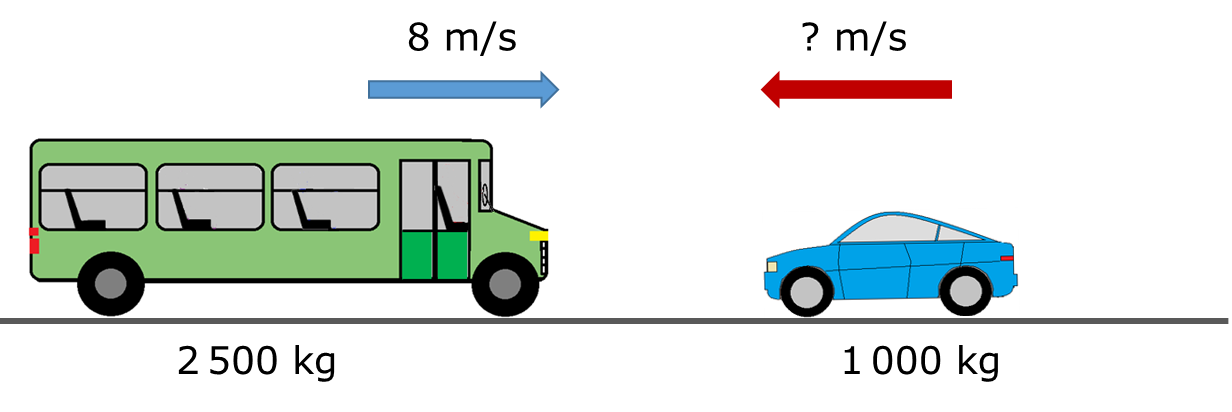
**Crash test**

Crash tests are used to check safety features on vehicles.

A car and a bus are crashed into each other.

They both come to a stop at the place where they hit.



**1.** **Calculate** the momentum of the bus before the collision.

*Give its size and direction.*

**2.** **State** the momentum of the car before the collision.

*Give its size and direction.*

**3.** How does the total momentum after the collision **compare** to the total momentum before the collision?

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

|  |
| --- |
| **Response activity** |
| **Crash test** |

**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: | Describe what happens to the motion of objects colliding head on. |
| Question type: | Application and practice – problem |
| Key words: | Momentum, mass, velocity, state, compare |

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

* Diagnostic question: Gaining momentum
* Diagnostic question: Rugby tackle
* Diagnostic question: Boom!

**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.

Students often do not understand Newton’s third law and how it is related to momentum change and the conservation of momentum. Students who do know that forces occur in interaction pairs may not realise that forces are equal in size and act on *different* objects. They may think wrongly that two equal and opposite forces acting on a single object make up an interaction pair.

In a study of 78 high school students in the US, Brown (1989) found many students believed a moving billiard ball would exert a greater force on a stationary ball than the stationary ball would exert on the moving ball in a collision. These students argued that the moving ball ‘had’ more force than the stationary ball. The lack of understanding of forces as interactions ‘sabotages’ students conceptual reasoning and quantitative problem solving (Brown, 1989), and their understanding of momentum and momentum conservation.

**Ways to use this question**

This activity gives students the opportunity to practise applying their understanding and to clarify their thinking through discussion. To support this, students should answer the question in pairs or small groups.

Listening to individual groups as they work often highlights any difficulties they might have. These can often be overcome, through a whole class clarification or redirection part way through the activity.

Asking students to share their answer is a useful check. After a group has fed back, it might be helpful to model an even better answer. You could do this, for example, by asking another group to add to, or clarify, the first observation. Then ask another group to sum up the important part of the observation, and so on.

*Differentiation*

If some students are working with a teaching assistant, then a list of prompt questions for the teaching assistant could help to make this activity more purposeful.

**Expected answers**

1. p = m x v p = 2 500 kg x 8 m/s p = 20 000 kg m/s to the right (or +20 000 kg m/s)

2. p = 20 000 kg m/s to the left (or -20 000 kg m/s)

*The + and - signs for Q1 and Q2 may be reversed. The ‘positive’ direction of momentum is determined by the person calculating, and must be applied consistently.*

3. Total momentum after the crash is equal to zero because there is no movement. The momentum of the bus before the collision added to the momentum of the car before the collision also equals zero, so there is no change. (Momentum is conserved *for the system*.)

**Acknowledgments**

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

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