**Gaining momentum**

An object is two times harder to stop if its momentum doubles.

Doubling its mass doubles its momentum.

Doubling its velocity doubles its momentum.

*This relationship can be written in shorthand as:*

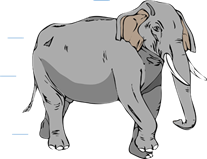
momentum = mass × velocity

**p = m × v**

momentum, *p*, in kilogram metres per second (kg m/s)

mass, *m*, in kilogram (kg)

velocity, *v*, in metres per second (m/s)



***Velocity*** *is speed in a particular direction. It is a vector.*

***Momentum*** *is a vector too.*

*It matters whether the momentum of an elephant is towards you or away from you!*

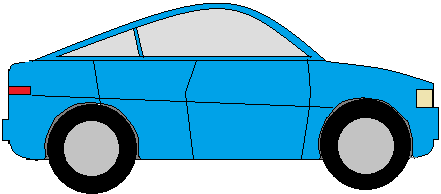
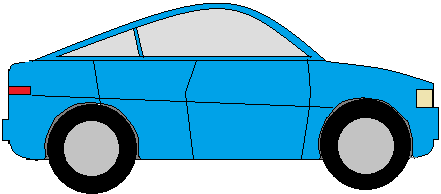
**1.** Both cars have the same mass.

The orange car is moving forwards twice as quickly as the blue one.

Orange car

Blue car

p = m x v



p = m x **v**

What is the momentum of the orange car?

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

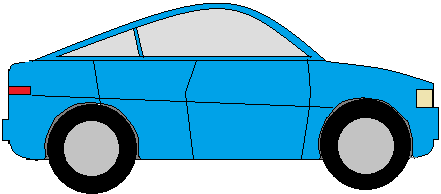
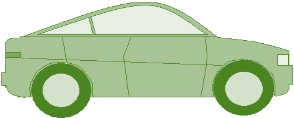
|  |  |  |
| --- | --- | --- |
| **A** | Two times smaller than the momentum of the blue car. |  |
|  |  |  |
| **B** | The same momentum as blue car. |  |
|  |  |  |
| **C** | Two times bigger than the momentum of the blue car. |  |

**2.** Both cars have the same velocity.

The blue car is fully loaded and has twice the mass of the green car.

Green car

Blue car



p = **m** x v

p = m x v

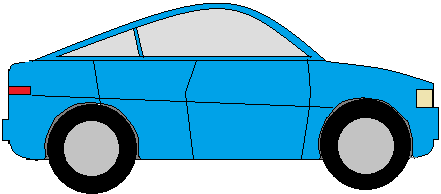
What is the momentum of the green car?

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

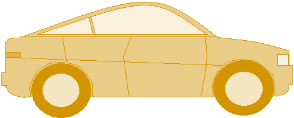
|  |  |  |
| --- | --- | --- |
| **A** | Two times smaller than the momentum of the blue car. |  |
|  |  |  |
| **B** | The same momentum as blue car. |  |
|  |  |  |
| **C** | Two times bigger than the momentum of the blue car. |  |

**3.** The yellow car has half the velocity and two times the mass of the blue car.

p = m x v



p = **m** x **v**



Yellow car

Blue car

What is the momentum of the yellow car?

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

|  |  |  |
| --- | --- | --- |
| **A** | The same momentum as blue car. |  |
|  |  |  |
| **B** | Two times bigger than the momentum of the blue car. |  |
|  |  |  |
| **C** | Four times bigger than the momentum of the blue car. |  |

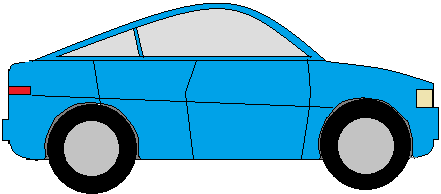
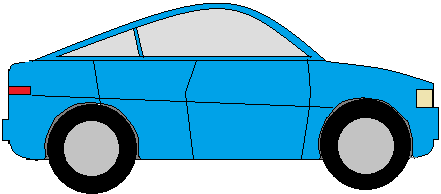
**4.** The blue car has half the velocity that the grey car has.

The grey car has twice the mass as the blue car.

Grey car

Blue car

p = m x **v**



p = **m** x v

What is the momentum of the grey car?

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

|  |  |  |
| --- | --- | --- |
| **A** | The same momentum as blue car. |  |
|  |  |  |
| **B** | Two times bigger than the momentum of the blue car. |  |
|  |  |  |
| **C** | Four times bigger than the momentum of the blue car. |  |

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

|  |
| --- |
| **Diagnostic question** |
| **Gaining momentum** |

**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: | Calculate momentum using p = m x v. |
| Question type: | Simple multiple choice |
| Key words: | Momentum, mass, velocity |

|  |  |
| --- | --- |
| **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. |

**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).

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. C 2. A 3. A 4. C

**How to respond - what next?**

These questions require students to think about the equation and the quantitative relationship between the variables, without simply substituting numbers into an equation.

1. Most students should get this question correct.

2. Some students may choose option C because they are balancing the right-hand side of the two equations with each other.

3. The two changes cancel out, although some students may be confused by opposite changes.

4. Students with the wrong answer have probably not worked systematically through what the changes mean to the momentum of each car. Comparing the momentum of each car after a different variable for each car is changed is conceptually demanding for many students.

If students have misunderstandings about using the equation to predict relationships, rather than simply calculate without understanding, it can help to work through each example systematically with the class. One strategy is to first use simple numbers for mass and velocity in order to work out values for the momentum of each car to compare. Later, the same process can be repeated using the terms doubling and halving to describe the same changes.

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

* Response activity: Crash test

**Acknowledgments**

Developed by Simon Carson (UYSEG) and Peter Fairhurst (UYSEG).

Images: Elephant by Clker-Free-Vector-Images from Pixabay, other images by Simon Carson (UYSEG).

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