**From velocity to displacement**

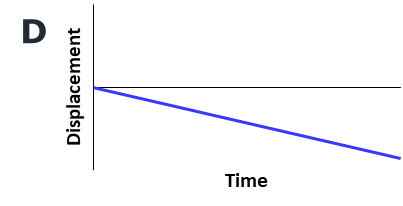
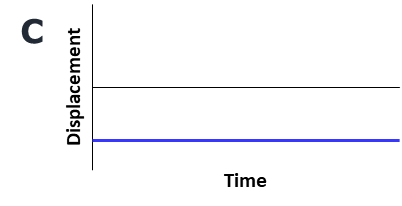
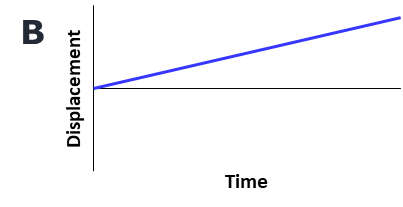
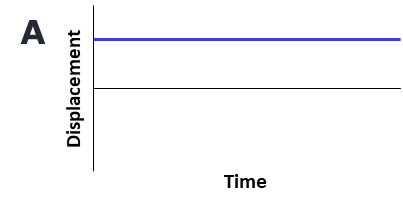
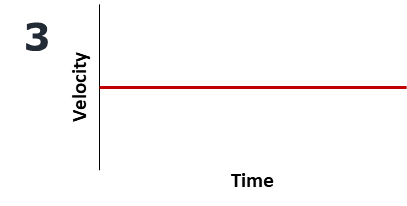
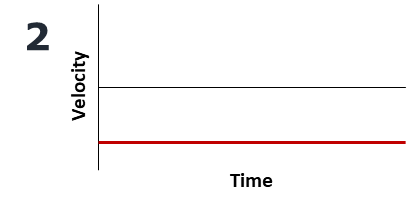
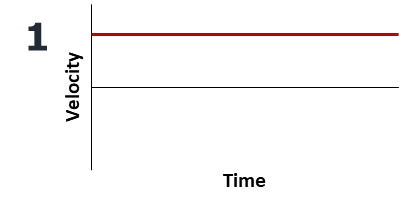
The movement of an object can be shown on different types of graph.

Which displacement-time graph shows the same movement as each velocity-time graph?

*Rule a line from each velocity-time graph to the correct displacement-time graph.*

**Velocity-time graphs**

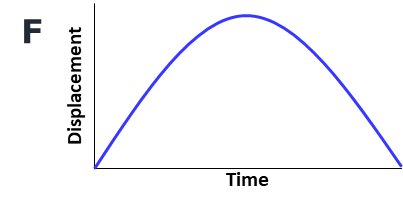
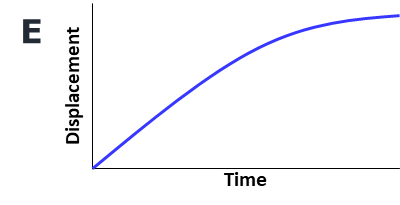
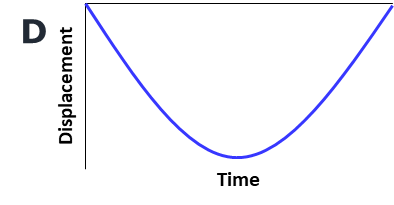
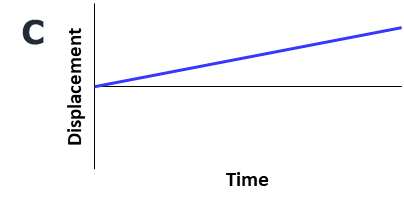
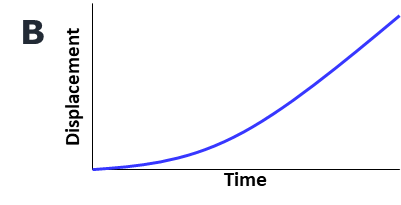
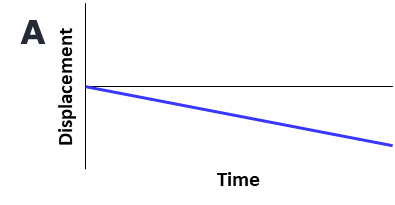
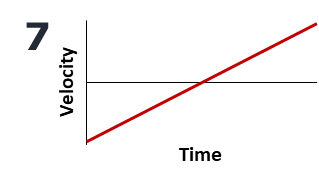
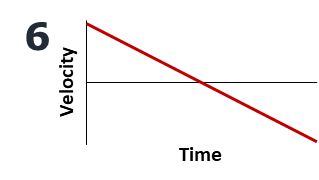
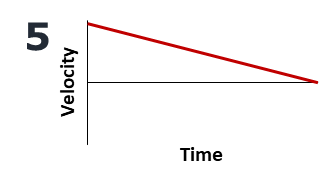
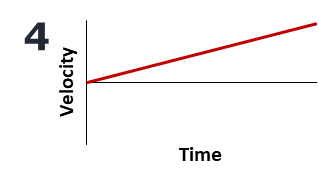
**Displacement-time graphs**



*Rule a line from each of these displacement-time graph to the correct velocity-time graph.*

**Velocity-time graphs**

**Displacement-time graphs**



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

|  |
| --- |
| **Diagnostic question** |
| **From velocity to displacement** |

**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: | Identify the velocity-time graph corresponding to a given displacement-time graph, and vice versa. |
| Question type: | Linking ideas |
| Key words: | Displacement, velocity, time, graph |

**What does the research say?**

It is common for teachers to assume students can readily extract information from graphs when this is not necessarily the case (Beichner, 1994). Misunderstandings and difficulties in interpreting graphs arise even when students have a good understanding of kinematic concepts (position, displacement, velocity and acceleration) and are evident amongst different student populations and across different academic levels (McDermott, Rosenquist and van Zee, 1987). Even when students have the necessary mathematical knowledge about how to plot and read graphs, and how to calculate gradients and areas, they may struggle with the same skills in a physics context (McDermott, Rosenquist and van Zee, 1987; Bollen et al., 2016).

When asked to think about graphical representations of velocity, students often think only about speed (Goldberg and Anderson, 1989). They may be aware that velocity is a vector quantity, with both a magnitude and a direction, but see these as completely separate properties that are not combined in a graphical representation. For these reasons, they may struggle to read velocity-time graphs, especially those that include both positive and negative values of velocity. Some students may believe that a negative quantity on a velocity-time graph implies a speed that is less than zero, which makes no sense, rather than interpreting the negative sign as meaning “in the opposite direction”.

A common error that some students make is to see a graph as a literal picture of a physical situation and, rather than viewing a graph as a mathematical representation of a motion, they may see it as a sort of ‘photograph’ that duplicates the motion (Clement, 1985; Leinhardt, Zaslavsky and Stein, 1990; Beichner, 1994; Bollen et al., 2016). This can make it hard for them to describe qualitatively a motion represented by a graph, or to draw the shape of a graph from a description of a motion.

Students who struggle with this ‘iconic interpretation’ may believe that plotting different kinematic variables (displacement, velocity, acceleration) against time does not change the appearance of a graph. They can find it difficult to match distance-time graphs to corresponding speed-time graphs, or displacement-time graphs to corresponding velocity-time graphs, and vice versa (Beichner, 1994).

**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.

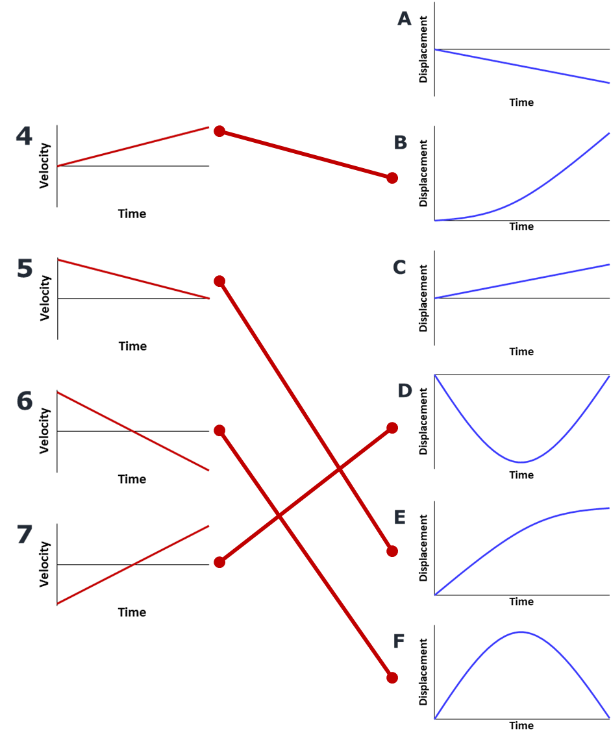
If there is a range of answers, you may choose to respond through structured class discussion. Ask one student to explain why they gave the answer they did; ask another student to explain why they agree with them; ask another to explain why they disagree, and so on. This sort of discussion gives students the opportunity to explore their thinking and for you to really understand their learning needs.

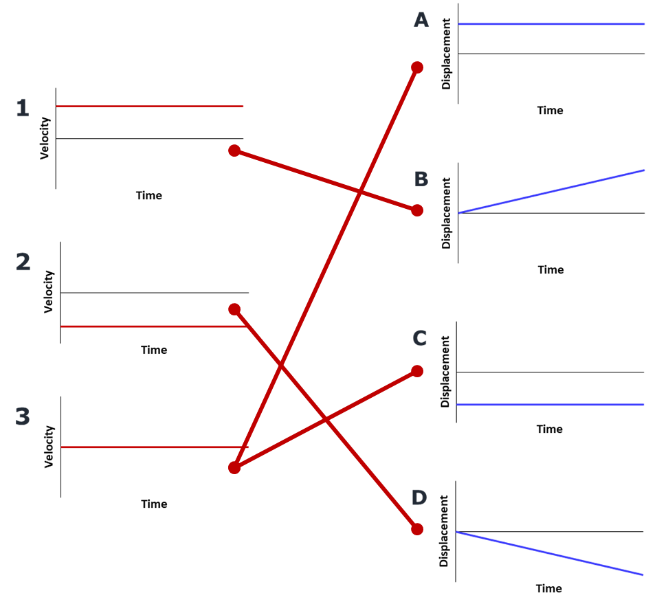
*Differentiation*

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.

If teachers find that their students have an excellent grasp of the ideas explored here, taking the final two velocity-time graphs, and re-drawing them so that they cross the time axis, and therefore have both positive and negative values of velocity, will present students with additional challenge.

**Expected answers**

****

****

**How to respond - what next?**

These questions test whether or not students have a good qualitative understanding of velocity-time graphs that allows them to translate from velocity-time to displacement-time graphs.

In the first set of questions, the velocity-time graphs are all horizontal lines, corresponding to linear displacement-time graphs. The velocities are positive, negative and zero. In the second set of questions, the velocity-time graphs are linear, but the displacement-time graphs are curves and velocities are both positive and negative.

*First set of questions*

* Students who match velocity-time graphs to the displacement-time graphs that look the same may be seeing the graphs as literal pictures of the motion.
* If the velocity is constant and positive, then the displacement-time graph has a constant positive gradient as the displacement increases at a constant rate.
* Students may struggle to appreciate that the significance of a constant negative velocity is that the displacement must be decreasing.
* When the velocity is zero, then the displacement does not change, and there are two displacement-time graphs that satisfy this requirement. Explore with students both these possibilities.

In discussing this question with students, it is worth exploring with students the significance of whether or not the displacement graph crosses the time axis. The answer is that it does not matter in matching the graphs.

*Second set of questions*

* Students who match velocity-time graphs to the displacement-time graphs that look the same may be seeing the graphs as literal pictures of the motion.
* Students need to think about the velocity-time graphs as representing the gradient of the displacement-time graphs. As the velocity rises, the displacement-time graph gets progressively steeper.
* The second velocity-time graph falls at a steady rate, and students may want to match this with a displacement-time graph which is also falling, even if they are aware of velocity as the gradient of the displacement-time graph. However, even though the velocity falls, it is always positive, so that the displacement must always be increasing.
* In the third velocity-time graph, the first half of the graph is the same as the second graph. The velocity then passes through zero, corresponding to a point on the displacement-time graph where the gradient is zero, before becoming negative, meaning that the displacement is decreasing. To identify the correct displacement-time graph, students need to understand the significance of both a zero value for the velocity, and a negative value.
* The final velocity-time graph is a reflection of the third graph in the time axis, and the displacement-time graph can be drawn by flipping the previous graph vertically. Students who understand velocity as the gradient of a displacement-time graph may still confuse the last two answers, expecting the displacement-time graph initially to rise or fall as the velocity-time graph does. This is perhaps a further manifestation of the graph as picture misconception.

If students have misunderstandings about translating velocity-time graphs to displacement-time graphs, the following BEST ‘response activity’ could be used in follow-up to this diagnostic question:

* Response activity: Translating motion graph

**Acknowledgments**

Developed by Simon Carson (UYSEG).

Images: Simon Carson (UYSEG)

**References**

Beichner, R.J. (1994) ‘Testing student interpretation of kinematics graphs’, *American Journal of Physics*, 62(8), pp. 750–762. doi:10.1119/1.17449.

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.

Clement, J. (1985) ‘Misconceptions in Graphing’, in *Proceedings of the Ninth Conference of the International Group for the Psychology of Mathematics Education*. *Ninth Conference of the International Group for the Psychology of Mathematics Education, Noordwijkerhout, The Netherlands, July, 1985.*, Netherlands, p. 8.

Goldberg, F.M. and Anderson, J.H. (1989) ‘Student difficulties with graphical representations of negative values of velocity’, *The Physics Teacher*, 27(4), pp. 254–260. doi:10.1119/1.2342748.

Leinhardt, G., Zaslavsky, O. and Stein, M.K. (1990) ‘Functions, Graphs, and Graphing: Tasks, Learning, and Teaching’, *Review of Educational Research*, 60(1), p. 64.

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.