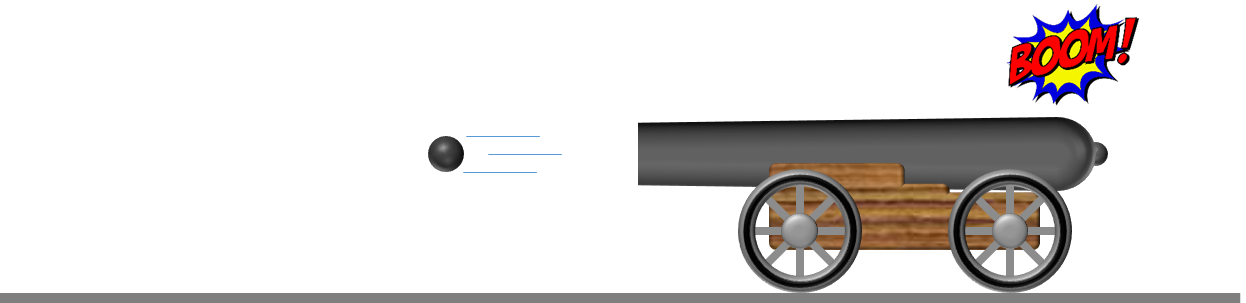
**Boom!**

A cannonball is fired out of a cannon.

It starts from rest at the back of the cannon.

It leaves the cannon at a speed of 400 m/s.



The cannon has the mass of 200 cannonballs.

What happens when the cannonball is fired?

For each statement, tick (✓) **one** column to show what you think*.*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | | I am **sure** this is right | I think this is right | I think this is wrong | I am **sure** this is wrong |
| **A** | The cannon does not move. |  |  |  |  |
| **B** | The cannonball pushes back on the cannon. |  |  |  |  |
| **C** | The force on the cannonball is bigger than the force on the cannon. |  |  |  |  |
| **D** | The cannon moves backwards at 2 m/s. |  |  |  |  |

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

|  |
| --- |
| **Diagnostic question** |
| **Boom!** |

**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: | Confidence grid |
| Key words: | Momentum, mass, velocity |

**What does the research say?**

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**

Students should complete the confidence grid 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.

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**

Statements B and D are right; and statements A and C are wrong.

**How to respond - what next?**

When the cannon is fired the explosion between the cannon and the cannonball pushes on both. The force of the cannon on the cannonball is the same size and in the opposite direction as the force of the cannonball on the cannon. Both forces act for the same length of time.

This is the exact reverse of two objects colliding head on.

The force of the cannonball on the cannon pushes it backwards. Because the cannon has a mass that is 200 times bigger than the cannonball, the same sized force pushes it back 200 times more slowly (the magnitude of its velocity is 200 times smaller).

A Very few students will have experienced a cannon firing. In films, cannonballs are fired out with great speed and the action usually focuses on the damage they cause, rather than the recoil of the cannon. As cannons are usually fired from a fixed position and are very heavy, it is relatively common for students to reason (wrongly) that they do not move.

B Strictly speaking, expanding air from the explosion pushes on both the cannon and the cannonball with equal sized forces in opposite directions.

C It is relatively common for students to think wrongly that because the intention is for the cannon to fire the cannonball, and is much bigger, it exerts a bigger force on the cannonball than the cannonball exerts on the cannon.

D From ‘gut instinct’ some students may be aware of a cannon’s recoil, but think that it does so at a much smaller speed than this. If they do not think this statement is correct, they are not applying the relationship between mass and change of speed from a force correctly, or at all.

If students have misunderstandings about what happens when the cannon and the cannonball push against each other, it can help to demonstrate what happens with two dynamics trolleys that are set up to push apart (by triggering the spring loaded plunger), where one has a bigger mass than the other.

Careful questioning should also elicit understanding that:

* the force on each trolley is the same size and in the opposite direction
* the force on each trolley acts for the same length of time
* the speed (magnitude of velocity) of each trolley is changed less if it has more mass
* If mass of one trolley is double (triple) the mass of the other, its speed increases by half (one third) as much
* the momentum of each trolley is changed by the same amount

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: Simon Carson (UYSEG), Peter Fairhurst (UYSEG), and ‘Boom!’ flash by aitoff from Pixabay.

**References**

Brown, D. E. (1989). Students' concept of force: the importance of understanding Newton's third law. *Physics Education,* 24(6)**,** 353-358.