

Newton's three laws of motion

Grade 8 science (Year 9 · Class 8) · Lesson

Quick answer: Newton's first law says an object keeps its motion unless an unbalanced force acts on it. The second law says net force equals mass times acceleration, $F = m \times a$. The third law says forces come in equal and opposite pairs acting on two different objects.

Level: Grade 8 science (Year 9 · Class 8) · **Curriculum:** MS-PS2-1, MS-PS2-2

What is inertia, and what does Newton's first law say?

A football stays on the grass until someone kicks it, and once a hockey puck is sliding it keeps sliding until something slows it down. Objects resist changes to their motion.

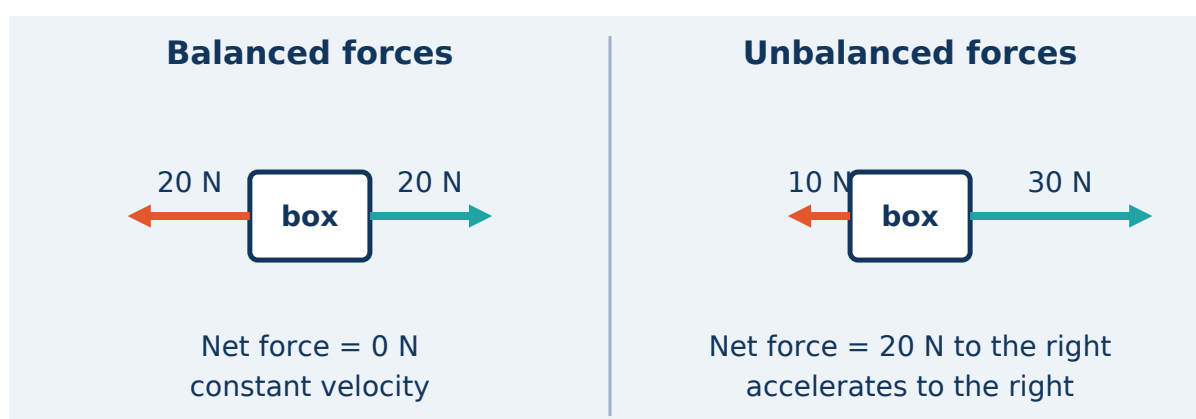
Definition

Inertia is the tendency of an object to keep doing what it is already doing: staying at rest or moving at constant velocity. The bigger the mass, the bigger the inertia.

Newton's first law

An object stays at rest, or keeps moving in a straight line at constant speed, unless an unbalanced force acts on it.

Forces are balanced when they are equal and opposite, so the net force is zero. A box with 20 N pushing each way does not accelerate. If one force is bigger, the net force is not zero and the motion changes.



Balanced forces give no change in motion. Unbalanced forces change it.

How do forces change motion? Newton's second law

An unbalanced force makes an object accelerate. The acceleration is bigger for a bigger net force and smaller for a bigger mass.

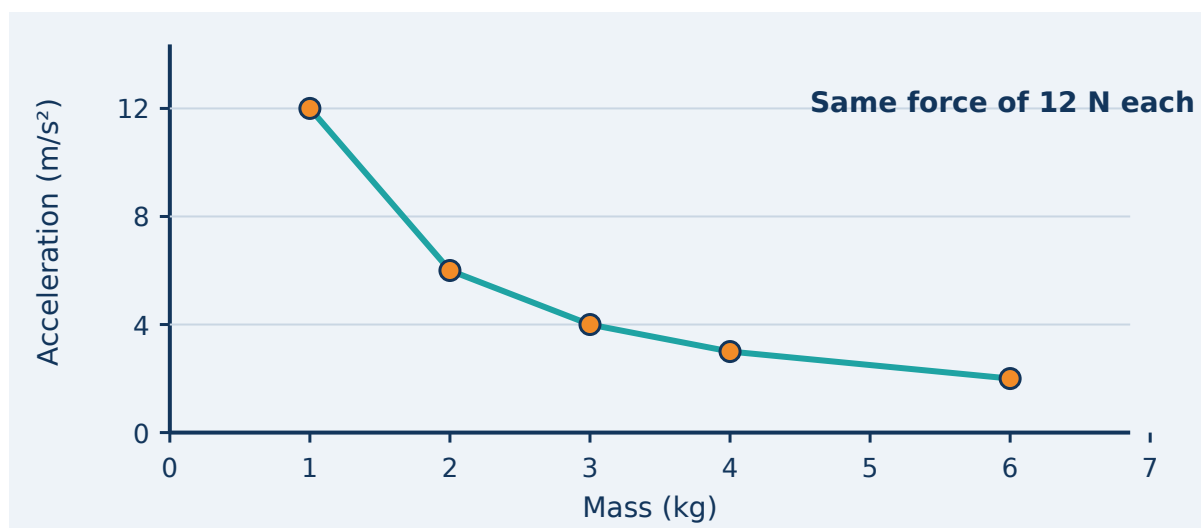
Formula

$$F = m \times a$$

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

One newton is the net force that gives a 1 kg mass an acceleration of 1 m/s^2 . Rearranged: $a = F \div m$ and $m = F \div a$. The table shows what happens when the same net force of 12 N is applied to different masses.

Mass (kg)	Net force (N)	Acceleration (m/s^2)
1	12	12
2	12	6
3	12	4
4	12	3
6	12	2



A bigger mass gives a smaller acceleration for the same force.

Worked example 1

A cart of mass 20 kg is pushed with a net force of 50 N. Find its acceleration.

$$a = F \div m = 50 \text{ N} \div 20 \text{ kg} = \mathbf{2.5 \text{ m/s}^2}.$$

Worked example 2

A motorbike and rider have a total mass of 200 kg. The engine drives them forward with 600 N and friction and air resistance push back with 200 N. Find the acceleration.

$$\text{Net force} = 600 - 200 = 400 \text{ N}.$$

$$a = F \div m = 400 \text{ N} \div 200 \text{ kg} = \mathbf{2.0 \text{ m/s}^2}.$$

Mass is the amount of matter in an object, measured in kg. Weight is the pull of gravity on that mass, so it is a force: $W = m \times g$, where $g = 9.8 \text{ N/kg}$. A 5 kg bag weighs $5 \times 9.8 = 49 \text{ N}$.

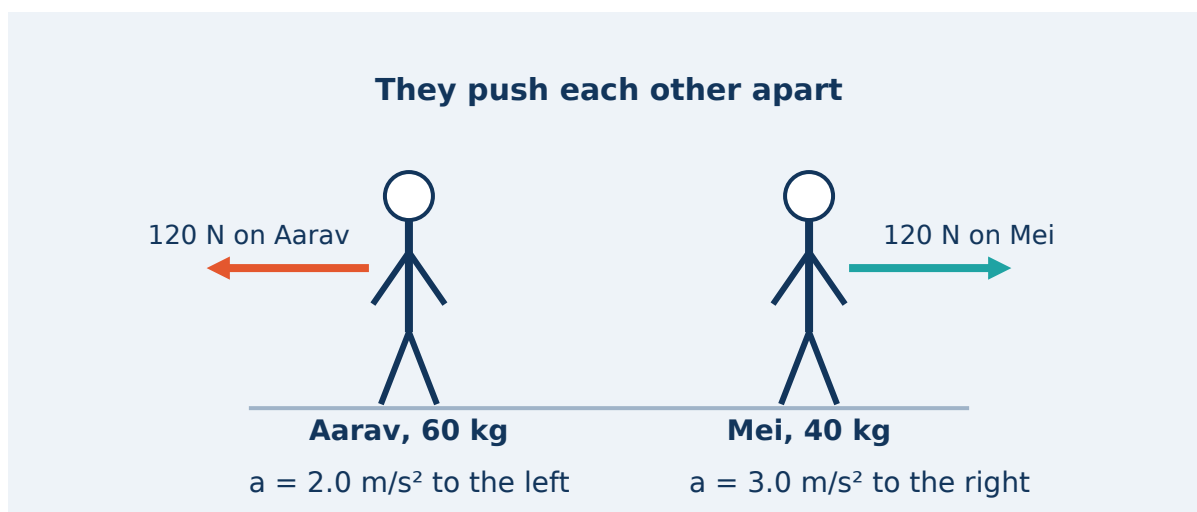
What is Newton's third law?

Forces never come alone. When you push a wall, the wall pushes back on you.

Newton's third law

When object A exerts a force on object B, object B exerts an equal and opposite force on object A. The two forces are an action-reaction pair.

The pair is always the same type of force, equal in size, opposite in direction, and acting on two different objects. A swimmer pushes the water backward and the water pushes the swimmer forward. A rocket pushes gas down and the gas pushes the rocket up.



Equal and opposite forces act on two different skaters. The lighter skater accelerates more.

Worked example 3

Aarav (60 kg) and Mei (40 kg) stand on skateboards and push each other apart with a force of 120 N. Find each acceleration.

Aarav: $a = 120 \div 60 = \mathbf{2.0 \text{ m/s}^2}$.

Mei: $a = 120 \div 40 = \mathbf{3.0 \text{ m/s}^2}$.

The forces are equal, but the smaller mass accelerates more.

Common mistake

Action and reaction forces do not cancel each other, because they act on different objects. Only forces on the same object can be added to find a net force.

Lina's tip

Before using $F = m \times a$, draw the object alone with an arrow for each force on it. Add the arrows to find the net force, then divide by the mass.

Key points to remember

- First law: no net force means no change in velocity (inertia)
- Second law: $F = m \times a$, with $N = \text{kg} \cdot \text{m/s}^2$

- Weight $W = m \times g$, with $g = 9.8 \text{ N/kg}$
- Third law: action and reaction are equal, opposite and on different objects
- More mass means more inertia and less acceleration for the same force

Newton's three laws of motion: frequently asked questions

What is inertia?

Inertia is the tendency of an object to resist changes to its motion. It stays at rest or keeps moving at constant velocity unless a force acts, and a bigger mass has more inertia.

How do you calculate acceleration from force and mass?

Use $a = F \div m$, where F is the net force in newtons and m is the mass in kilograms. A 50 N net force on a 20 kg cart gives 2.5 m/s^2 .

What is a newton?

A newton is the net force that gives a 1 kg mass an acceleration of 1 m/s^2 . It equals $1 \text{ kg} \cdot \text{m/s}^2$.

Why do action and reaction forces not cancel?

They act on two different objects. Forces only cancel when they act on the same object, so each object can accelerate.

What is the difference between mass and weight?

Mass is the amount of matter, measured in kilograms. Weight is the gravitational force on that mass, measured in newtons, found with $W = m \times g$.