**Stop that!**

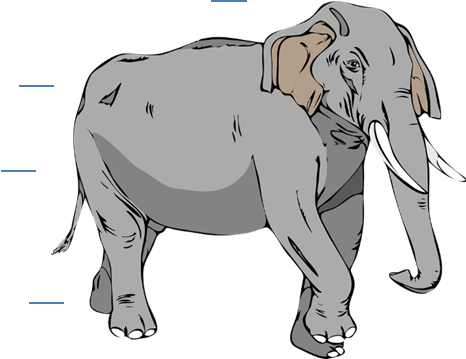
An object is harder to stop quickly if it has more **momentum**.

A campervan has more momentum if it is moving faster.

An elephant has more momentum if it has more mass.

The elephant and the campervan are both moving at top speed towards you.

**a.** Which one is hardest to stop quickly?



Elephant

Mass = 6000 kg

Top speed = 11 m/s

**A**

Campervan

Mass = 2000 kg

Top speed = 30 m/s



**B**

**b.** What is the best reason for your last answer?

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

|  |  |  |
| --- | --- | --- |
| **A** | Mass has a bigger effect on momentum than speed. |  |
|  |  |  |
| **B** | Speed has a bigger effect on momentum than mass. |  |
|  |  |  |
| **C** | Mass x speed towards you is bigger. |  |
|  |  |  |
| **D** | ½mv2 is bigger. |  |

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

|  |
| --- |
| **Diagnostic question** |
| **Stop that!** |

**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: | Two-tier multiple choice |
| Key words: | Momentum, mass, velocity, change of momentum, energy |

**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 questions 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 follow-on question will give you insights into how they are thinking and highlight specific misconceptions that some may hold.

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**

**a.** A **b.** C

**How to respond - what next?**

The mass of the elephant multiplied by its speed towards you (its velocity) gives a momentum that is bigger than the momentum of the campervan, which means it is harder to stop. It will take more force to stop it in the same amount of time as the campervan because the momentum needs to change at a faster rate.

*Part a*

Often students use gut feelings to determine answers to questions such as this one, and do not apply general principles, such as ‘a bigger momentum means it is harder to stop quickly’. Either option to part a could be guessed in this way, and part b is needed to check students’ understanding.

*Part b*

A Students choosing this option probably associate more mass with a bigger force to stop (perhaps because a bigger mass needs more force to lift it up).

B A few students may choose this option, perhaps because in learning about the energy of a moving object they learned that speed has a bigger effect on energy than mass.

D This is the equation students learned for calculating the energy an object has because it is moving. They may have learned that the more energy an object has because it is moving, the more change it can cause when it is stopped. Therefore, the assumption is that the object is harder to stop quickly. This is a common misunderstanding.

It is momentum that determines the size of a force needed to stop an object in a fixed amount of time. The campervan has more energy because of its movement, but requires less force to stop it in the same time as the elephant is stopped – but because it is travelling faster, the smaller force will be applied over a greater distance (work done stopping it = force x distance).

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 pairs, or groups, of objects for students to compare, and to work out which needs most force in order to stop it quickly. Examples in which objects are slowed or sped up may also be used to emphasise that it is the *change of momentum* that is important.

For some classes, it may be appropriate to explore the understanding describe in the notes about option D in part b, above.

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: campervan by OpenClipart-Vectors and elephant by Clker-Free-Vector-Images, both from Pixabay.

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