

Electric and magnetic fields

International Baccalaureate · IB Diploma · Physics · HL

Scope and prerequisites

This handout covers selected HL topics for the course first assessed in 2025; it is not the whole syllabus.

Prerequisites: read the stated quantities and units, and use arithmetic and the model conditions below.

The examples are original and fictional: they are not real measurements or real student investigations.

Electric fields: force and a positive test charge

■ What would explain this observation?

- A negatively charged particle experiences an electric force opposite to the field direction. Field direction is defined using a positive **test charge**.

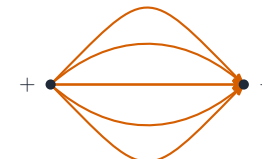
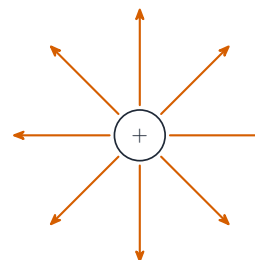
■ Build the model

- **Electric field strength** is force per unit positive test charge.
- Like charges repel and unlike charges attract.
- Field lines point away from positive charges and toward negative charges.
- Closely spaced lines represent a stronger field within a consistently drawn diagram.
- electric field strength: Electric force per unit positive test charge.
- test charge: A small charge used to probe an electric field.

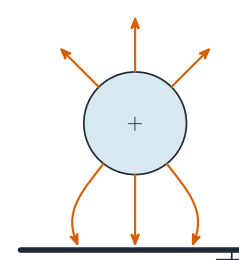
a) parallel plates (uniform field)



b) dipole (+ and -)



c) point charge (radial)



d) sphere above earthed plate

Field lines run from positive to negative; between parallel plates they are evenly spaced, so the field is uniform

■ Choose evidence that can test it

- In a uniform field between ideal parallel plates, $E = V/d$ away from edge effects.
- The force is $F = qE$, so its direction reverses for a negative charge.
- Coulomb force between ideal point charges decreases with separation squared.

In the lab: Sketch labelled plate polarities, field arrows and the charge before calculating. Convert separation to metres. In school, use simulations or approved low-voltage electrostatic models rather than exposed high-voltage equipment.

■ Work from known quantities

- Known: plate potential difference is 120 V and separation is 0.020 m.
- $E = V/d = 6,000 \text{ V/m}$.
- A +2.0 microcoulomb charge experiences $F = qE = 0.012 \text{ N}$ along the field; a -2.0 microcoulomb charge experiences the same magnitude opposite to it.

Your turn: Use $E = V/d$. Find E for 100 V across 0.025 m.

■ Check the conclusion and its limits

- Field strength is a vector.
- Potential difference is energy per charge and is not the same quantity.
- A field-line drawing is a model, not a set of physical threads.

Not true: Every charged particle experiences a force along the electric field direction. Field direction is defined by the force on a POSITIVE charge. A negative particle feels a force opposite to the field, so the field direction is not every particle's force direction.

Key:

- Electric field strength is force per unit positive test charge.
- In a uniform field between ideal parallel plates, $E = V/d$ away from edge effects.
- Watch for: field strength is a vector.

■ Write from a field of 5000 volts per metre

- A potential difference of 80 V is across a gap of 0.016 m.
- Find the electric field strength. A negative charge feels the opposite force.

■ Write from an energy gain of 3.2 times ten to the minus 17 joules

- A proton (charge 1.6×10^{-19} C) accelerates through 200 V.
- Energy = $qV = 3.2 \times 10^{-17}$ J = 200 eV – the volt is energy per unit charge, so a 200 V gap gives a proton exactly 200 eV.

■ Write from a zero-work path

- A charge moves along an equipotential surface.
- $\Delta V = 0$, so the energy change $q\Delta V = 0$ – the field does no work; motion perpendicular to field lines changes nothing.

■ Write from a force pair in one field

- Between plates with $E = 6,000$ V per metre, charges of +2.0 and –2.0 micro-coulombs sit in turn.
- Each feels a 0.012 N force – SAME size, opposite directions: the field acts on the charge, never for it.

■ Write from a field between plates

- Parallel plates 0.040 m apart carry a potential difference of 160 V.
- $E = V \div d = 4,000$ V per metre, uniform between the plates – the field a charge feels everywhere in the gap.