

LESSON SLIDES

Forces and Newton's Laws of Motion

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

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

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

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

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

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

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

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

 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

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

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

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

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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 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

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