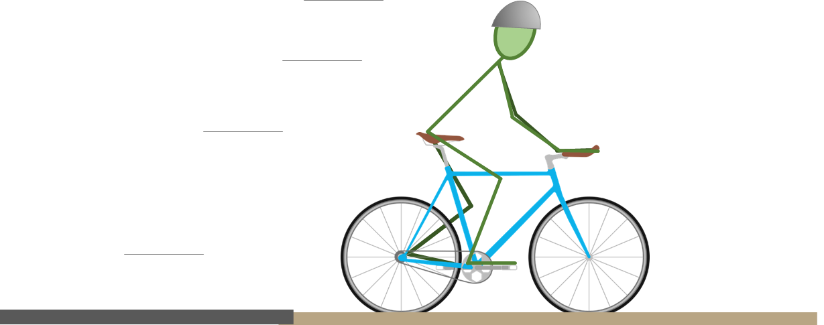
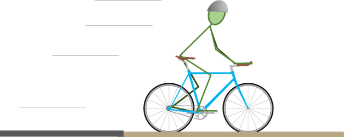
**Wet sand**

David rides off a road into some wet sand.

The force of the sand pushing on his tyres makes him stop.

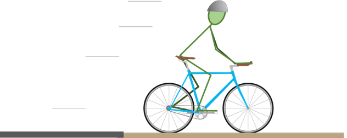


**1.** David cycles twice as fast and has **two times the momentum**.

How long does it take for the sand to stop him now?

*Put a tick (✓) in the box next to the best answer.*

|  |  |  |
| --- | --- | --- |
| **A** | The same time. |  |
|  |  |  |
| **B** | Two times longer. |  |
|  |  |  |
| **C** | Four times longer. |  |

**2.** Later, David cycles into sand that pushes on his tyres with **half the force**.

He is cycling at his original speed.

How long does it take for the sand to stop him now?

*Put a tick (✓) in the box next to the best answer.*

|  |  |  |
| --- | --- | --- |
| **A** | Half as long. |  |
|  |  |  |
| **B** | The same time. |  |
|  |  |  |
| **C** | Two times longer. |  |

*Physics > Big idea PFM: Forces and motion > Topic PFM6: Forces make things change > Key concept PFM6.3: Changing momentum*

|  |
| --- |
| **Diagnostic question** |
| **Wet sand** |

**Overview**

|  |  |
| --- | --- |
| Learning focus: | In a collision (or any closed system), momentum is conserved and the size of the forces are equal to the rate of change of momentum. |
| Observable learning outcome: | Explain and use the relationship between force, change in momentum and time the force is acting |
| Question type: | Simple multiple choice |
| Key words: | Momentum, mass, velocity |

**What does the research say?**

Students may be able to use Newton’s laws, including the third law, and ideas about momentum and its conservation, when performing calculations, but a superficial knowledge of the use of formulae may mask qualitative misunderstandings (Viennot, 1979; Clement, 1982).

Whilst most students readily accept that both mass and velocity have a direct impact on the damage that a moving object can cause when it collides with other objects, it is common for them to confuse ideas about momentum with ones about energy in a kinetic store (Bryce and MacMillan, 2009).

Herrington (2011), discussing the teaching of specific heat capacity, suggests that the traditional methods of teaching involving learning definitions and using equations can contribute to confusion. Although students are often able to calculate values with equations, they often do not often understand the physical concepts.

Whilst carrying out calculations is an important part of students’ learning, success in using equations is not the same thing as developing conceptual understanding, as Kim and Pak (2002) demonstrated for mechanics, and misunderstandings may remain. To expert physicists, symbols stand for physical quantities, and the results of the mathematical manipulations must be interpreted in terms of their meaning for a given physical system. Experts draw on their experience and (often tacit) knowledge of physical systems in order to make meaning from the mathematics (Carson, 1999; Redish and Kuo, 2015). To novices, the manipulation of the symbols, and the substitution of numbers into formulae may be ends in themselves, devoid of physical meaning. It is therefore important to ask students to think qualitatively and quantitatively about mathematical formulae as well as substituting in numbers in order to carry out calculations.

**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 **2.** C

**How to respond - what next?**

These questions require students to apply an understanding of the relationships between force, time and changing momentum. Often students respond with gut instinct rather than a careful application of general principles.

*Question 1*

The force of the sand on the tyres slows the bicycle and changes its momentum by the same amount each second. So, if its initial momentum is two times bigger, it takes two times longer to stop it.

A Some students may choose this option if they think the greater momentum will make the bicycle tyres dig deeper into the sand, with more force exerted as a consequence.

C A few students may confuse momentum with the energy the bicycle has because it is moving, which is calculated as E = ½ mv2. They may reason that doubling speed will increase the energy by a factor of four and interpret that as meaning the bicycle will take four times as long to be brought to a halt.

*Question 2*

The force of the sand is half as big so the bicycle is slowed at half the rate and it takes two times as long for its momentum to change and for it to come to a stop.

A Those students choosing this option are likely to have misapplied the relationship between the size of force and the speed that the bicycle is slowed down – most likely by not thinking carefully through the situation.

Some students may interpret ‘half the force’ as meaning the sand pushed upwards with half the force and the bicycle sinks twice as deep in the sand – and that the force of the sand pushing back on the bicycle is twice as big.

B A few may choose this option, perhaps because the initial momentum of the bicycle is unchanged. These students are not correctly taking account of the stopping force.

If students have misunderstandings about explaining and using the relationship between force, change in momentum and time the force is acting, it can help to provide further examples for students to think about.

Calculations could be set involving the equation, perhaps with students challenged to explain what they think their answers will be like before they calculate. (This can be usefully carried out as a two-step exercise, with students explaining their predictions to several examples and then checking their predictions by carrying out calculations.)

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

* Response activity: Crumple zones

**Acknowledgments**

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Images: Peter Fairhurst (UYSEG), with bicycle by MilanWulf from Pixabay.

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