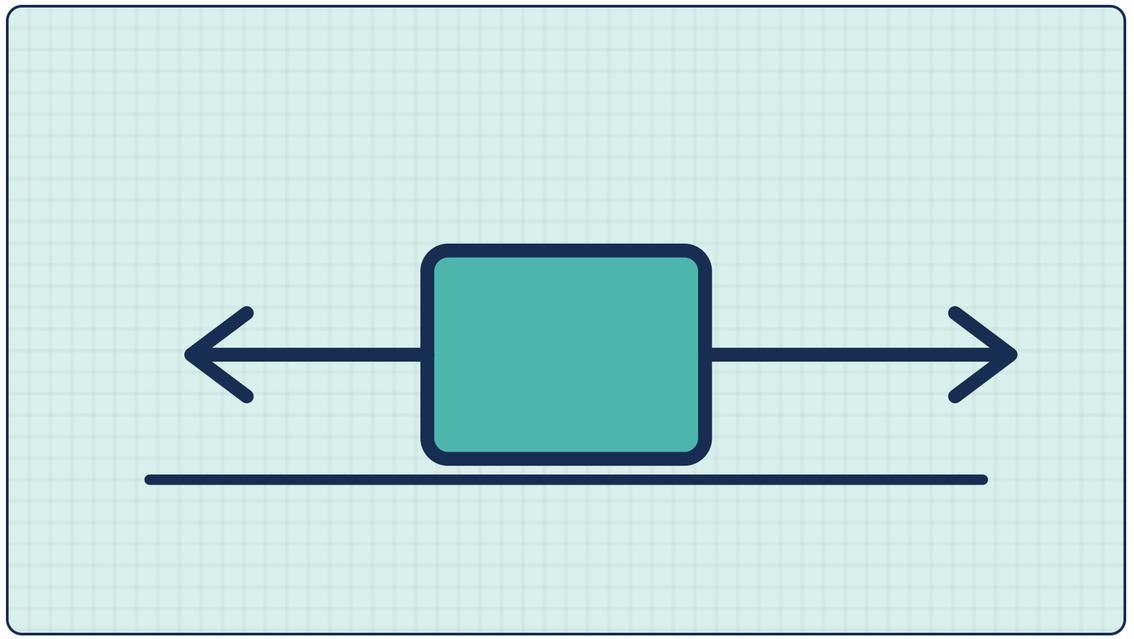
Physics · Why things start, stop, speed up and change direction

Forces and Newton's Laws of Motion



Goals

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 × 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

Worked example

Worked example: a car pulling away

- Car mass: 1,200 kg
- Driving force 3,000 N; friction and air resistance 600 N
- Resultant force = 3,000 – 600 = 2,400 N forwards
- a = F ÷ m = 2,400 ÷ 1,200
- a = 2 m/s² 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 $g \approx 9.8$ 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

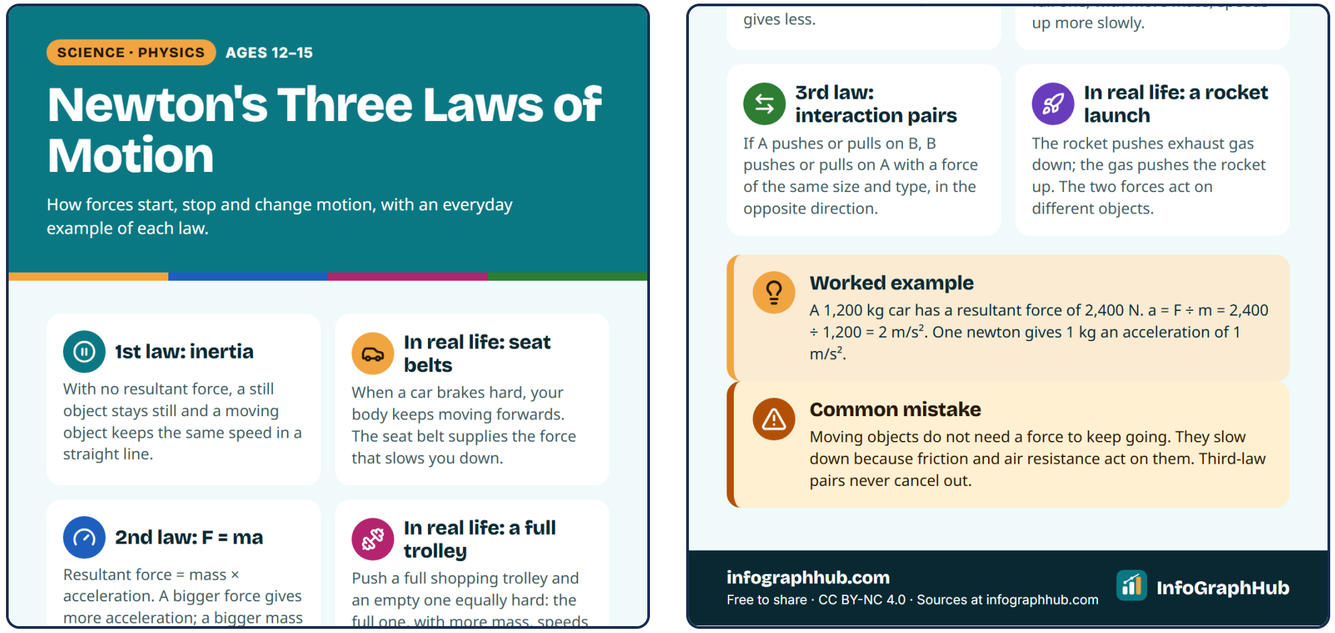
- Two forces on two different objects
- Always the same type of force
- Never cancel, because they act on different objects
- Book pulls Earth up; Earth pulls book down

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.



Poster: Newton's Three Laws of Motion Explained

Quick check

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

A. 12 m/s^2

B. 3 m/s^2

C. 0.33 m/s^2

D. 8 m/s^2

Summary

Key takeaways

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