time 1, they both have the same velocity. |  |  |  |  |
| At time 2, they both have the same velocity. |  |  |  |  |
| At time 2, the blue car has a bigger velocity. |  |  |  |  |
| At time 3, they both have the same velocity. |  |  |  |  |

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

|  |
| --- |
| **Diagnostic question** |
| **Spaghetti junction** |

**Overview**

|  |  |
| --- | --- |
| Learning focus: | Velocity and acceleration are vector quantities. Velocity measures how much the displacement changes in a given time, and acceleration measures how much velocity changes in a given time. |
| Observable learning outcome: | Identify the difference between speed, instantaneous velocity and average velocity for two-dimensional motion. |
| Question type: | Confidence grid |
| Key words: | speed, velocity |

**What does the research say?**

Research shows that when thinking about motion, students often do not differentiate clearly between speed and velocity (Halloun and Hestenes, 1985; de Winter and Hardman, 2021); and that it is quite common for students to be able to solve problems by substituting numbers into equations, whilst retaining some conceptual misunderstandings (Kim and Pak, 2002).

At ages 14-16, students are taught that:

and that velocity is speed in a certain direction. This teaching may strengthen ideas that speed and velocity are largely equivalent by suggesting that, to find the velocity, speed must first be calculated and a direction then added. By describing velocity as speed in a certain direction, students may come to think that the magnitude of the velocity is always equal to the speed, and this is usually not true when the average speed or average velocity is calculated.

A better definition of velocity is:

This emphasises the vector nature of velocity from the outset by relating it to displacement, which is also a vector.

Instantaneous velocity be thought of as average velocity calculated for an extremely short time interval. (Mathematically, it is the limit of the average velocity for smaller and smaller time intervals.)

The use of language is important. Teachers need to always talk about velocity with a direction, and insist that when velocity is calculated, its direction is always stated. Not doing this can reinforce the idea that direction is of secondary importance.

**Ways to use this question**

Students should complete the confidence grid 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.

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. Statements A, B and D are right; and statement C is wrong.

2. Statement B is right; and statements A, C and D are wrong.

**How to respond - what next?**

1. The cars have the same speed at all times, because speed is the measure of how quickly each car is moving along the road.

If students think that the blue car is travelling faster than the red car at time 2, they may be confusing position with speed. Students sometimes believe that when one car passes another, at the moment they are side by side they must have the same speed (Trowbridge and McDermott, 1980; Jones, 1983). They may also believe that the car in front may be travelling faster.

A few students may consider the blue car to have a higher speed at time 2 (option C) because they have experience of the need to sometimes slow down around a bend.

2. At time 2 the cars are travelling at the same speed in the same direction, so they each have the same velocity (statement B).

Students who get question 2 wrong are probably not taking direction into account. The blue car is deliberately drawn ahead of the red car at time 2 to avoid students getting the right answer for the wrong reason: as noted above, students may believe that two objects moving side by side must have the same speed, even if one is passing the other.

A few students may think wrongly that statements A and D are correct if they have confused velocity with speed. And a few may choose these options if they think the direction of velocity is ‘forwards along the road’.

Option C may again be chosen by students who are basing their choice on their experience of being able to travel faster along a straight road, rather than on understanding of velocity.

If students have misunderstandings about the difference between speed and velocity, the following BEST ‘response activity’ could be used in follow-up to this diagnostic question:

* Response activity: Velocity and speed in two dimensions.

**Acknowledgments**

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Images: Simon Carson (UYSEG)

**References**

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