Exercise walk-through

Electric fields and field lines ▪ 18.1

eXercise

You must be able to

- define **electric field strength** as force per unit positive charge
- use $F = qE$
- represent an electric field with **field lines**

Method — Field strength

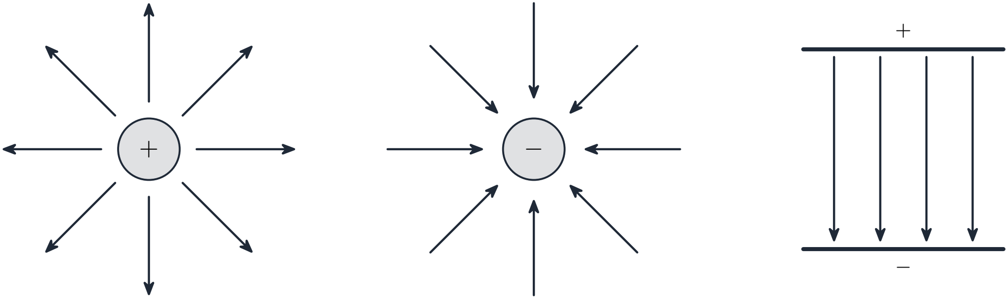
The **electric field strength** is the force per unit **positive** charge:

$$E = \frac{F}{q} \quad (\mathsf{N\ C}^{-1} = \mathsf{V\ m}^{-1}), \qquad F = qE.$$

Method — Field lines

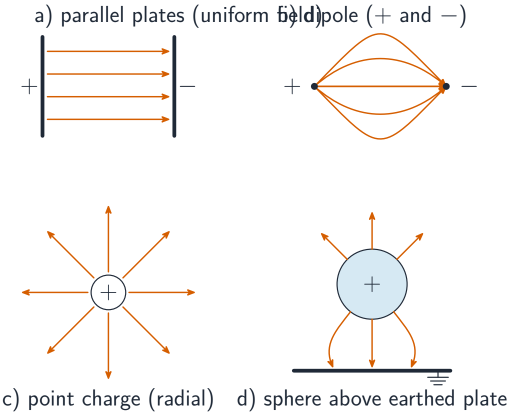
Field lines point the way the force acts on a **positive** charge: Outward from $+$, inward to $-$, and uniform between charged plates. Closer lines $\rightarrow$ stronger field.

Method — Field lines



(a) + charge (b) − charge (c) uniform

Method — Field lines



Electric field line patterns

Practice 2.1 ▪ 1 mark

Define **electric field strength**.

Solution 2.1

Worked steps

The **force per unit positive charge** on a small test charge $(E = F/q)$ B1.

Practice 2.2 ▪ 1 mark

State the unit of electric field strength.

Solution 2.2

Worked steps

N C^{-1} (or V m^{-1}) **B1**.

Practice 2.3 ▪ 1 mark

Write the equation for the **force** on a charge q in a field E.

Solution 2.3

Method: Field lines

Worked steps

$F = qE$ **B1**.

Practice 2.4 ▪ 1 mark

State the **direction** of the field lines around a **positive** point charge.

Solution 2.4

Method: Field lines

Worked steps

Outward (away from the charge) B1.

Exam-style 3.1 ▪ 1 mark

Electric field strength is the force per unit:

A mass

B positive charge

C area

D length

Solution 3.1

- **A** mass
- **B** positive charge ✓
- **C** area
- **D** length

Worked steps

B — positive charge.

Exam-style 3.2 ▪ 2 marks

A charge of 2.0×10^{-6} C experiences a force of 0.10 N in a field. Find the **field strength**.

Solution 3.2

Method: Field strength

Worked steps

$E = F/q = 0.10/(2.0 \times 10^{-6}) = 5.0 \times 10^{4}$ N C^{-1} **M1** **A1**.

Exam-style 3.3 ▪ 2 marks

Sketch the field lines around (a) a positive and (b) a negative point charge.

Solution 3.3

Method: Field lines

Worked steps

(a) radial lines pointing **outward** from the positive charge **B1**; (b) radial lines pointing **inward** to the negative charge **B1**.

Exam-style 3.4 ▪ 1 mark

Two parallel horizontal metal plates are 0.067 m apart in a vacuum, with a potential difference of 430 V between them. The upper plate is positive. An electron travels horizontally into the region between them at 2.6×10^{7} m s^{-1}. Take $e = 1.60 \times 10^{-19}$ C.

(a) **Define** electric field strength.

(b) **Describe** the pattern of the electric field between the plates, away from their edges, and **state** the direction of the field.

(c) **Determine** the electric field strength between the plates.

(d) **Determine** the magnitude and direction of the electric force on the electron.

(e) **Describe** the path of the electron while it is between the plates, and after it leaves them.

Exam-style 3.4 ▪ 1 mark

(f) A uniform magnetic field is now applied in the same region so that the electron passes through **undeviated**. **Determine** the flux density required, and **state** how the magnetic force must be directed.

Solution 3.4

Method: Field lines

Worked steps

(a) The **force per unit positive charge** acting at that point **B1**.

(b) The field lines are **straight, parallel and evenly spaced**, so the field is **uniform** **B1** **B1**; they run from the **positive** plate to the negative one, i.e. vertically **downwards** here **B1**.

(c) $E = \dfrac{V}{d} = \dfrac{430}{0.067}$ **M1** $= 6.4 \times 10^3$ V m^{-1} **A1**.

(d) $F = Eq = 6.4 \times 10^3 \times 1.60 \times 10^{-19}$ **M1** $= 1.0 \times 10^{-15}$ N **A1**, directed **upwards** — the field points down but the electron's charge is negative **A1**.

(e) Between the plates the horizontal velocity is unchanged while a constant vertical

Solution 3.4

force acts, so the path is a **parabola** curving upwards, towards the positive plate B1 B1. Beyond the plates there is no field, so it travels in a **straight line** in whatever direction it had on leaving B1.

(f) Undeviated means the magnetic force balances the electric one: $Bqv = Eq$, so $B = \frac{E}{v} = \frac{6.4 \times 10^3}{2.6 \times 10^7}$ M1 $= 2.5 \times 10^{-4}$ T A1. The magnetic force must be **downwards**, opposite to the electric force on the electron B1.