

Charge, fields and sparks

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

Quick answer: Static electricity is electric charge that builds up on insulators when electrons are transferred by rubbing. Like charges repel and unlike charges attract. A charged object has an electric field around it, and the charge that flows in a current follows $Q = I \times t$, with charge measured in coulombs.

Level: Physics grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · **Curriculum:** GCSE P2, HS-PS2-4

What is static electricity?

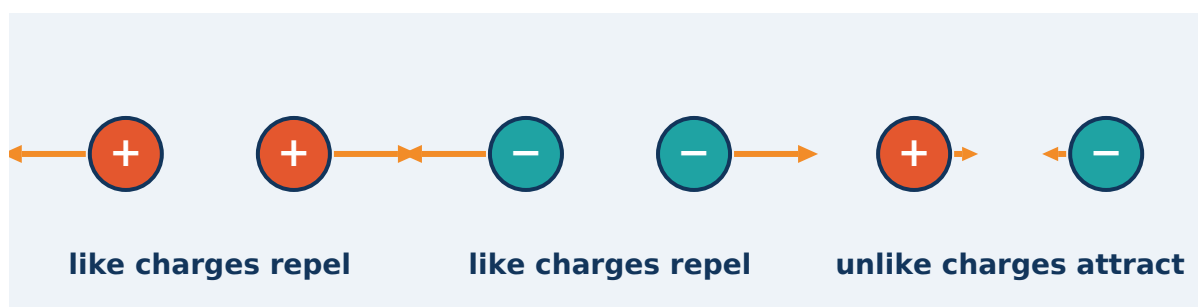
A comb pulled through dry hair can lift tiny pieces of paper, and a jumper pulled off in the dark can crackle. These effects come from **static electricity**: electric charge that stays in one place instead of flowing round a circuit.

Definition

Electric charge comes in two kinds, positive and negative. It is measured in **coulombs (C)**. Objects are normally neutral because they hold equal amounts of both kinds. An object is **charged** when it has gained or lost electrons.

Key law

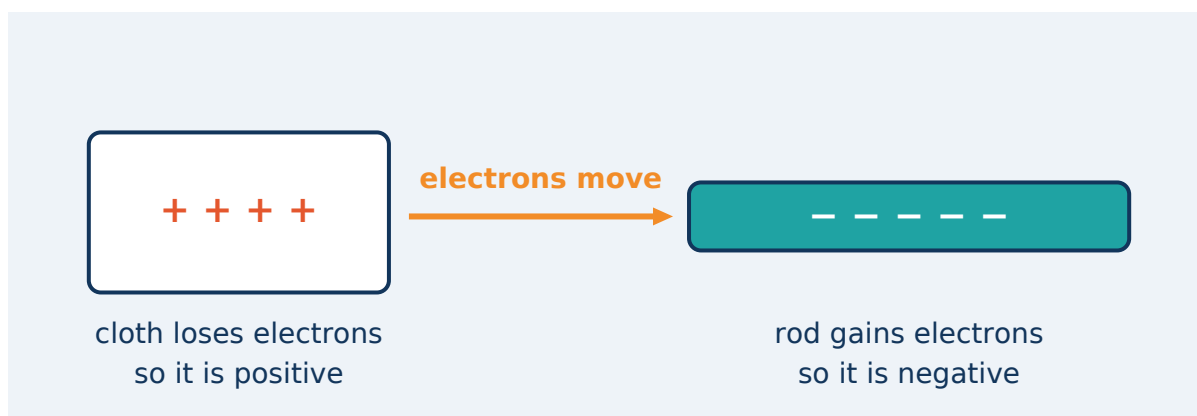
Like charges repel; unlike charges attract. The force is stronger when the charges are bigger or closer together.



Arrows show the force on each sphere. Like charges repel; unlike charges attract.

How does rubbing charge an object?

Atoms contain positive protons that stay locked in the nucleus and negative electrons that can be pulled away. When two **insulators** are rubbed together, electrons are scraped off one material and stick to the other. Only electrons move, never protons.



Rubbing transfers electrons only. The rod gains them and becomes negative; the cloth loses them and becomes positive.

Pair rubbed together	Gains electrons	Result
Polythene rod and cloth	Rod	Rod negative, cloth positive
Acetate rod and cloth	Cloth	Rod positive, cloth negative
Balloon and hair	Balloon	Balloon negative, hair positive
Glass rod and silk	Silk	Glass positive, silk negative

Metals are **conductors**: their electrons move freely, so charge spreads out or leaks away at once. That is why you only see charging by friction clearly on plastics, glass and rubber. A charged object attracts neutral scraps because its field pushes charge to one side of the scrap, so the nearer side has opposite charge.

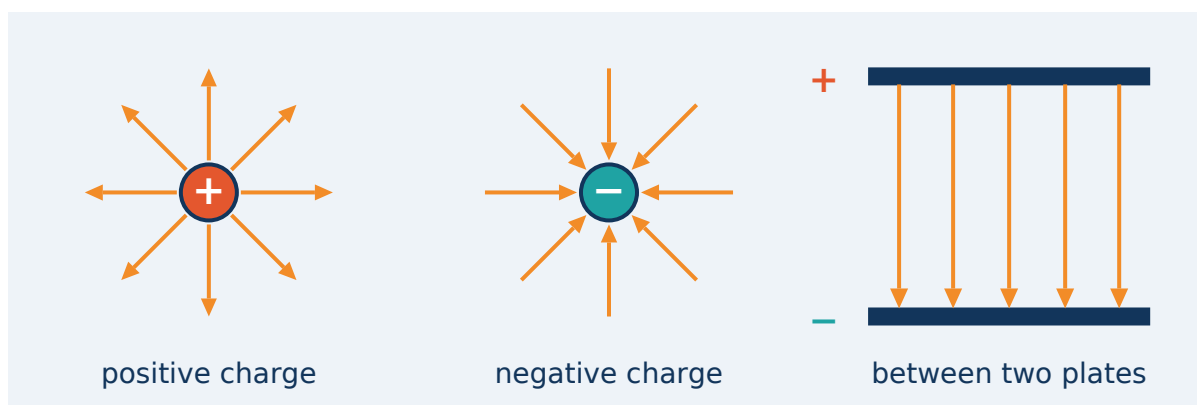
Common mistake

Saying that protons move from one material to the other, or that a rod becomes positive by "gaining positive charge". A rod becomes positive by *losing electrons*.

What is an electric field?

Definition

An **electric field** is a region where a charged object feels a force. The field direction is the direction of the force on a small positive charge, so field lines point away from positive charges and towards negative ones.



Field lines show the direction of the force on a small positive charge. Close lines mean a strong field; parallel, evenly spaced lines mean a uniform field.

Lines drawn close together show a strong field, which is why sparks form at sharp points. A charged particle placed in a field feels a force: positive particles move along the field lines, and electrons move against them.

Why do sparks happen, and what is the link between charge and current?

When a lot of charge builds up, the field in the air between the charged object and the earth or a conductor becomes so strong that air molecules ionise. The air then conducts for a moment, and the charge rushes across as a spark. Lightning is a huge spark. Sparks are dangerous near fuel vapour, so tankers and aircraft are earthed during refuelling. Electrostatics is also useful: inkjet printers steer charged droplets, smoke precipitators remove dust from chimneys, and spray painting charges droplets so that they coat a surface evenly.

Current is the rate of flow of charge, so charge and current are linked by a simple equation.

Formula

$$Q = I \times t$$

Q = charge (C), I = current (A), t = time (s). One coulomb is the charge carried by a current of 1 A in 1 s. One electron carries 1.6×10^{-19} C.

Worked example 1

A torch in Nairobi draws a current of 0.80 A for 25 s. Calculate the charge that flows.

$$Q = I \times t = 0.80 \times 25 = \mathbf{20 \text{ C}}$$

Worked example 2

A balloon carries a charge of 2.4×10^{-9} C. Calculate how many extra electrons it holds.

$$N = Q \div e = 2.4 \times 10^{-9} \div 1.6 \times 10^{-19} = \mathbf{1.5 \times 10^{10} \text{ electrons}}$$

Lina's tip

Convert first: milliamps (mA) $\div$ 1000 to amps, minutes $\times$ 60 to seconds, nanocoulombs $\times$

10^{-9} to coulombs. Then the equation always works.

Key points to remember

- Rubbing transfers electrons: the gainer is negative, the loser positive.
- Like charges repel; unlike charges attract.
- Electric field lines point from positive to negative.
- $Q = I \times t$ (coulombs = amperes $\times$ seconds).
- One electron carries 1.6×10^{-19} C.

Charge, fields and sparks: frequently asked questions

Why does rubbing make an object charged?

Rubbing transfers electrons from one insulator to the other. The material that gains electrons becomes negative and the one that loses them becomes positive. No new charge is created.

What is the unit of electric charge?

The coulomb (C). One coulomb is the charge delivered by a current of 1 ampere in 1 second, and one electron carries 1.6×10^{-19} C.

How do you calculate charge from current?

Multiply current by time: $Q = I \times t$. Use amps and seconds, so 250 mA for 2.0 minutes is $0.25 \times 120 = 30$ C.

In which direction do electric field lines point?

They point away from positive charges and towards negative charges. They show the direction of the force on a small positive charge placed in the field.

Why are fuel tankers earthed?

Fuel flowing through pipes can build up charge. If it sparked to an unearthed object, the spark could ignite petrol vapour, so an earthing wire lets the charge flow safely to the ground.