**Follow through**

A force acting on an object can cause a change in its momentum.

* The bigger the force, the bigger the change.
* The longer the force is acting, the bigger the change.

**change in momentum = force x time the force is acting**

*Usually written as:*

**force =**

**change in momentum**

**time the force is acting**

Force, F, in Newton (N).

Change in momentum, Δp, in kilogram metres per second (kg m/s).

Time the force is acting, Δt, in second (s).

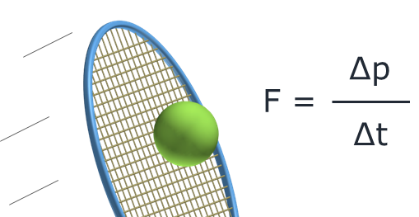
**F =**

**∆p**

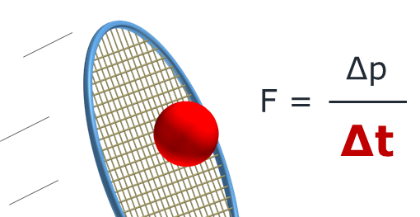
**∆t**

*Force and change in momentum are vectors, both in the same direction.*

**1.** By following through, the red ball is in contact with the racket two times longer than the green ball. The force on each is the same.



Green ball



Red ball

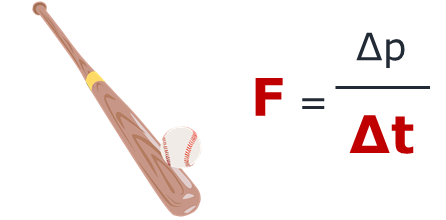
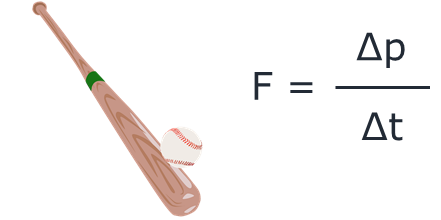
What is the change of momentum of the red ball?

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

|  |  |  |
| --- | --- | --- |
| **A** | Two times less than the change in momentum of the green ball. |  |
|  |  |  |
| **B** | The same as the change in momentum of the green ball. |  |
|  |  |  |
| **C** | Two times more than the change in momentum of the green ball. |  |

**2.** The yellow bat hits the ball with twice the force of the green bat.

The yellow bat follows through, making contact for twice as long.



Yellow bat

Green bat

What is the change of momentum of the ball hit by the yellow bat?

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

|  |  |  |
| --- | --- | --- |
| **A** | The same as the one hit by the green bat. |  |
|  |  |  |
| **B** | Two times more than the one hit by the green bat. |  |
|  |  |  |
| **C** | Four times more than the one hit by the green bat. |  |

**3.** The red player kicks a ball with twice the force of the blue player.

The blue player follows through, making contact for twice as long.



Blue player



Red player

What is the change of momentum of the blue player’s ball?

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

|  |  |  |
| --- | --- | --- |
| **A** | Four times less than the red player’s ball. |  |
|  |  |  |
| **B** | Two times less than the red player’s ball. |  |
|  |  |  |
| **C** | The same as the red player’s ball. |  |
|  |  |  |
| **D** | Two times more than the red player’s ball. |  |

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

|  |
| --- |
| **Diagnostic question** |
| **Follow through** |

**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: | Apply an understanding of F=Δp/Δt to explain how forces and momentum can be controlled. |
| Question type: | Simple multiple choice |
| Key words: | Change of momentum, follow through, time force is acting |

|  |  |
| --- | --- |
| **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 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. C 3. 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 or relying on gut feelings.

Q1. A To ‘balance’ the right-hand side of the equation, it is common for students to halve one value when the other is doubled, regardless of whether they are divided or multiplied.

B A few students may consider that the same force always produces the same change in momentum – probably because when they hit something harder it tends to move faster.

Q2. A Some students may consider the doubling of a term on both sides of the equation leaves the third term unchanged, regardless of whether terms are multiplying or dividing each other.

B Others may use gut feeling to decide that hitting the ball twice as hard will double its change of momentum.

Q3. A Some students may think that doubling two terms will quadruple the change of momentum, even though they are not changes to the same ball. Changes to different variables acting on two different balls are very challenging for some students to think through logically.

B Students choosing this answer are perhaps only focusing on the different forces causing the change of momentum and have not factored in the time over which the forces act.

D This answer ignores the change of force on the red ball and does not compare the change of momentum for each ball.

If students have misunderstandings about applying an understanding of F=Δp/Δt to each situation, it can help to work through each example systematically with the class. One strategy is to first use simple numbers for *force* and the *time the force is acting* to work out how the changes of momentum compare. Later, the same process can be repeated using the terms doubling and halving to describe the changes.

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

* Response activity: Crumple zones

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Images: Peter Fairhurst (UYSEG), with baseball and baseball bat by Clker-Free-Vector-Images from Pixabay and the boot and ball by OpenClipart-Vectors from Pixabay.

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