**Accelerating cars**

A red car starts from rest and speeds up steadily.

Four seconds later a blue car passes the starting point.

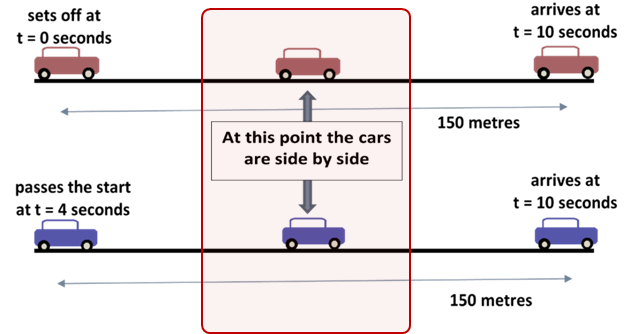
The blue car is travelling at a steady speed.

Graphical user interface

Description automatically generated

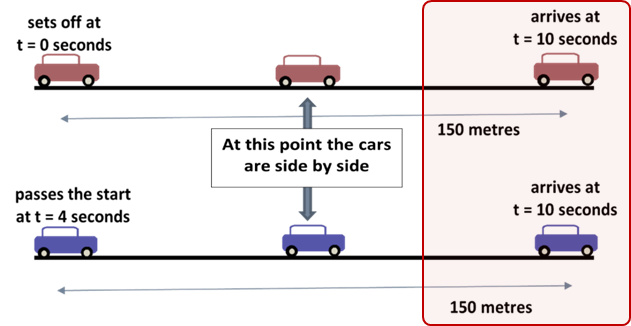
The blue car overtakes the red car.

The red car catches up again at the 150-metre point.

**1.** What can you say about the **velocity** of each car when they are side-by-side?

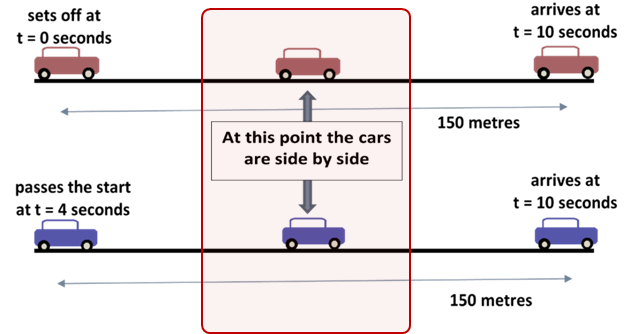
*For each statement, tick (✓)* ***one*** *column to show what you think.*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | | I am **sure** this is right | I think this is right | I think this is wrong | I am **sure** this is wrong |
| **A** | Both cars are travelling with the same velocity. |  |  |  |  |
| **B** | The red car has a greater velocity than the blue car. |  |  |  |  |
| **C** | The blue car has a greater velocity than the red car. |  |  |  |  |

**2.** What can you say about the **velocity** of each car when they reach the 150 m point?

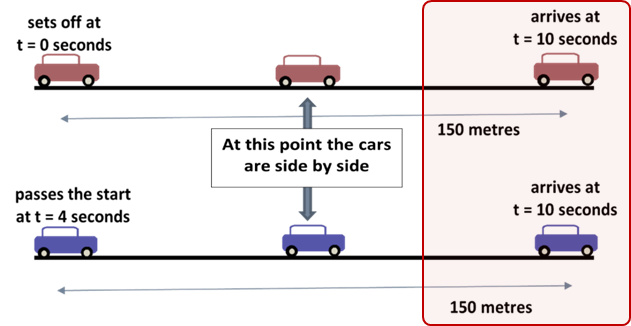
*For each statement, tick (✓)* ***one*** *column to show what you think.*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | | I am **sure** this is right | I think this is right | I think this is wrong | I am **sure** this is wrong |
| **A** | Both cars are travelling with the same velocity. |  |  |  |  |
| **B** | The red car has a greater velocity than the blue car. |  |  |  |  |
| **C** | The blue car has a greater velocity than the red car. |  |  |  |  |

3. What can you say about the **acceleration** of each car when they are side by side?

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

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Statements about the **acceleration** of the cars in the **middle** of the journey | | I am **sure** this is right | I think this is right | I think this is wrong | I am **sure** this is wrong |
| **A** | Both cars are accelerating. |  |  |  |  |
| **B** | The red car has a greater acceleration than the blue car. |  |  |  |  |
| **C** | The blue car has a greater acceleration than the red car. |  |  |  |  |
| **D** | Neither car is accelerating. |  |  |  |  |

**4.** What can you say about the **acceleration** of each car when they reach the 150 m point?

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

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Statements about the **acceleration** of the cars at the **end** of the journey | | I am **sure** this is right | I think this is right | I think this is wrong | I am **sure** this is wrong |
| **A** | Both cars are accelerating. |  |  |  |  |
| **B** | The red car has a greater acceleration than the blue car. |  |  |  |  |
| **C** | The blue car has a greater acceleration than the red car. |  |  |  |  |
| **D** | Neither car is accelerating. |  |  |  |  |

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

|  |
| --- |
| **Diagnostic question** |
| **Accelerating cars** |

**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: | Describe acceleration and differentiate between displacement, velocity and acceleration. |
| Question type: | Confidence grid |
| Key words: | Velocity, acceleration |

**What does the research say?**

Students may not differentiate clearly between distance, speed and acceleration when thinking about motion, merging different scientific concepts into a general idea of ‘motion’ (de Winter, 2021). They can find the concepts very difficult, partly because their prior ideas are established through experience, and partly because the formal scientific ideas are difficult to understand (Driver et.al., 1994).

Some students may think that when one moving object passes another they must have the same speed at that moment, even if only for a very short time (Trowbridge and McDermott, 1980; Jones, 1983). These students may be conflating their understanding of velocity and acceleration and think that when an object is moving faster, it has a greater acceleration than one which is moving more slowly, regardless of what the actual accelerations may be.

They may also think of acceleration as ‘catching up’, and fail to differentiate between velocity and change in velocity. For example, if one object catches up with a second object, it may be seen as having a greater acceleration, instead of, or as well as, having a greater velocity (Trowbridge and McDermott, 1981).

When they do consider changes in velocity, students may not account for the time interval over which the change in velocity occurs and can struggle to understand the idea of velocity at a particular instant of 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 choices are simple and further discussion/questioning should be used to elicit students’ thinking. 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. Statement C is right; and statements A and C are wrong.

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

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

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

**How to respond - what next?**

These questions are about a situation in which one car is accelerating whilst the other moves at constant speed in such a way that the cars pass each other, and so are in the same position, twice. Answering the questions correctly requires that students distinguish clearly between displacement, velocity, and acceleration.

The blue car moves at a steady speed and sets off later than the red car. It catches up and passes the red car at the midpoint. and must be travelling faster at this point. However, at the end of the journey the red car catches up again, because it is accelerating and is now travelling faster than the blue car.

Q1, Q2 The most likely incorrect responses are that the two cars are travelling with the same velocity at the two passing points. Some students may confuse position with velocity.

If students have misunderstandings about velocity and position, you might ask students to think about the situation just before the cars are in the same position for the first time, when the blue car is behind, and again just after, when the blue car is ahead – and ask how the velocities of the two cars compare over this short time interval.

Careful questioning should elicit understanding that:

* The blue car travels further;
* The blue car has a greater mean velocity;
* When the cars are level, in the middle of the journey, the blue car is travelling at a faster velocity;
* The red car must be travelling faster at the end of the journey;
* The velocity of the red car increases through the journey (it is accelerating).

Q3, Q4 The most likely incorrect response is that both cars are accelerating, and that the accelerations are the same at the passing points. Some students may confuse position with acceleration.

Students who think that the blue car has the greatest acceleration in the middle, and the red car has the greatest acceleration at the end of the journey may be confusing velocity with acceleration.

If students have misunderstandings about velocity and acceleration, setting up a practical demonstration of this situation will help students to talk about their thinking and to consider the motions of the cars separately.

This can be done using a ‘red’ student starting slowly (walking) and speeding up along a straight line. A ‘blue’ student jogging at a steady speed, sets off a short time after the ‘red’ student. Trial and error should enable the blue student to overtake the red one, with the red one speeding up to catch up again later.

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

* Response activity: To the top of the hill and down again

**Acknowledgments**

Developed by Simon Carson (UYSEG).

Images: Simon Carson (UYSEG)

**References**

de Winter, J. (2021). Forces. In de Winter, J. & Hardman, M. (eds.) *Teaching Secondary Physics.* 3rd ed. London: Hodder Education.

Jones, A. T. (1983) Investigation of students’ understanding of speed, velocity and acceleration, *Research in Science Education*, 13(1), pp. 95–104. doi: 10.1007/BF02356696.

Trowbridge, D. E. and McDermott, L. C. (1981a) Investigation of student understanding of the concept of acceleration in one dimension, *American Journal of Physics*, 49(3), pp. 242–253. doi: 10.1119/1.12525.

Trowbridge, D. E. and McDermott, L. C. (1981b) Investigation of student understanding of the concept of acceleration in one dimension, *American Journal of Physics*, 49(3), pp. 242–253. doi: 10.1119/1.12525.