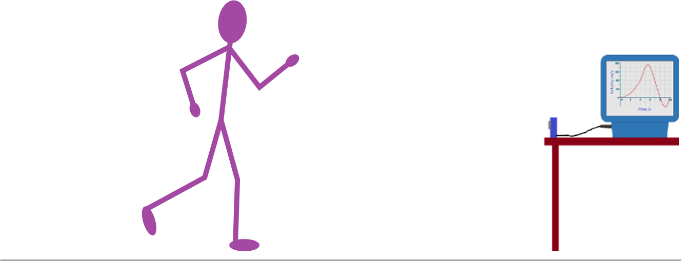
**Drawing the story**

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A motion sensor is used to help plot a velocity-time graph.

Isaac walks up and down in front of the sensor.

He follows a set of instructions.

*Instructions for Isaac:*

1. Start from rest at the motion sensor.
2. Walk away and speed up quickly.
3. Walk at a steady pace for a short distance.
4. Slow down quickly and stop.
5. Turn around and stand still for a short time.
6. Walk back towards the motion sensor, start slowly and speed up.
7. Slow down and stop.

Think about the velocity of the student. What would a velocity-time graph of the story look like?

**Predict**

Sketch a velocity-time graph of the motion.

*You don’t need numbers on the axes.*

Time / s

Velocity / m/s

**Explain**

Explain why you think the graph will look like this.

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| --- |
| **Use the motion sensor to plot a velocity-time graph using the instructions.** |

**Observe**

How does the graph compare the graph with your prediction?

………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………………

**Explain**

Were your prediction and explanation correct?

Try to improve your first explanation to explain what happens more clearly.

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

|  |
| --- |
| **Response activity** |
| **Drawing the story** |

**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: | Describe the motion of an object from a velocity-time graph, and identify the velocity-time graph from a description of motion. |
| Activity type: | PEOE (Predict-explain-observe-explain) |
| Key words: | Velocity, time, graph |

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

* Diagnostic question: Telling the story

**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).

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.

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”.

It has been found in large studies that students who demonstrate a good command of kinematical concepts, and who have a good grasp of how to plot and to read graphs and of how to calculate gradients from their study of mathematics, often misinterpret what the gradient of a velocity-time graph represents (McDermott, Rosenquist and van Zee, 1987; Bollen et al., 2016).

**Ways to use this activity**

Students should complete this activity in pairs or small groups, and the focus should be on the discussions. It is through the discussions that students can check their understanding and rehearse their explanations.

To begin, each group should discuss the activity and use their scientific understanding, firstly to predict *what* they think the graph will look like, and then to explain *why* they think they are going to be right. If students in any group cannot agree, you may be able to direct them with some careful questioning.

Students now carry out the practical, or watch a demonstration. You will need to decide whether it is better for each group to carry out the practical (and risk some unexpected observations), or to demonstrate the activity so that everyone *observes* the same thing. This may depend on the resources available.

It is very unlikely that there will be room in a science laboratory for pairs of students to carry out the practical as it is described.

As an alternative, students can plot the same graph by moving a dynamics trolley backwards and forwards along a bench in front of a motion sensor.

After the practical each group should be given the opportunity to change, or improve their explanation, and to identify where they went wrong, and why. A good way to review your students’ thinking might be through a structured class discussion. You could ask several groups for their *explanations* and put these on the whiteboard. Then ask other groups to suggest which explanation is the most accurate and the most clearly expressed, and through careful questioning work up a clear ‘class explanation’.

A useful follow up is for individual students to then write down explanations in their own words – without reference to the class explanation on the board (i.e. cover it up).

*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 a 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.

**Equipment**

For each group (As a demonstration, the dynamics trolley is not needed.):

* Motion sensor
* Data-logger
* Connecting cables
* Computer
* Dynamics trolley – see ‘ways to use this activity’ above

**Technician notes**

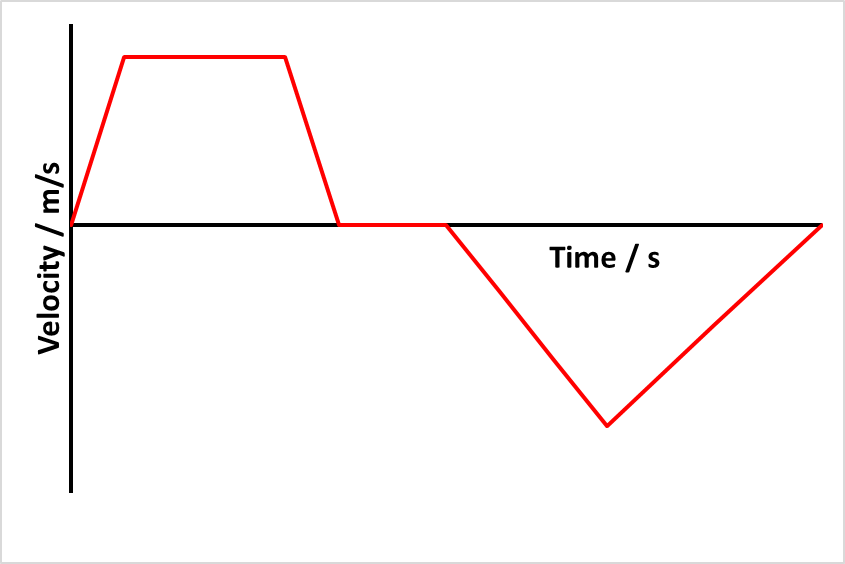
There is a wide variety of motion sensors available, and each type needs to be tested in order that settings are adjusted to obtain the best results. Software should be set up so that students see a velocity-time graph.

**Health and safety**

There is likely to be a significant amount of movement during this practical if groups carry out the experiment themselves.

Practical work should be carried out in accordance with local health and safety requirements, guidance from manufacturers and suppliers, and guidance available from CLEAPSS.

**Expected answers**

The graph should look something like this:

It is unlikely that a real velocity-time graph will have such clear linear sections, and it is worth discussing the differences with students. Why, for example, does a real velocity-time graph not have sharp corners? (Because changes do not happen in an instant.)

In discussion, students should be able to explain how they can tell from the graph:

* where an object is speeding up or slowing down;
* when an object is moving at a steady speed;
* when an object is stationary;
* and which direction an object is moving in.

**Acknowledgments**

Developed by Simon Carson (UYSEG).

Images: Peter Fairhurst (UYSEG) and Simon Carson (UYSEG)

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