

Static electricity

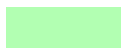
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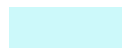
Revision notes for one topic, free to download.

These are the summary notes only. The full edition of this booklet also carries the worked examples, the required practicals and the formula sheets, with every topic in one place.

Colour Codes



Definitions



Diagrams



Notes and warnings



Sub-topic headings

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Define Static electricity

- electric charge built up on an insulator that stays in one place rather than flowing as a current.

Define Electron

- the negatively charged particle on the outside of an atom; the only charged particle that moves when an insulator is charged.

Define Charging by friction

- rubbing two insulators together so electrons transfer from one to the other.

Define Positively charged

- having lost electrons, so there are fewer electrons than protons.

Define Earthing

- connecting a charged object to the ground with a conductor so electrons flow and the excess charge is removed.

Define Electric field

- the region where an electric charge experiences a force (11.8P).

Define Uniform field

- a field of the same strength and direction everywhere, shown by parallel, evenly spaced field lines.

NOTE

PHYSICS ONLY — THIS TOPIC IS NOT IN COMBINED SCIENCE

The whole of Topic 11 is physics only. Every statement carries a P (11.1P–11.10P), and Edexcel drops Topic 11 entirely from GCSE Combined Science (1SC0). Because every item is physics only,

PHYSICS ONLY .

everything below is tagged

Define Insulator

- a material with no free charges, so charge placed on it cannot flow away.

Define Negatively charged

- having gained electrons, so there are more electrons than protons.

Define Attraction by induction

- a charged object pulling on an uncharged one because it pushes or pulls the charges inside it out of position.

Define Spark

- a sudden flow of charge through the air when the charge is large enough to make the air conduct.

Define Field line

- a line drawn to show the direction of the force on a small **positive** charge placed in the field.

Define Electrostatic precipitator

- a device that uses charge to remove smoke particles from waste gases.

11.1 Charging insulators by friction (11.1P, 11.2P)

PHYSICS ONLY When two **insulators** are rubbed together, **electrons** are rubbed off one surface onto the other. Only electrons move — protons are locked in nuclei and never transfer.

- **PHYSICS ONLY** The material that **gains electrons** becomes **negatively charged**. (11.2P)
- **PHYSICS ONLY** The material that **loses electrons** is left with an **equal positive charge** — the same size of charge, opposite sign. (11.2P)
- **PHYSICS ONLY** Charge is only ever *moved*, never created, so the two charges must be equal and opposite.
- **PHYSICS ONLY** It only works on insulators, because the charge cannot flow away again. Rub a metal rod held in your hand and the charge runs through the metal and through you to earth.

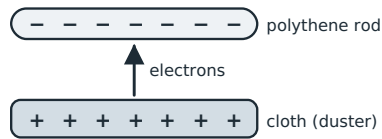
The standard example. A polythene rod rubbed with a duster gains electrons from the duster: the rod becomes negative and the duster is left equally positive. An acetate rod rubbed with the same duster loses electrons to it: the rod becomes positive and the duster negative.

Charging by friction, forces between charges and electric fields

Physics only

Charging an insulator by friction

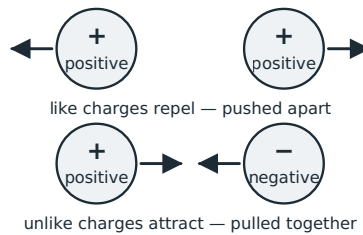
Rub the rod with the cloth:



The rod gains electrons, so it becomes negatively charged.

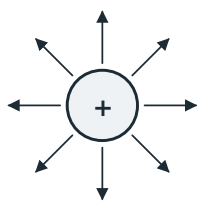
The cloth loses the same number of electrons, so it is left with an equal positive charge.

Forces between charged objects



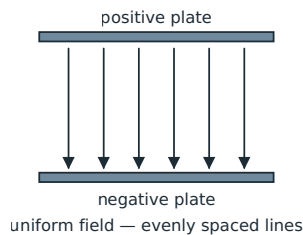
Electric fields

Around a point charge



radial lines — further apart

Between parallel plates



An electric field is the region where an electric charge feels a force.

Arrows point the way a positive charge would be pushed.

Lines closer together means a stronger field.

Uses and dangers of electrostatic charge

Two uses

Insecticide sprayer: the nozzle charges the droplets. Like charges repel, so the spray spreads into a fine, even cloud, and the droplets are attracted to the earthed plant.

Electrostatic paint spraying works the same way, so the paint reaches every part of a car body and less paint is wasted.

Two dangers

Sparking when fuelling a car: friction between the fuel and the pipe builds up charge. If it grows large enough it jumps as a spark and can ignite the fuel vapour.

Shocks from everyday objects, and lightning, happen when built-up charge discharges suddenly through a person or the air.

Earthing removes excess charge

A conductor connects the charged object to the ground, so electrons flow to or from earth until the object is no longer charged. Fuel tankers and aircraft are earthed before fuelling to prevent a dangerous build-up of charge, so no spark can form.

WATCH OUT

"The rod gained protons" and "positive charge flowed onto the duster" are both wrong. **Always explain charging in terms of electrons moving.** A positive charge is a *shortage* of electrons.

ANALOGY

Electrons are like loose coins in a pocket. Rubbing two coats together shakes some coins from one pocket into the other: no coins are made or destroyed — one coat ends up with extra coins (negative) and the other with exactly that number missing (positive). Because the coats are insulators, the coins stay where they land.

11.2 Forces between charges (11.3P)

PHYSICS ONLY Like charges repel; unlike charges attract. (11.3P)

- Two negatives push apart; two positives push apart; a positive and a negative pull together.
- The force acts on **both** objects — the pair of forces is equal and opposite.
- The force gets stronger as the charges get closer together and as the charges get bigger.

To show it: suspend a charged polythene rod in a cradle and bring a second charged polythene rod near — it swings away. Bring a charged acetate rod near instead — it swings towards it.

11.3 Everyday electrostatic phenomena (11.4P)

PHYSICS ONLY Statement 11.4P asks you to **explain** these in terms of the movement of electrons — not just describe them.

a Shocks from everyday objects.

- Walking across a nylon carpet rubs electrons onto (or off) your shoes and body, so you become charged.
- When you touch an earthed metal door handle, electrons move suddenly between you and the metal to cancel the charge. That rapid movement of electrons through your skin is felt as a shock.

b Lightning.

- Ice crystals and water droplets rub against each other in a storm cloud, transferring electrons, so the **bottom of the cloud becomes negatively charged** and the top positive.
- The negative cloud base repels electrons in the ground below, leaving the ground surface positively charged (induction).
- When the charge is big enough, the p.d. between cloud and ground makes the air conduct, and electrons rush to the ground as a huge spark — lightning.

c Attraction by induction.

- A charged balloon held against a wall sticks to it: the balloon's negative charge **repels electrons in the wall's surface** deeper into the wall, leaving the surface positive. Opposite charges are now nearer than like charges, so there is a net attraction.
- A comb charged by combing dry hair picks up small pieces of paper the same way — the near face of each piece of paper ends up oppositely charged, and is attracted.
- Key point: the wall and the paper are **uncharged overall**. Induction only moves charge around *inside* them.

11.4 Earthing (11.5P)

PHYSICS ONLY Earthing means connecting a charged object to the ground through a conductor. (11.5P)

- If the object is **negatively charged**, the excess electrons flow **from the object to earth**.
- If the object is **positively charged**, electrons flow **from earth to the object** to fill the shortage.
- Either way, electrons move until the object is neutral. The earth is so large it can accept or supply electrons without becoming noticeably charged itself.

WATCH OUT

"Earthing lets the positive charge escape to the ground."
Positive charge does not move. Say instead: **electrons flow from earth up to the object**, cancelling the positive charge.

11.5 Uses of electrostatic charge (11.6P)

PHYSICS ONLY Statement 11.6P names **insecticide sprayers**; the same physics is examined through paint spraying and precipitators.

Electrostatic insecticide and paint sprayers.

1. The nozzle charges the droplets as they are sprayed out — all droplets get the **same** charge.
2. Like charges repel, so the droplets spread apart into a fine, even cloud instead of clumping.
3. The plant (or car panel) is given the **opposite** charge, or is earthed.
4. The droplets are attracted to it and pulled round to coat the **underside and far side** as well as the face towards the nozzle.
5. Result: even coverage, less waste, less insecticide or paint needed.

Electrostatic dust precipitators (removing smoke particles from a chimney).

1. A charged metal grid at the base of the chimney charges the smoke and dust particles as they pass.
2. Metal collecting plates higher up are given the **opposite** charge, so the particles are attracted and stick to them.
3. The plates are shaken periodically so the dust falls into a collector, and cleaner gas leaves the chimney.

Photocopiers and laser printers use the same idea — charged toner powder is attracted to a charged image on a drum.

11.6 Dangers of sparking, and using earthing to prevent it (11.7P)

PHYSICS ONLY If charge builds up on an insulator, the p.d. between it and a nearby earthed object can grow large enough to make the air conduct. Electrons jump across as a **spark**, releasing energy that can ignite flammable vapour or dust.

Refuelling a car or an aircraft.

- Fuel rubbing against the pipe as it flows transfers electrons, so the pipe, the tanker and the fuel become charged.
- Petrol vapour around the filler is highly flammable, so a spark from the charged nozzle to the earthed car body could ignite it, causing a fire or explosion.

Other dangers. Sparks can ignite fine flour or custard powder suspended in the air in a mill, or anaesthetic gases in an operating theatre, and can destroy electronic components.

Preventing it — earthing and bonding.

- Fuel tankers are connected to the fuel store by an **earthing (bonding) strap** before pumping starts, so electrons flow to earth continuously and no charge builds up.
- Aircraft are earthed to the fuel bowser before refuelling.
- Fuel pipes are made of, or lined with, a **conductor** so charge cannot stay on them.
- Electronics workers wear an earthed wrist strap; anti-static flooring is used in theatres.

11.7 Electric fields (11.8P, 11.9P, 11.10P)

PHYSICS ONLY An electric field is the region where an electric charge experiences a force. (11.8P)

Drawing field lines (11.9P).

- Field lines show the **direction of the force on a small positive charge** placed in the field.
- Around an **isolated positive point charge**: straight lines pointing **radially outwards**, evenly spaced.
- Around an **isolated negative point charge**: straight radial lines pointing **inwards** towards the charge.
- Between **two parallel charged plates**: straight, parallel, evenly spaced lines running from the **positive plate to the negative plate** — a **uniform field** (it bulges outwards only at the edges).
- **Field strength is shown by how close together the lines are.** So a point charge's field is strongest next to the charge and weakens with distance, while the field between parallel plates is the same strength everywhere in the middle.
- Field lines never cross.

ANALOGY

Field lines are like the arrows on a weather map. They show which way something would be pushed, and where they crowd together the push is strongest. Nothing "flows" along a field line — it only tells you the direction and strength of the force at that point.

Using the field idea to explain static electricity (11.10P).

- A charged object is surrounded by an electric field, so another charge entering that field feels a **force without the objects touching** — this is why a charged rod pulls paper towards it from a distance.
- The field of a charged balloon reaches into the wall and pushes the wall's electrons away, producing the induced charges that cause attraction.
- Near a **sharp point** the field lines are crowded, so the field is very strong and the air breaks down there first — hence sparks jumping from points, and pointed lightning conductors.
- A **spark** happens when the field becomes strong enough to tear electrons off air molecules, turning the air into a conductor.
- Bringing an earthed conductor near a charged object strengthens the field between them, which is why the shock happens as your hand approaches the handle rather than while it is far away.

Use of mathematics — maths skill 5b: translating between graphical and numerical forms, i.e. reading and drawing electric field diagrams (11.8P, 11.9P).