**Faster, slower**

Some students have set up an experiment to investigate acceleration.

They have attached a trolley to two springs so that it goes backwards and forwards.

**1.** The trolley is moving **to the left**.

A picture containing graphical user interface

Description automatically generated

Some students are talking about the motion of the trolley.

**William**: The slower the trolley goes, the smaller its acceleration is.

**Susan**: The trolley is accelerating because its speed is changing.

**Ruby**: The direction of the acceleration is to the right.

**John**: The trolley is slowing down.

It can’t be accelerating.

**To answer:**

1. Who is right about the acceleration of the trolley?

*Explain your answer*

2. Who is wrong about the acceleration of the trolley?

*What would you say to help them understand?*

**2.** The trolley is **just about to start moving to the right**

A picture containing icon

Description automatically generated

Some students are talking about the motion of the trolley.

**William**: The trolley has stopped moving so its acceleration is zero.

**Susan**: The trolley is accelerating because its speed is changing.

**Ruby**: The direction of the acceleration is to the right.

**John**: The trolley is accelerating because it is changing direction.

**To answer:**

1. Who is right about the acceleration of the trolley?

*Explain your answer*

2. Who is wrong about the acceleration of the trolley?

*What would you say to help them understand?*

**3.** The trolley is now **moving to the right.**

Graphical user interface

Description automatically generated with medium confidence

Some students are talking about the motion of the trolley.

**William**: The trolley is getting faster so its acceleration is increasing.

**Susan**: The trolley is accelerating because its speed is changing.

**Ruby**: The direction of the acceleration is to the right.

**John**: The trolley is speeding up.

It is accelerating now.

**To answer:**

1. Who is right about the acceleration of the trolley?

*Explain your answer*

2. Who is wrong about the acceleration of the trolley?

*What would you say to help them understand?*

4. The trolley is **in the middle** and is **moving to the right.**

Rectangle

Description automatically generated with medium confidence

Some students are talking about the motion of the trolley.

**William**: The faster the trolley goes, the greater its acceleration is.

**Susan**: The trolley is accelerating because its speed is changing.

**Ruby**: Just for a moment, the trolley isn’t accelerating.

**John**: The trolley is moving fast, so it must be accelerating.

**To answer:**

1. Who is right about the acceleration of the trolley?

*Explain your answer*

2. Who is wrong about the acceleration of the trolley?

*What would you say to help them understand?*

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| --- | --- |
| Cards for  **Faster, slower**  **Question 1** |  |
| Q1  **John:** The trolley is slowing down. It can’t be accelerating. | Q1  **Susan:** The trolley is accelerating because its speed is changing. |
| Q1  **Ruby:** The direction of the acceleration is to the right. | Q1  **William:** The slower the trolley goes, the smaller its  acceleration is. |

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| --- | --- |
| Cards for  **Faster, slower**  **Question 2** |  |
| Q2  **John:** The trolley is accelerating because it is changing direction. | Q2  **Susan:** The trolley is accelerating because its speed is changing. |
| Q2  **Ruby:** The direction of the acceleration is to the right. | Q2  **William:** The trolley has stopped moving so its acceleration  is zero. |

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| Cards for  **Faster, slower**  **Question 3** |  |
| Q3  **John:** The trolley is speeding up. It is accelerating now. | Q3  **Susan:** The trolley is accelerating because its speed is changing. |
| Q3  **Ruby:** The direction of the acceleration is to the right. | Q3  **William:** The trolley is getting faster so its acceleration is increasing. |

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| Cards for  **Faster, slower**  **Question 4** |  |
| Q4  **John:** The trolley is moving fast, so it must be accelerating. | Q4  **Susan:** The trolley is accelerating because its speed is changing. |
| Q4  **Ruby:** Just for a moment, the trolley isn’t accelerating. | Q4  **William:** The faster the trolley goes, the greater its  acceleration is. |

*Physics > Big idea PFM: Forces and Motion > Topic PFM4:Measuring and calculating motion > Key concept PFM4.2: Acceleration*

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| --- |
| **Response activity** |
| **Faster, slower** |

**Overview**

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| --- | --- |
| Learning focus: | Acceleration, like displacement and velocity, is a vector quantity. Acceleration measures by how much velocity changes in a given time interval. |
| Observable learning outcome: | Recall that acceleration in one dimension describes the motion of an object that is speeding up or slowing down. |
| Question type: | Talking heads |
| Key words: | Speed, velocity, acceleration |

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| **P** | **PRIOR UNDERSTANDING**  This diagnostic question probes understanding of ideas that are usually taught at age 11-14, to aid transition from earlier stages of learning. |

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

* Diagnostic question: Going faster

**What does the research say?**

Students often have an undifferentiated understanding of the kinematical terms speed, velocity and acceleration, merging them together into a general idea of ‘motion’. They may conflate pairs of words such as distance and displacement, speed and velocity, or velocity and acceleration, not always realising the important differences between them. Although these terms are connected, the differences matter, and teachers should use terms carefully, taking care to be precise in their use of language. (de Winter, 2021)

Students may use a position criterion to compare the accelerations of different objects, or may equate acceleration with ‘catching up’ or ‘going faster’ (Trowbridge and McDermott, 1981; Jones, 1983), thinking that if speed increases, acceleration must also be increasing. Acceleration is a particularly difficult concept for students to understand as it is a rate of change of a rate of change.

In everyday language, ‘acceleration’ may be taken to mean ‘speeding up’, rather than describing the rate of change of velocity. Hence, this concept has a meaning different from that of the word acceleration used in everyday life and is liable to misinterpretations due to students' pre-existing knowledge (Reif and Allen, 1992). The use of correct language (referring to change in *velocity*, not change in *speed*) can help students to understand that to a physicist, acceleration can refer to speeding up, slowing down, or changing direction.

Students need to be clear about the vector nature of quantities such as displacement, velocity, change in 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). When thinking about the directions of velocity and acceleration, students tend to think that these must be in the same direction, and that if velocity is zero, even if only instantaneously, then so must be acceleration. When given information about acceleration, students are less likely to reason correctly about the velocity of an object than when asked to reason about acceleration, given information about velocity. There is an asymmetry in their thinking about the relationship between these quantities (Rosenblatt and Heckler, 2011).

**Ways to use this question**

This task is intended for discussion in pairs or small groups. It can be done as a pencil and paper exercise or projected onto a screen.

Students should read the statements and follow the instructions on either the worksheet or the PowerPoint. Listening in to the conversations of each group will often give you insights into how your students are thinking. Each member of a group should be able to report back to the class.

Feedback from each group can be used, with careful teacher questioning, to bring out a clear description or explanation of the science.

*Differentiation*

The quality of the discussions can be improved with a careful selection of groups; or by allocating specific roles to students in the group. For example, you may choose to select a student with strong prior knowledge as the 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.

NB in any class, small group discussions typically improve over time and a persistence with this strategy is often very successful in the medium to long term.

**Equipment**

It may be useful to demonstrate the experiment in order to help students to understand the diagrams and to help them to frame their thinking. However, it is important to be aware that sometimes students may see objects as either at rest or moving. The period of change is less frequently focused (Driver *et al.*, 1994). Moving objects that undergo a constant acceleration may be perceived as if velocity is constant (Lemmer, 2013). Students may not perceive the acceleration of the trolley and may think that the speed is constant between the endpoints of the motion.

For the class:

* dynamics trolley, two identical springs, two clamp stands and G-clamps to hold clamp stands stationary on the bench

**Expected answers**

*Question 1*

Susan and Ruby are both right, and putting their answers together gives a more complete explanation: the trolley is moving to the left and slowing down, so that its acceleration is to the right.

John may be thinking that accelerating means speeding up; this is the everyday meaning of the word, but not the scientific one. William may be conflating acceleration and velocity as he thinks that a slower speed means a smaller velocity.

*Question 2*

John, Susan and Ruby all have elements of the correct answer. The velocity of the trolley is changing – and therefore the trolley is accelerating – because it is changing direction, and its speed is changing from zero to non-zero. The acceleration, again, is towards the right.

Once again, William is conflating acceleration and velocity believing that if the speed or velocity is zero, the acceleration must be, too.

*Question 3*

John, Susan and Ruby are all correct. The trolley is speeding up, and its speed is therefore changing. The acceleration is towards the right.

William is conflating acceleration and velocity and so thinks that if the speed is increasing, the acceleration is also increasing.

*Question 4*

Ruby is correct. The speed has stopped increasing and is about to start decreasing as the trolley moves through the centre of its motion so momentarily the velocity of the trolley is constant.

A velocity that is constant only instantaneously may be a difficult notion for students to grasp, and Susan may be confused by this. Thinking about the forces exerted by the springs may help, which at this point give a resultant force of zero, so there is no force *left over* to change the motion.

Here, both John and William may be conflating velocity and acceleration.

**Acknowledgments**

Developed by Simon Carson (UYSEG) from an idea by Rosenblatt and Heckler (2011)

Images: Simon Carson (UYSEG)

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