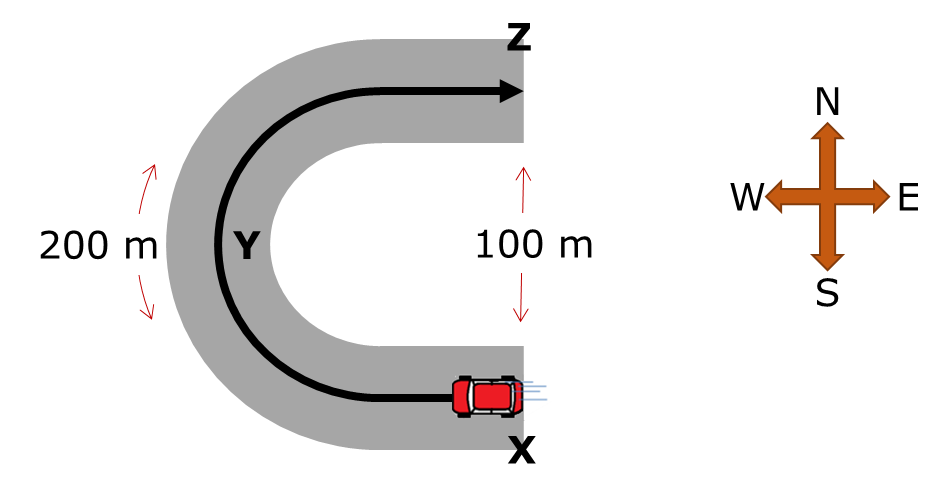
**Velocity and speed in two dimensions**

**1.** A car travels around a bend, moving from X to Z.

The car travels at a constant speed of 20 m/s.



**a.** Find the average velocity of the car as it travels from X to Z.

**b.** Find the instantaneous velocity of the car at X.

**c.** Find the instantaneous velocity of the car at Y.

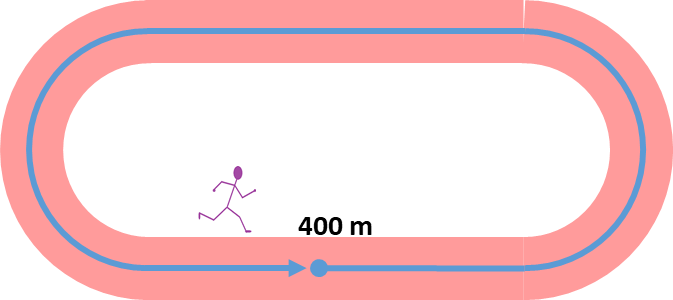
**d.** Find the instantaneous velocity of the car at Z.

**e.** The magnitude of the instantaneous velocity is different from the magnitude of the average velocity as the car travels from X to Z. Explain why.

**f.** At what point is the direction of the instantaneous velocity equal to the direction of the average velocity?

**g.** How does the instantaneous velocity at X compare to the instantaneous velocity at Z?

**2.** An athlete runs around a track. She runs 400 metres in 50 seconds.



**a.** Find her average speed.

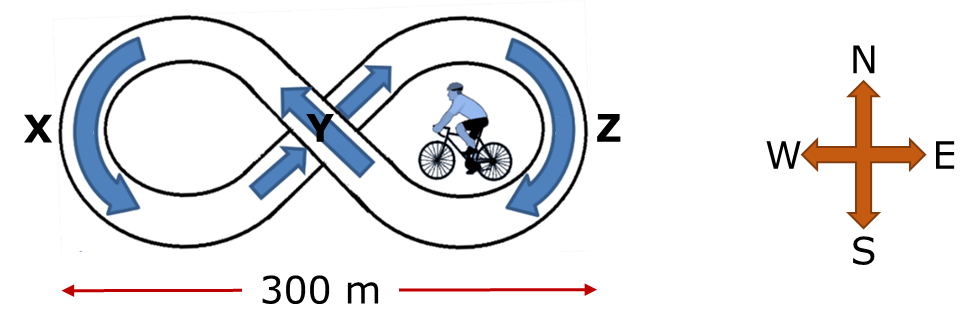
**b**. Find the magnitude of her average velocity over one full lap.

**c.** State the direction of her average velocity over one full lap.

**3.** The figure of eight track is 900 m long.

Bradley cycles round at a constant speed.

He completes a full lap in 2.5 minutes.



**a.** Find Bradley’s average speed over one full lap.

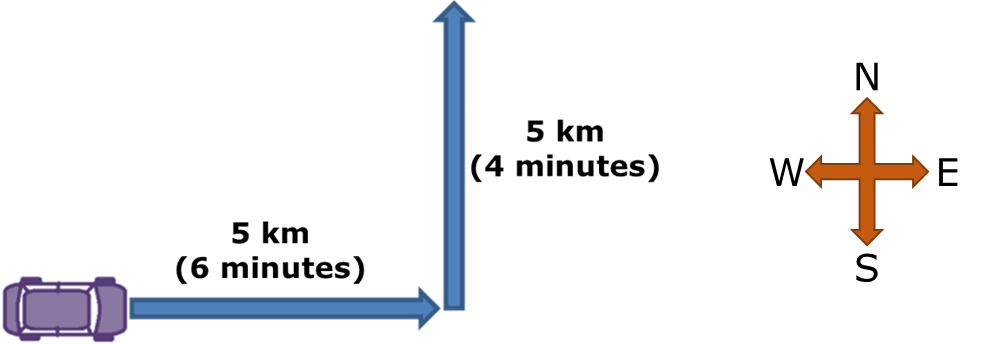
**b.** Find Bradley’s average velocity from X to Z.

**c.** Find his instantaneous velocity at point X.

**d.** Find his instantaneous velocity at point Z.

**e.** Find his instantaneous velocity at point Y (on top of the bridge).

1. A car travels 5 km east in 6 mins and then 5 km north in another 4 mins.



**a.** Find the average speed of the car for the whole journey.

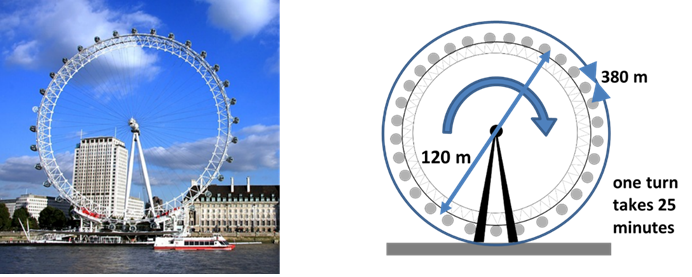
**b.** Find the average velocity of the car for the whole journey.

1. In 2000, the London Eye was the biggest Ferris wheel in the world.

Passengers travel on it in capsules around the outside.

It has a diameter of about 120 m and a circumference of about 380 m.

It takes about 25 minutes to turn around once.



**a.** Find the average speed of one of the capsules in metres/second.

**b.** Find the magnitude of the average velocity of one of the capsules:

**i.** as it moves from the bottom to the top

**ii.** over one full turn

**iii.** during one and a half turns, starting at the bottom.

**c.** For each of the questions in *part b*, draw an arrow to show the direction of the average velocity.

**d.** Draw an arrow to show the direction of the average velocity of a capsule, beginning from the bottom:

**i.** during the first quarter of a turn

**ii.** during the first three quarters of a turn.

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

|  |
| --- |
| **Response activity** |
| **Velocity and speed in two dimensions** |

**Overview**

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

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

* Diagnostic question: Spaghetti junction
* Diagnostic question: Round the bend

**What does the research say?**

Research shows that when thinking about motion, students often do not differentiate clearly between speed and velocity (Halloun and Hestenes, 1985; de Winter and Hardman, 2021); and that it is quite common for students to be able to solve problems by substituting numbers into equations, whilst retaining some conceptual misunderstandings (Kim and Pak, 2002).

At ages 14-16, students are taught that:

and that velocity is speed in a certain direction. This teaching may strengthen ideas that speed and velocity are largely equivalent by suggesting that, to find the velocity, speed must first be calculated and a direction then added. By describing velocity as speed in a certain direction, students may come to think that the magnitude of the velocity is always equal to the speed, and this is usually not true when the average speed or average velocity is calculated.

A better definition of velocity is:

This emphasises the vector nature of velocity from the outset by relating it to displacement, which is also a vector.

Instantaneous velocity be thought of as average velocity calculated for an extremely short time interval. (Mathematically, it is the limit of the average velocity for smaller and smaller time intervals.)

The use of language is important. Teachers need to always talk about velocity with a direction, and insist that when velocity is calculated, its direction is always stated. Not doing this can reinforce the idea that direction is of secondary importance.

**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.

*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. 10 m/s north

b. 20 m/s west

c. 20 m/s north

d. 20 m/s east

e. , The distance travelled is 200 metres,

whereas the change in displacement of the car is only 100 metres north as this is measured in a straight line. The time taken for these changes is the same in each case.

f. Y

g. The velocities have the same magnitude and opposite directions.

2. a. 8 m/s

b. 0 m/s

c. no direction

3. a. 6 m/s

b. 4 m/s east

c. 6 m/s south

d. 6 m/s south

e. 6 m/s northwest

4. a. 1 km/min = 16.7 m/s

b. 7.07 m/s northeast

5. a. 0.25 m/s

b. (i) 0.16 m/s, (ii) 0 m/s, (iii) 0.05(3) m/s

c. (i) up, (ii) none, (iii) up

d. (i) towards top left, (ii) towards top right

**Acknowledgments**

Developed by Simon Carson (UYSEG)

Images: Simon Carson (UYSEG)

**References**

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

Halloun, I. A. and Hestenes, D. (1985) Common sense concepts about motion, *American Journal of Physics*, 53(11), pp. 1056–1065. doi: 10.1119/1.14031.

Jones, A. T. (1983) Investigation of students’ understanding of speed, velocity and acceleration, *Research in Science Education*, 13(1), pp. 95–104. doi: 10.1007/BF02356696.

Kim, E. and Pak, S.-J. (2002) Students do not overcome conceptual difficulties after solving 1000 traditional problems, *American Journal of Physics*, 70(7), pp. 759–765. doi: 10.1119/1.1484151.

Trowbridge, D. E. and McDermott, L. C. (1980) Investigation of student understanding of the concept of velocity in one-dimension, *American Journal of Physics*, 48(12), pp. 1020–1028. doi: 10.1119/1.12298.