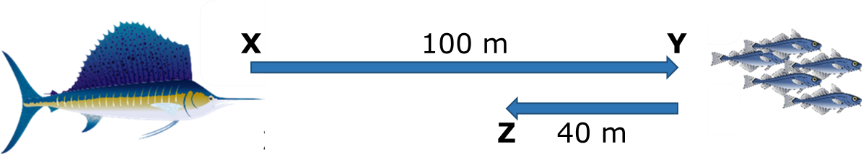
**There and back again**

A sailfish can swim at up to 30 metres per second (30 m/s).

A sailor sees a sailfish swim after some smaller fish.

She watches it turn around and swim back the way it came.



As she watches, she uses a stopwatch to time the sailfish.

The stopwatch reads 0 seconds when the sailfish starts at X.

The stopwatch reads 4 seconds when the sailfish arrives at Y.



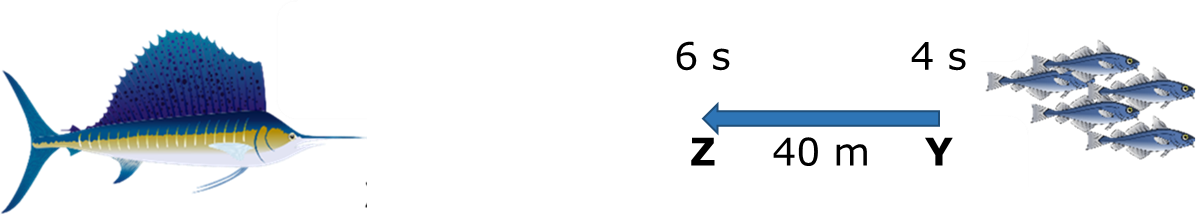
1. What do you think about its **average** **velocity** between X and Y?

*For each statement, tick (✓)* ***one*** *column to show what you think.*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | | I am **sure** this is right | I think this is right | I think this is wrong | I am **sure** this is wrong |
| **A** | Its average velocity is 25 m/s |  |  |  |  |
| **B** | Its average velocity is 25 m/s to the right |  |  |  |  |
| **C** | Its average velocity is -25 m/s |  |  |  |  |
| **D** | Its average velocity is -25 m/s to the left |  |  |  |  |

The stopwatch reads 4 seconds when the sailfish leaves Y.

The stopwatch reads 6 seconds when the sailfish arrives at Z.



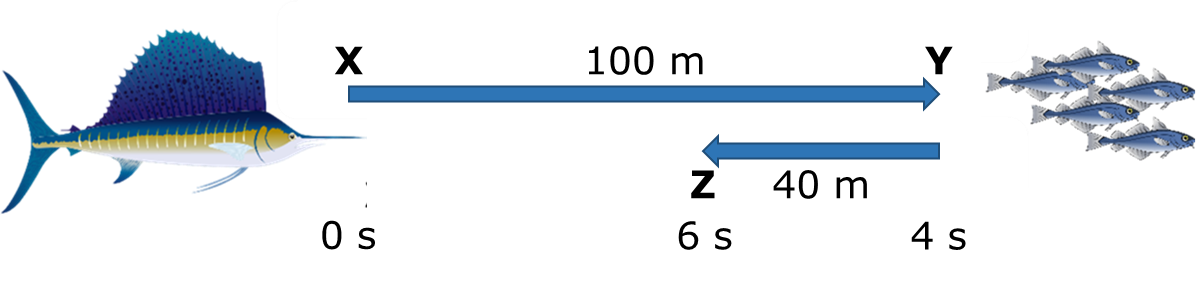
**2.** What do you think about its **average** **velocity** between Y and Z?

*For each statement, tick (✓)* ***one*** *column to show what you think.*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | | I am **sure** this is right | I think this is right | I think this is wrong | I am **sure** this is wrong |
| **A** | Its average velocity is 6.67 m/s |  |  |  |  |
| **B** | Its average velocity is 20 m/s |  |  |  |  |
| **C** | Its average velocity is 6.67 m/s to the left |  |  |  |  |
| **D** | Its average velocity is 20 m/s to the left |  |  |  |  |

The stopwatch reads 0 seconds at X and 4 seconds at Y.

When the sail fish arrives at Z it reads 6 seconds.

****

**3.** What do you think about its **average** **velocity** for the whole journey, from X to Y and back to Z?

*For each statement, tick (✓)* ***one*** *column to show what you think.*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | | I am **sure** this is right | I think this is right | I think this is wrong | I am **sure** this is wrong |
| **A** | Its average velocity is 23.3 m/s |  |  |  |  |
| **B** | Its average velocity is 23.3 m/s to the right |  |  |  |  |
| **C** | Its average velocity is 10 m/s |  |  |  |  |
| **D** | Its average velocity is 10 m/s to the right |  |  |  |  |

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

|  |
| --- |
| **Diagnostic question** |
| **There and back again** |

**Overview**

|  |  |
| --- | --- |
| Learning focus: | Velocity and displacement are vector quantities. Velocity measures by how much displacement changes in a given time interval. |
| Observable learning outcome: | Find and compare average speed and average velocity in situations where the magnitude of the average velocity is not equal to the average speed. |
| Question type: | Simple multiple choice |
| Key words: | Displacement, velocity, average |

**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, velocity and acceleration. Despite being taught about vectors at school, very many students on undergraduate introductory physics courses in the USA have no *useful* knowledge of vectors (Aguirre, 1988; Knight, 1995).

Students’ misunderstandings of vector ideas may be compounded by the different approaches taken in school mathematics and physics teaching. Although students may be taught to add and subtract column vectors in mathematics, graphical addition and subtraction of vectors of the sort more likely to be encountered in physics proved more problematic (Tairab *et al.*, 2020). It is important, therefore, to establish a good understanding of displacement and velocity as vectors before studying accelerations and forces.

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.

It is worth emphasising that velocity is the rate of change of both the direction and the magnitude of the displacement, and acceleration is the rate of change of both the direction and the magnitude of the velocity (Reif and Allen, 1992).

**Ways to use this question**

Students should complete the question individually. This could be a pencil and paper exercise, or you could use an electronic ‘voting system’ or mini white boards and the PowerPoint presentation.

The answers to the question will show you whether students understood the concept sufficiently well to apply it correctly.

If there is a range of answers, you may choose to respond through structured class discussion. Ask one student to explain why they gave the answer they did; ask another student to explain why they agree with them; ask another to explain why they disagree, and so on. This sort of discussion gives students the opportunity to explore their thinking and for you to really understand their learning needs.

*Differentiation*

You may choose to read the questions to the class, so that everyone can focus on the science. In some situations it may be more appropriate for a teaching assistant to read for one or two students.

**Expected answers**

1. B and D are correct.

2. D is correct.

3. D is correct.

**How to respond - what next?**

1. Question 1 provides a simple of test of whether or not students appreciate the need to specify a direction, and also tests an understanding of the meaning of minus signs with respect to a particular direction. Vectors in 1-dimension are sometimes written with + and – signs to indicate directions, without the direction being explicitly defined. Although experts might have an implicit understanding of the reference direction, this may not be true of novices, and it is good practice always to define the direction.

2. Question 2 similarly tests students’ understanding of the vector nature of velocity, and also tests that students appreciate that it is the time *interval* that appears in the denominator. Students choosing options A or C are using the time (6 seconds) at which the sailfish arrives at Z, rather than the interval between Y and Z (2 seconds).

3. Question 3 takes the process one step further. Calculating the correct answer requires students to appreciate the vector nature of displacement in calculating average velocity. Students choosing A or B are calculating the average speed by taking the total distance travelled, 140 metres, and dividing by the total time, 6 seconds.

If students have misunderstandings about the vector nature of displacement and velocity, discussing directed numbers, with which they are familiar from mathematics, may help them to understand the significance of the minus sign. Examples from science include the temperature scale on a thermometer or the minus sign on an ammeter. These examples need to be handled carefully, as they are scalar quantities, and velocity is a vector.

To develop an understanding of displacement as a vector, asking a student to walk around the classroom, and asking other students to discuss the distance travelled by the student, and the student’s displacement from the original position provides a concrete example for students. This example can be developed in one or two dimensions.

The following BEST ‘response activity’ could be used in follow-up to this diagnostic question:

* Response activity: Calculating average speed and average velocity

**Acknowledgments**

Developed by Simon Carson (UYSEG).

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**References**

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