Inertia and Newton's Third Law

Inertia and Newton's Third Law can seem simple on the surface, but they can quickly get confusing. Make sure you really understand what's going on with them — especially if an object is in equilibrium.

Inertia is the Tendency for Motion to Remain Unchanged

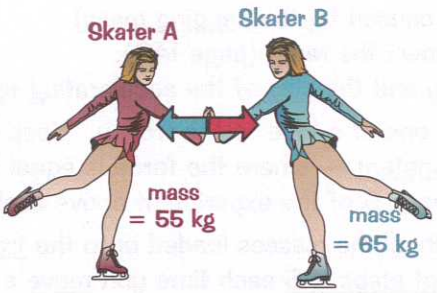
1) Until acted on by a resultant force, objects at rest stay at rest and objects moving at a constant velocity will stay moving at that velocity (Newton's First Law).
2) This tendency to keep moving with the same velocity is called inertia.
3) An object's inertial mass measures how difficult it is to change the velocity of an object.
4) Inertial mass can be found using Newton's Second Law of $F = ma$ (p.149). Rearranging this gives $m = F \div a$, so inertial mass is just the ratio of force over acceleration.

Newton's Third Law: Reaction Forces are Equal and Opposite

Newton's Third Law says:

When two objects interact, the forces they exert on each other are equal and opposite.

1) If you push something, say a shopping trolley, the trolley will push back against you, just as hard.
2) And as soon as you stop pushing, so does the trolley. Kinda clever really.
3) So far, so good. The slightly tricky thing to get your head round is this — if the forces are always equal, how does anything ever go anywhere? The important thing to remember is that the two forces are acting on different objects.



When skater A pushes on skater B (the 'action' force), she feels an equal and opposite force from skater B's hand (the 'normal contact' force). Both skaters feel the same sized force, in opposite directions, and so accelerate away from each other.

Skater A will be accelerated more than skater B, though, because she has a smaller mass — remember $a = F \div m$.

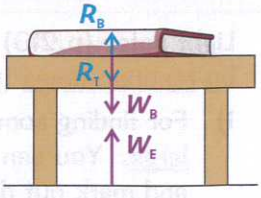
These equally-sized forces in opposite directions also explain the principle of conservation of momentum (see pages 153-154).

4) It's a bit more complicated for an object in equilibrium (p.182). Imagine a book sat on a table:

The weight of the book pulls it down, and the normal reaction force from the table pushes it up. These forces are equal to each other — the book is in equilibrium and doesn't move.
This is NOT Newton's third law. These forces are different types and they're both acting on the book.

The pairs of forces due to Newton's third law in this case are:

- The book is pulled down by its weight due to gravity from Earth (W_B) and the book also pulls back up on the Earth (W_E).
- The normal contact force from the table pushing up on the book (R_B) and the normal contact force from the book pushing down on the table (R_T).



I have a reaction to forces — they bring me out in a rash...

Newton's 3rd law really trips people up, so make sure you understand exactly what objects the forces are acting on and how that results in movement (or lack of it). Then have a crack at this question to practise what you know.

Q1 A full shopping trolley and an empty one are moving at the same speed. Explain why it is easier to stop the empty trolley than the full trolley over the same amount of time. [1 mark]

Inertia and Newton's Third Law

Warm-Up

Which of the following is Newton's Third Law? Tick **one** box.

- A non-zero resultant force is needed to cause a change in speed or direction. ☐
- A resultant force is inversely proportional to the mass of an object. ☐
- When two objects interact, they exert equal and opposite forces on each other. ☐
- A resultant force of zero leads to an equilibrium situation. ☐

1 All objects have an inertial mass. Grade 6-7

a) State the meaning of the term inertial mass.

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[1]

Three identical shopping trolleys, A, B and C, are filled with different items and so that each trolley has a different mass. Each trolley is pushed with an equal force from the same starting point, and its velocity is recorded immediately afterwards. **Figure 1** shows the results.

Figure 1

Trolley	A	B	C
Velocity (m/s)	1.5	0.7	2.2

b) State which trolley has the highest inertial mass. Explain your answer.

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[2]

[Total 3 marks]

2 Two students each stand at rest on a skateboard by a wall. They both push against the wall with a force of 24 N. You can assume there is no friction between the skateboards and the ground. Grade 6-7

a) Explain in terms of forces why the students would move away from the wall.

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[2]

b) Student A and his skateboard have a combined mass of 80 kg. Student B and his skateboard have a combined mass of 40 kg. What is the difference in their accelerations?

☐ **A** 0.3 m/s^2 ☐ **B** 0.6 m/s^2

☐ **C** 1.6 m/s^2 ☐ **D** 3.3 m/s^2

[1]

[Total 3 marks]

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