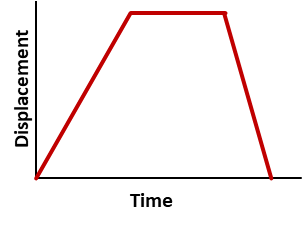
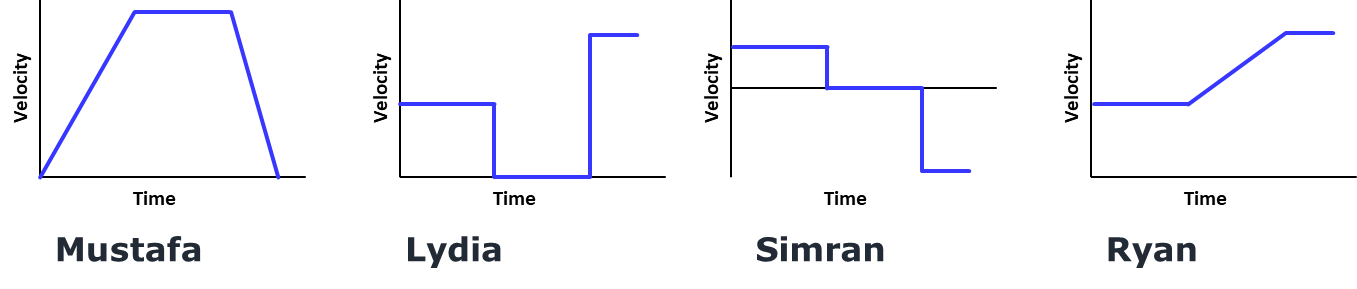
**Translating motion graphs (1)**

Some students have had a go at drawing a velocity-time graph.

They want to show the same movement as this displacement-time graph.



These are the graphs they drew:

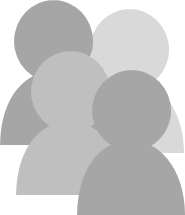


The students are discussing the graphs they have drawn.

**Mustafa:** It has the same shape as the d-t graph because it shows the same motion.

**Ryan:** At first the velocity is positive and in the last part, the object is moving faster, so it must speed up in the middle.

**Lydia:** At first velocity is positive and in the middle velocity is zero. In the last bit, movement is faster, because the line on the d-t graph is steeper.



**Simran:** I agree with Lydia mostly, but in the last part, movement is in the opposite direction so velocity is negative.

**To answer:**

1. Which of student has drawn the correct graph?

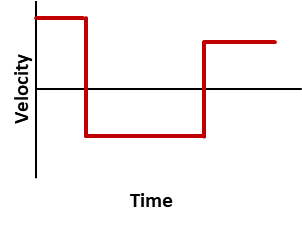
2. What would you say to help the students who are wrong?

3. What advice would you give to make the correct graph even better?

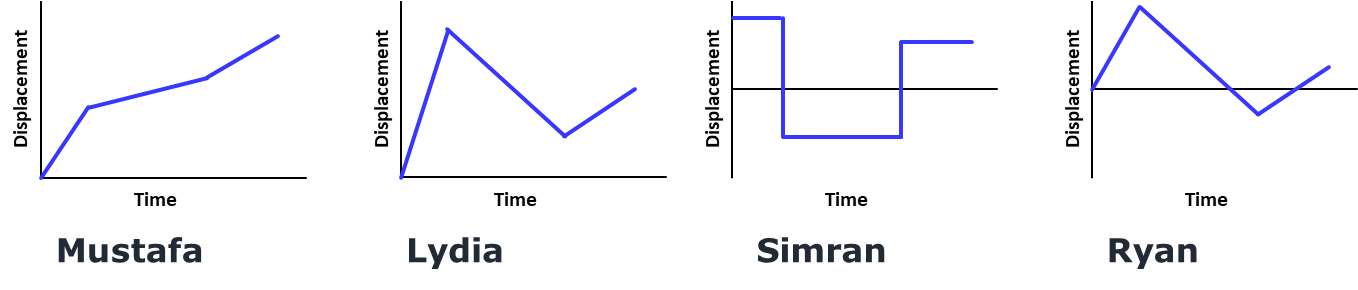
**Translating motion graphs (2)**

The students have also had a go at drawing a displacement-time graph.

They want to show the same movement as this velocity-time graph.



These are the graphs they drew:



The students are discussing the graphs they have drawn.

**Mustafa:** The line on the d-t graph is steeper when velocity is bigger. Velocity starts high, then it is low, and then high again – but not as high as at the start.

**Lydia:** At first velocity is positive, so the line goes up. In the middle, velocity is negative, so the line goes down. At the end, the graph must go up again.

**Simran:** When velocity is positive, movement is away from the start, and displacement must be positive. When velocity is negative, displacement is negative too.



**Ryan:** At first the graph goes up because velocity is positive. In the middle it goes down because movement is backwards. There is more movement backwards than forwards, so displacement must go negative.

**To answer:**

1. Which of student has drawn the correct graph?

2. What would you say to help the students who are wrong?

3. What advice would you give to make the correct graph even better?

|  |  |
| --- | --- |
| Cards for  **Translating motion graphs (1)** |  |
| 1. **Mustafa:** It has the same shape as the d-t graph because it shows the same motion. | **1. Lydia:** At first velocity is positive and in the middle velocity is zero. In the last bit, movement is faster, because the line on the d-t graph is steeper. |
| **1. Simran:** I agree with Lydia mostly, but in the last part, movement is in the opposite direction so velocity is negative. | **1. Ryan:** At first the velocity is positive and in the last part, the object is moving faster, so it must speed up in the middle. |

|  |  |
| --- | --- |
| Cards for  **Translating motion graphs (2)** |  |
| **2. Mustafa:** The line on the d-t graph is steeper when velocity is bigger. Velocity starts high, then it is low, and then high again – but not as high as at the start. | **2. Lydia:** At first velocity is positive, so the line goes up. In the middle, velocity is negative, so the line goes down. At the end, the graph must go up again. |
| **2. Simran:** When velocity is positive, movement is away from the start, and displacement must be positive. When velocity is negative, displacement is negative too. | **2. Ryan:** At first the graph goes up because velocity is positive. In the middle it goes down because movement is backwards. There is more movement backwards than forwards, so displacement must go negative. |

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

|  |
| --- |
| **Diagnostic question** |
| **Translation** |

**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: | Talking heads |
| Key words: | Displacement, velocity, time, graph |

This activity can help develop students’ understanding by addressing the sticking-points revealed by the following diagnostic questions:

* Diagnostic question: From displacement to velocity
* Diagnostic question: From velocity to displacement

**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**

This task is intended for discussion in pairs or small groups. It can be done as a pencil and paper exercise or projected onto a screen.

Students should read the statements and follow the instructions on either the worksheet or the PowerPoint. Listening in to the conversations of each group will often give you insights into how your students are thinking. Each member of a group should be able to report back to the class.

Feedback from each group can be used, with careful teacher questioning, to bring out a clear description or explanation of the science.

*Differentiation*

The quality of the discussions can be improved with a careful selection of groups; or by allocating specific roles to students in each group. For example, you may choose to select a student with strong prior knowledge as the scribe, and forbid them from contributing any of their own answers. They may question the others and only write down what they have been told. This strategy encourages contributions from more members of each group.

NB in any class, small group discussions typically improve over time and a persistence with this strategy is often very successful in the medium to long term.

**Expected answers**

*Part 1*

1. Simran has drawn the correct graph.

2. Mustafa may be making the error of seeing graphs as a picture of the motion, so that he does not distinguish between different types of motion graph.

Lydia is almost correct, but has plotted a graph of speed rather than velocity: she has failed to take account of the vector nature of velocity. The final part of the displacement-time graph has a negative gradient, which corresponds to a negative velocity.

Ryan has correctly identified the relative speeds at the start and end, but has not taken account of the vector nature of velocity, and has not understood that a constant value of displacement corresponds to zero velocity.

1. Although Simran is correct, her explanation could be improved by relating the velocity to the gradient of the displacement-time graph.

*Part 2*

1. Ryan has drawn the correct graph.

2. Mustafa has correctly interpreted a positive constant value of velocity as corresponding to an increasing value of displacement. However, he has not taken into account the fact that the middle portion of the velocity-time graph has a negative value, corresponding to decreasing displacement. He has identified that the velocity is lower in the middle section, and has drawn a displacement-time graph with a lower gradient in this middle section.

Lydia is almost correct. She has the correct signs for the gradient of the displacement-time graph. However, she has not taken into account the times for which the object travels at the different values of the velocity. The area between the curve and the time axis of the velocity-time graph in the middle section is greater than the initial section, so that the total displacement at the end of the middle section is negative. The increasing displacement in the final section of the journey takes the total displacement to a positive value.

Simran does not appear to have a clear idea about what negative velocity or negative displacement are and has the misunderstanding that when velocity is negative, displacement is too.

Ryan is correct, but his answer could be improved by giving a more detailed explanation of the connection between the values on the velocity-time graph and the gradient of the displacement-time graph.

**Acknowledgments**

Developed by Simon Carson (UYSEG).

Images: Simon Carson (UYSEG)

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