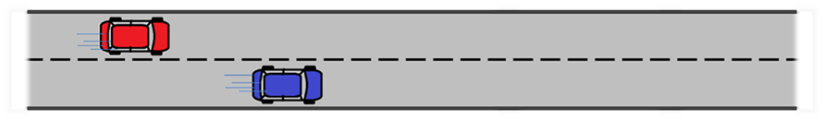
**Speeding up**

Two cars are travelling on a long straight road.

At first, the blue car is travelling faster than the red car.



This velocity-time graph shows the motion of the two cars.

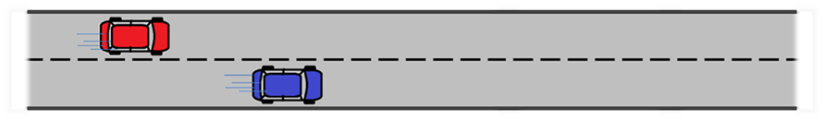


**1.** At what time do the cars have the ***same acceleration***?

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

|  |  |  |
| --- | --- | --- |
| **A** | At a point between W and X. |  |
|  |  |  |
| **B** | At X. |  |
|  |  |  |
| **C** | At a point between X and Y. |  |
|  |  |  |
| **D** | At Y. |  |
|  |  |  |
| **E** | At a point between Y and Z. |  |

Later on, the red car has the bigger velocity than the blue car.



This velocity-time graph shows what happens next.



**2.** When does the blue car have a ***greater acceleration*** than the red car?

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

|  |  |  |
| --- | --- | --- |
| **A** | At times W and X. |  |
|  |  |  |
| **B** | At times Y and Z. |  |
|  |  |  |
| **C** | At times X and Y. |  |
|  |  |  |
| **D** | At time Z only. |  |

*Physics > Big idea PFM: Forces and Motion > Topic PFM4: Measuring and calculating motion > Key concept PFM4.3: Velocity-time graphs*

|  |
| --- |
| **Diagnostic question** |
| **Speeding up** |

**Overview**

|  |  |
| --- | --- |
| Learning focus: | A velocity-time graph of an object moving in one dimension can be read to find the object’s velocity at any moment of time. The gradient of the graph at a given time gives the object’s acceleration; and the area under the graph between any two times gives the change in the object’s displacement, or the distance it has travelled. |
| Observable learning outcome: | Calculate, and explain how to work out, the acceleration of an object from the gradient of a velocity-time graph. |
| Question type: | Simple multiple choice |
| Key words: | Acceleration, velocity, time, graph |

**What does the research say?**

In a study of 700 undergraduates in Ireland, Belgium and Spain (Bollen *et al.*, 2016), students demonstrated two misunderstandings associated with the gradient of a graph: ‘interval-point’ confusion, when students focus on a single point when they should be using a range of values (for example when calculating the gradient of a graph that does not pass through the origin); and ‘slope-height’ confusion, where students confuse the height of a graph with its slope when, for example, calculating acceleration from a velocity-time graph. In a study of several hundred undergraduates and high school students in the USA, McDermott and colleagues found the same misunderstandings (McDermott, Rosenquist and van Zee, 1987). These researchers found these misunderstandings even amongst students who demonstrated a good command of kinematical concepts, and who had a good grasp of how to plot and to read graphs and of how to calculate gradients from their study of mathematics, often misinterpret what the gradient of a velocity-time graph represents.

**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. C 2. C

**How to respond - what next?**

To compare the accelerations of the two cars, students have to know that acceleration is determined by the gradient of a velocity-time graph. The steeper the line, the bigger the acceleration.

Q1. The two cars have the same acceleration at the point where the gradient of each line is the same, which is somewhere between points X and Y.

The most likely incorrect answer is that the cars have the same acceleration where the graphs cross, i.e. at point Y.

At point X, the red curve has zero gradient, so the acceleration is zero here. The division of the graph into the different sections allows the teacher to discuss both the velocity and the acceleration of each of the cars in these regions, and to compare them.

Q2. The blue car has a greater acceleration at any time at which its line is steeper than that of the red car.

At W, the red car has both the greater acceleration, as the gradient of the red curve is greater, and the greater velocity. At X, however, although the red car has the greater velocity, the blue curve is steeper, so that the blue car has the greater acceleration. At Y, the blue car has both the greater velocity and the greater acceleration, and at Z, both cars have zero acceleration.

The most likely incorrect answer in this case is B; students in this case are confusing height with slope.

Students choosing option Z are thinking only of the values of the curve, and are ignoring the slope altogether.

Option A is offered in opposition to C, but is unlikely to be chosen except in error.

If students have misunderstandings about the meaning of the gradient of a velocity-time graph, or confuse height with slope, the following BEST ‘response activity’ could be used in follow-up to this diagnostic question:

* Response activity: Using the gradient

**Acknowledgments**

Developed by Simon Carson (UYSEG).

Images: Simon Carson (UYSEG)

**References**

Bollen, L. *et al.* (2016) ‘Generalizing a categorization of students’ interpretations of linear kinematics graphs’, *Physical Review Physics Education Research*, 12(1), p. 010108. doi:10.1103/PhysRevPhysEducRes.12.010108.

McDermott, L.C., Rosenquist, M.L. and van Zee, E.H. (1987) ‘Student difficulties in connecting graphs and physics: Examples from kinematics’, *American Journal of Physics*, 55(6), pp. 503–513. doi:10.1119/1.15104.