**Calculating average speed and average velocity**

Average speed and average velocity can be calculated using:

**average speed =**

**average velocity =**

**distance travelled**

**time taken**

**time taken**

**total displacement**

*Speed is a scalar quantity; it has a magnitude only.*

*Velocity is a vector quantity; it has both a magnitude and a direction.*

**To do:**

*Answer the questions.*

*Show clearly every step of your calculations.*

**1.** A car travels 10 kilometres east in 10 minutes.

A picture containing logo

Description automatically generated

**a.** Find the **average** **speed** of the car in metres per second (m/s).

**b.** Find the **average** **velocity** of the car in m/s.

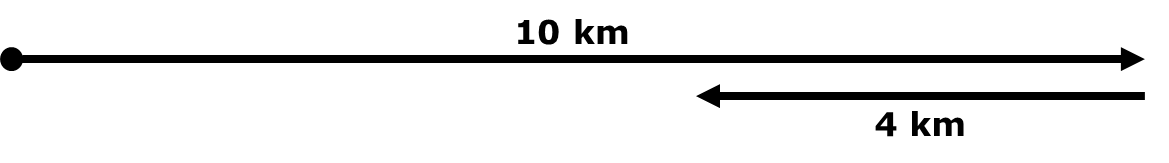
**2.** The car then travels 4 kilometres west at the same speed (10 km in 10 minutes).

Shape, rectangle

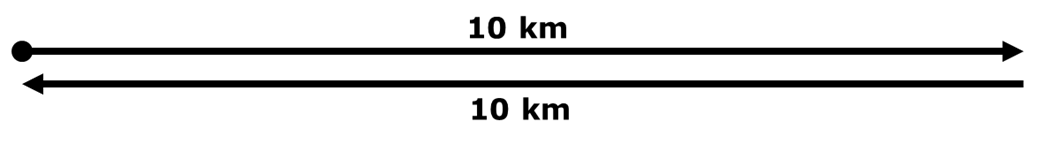
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**a.** How long does it take the car to travel 4 km?

**b.** Find the **average velocity** of the car for the whole journey.



**3.** The car continues to travel west, and arrives back at its starting point 20 minutes after it left.



Find the **average velocity** of the car for the whole journey. On a different journey, the car travels at a velocity of 20 m/s north for 30 minutes.

**4.** A red car travels at a velocity of 20 m/s north for 30 minutes.

Find the total displacement of the car.

**5.** A green car travels at a velocity of 15 m/s south.

The total displacement for the journey is 6 kilometres south.

How long did the journey take?

**6.** A cyclist travels along a straight road.

She cycles the first 60 metres in 15 seconds.

She cycles the next 40 metres in 5 seconds.

A screenshot of a bicycle

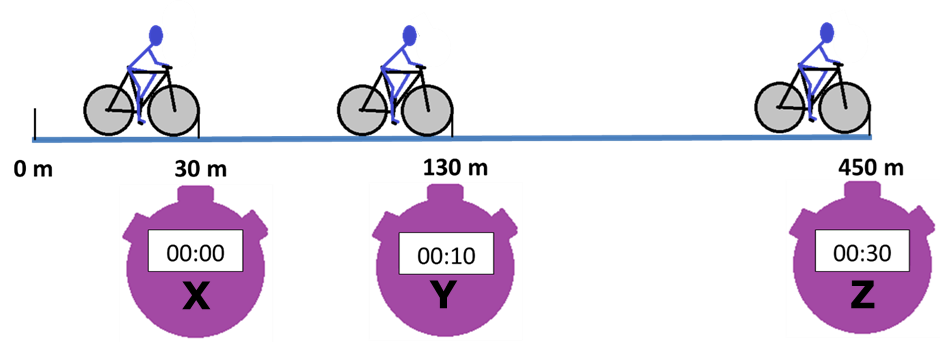
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**a.** Find the magnitude of her average velocity during the first part of the ride.

**b.** Find the magnitude of her average velocity during the second part of the ride.

**c.** Find the magnitude of her average velocity during the whole ride.

**7.** The cyclist travels along a straight track. Her friends time her using a stopwatch as she passes marks along the track.



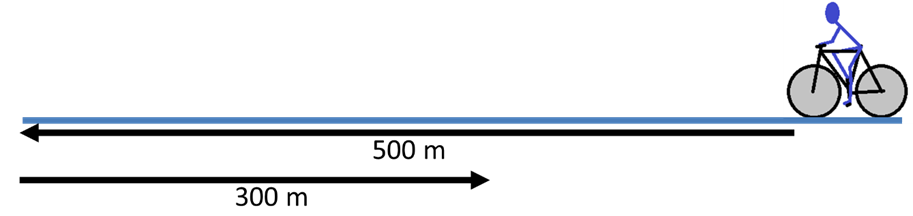
**a.** Find the magnitude of her average velocity between **X** and **Y**.

**b.** Find the magnitude of her average velocity between **Y** and **Z**.

**c.** Find the magnitude of her average velocity between **X** and **Z.**

**8.** The cyclist travels 500 metres along a track. She then turns around and cycles 300 metres back the other way.

She travels at a steady speed of 5 m/s.



**a.** Find the magnitude of her total displacement for the whole journey.

**b.** How long does it take her to complete the whole journey?

**c.** Find the magnitude of her average velocity for the whole journey.

**9.** The cyclist travels 800 metres along a track. She then turns around and cycles 1 600 metres in the other direction.

The whole journey takes 400 seconds.

A blue and white logo

Description automatically generated with low confidence

**a.** Find the total distance travelled by the cyclist.

**b.** Find the average speed of the cyclist.

**c.** Find the total displacement of the cyclist for the whole journey.

**d.** Find the average velocity of the cyclist for the whole journey.

*Physics > Big idea PFM: Forces and Motion > Topic PFM4: Describing and calculating motion > Key concept PFM4.1: Velocity*

|  |
| --- |
| **Response question** |
| **Calculating average speed and average velocity** |

**Overview**

|  |  |
| --- | --- |
| Learning focus: | Velocity and displacement are vector quantities. Velocity measures by how much displacement changes in a given time interval. |
| Observable learning outcome: | Calculate displacement and velocity for one-dimensional motion. |
| Question type: | Application and practice - calculations |
| Key words: | Distance, speed, displacement, velocity, average |

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

* Diagnostic question: Displacement and velocity
* Diagnostic question: There and back again

**What does the research say?**

Students have a somewhat undifferentiated understanding of the kinematical terms speed, velocity and acceleration, merging them together into a general idea of ‘motion’, and conflate words that have related meanings, such as distance and displacement, or speed and velocity, not always realising the important differences between them (de Winter and Hardman, 2021). Although these terms are connected, the differences matter, and teachers should use terms carefully, taking care to be precise in their use of language. Students need to be clear about the vector nature of quantities such as displacement, and velocity.

Velocity is a vector quantity, and is sometimes defined as “speed in a given direction”. This is not a good definition. It is true that the magnitude of the instantaneous velocity is equal to the instantaneous speed, but the magnitude of the average velocity is not, in general, equal to the average speed.

Velocity is not simply speed with a direction tacked on. An accurate definition of velocity is that velocity is equal to rate of change of displacement.

Average velocity is the change in the displacement divided by the time interval over which the change occurs:

The bold typeface, for **v** and **s**, is used to denote a vector quantity.

A potential source of confusion here is in the symbols that physicists conventionally use for these quantities (de Winter and Hardman, 2021). The same letter is used for distance and displacement, and for speed and velocity, despite these being neither the same type of quantity (scalar or vector), nor even necessarily numerically equal. Here is a case where the use of language matters: if teachers speak of velocity, and calculate a scalar speed by dividing distance by time, making no reference to displacement or to direction, the equivalence of speed and velocity in students’ minds will be reinforced.

Rearranging formulae is something that students can find challenging (Boohan, 2016). Boohan describes four steps to rearranging formulae involving multiplication and division. First, swap sides if necessary, so the variable to be made the subject of the formula is on the left; multiply or divide both sides by the same variable(s) to leave the subject of the equation on its own; cancel out these variables on the left-hand side. Finally, students should always check that the meaning of the new equation makes sense. Boohan recommends that teaching always emphasises an understanding of the principles by carrying out all the steps.

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).

**Ways to use this question**

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 question 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.

*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**

1.(a) 16.7 m/s (b) 16.7 m/s east or right

2.(a) 4 minutes or 240 seconds (b) 7.14 m/s east or right

3. 0 (there is no need for a unit, but it is not wrong to give one)

4. 36 km north

5. 6.7 minutes or 400 seconds

6.(a) 4 m/s (b) 8 m/s (c) 100 m (d) 5 m/s

7.(a) 10 m/s (b) 16 m/s (c) 420 m (d) 14 m/s

8.(a) 200 m (b) 160 s (c) 1.25 m/s

9.(a) 2 400 m (b) 6 m/s (c) 800 m right (d) 2 m/s right

**Acknowledgments**

Developed by Simon Carson (UYSEG)

Images: Simon Carson (UYSEG)

**References**

Boohan, R. (2016) *The language of mathematics in science: a guide for teachers of 11-16 science*. Hatfield: Association for Science Education.

de Winter, J. and Hardman, M. (2021) *Teaching secondary physics.*