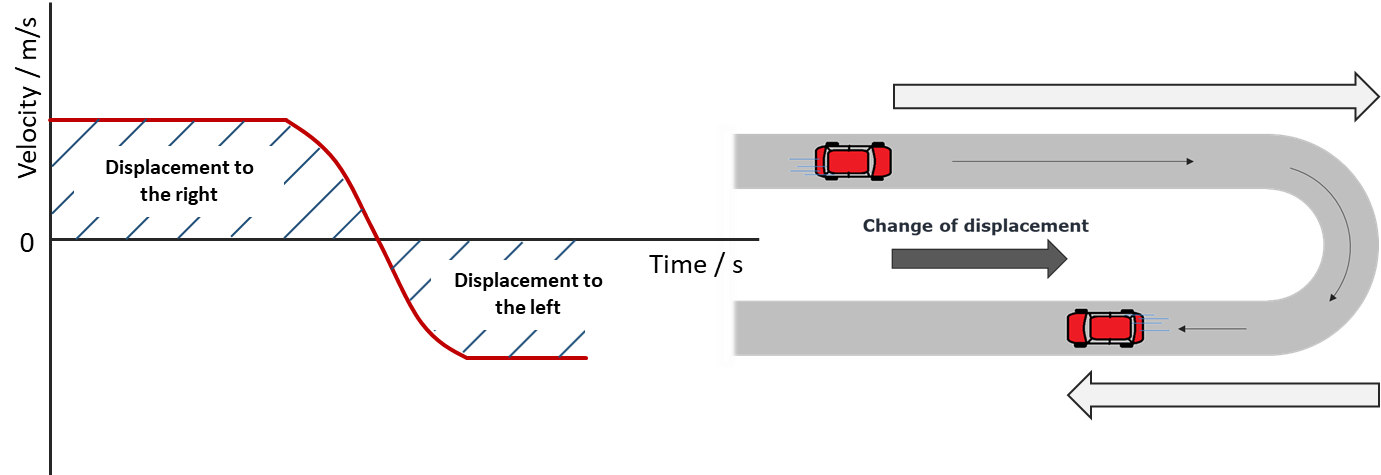
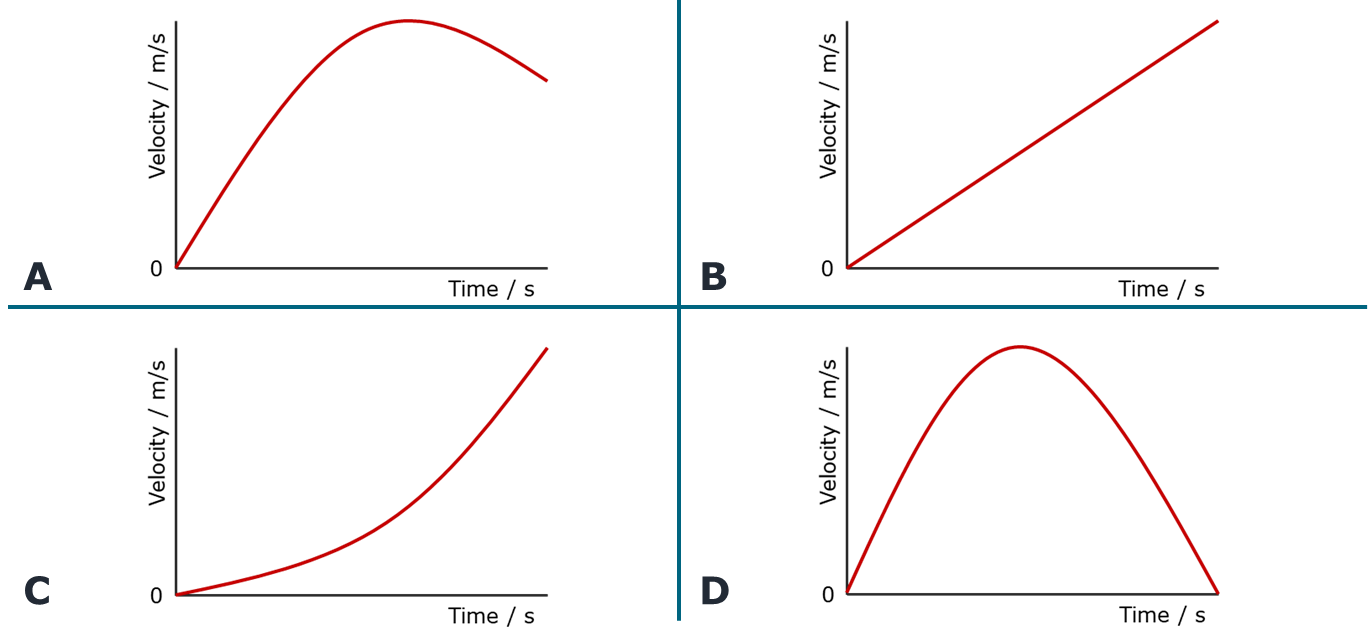
**Are we there yet?**

The change in displacement of an object between two times,

is equal to the area under a velocity-time graph between those times.

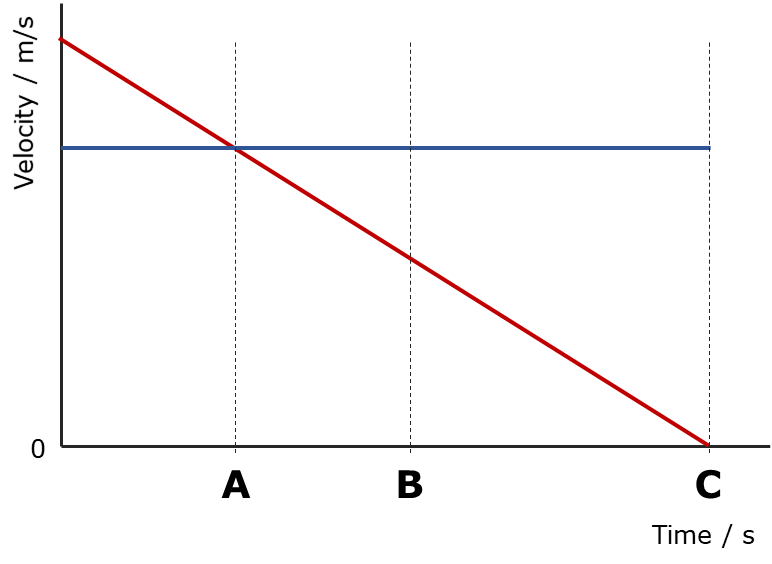


**1.** Which graph shows the greatest displacement from the starting point?

**

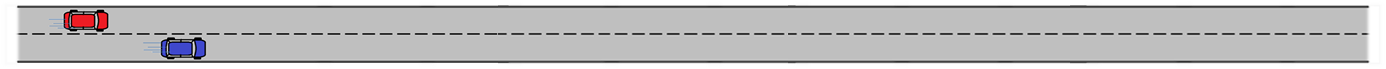
**2.** This velocity-time graph shows how two cars are moving.

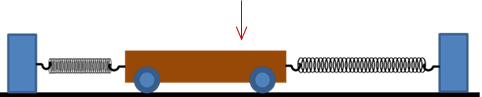
At which point does the red car overtake the blue car?



Red car

Blue car

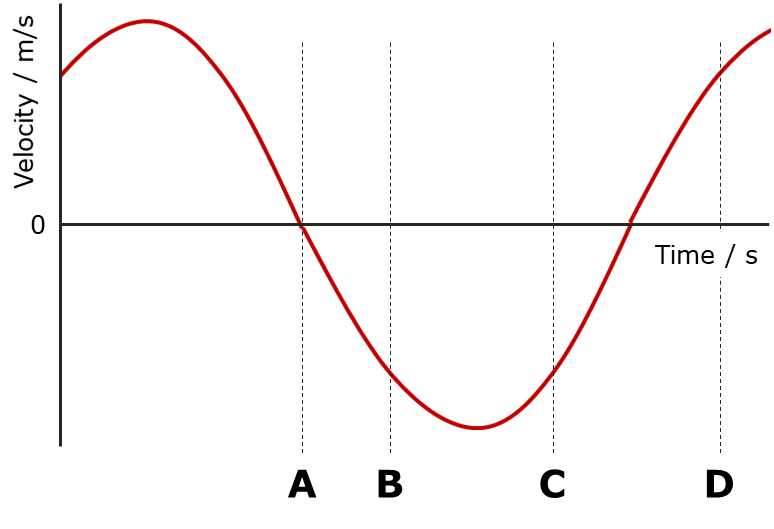


**3.** A trolley is released from this position.

The velocity-time graph shows how it

is pulled forwards and backwards by the springs.

When does the trolley **first** get back to where it started?



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

|  |
| --- |
| **Diagnostic question** |
| **Are we there yet?** |

**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 change in displacement of an object, or the distance it has travelled, from the area under a velocity-time graph. |
| Question type: | Simple multiple choice |
| Key words: | Displacement, velocity, time, graph |

**What does the research say?**

Students do not always understand the meaning of the area under a speed-time or velocity-time graph, perhaps because they do not understand how an area can represent a length (a distance or displacement) (McDermott, Rosenquist and van Zee, 1987; Beichner, 1994; Billings and Klanderman, 2000). On graphs showing both positive and negative velocities, students may ignore the v=0 axis and fail to understand its role in defining positive and negative areas. They may not therefore associate a positive area (an area above v = 0) with a positive displacement, and a negative area (and area below v = 0) with a negative displacement (McDermott, Rosenquist and van Zee, 1987).

**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.** A **2.**  B **3.**  C

**How to respond - what next?**

These questions test whether students understand the significance of the area under a velocity-time graph as representing displacement. Both velocity and displacement are vector quantities, so that the values on the velocity axis, and the area, can have positive or negative values.

*Question 1*

Graph A represents the greatest displacement because it has the largest area under its curve.

All the graphs have the same maximum value of velocity.

Options B or C may be chosen by student who confuse the highest point on the graph with the biggest displacement. It is common for students to connect the highest point on a graph with the largest of something, either because they have not read and understood what the vertical axis is showing, or because they do not understand the curve.

Some students may choose option D because they are thinking of the graph as a picture and this option has the greatest ‘up and down’ movement. Other students may select this option if they think it has a greater area than option A.

A few students may try to work out displacement from the gradient of the graph and are likely to choose option C.

*Question 2*

Up until A, the red car is displaced more than the blue car, by an amount represented by the area of the triangle between the red and blue lines on the graph. Between A and B, the blue car is displaced more than the red car by the same amount. The area of the triangles between the red and blue lines between 0 & A and between A & B are of equal size.

It is quite common for students to choose option A, where the lines cross on the graph. These students are misunderstanding this feature of the graph and are interpreting it as the point where the cars are together, in the same way as the lines. However, the lines on the graph do not show the positions of the cars.

*Question 3*

For velocities above the line, where v = 0, the trolley is moving to the right; and for velocities below the line it is moving left. Its displacement to the right is equal to the area between the positive parts of curve and the v = 0 line; and its displacement to the left is equal to the area between the negative parts of the curve and the v = 0 line. These areas are equal at point C, which is where it returns to its original position.

Those choosing option A have the misunderstanding that when the graph is zero, the change in displacement is zero.

Option B shows where the line of the graph first reaches the same distance below the v = 0 axis as it was above the axis when the trolley was released. Those choosing this option may be confusing velocity with displacement on the y-axis.

Option D represents the point where the trolley is repeating the same movement as it was at the start, when it has the same positive velocity. By this point, the trolley will have passed its starting point in the opposite direction first.

If students struggle with these questions, it may be worth setting up the experiment with a motion sensor that allows a velocity-time graph to be plotted. The trolley can be moved backwards and forwards by hand, as well as by the springs, so that it can be moved slowly enough for students to see the motion simultaneously with the graph being plotted.

If students have misunderstandings about the meaning of the area under a velocity-time graph, the following BEST ‘response activity’ could be used in follow-up to this diagnostic question:

* Response activity: Calculating displacement

**Acknowledgments**

Developed by Simon Carson (UYSEG).

Images: Simon Carson (UYSEG)

**References**

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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.