**Crumple zones**

When it crashes, a car’s body will crumple around the point of impact.

Safety tests are carried out on all types of car.

Cars are tested to make them as safe as possible for passengers.



What happens when a car crashes and comes to a stop?

Pick ***one*** phrase in each line to explain what happens.

* The car’s body will crumple around the point of impact.
* As it crumples the car slows down.
* Crumpling makes it take less time / a little longer /

about the same time to stop fully.

* Its momentum changes less quickly / more quickly /

at the same rate .

* Which means that less force / more force / the same force is used to stop the car.

The passengers feel less force / more force / the same force .

***To answer:***

1. Do you think cars are designed to crumple when they crash?

1. Describe how much a car should crumple when it crashes and explain why?

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

|  |
| --- |
| **Response activity** |
| **Crumple zones** |

**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.  Apply an understanding of F=Δp/Δt to explain how forces and momentum can be controlled. |
| Activity type: | Explanation story |
| Key words: | Change of momentum, time force is acting |

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

* Diagnostic question: Stop that!
* Diagnostic question: Wet sand
* Diagnostic question: Follow through

|  |  |
| --- | --- |
| **B** | **BRIDGING**  This activity explores ideas that are usually taught at age 16-19, to build a bridge to later 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).

Students find questions involving impulse and change in momentum more difficult than the ‘special case’ questions where momentum is conserved (Lawson and McDermott, 1987; Pride, Vokos and McDermott, 1998; Singh and Rosengrant, 2003). In a study of over a thousand undergraduates in the US, only about 5% of students were correctly able to answer a question about momentum change caused by an impulse, regardless of the amount of instruction about the impulse-momentum theorem (Pride et al., 1998).

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 activity**

This task is intended for discussion in pairs or small groups. It is best done as a pencil and paper exercise.

Students should read the statements and follow the instructions on the worksheet. 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 each 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.

**Expected answers**

* The car’s body will crumple around the point of impact.
* As it crumples the car slows down.
* Crumpling makes it take a little longer to stop fully.
* Its momentum changes less quickly.
* Which means that less force is used to stop the car.
* The passengers feel less force.

1. Yes, because it reduces the forces on the passengers in the event of a collision.

2. A car should crumple as much as possible without intruding into the passenger area. It needs to resist enough so that it is able to continue to crumple throughout the time it takes to stop the car in a high-speed collision. If the car crumpled to its maximum extent before it was at rest, then the remaining momentum it has at that point in time is reduced very quickly and could result in very great forces.

**Acknowledgments**

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

Images: Simon Carson (UYSEG).

**References**

Carson, S. (1999). Physics in mathematical mood. *Physics World,* 12(4)**,** 48-48.

Clement, J. (1982). Students' preconceptions in introductory mechanics. *American Journal of Physics,* 50(1)**,** 66-71.

Herrington, D. G. (2011). The heat is on: an inquiry-based investigation for specific heat. *Journal of Chemical Education,* 88(11)**,** 1558-1561.

Kim, E. and Pak, S.-J. (2002). Students do not overcome conceptual difficulties after solving 1000 traditional problems. *American Journal of Physics,* 70(7)**,** 759-765.

Lawson, R. A. and McDermott, L. C. (1987). Student understanding of the work-energy and impulse-momentum theorums. *American Journal of Physics,* 55(9)**,** 811-817.

Pride, T. O., Vokos, S. and McDermott, L. C. (1998). The challenge of matching learning assessments to teaching goals: An example from the work-energy and impulse-momentum theorums. *American Journal of Physics,* 66(2)**,** 147-157.

Redish, E. F. and Kuo, E. (2015). Language of physics, language of math: Disciplinary culture and dynamic epistemology. *Science and Education,* 24**,** 561-590.

Singh, C. and Rosengrant, D. (2003). Multiple-choice test of energy and momentum concepts. *American Journal of Physics,* 71(6)**,** 607-617.

Viennot, L. (1979). Spontaneous Reasoning in Elementary Dynamics. *European Journal of Science Education,* 1(2)**,** 205-221.