

Inertia, resultant force and reaction pairs

Physics grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · Lesson

Quick answer: Newton's three laws describe how forces change motion. The first law says an object keeps its velocity unless a resultant force acts on it. The second law says resultant force equals mass times acceleration, $F = m \times a$. The third law says that when A pushes B, B pushes A with an equal, opposite force of the same type.

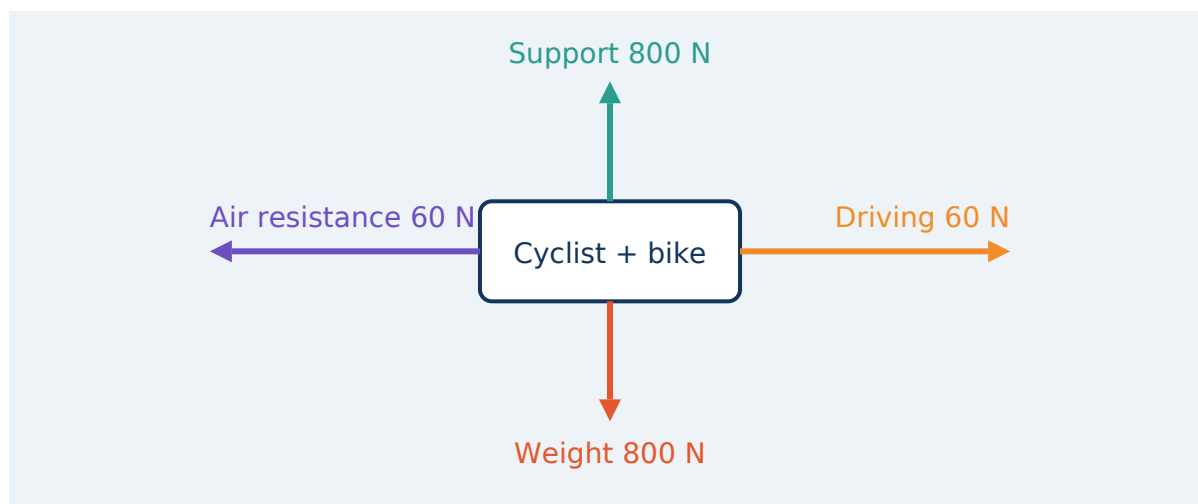
Level: Physics grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · **Curriculum:** HS-PS2-1, GCSE P5

What does Newton's first law say?

Newton's first law explains why things keep doing what they are already doing. Push a puck across smooth ice and it keeps gliding; leave a stone on the ground and it stays there. Only a **resultant force** can change how something moves.

Definition

Inertia is the tendency of an object to keep its state of rest or its steady velocity. The more mass an object has, the more inertia it has. First law: if the resultant force on an object is zero, it stays at rest or moves in a straight line at constant speed.



Balanced forces on a cyclist moving at a steady speed: the resultant force is zero.

The cyclist in the figure rides at a steady speed because the driving force and the air resistance are equal. The forces are balanced, so nothing changes. Zero resultant force does not mean zero motion.

How does $F = ma$ link force, mass and acceleration?

When the forces on an object are unbalanced, its velocity changes. The second law tells you by how much: a bigger resultant force gives a bigger acceleration, and a bigger mass gives a

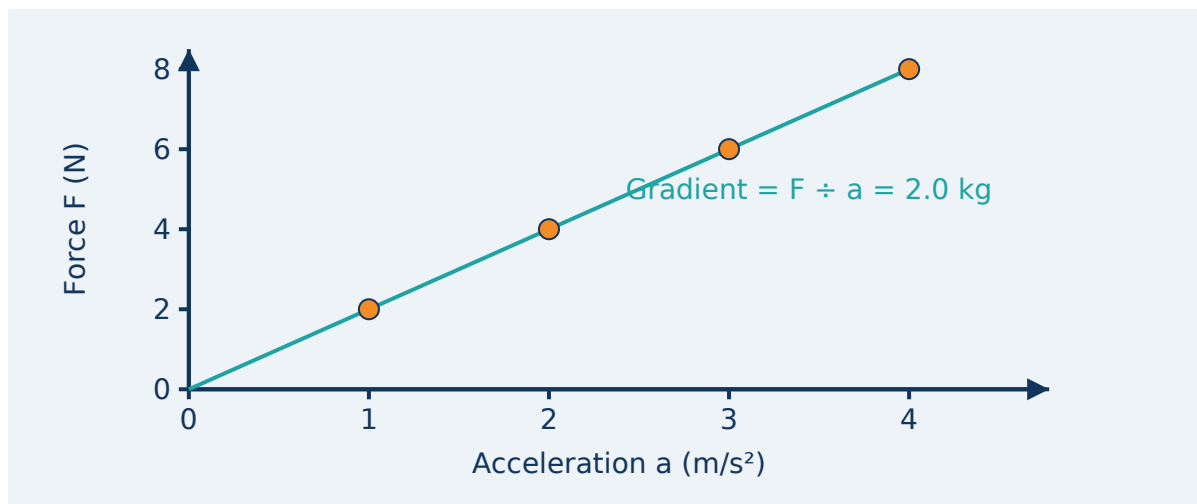
smaller one.

Formula

$$\mathbf{F = m \times a}$$

F = resultant force in newtons (N), m = mass in kilograms (kg), a = acceleration in metres per second squared (m/s^2).

One newton is the force that gives 1 kg an acceleration of 1 m/s^2 , so 1 N = 1 kg m/s^2 .



A trolley of mass 2.0 kg: force is directly proportional to acceleration, and the gradient equals the mass.

Worked example 1

A car of mass 1200 kg is pushed forward by an engine force of 3000 N. Air resistance and friction total 600 N.

Resultant force = 3000 N – 600 N = 2400 N.

$a = F \div m = 2400 \div 1200 = \mathbf{2.0 \text{ m/s}^2}$.

Worked example 2

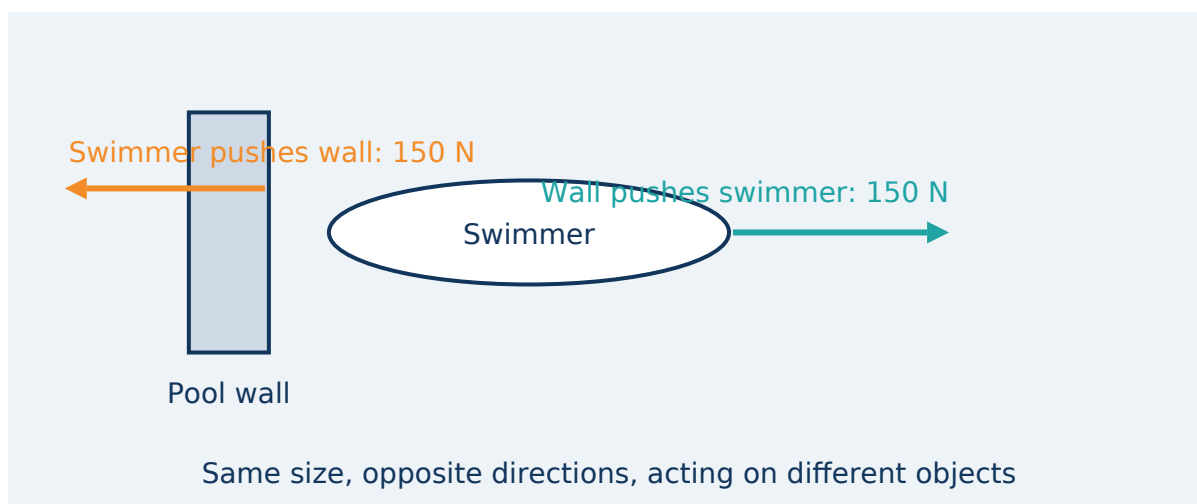
Wanjiru in Nairobi sprints with a push-off acceleration of 5.0 m/s^2 . Her mass is 55 kg. What resultant force acts on her?

$F = m \times a = 55 \times 5.0 = \mathbf{275 \text{ N}}$.

Weight is a force too. It is the pull of gravity: $\mathbf{W = m \times g}$, where $g = 9.8 \text{ N/kg}$ near the Earth's surface. A 50 kg student weighs $50 \times 9.8 = 490 \text{ N}$, but on the Moon ($g = 1.6 \text{ N/kg}$) the same student weighs only 80 N. The mass stays 50 kg.

What is Newton's third law?

Forces never act alone. If object A pushes or pulls object B, then B pushes or pulls A with a force that is equal in size, opposite in direction and of the same type (both contact forces, both gravitational, and so on).



A third-law pair: two forces of equal size and opposite direction acting on two different objects.

Common mistake

Students often say the two forces of a third-law pair cancel out. They do not, because they act on different objects. Only forces acting on the same object can be added to find the resultant.

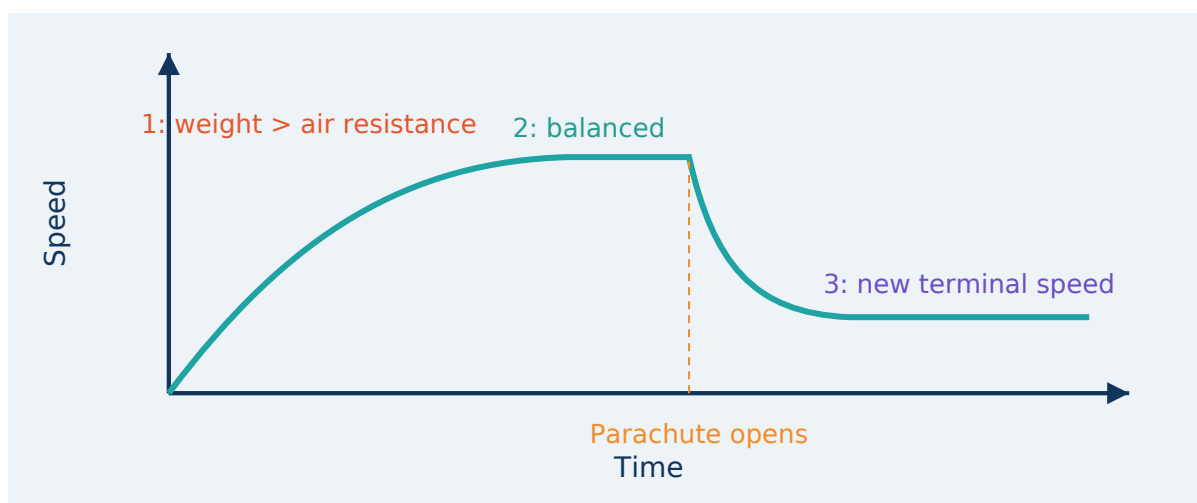
That pair explains how walking, swimming and rockets work. Your foot pushes the ground backwards; the ground pushes you forwards. The object that is pushed forward is you, so you accelerate.

What is terminal velocity?

A falling object meets air resistance (drag), which grows with speed. A skydiver therefore accelerates less and less until the drag equals the weight. The resultant force is then zero and the speed stays constant.

Definition

Terminal velocity is the constant speed reached by a falling object when the upward drag force equals the downward weight.



A skydiver accelerates, reaches terminal velocity, then slows when the parachute opens and settles at a lower

terminal velocity.

Stage	Weight	Air resistance	Resultant force	Motion
Just after jumping	800 N	small	large, downwards	accelerates quickly
Falling faster	800 N	growing	getting smaller	accelerates less
Terminal velocity	800 N	800 N	zero	steady speed
Parachute opens	800 N	much larger	upwards	slows down

Opening the parachute increases the drag far above the weight, so the skydiver slows until a smaller drag balances the weight again. That final steady speed is much lower and is safe for landing.

Lina's tip

Always draw the forces on ONE object only, then find the resultant before using $F = m \times a$. If you catch yourself using a force that acts on a different object, stop and check.

How do the three laws compare?

Law	Key idea	Everyday example
First	No resultant force: constant velocity	Passengers lurch forward when a bus brakes
Second	$F = m \times a$	A loaded cart accelerates less than an empty one
Third	Equal and opposite forces on two objects	A rocket pushes gas down and is pushed up

Key points to remember

- First law: zero resultant force means constant velocity (or rest).
- Second law: $F = m \times a$, with F in N, m in kg and a in m/s^2 .
- Weight $W = m \times g$, with $g = 9.8 \text{ N/kg}$ on Earth.
- Third-law pairs are equal, opposite, the same type and act on different objects.
- Terminal velocity: air resistance equals weight, so the speed is steady.

Inertia, resultant force and reaction pairs: frequently asked questions

What is Newton's second law in simple words?

The acceleration of an object depends on the resultant force and its mass. In symbols $F = m \times a$, so the same force gives a small mass a large acceleration and a large mass a small one.

Why do action and reaction forces not cancel?

They act on two different objects. Cancelling only happens between forces on the same object. Each object feels only one force of the pair, so each one can accelerate.

Does a moving object need a resultant force to keep moving?

No. By the first law an object moves at constant velocity when the resultant force is zero. A force is needed only to change the speed or the direction.

What is the difference between mass and weight?

Mass is the amount of matter in kilograms and does not change with place. Weight is the pull of gravity in newtons, found from $W = m \times g$, so it changes from planet to planet.

Why does a skydiver stop accelerating?

Air resistance grows as speed grows. At terminal velocity it equals the weight, the resultant force becomes zero and the speed stays constant.