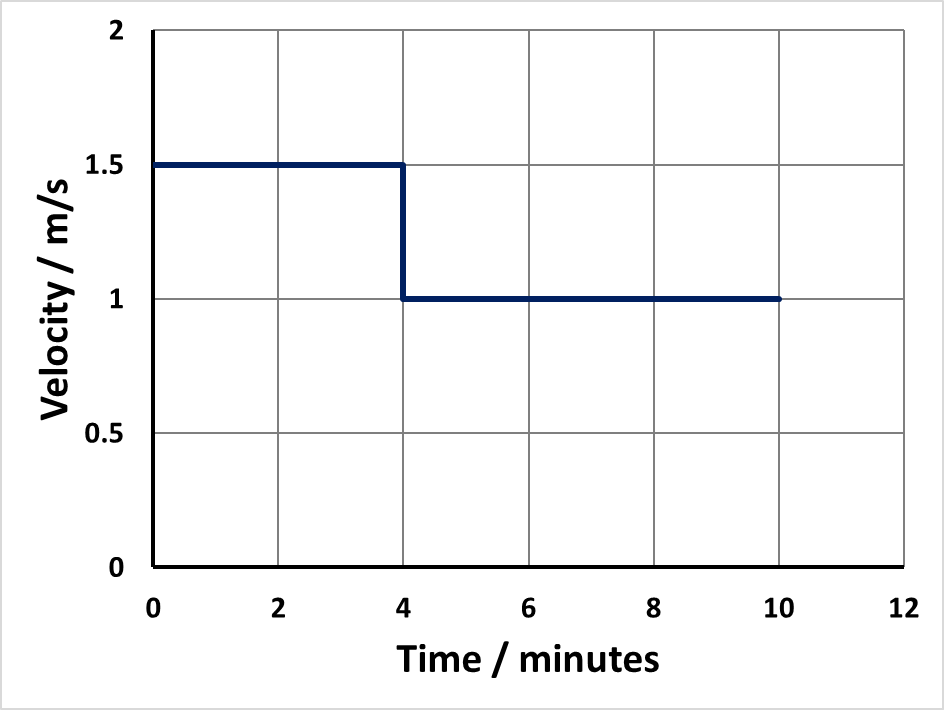
**Calculating displacement**

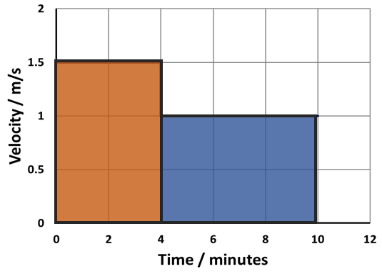
The change in displacement of an object between two times,

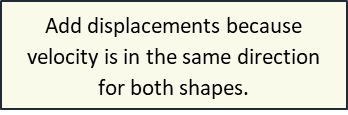
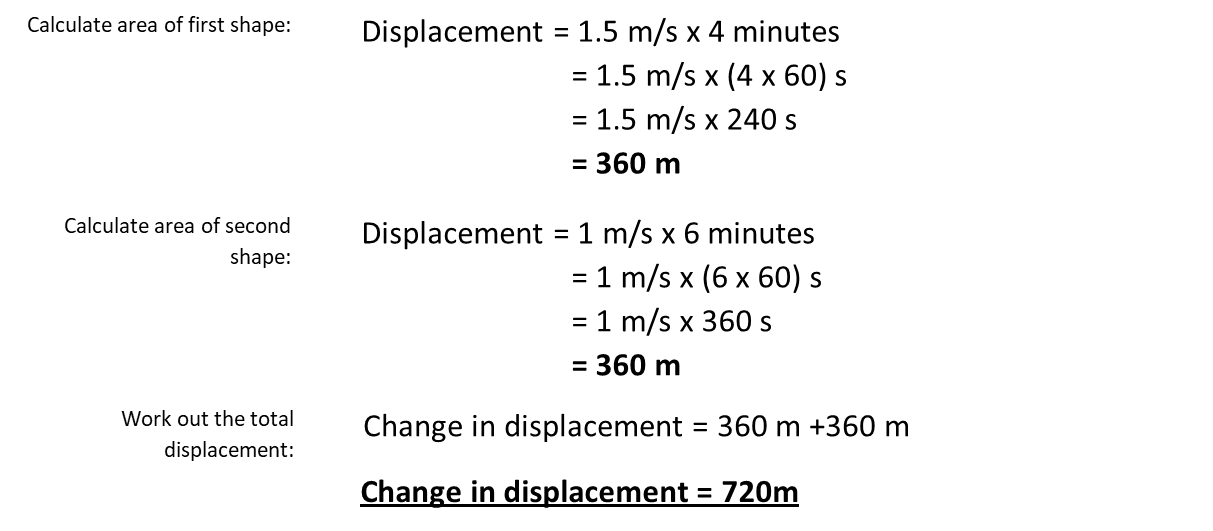
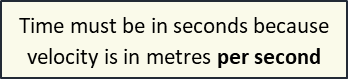
is equal to the area under a velocity-time graph between those times.

**Example:** The velocity-time graph shows the movement of an object.

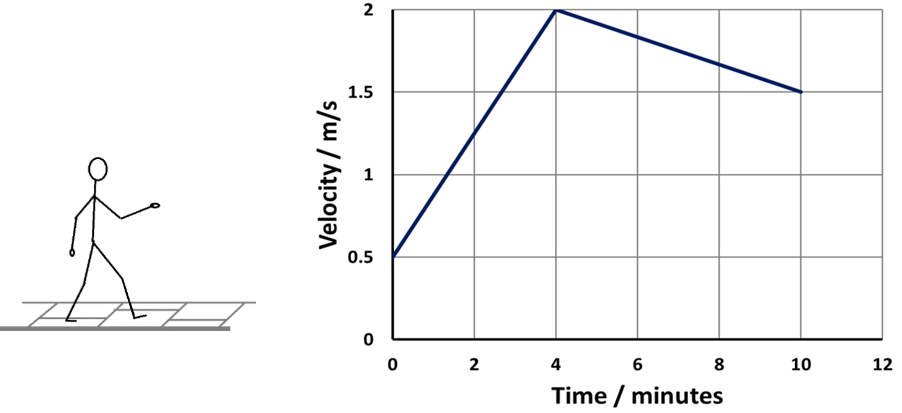
Use the graph to work out its change of displacement.

**Model Answer:**



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**1.** This velocity-time graph represents Susan’s journey.

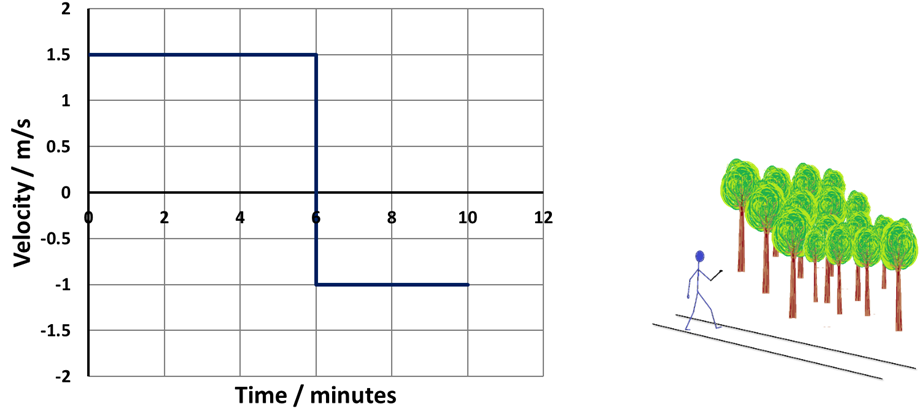


**a.** How far does Susan walk in the first 4 minutes?

**b.** How far does Susan walk in the last 6 minutes?

**c.** What is Susan’s total displacement from the starting point?

**2.** This velocity-time graph shows a different walk.



**a.** This time, how far does Susan walk in the first 6 minutes?

**b.** How far does Susan walk in the last 4 minutes?

**c.** What is Susan’s total displacement from the starting point?

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

|  |
| --- |
| **Response activity** |
| **Calculating 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: | 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. |
| Activity type: | Application and practice - calculations |
| Key words: | Displacement, velocity, time, graph, area |

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

* Diagnostic question: Are we there yet?

**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).

Units in equations should be treated explicitly and with care. It is good practice always to include units in calculations, not least because this may help students to appreciate that symbols refer to physical quantities. Keeping track of units can also help in checking that calculations make sense physically, and prepares the way for dimensional analysis post-16 (Boohan, 2016). The units of acceleration may be particularly problematic as acceleration is a rate of change of a rate of change, and is measured in metres/second2, a unit that is unfamiliar to students.

Whilst carrying out calculations is an important part of students’ learning, success in using equations is not the same thing as developing conceptual understanding in mechanics (Kim and Pak, 2002), and misconceptions may remain. To expert physicists, symbols stand for physical quantities, and the results of the mathematical manipulations must be interpreted in terms of their meaning for a given physical system. Experts draw on their experience and (often tacit) knowledge of physical systems in order to make meaning from the mathematics (Carson, 1999; Redish and Kuo, 2015). To novices, the manipulation of the symbols, and the substitution of numbers into formulae may be ends in themselves, devoid of physical meaning. This is why asking students to think qualitatively as well as quantitatively, about kinematical quantities is important.

**Ways to use this activity**

This activity gives students the opportunity to practise applying their understanding and to clarify their thinking through discussion. To support this, students should answer the questions in pairs or small groups. Listening to individual groups as they work often highlights any difficulties they might have. These can often be overcome, through a whole class clarification or redirection part way through the activity.

Allowing only one student in each pair or small group to write down the answer on behalf of the group encourages discussion of both the science and of the presentation of the answer. Mini-white boards allow groups to show you their answers for immediate feedback.

*Question 1*

To answer question 1, students need to divide the area under the graph into shapes whose areas they can calculate. The easiest way to do this is to divide the graph into two triangles and two rectangles.

*Question 2*

In order to calculate the total displacement, students have to recognise that the area below the axis represents a negative displacement.

*Differentiation*

If some students are working with a teaching assistant, then a list of prompt questions for the TA could help to make this activity more purposeful.

**Expected answers**

1a. 300 m b. 630 m c. 930 m

2a. 540 m b. 240 m c. 300 m

**Acknowledgments**

Developed by Simon Carson (UYSEG).

Images: Simon Carson (UYSEG)

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