A-LEVEL PHYSICS • EXERCISE SHEET

# 18.1 Electric fields and field lines

Name: ____________ Class: ________ Date: __________ **Total: 24 marks**

**KEY WORDS** electric field 电场 • field line 场线 • force 力 • electric field strength 电场强度 • point charge 点电荷

## Objective

Build the skills to answer exam questions on the **electric field** — its definition and field lines.

**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**

## 1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

### ■ Field strength

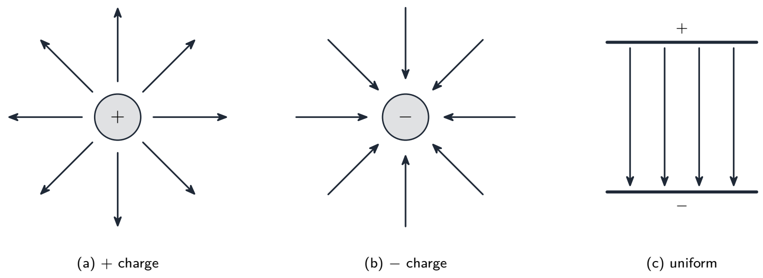
The **electric field strength** is the force per unit **positive** charge:

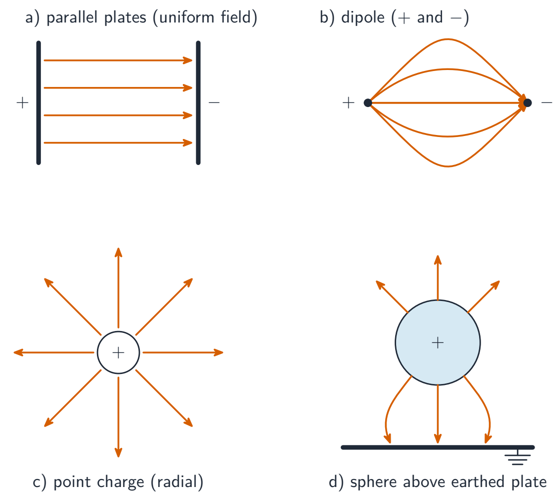
$$E = \frac{F}{q} \quad (\mathrm{N\ C^{-1} = V\ m^{-1}}), \qquad F = qE.$$

### ■ Field lines

Field lines point the way the force acts on a **positive** charge:






*Electric field line patterns*

Outward from +, inward to −, and uniform between charged plates. Closer lines → stronger field.

## 2 Practice

Now apply the methods above.

**2.1** Define **electric field strength**. [1]

**2.2** State the unit of electric field strength. [1]

**2.3** Write the equation for the **force** on a charge $q$ in a field $E$. [1]

**2.4** State the **direction** of the field lines around a **positive** point charge. [1]

## 3 Exam-style questions

**3.1** Electric field strength is the force per unit: [1]

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

**3.2** A charge of $2.0 \times 10^{-6}$ C experiences a force of 0.10 N in a field. Find the **field strength**. [2]

**3.3** Sketch the field lines around (a) a positive and (b) a negative point charge. [2]



**3.4** 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 $2.6 \times 10^{7}$ m s$^{-1}$. Take $e = 1.60 \times 10^{-19}$ C.

(a) **Define** electric field strength. [1]

(b) **Describe** the pattern of the electric field between the plates, away from their edges, and **state** the direction of the field. [3]

(c) **Determine** the electric field strength between the plates. [2]

(d) **Determine** the magnitude and direction of the electric force on the electron. [3]

(e) **Describe** the path of the electron while it is between the plates, and after it leaves them. [3]

(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. [3]



## Solutions

Each answer shows the steps, then the **result**.

**2.1**

- the **force per unit positive charge** on a small test charge ($E = F/q$)

**2.2**

- N C$^{-1}$ (or V m$^{-1}$)

**2.3**

- $F = qE$

**2.4**

- **outward** (away from the charge)

**3.1 B**

- field lines leave a **positive** charge

**3.2**

- $E = F/q$

$$E = \frac{0.10\ \text{N}}{2.0 \times 10^{-6}\ \text{C}} = \mathbf{5.0 \times 10^{4}}\ \text{N C}^{-1}$$

**3.3**

(a) radial lines pointing **outward** from the positive charge

(b) radial lines pointing **inward** to the negative charge

**3.4**

(a) the **force per unit positive charge** acting at that point

(b) the field lines are **straight, parallel and evenly spaced**, so the field is **uniform**

- they run from the **positive** plate to the negative one, i.e. vertically **downwards** here

(c) $E = V/d$

$$E = \frac{430\ \text{V}}{0.067\ \text{m}} = \mathbf{6.4 \times 10^{3}}\ \text{V m}^{-1}$$

(d) $F = Eq$

$$F = (6.4 \times 10^{3}\ \text{V m}^{-1})(1.60 \times 10^{-19}\ \text{C}) = \mathbf{1.0 \times 10^{-15}}\ \text{N}$$

- directed **upwards** — the field points down but the electron's charge is negative

(e) between the plates the horizontal velocity is unchanged while a constant vertical force acts, so the path is a **parabola** curving upwards, towards the positive plate

- beyond the plates there is no field, so it travels in a **straight line** in whatever direction it had on leaving

(f) undeviated means the magnetic force balances the electric one: $Bqv = Eq$, so $B = E/v$

$$B = \frac{6.4 \times 10^3 \text{ V m}^{-1}}{2.6 \times 10^7 \text{ m s}^{-1}} = \mathbf{2.5 \times 10^{-4}} \text{ T}$$

- the magnetic force must be **downwards**, opposite to the electric force on the electron