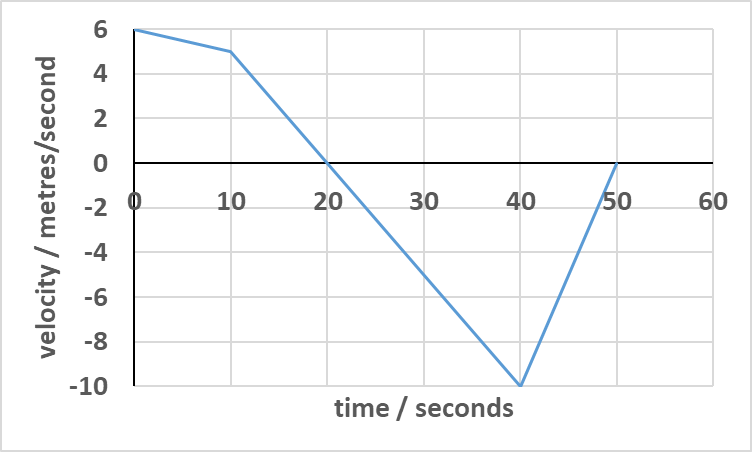
**Reading the graph**

A train is travelling along a straight track.



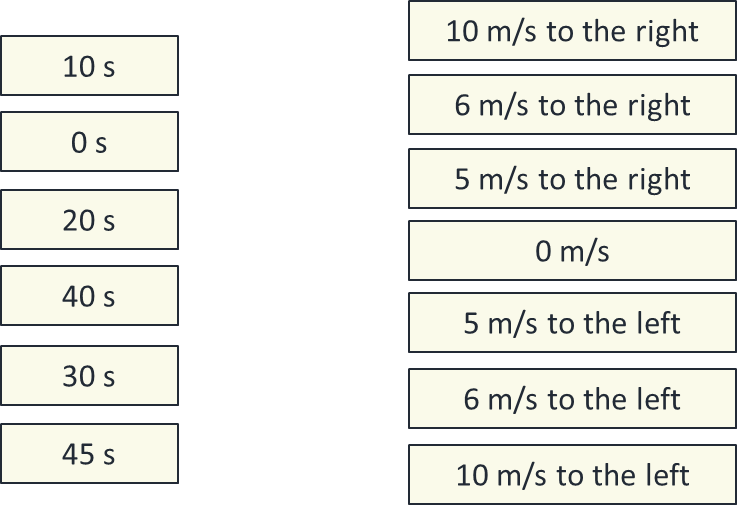
The graph shows the velocity of the train at different times.

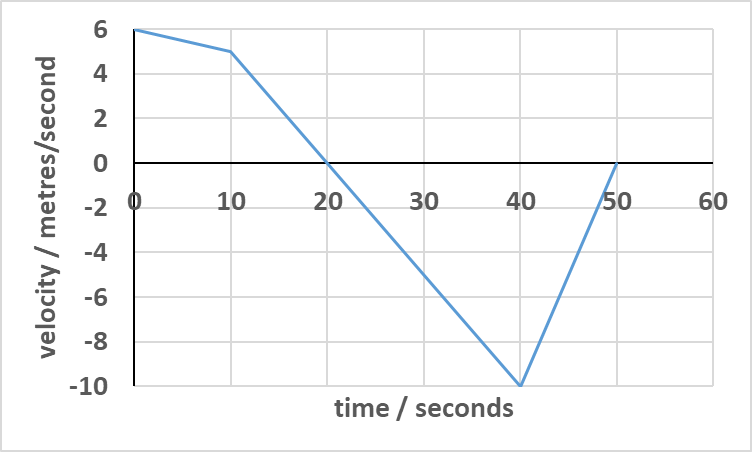
Initially, the train is moving to the right.



**1.** What is the velocity of the train at each time?

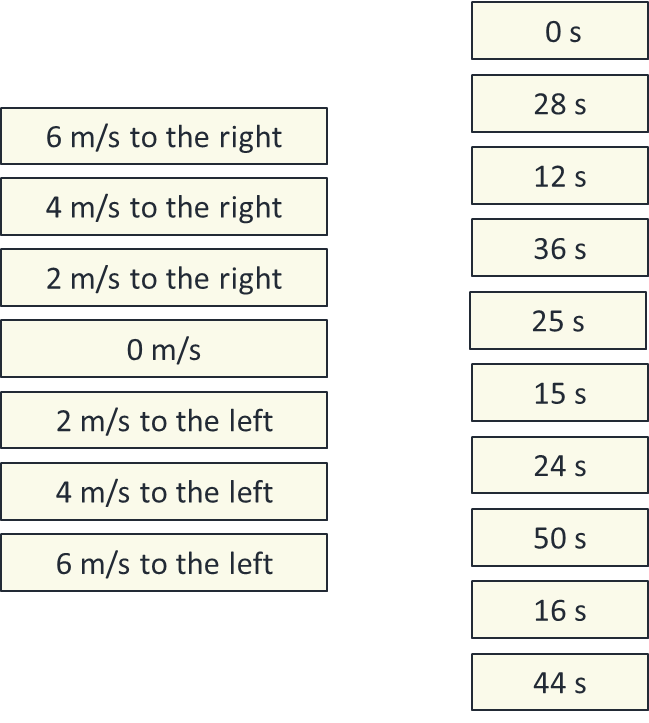
*Rule a line between each time and the correct velocity.*

**



**2.** At what time(s) is the train moving at each velocity?

*Rule a line between each velocity and the correct time(s).*

**

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

|  |
| --- |
| **Diagnostic question** |
| **Reading the graph** |

**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: | Read values of speed or velocity off a speed-time or velocity-time graph, and interpret the meaning of a negative velocity. |
| Question type: | Linking ideas |
| Key words: | Velocity, time, graph |

**What does the research say?**

The visual presentation of data in graphical form makes graphs valuable for analysing data and, perhaps more importantly, for showing relationships between data sets (Rogers, in Carson, 1999). 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”.

**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.

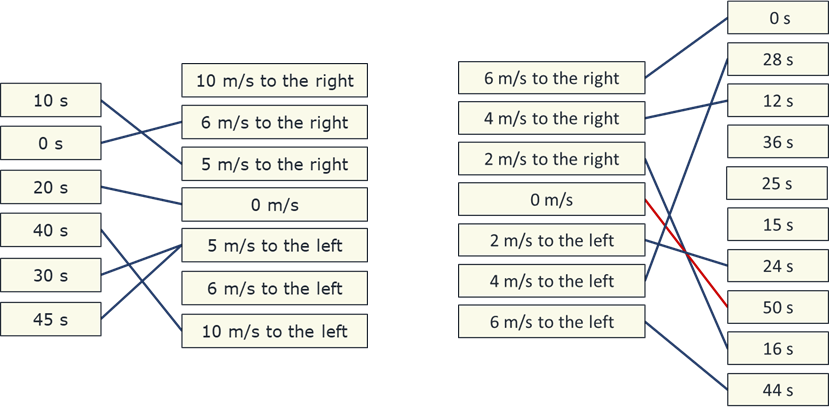
The answers to the question will show you whether students understood the concept sufficiently well to apply it correctly.

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 really to 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**

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**How to respond - what next?**

Students’ answers to these questions reveal whether they understand that a negative velocity indicates motion to the left in this example, as well as indicating whether they can read and interpret the scales on the axes.

In question 1, the times are chosen to lie on the grid lines, apart from the final time, 45 seconds. The velocities lie both on and between the grid lines. The final time, 45 seconds, requires students to read between the grid lines for both time and velocity.

The velocities are both positive and negative, so that the motion is to the right and to the left. If students do not understand the significance of the minus sign, they may choose the wrong direction, even if they choose the correct magnitude. In discussing answers with students it is important to ask them for their reasons for choosing particular answers in order to diagnose any misconceptions about the significance of the sign of the velocity.

In question 2, reading the values of the times is harder than in question 1 because several are between gridlines and not centrally between them. Reading off the times for velocities of 2 m/s and 4 m/s means interpolating carefully between times of 10 s and 20 s and avoiding the distractor of 15 s. There is a similar situation presented when reading off the times for velocities of -2 m/s and -4 m/s. When reading off the times for negative velocities there are also two possible values for the times, only one of which is given in the choices, so again careful interpolation is required if students are to avoid the distractors.

If students have misunderstandings about reading off values from the axes, or about interpreting the meaning of a negative velocity, the following BEST ‘response activity’ could be used in follow-up to this diagnostic question:

* Response activity: Drawing graphs

**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.

Carson, S. (1999) *Physics in mathematical mood*. Bristol: Institute of Physics Pub.

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.

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.