

Ages 12–15 · Science

LESSON SLIDES

Forces and Newton's Laws of Motion

Physics · Why things start, stop, speed up and change direction

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Forces and Newton's Laws of Motion

SPEAKER NOTES

Slide a book across the desk and let it stop. Ask: why did it stop? Collect answers without judging them; many students will say it 'ran out of force'. Tell them that by the end of the lesson they will be able to explain it with Newton's first law.

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By the end of this lesson you can

- 🎯 Describe forces and measure them in newtons
- 🎯 Find the resultant force on an object
- 🎯 State Newton's three laws of motion
- 🎯 Calculate with $F = ma$ and $W = mg$
- 🎯 Explain why third-law pairs do not cancel

By the end of this lesson you can

SPEAKER NOTES

Point out that two of the objectives involve calculations, so calculators are useful later. Ask students which law they have heard of before; most will know 'every action has an equal and opposite reaction', which is a loose version of the third law.

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What is a force?

- A force is a push or a pull on an object
- It has a size and a direction, so we draw it as an arrow
- Unit: the newton (N)
- Measured with a newton meter (force meter)
- A force can change an object's speed, direction or shape

What is a force?

SPEAKER NOTES

A longer arrow means a bigger force. Pass round a newton meter and let students feel 1 N: it is roughly the weight of a 100 g apple, because $0.1 \text{ kg} \times 9.8 \text{ N/kg}$ is about 1 N. Ask for one example of a force changing shape (squashing a sponge) and one changing direction (kicking a moving ball).

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Contact and non-contact forces

Contact forces

- Act only when objects touch
- Friction between surfaces
- Air resistance and water resistance (drag)
- Normal (reaction) force from a surface
- Tension in a rope or string

Non-contact forces

- Act across a gap, without touching
- Gravity (weight)
- Magnetic force
- Electrostatic force between charges

Contact and non-contact forces

SPEAKER NOTES

Hold a magnet above a paper clip to show a non-contact force in action. Ask students to name the forces on a book resting on a table: weight (non-contact) down and the normal force from the table (contact) up. Keep this example; it returns when we meet the third law.

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Resultant force: adding forces in a line

- Several forces on one object combine into one resultant force
- Same direction: add them
- Opposite directions: subtract the smaller from the larger
- The resultant acts in the direction of the larger force
- Example: 50 N right and 30 N left give 20 N right

Resultant force: adding forces in a line

SPEAKER NOTES

Draw a tug of war on the board with arrows of different lengths. Ask: what is the resultant if both teams pull with 400 N? Zero, so nothing changes. At this level we only add forces along one line; adding forces at angles comes later.

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Balanced and unbalanced forces

Balanced

- Resultant force is zero
- A still object stays still
- A moving object keeps the same speed and direction
- Example: a car cruising at a steady speed

Unbalanced

- Resultant force is not zero
- The object accelerates
- It speeds up, slows down or changes direction
- Example: a car braking at traffic lights

Balanced and unbalanced forces

SPEAKER NOTES

Stress the surprising half of this slide: balanced forces do not mean 'not moving'. A car at a steady 50 km/h (about 30 mph) on a straight road has balanced forces, because the driving force equals friction plus air resistance. This is the most common misconception in the topic.

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Newton's first law: inertia

- With no resultant force, an object at rest stays at rest
- A moving object keeps moving at constant speed in a straight line
- Inertia: the tendency to resist changes in motion
- More mass means more inertia
- Seat belts stop you carrying on forwards when a car brakes

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Newton's first law: inertia

SPEAKER NOTES

Return to the sliding book: it stopped because friction acted as an unbalanced force, not because its force ran out. In space, far from other objects, a probe keeps moving without its engines. Ask: why is it harder to start pushing a full shopping trolley than an empty one?

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Newton's second law: $F = ma$

- Resultant force = mass $\times$ acceleration
- F in newtons, m in kilograms, a in m/s^2
- 1 N gives a 1 kg mass an acceleration of 1 m/s^2
- Bigger force, same mass: bigger acceleration
- Same force, bigger mass: smaller acceleration

Newton's second law: $F = ma$

SPEAKER NOTES

Write the formula triangle if your students use one, and show the rearrangements $a = F \div m$ and $m = F \div a$. Make sure students use the resultant force, not just one of the forces. Acceleration is in the same direction as the resultant force.

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 Example

Worked example: a car pulling away

- 1 Car mass: 1,200 kg
- 2 Driving force 3,000 N; friction and air resistance 600 N
- 3 Resultant force = $3,000 - 600 = 2,400$ N forwards
- 4 $a = F \div m = 2,400 \div 1,200$
- 5 $a = 2 \text{ m/s}^2$ forwards

Worked example: a car pulling away

SPEAKER NOTES

Work through each line on the board. Ask what happens to the acceleration as the car speeds up and air resistance grows: the resultant force falls, so the acceleration falls. When air resistance plus friction equals 3,000 N, the forces balance and the car travels at a steady top speed.

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Mass and weight are different

Mass

- The amount of matter in an object
- Measured in kilograms (kg)
- The same everywhere in the universe
- Measured with a balance

Weight

- The force of gravity on an object
- Measured in newtons (N)
- $W = mg$; on Earth $g \approx 9.8 \text{ N/kg}$
- On the Moon g is about one-sixth as big

Mass and weight are different

SPEAKER NOTES

Example: a 50 kg student weighs $50 \times 9.8 = 490 \text{ N}$ on Earth, but only about one-sixth of that, roughly 80 N, on the Moon. Their mass is 50 kg in both places. Some courses round g to 10 N/kg; tell students which value your exam uses. Ask: why is 'I weigh 50 kg' not quite right in physics?

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Newton's third law: interaction pairs

- When A pushes or pulls on B, B pushes or pulls back on A
- The two forces are equal in size
- They act in opposite directions
- They act on different objects
- They are always the same type of force

Newton's third law: interaction pairs

SPEAKER NOTES

Examples: a swimmer pushes backwards on the pool wall and the wall pushes the swimmer forwards; your foot pushes backwards on the ground and the ground pushes you forwards; a rocket pushes gas backwards and the gas pushes the rocket forwards. Ask a pair of students on wheeled chairs (if safe) to push palms: both move apart.

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Third-law pair or balanced forces?

Third-law pair

- Two forces on two different objects
- Always the same type of force
- Never cancel, because they act on different objects
- Book pulls Earth up; Earth pulls book down

Balanced forces

- Two or more forces on one object
- Can be different types of force
- Add up to zero resultant force
- Weight down and table push up on a book

Third-law pair or balanced forces?

SPEAKER NOTES

This is the hardest idea in the lesson. The book's weight and the table's push are equal and opposite, but they are not a third-law pair: both act on the book and they are different types of force. The partner of the book's weight is the book's gravitational pull on the Earth.

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All three laws on one page

- First law: no resultant force, no change in motion. Second law: $F = ma$. Third law: forces come in equal and opposite pairs on different objects.

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Newton's Three Laws of Motion

How forces start, stop and change motion, with an everyday example of each law.

1st law: inertia

With no resultant force, a still object stays still and a moving object keeps the same speed in a straight line.

In real life: seat belts

When a car brakes hard, your body keeps moving forwards. The seat belt supplies the force that slows you down.

2nd law: $F = ma$

Resultant force = mass $\times$ acceleration. A bigger force gives more acceleration; a bigger mass gives less.

In real life: a full trolley

Push a full shopping trolley and an empty one equally hard: the full one, with more mass, speeds up more slowly.

3rd law: interaction pairs

If A pushes or pulls on B, B pushes or pulls on A with a force of the same size and type, in the opposite direction.

In real life: a rocket launch

The rocket pushes exhaust gas down; the gas pushes the rocket up. The two forces act on different objects.

Worked example

A 1,200 kg car has a resultant force of 2,400 N. $a = F \div m = 2,400 \div 1,200 = 2 \text{ m/s}^2$. One newton gives 1 kg an acceleration of 1 m/s^2 .

Common mistake

Moving objects do not need a force to keep going. They slow down because friction and air resistance act on them. Third-law pairs never cancel out.

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All three laws on one page

SPEAKER NOTES

Use the poster as a recap or print it for the classroom wall. Ask students to add their own everyday example under each law in their books, then share one with a partner. Good examples: a bus passenger lurching forwards (first), a full trolley being harder to accelerate (second), a rowing boat moving forwards as the oars push water back (third).

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 Quick check

**A 2 kg trolley is pulled with a resultant force of 6 N.
What is its acceleration?**

A 12 m/s²

B 3 m/s²

C 0.33 m/s²

D 8 m/s²

Quick check

SPEAKER NOTES

Answer: B, 3 m/s², from $a = F \div m = 6 \div 2$. Students who chose A multiplied instead of dividing; students who chose D added the numbers. Ask one student to explain how they rearranged $F = ma$.

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Key takeaways

- ✓ Forces are pushes or pulls, measured in newtons
- ✓ Balanced forces: no change in motion, even if moving
- ✓ Unbalanced forces cause acceleration: $F = ma$
- ✓ Weight is a force: $W = mg$
- ✓ Third-law pairs act on different objects and never cancel

Key takeaways

SPEAKER NOTES

Ask students to explain the sliding book from the start of the lesson using the first law. Then move to the five-question quiz. Homework idea: find three examples of Newton's laws at home or on the way to school and label the forces with arrows.