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.

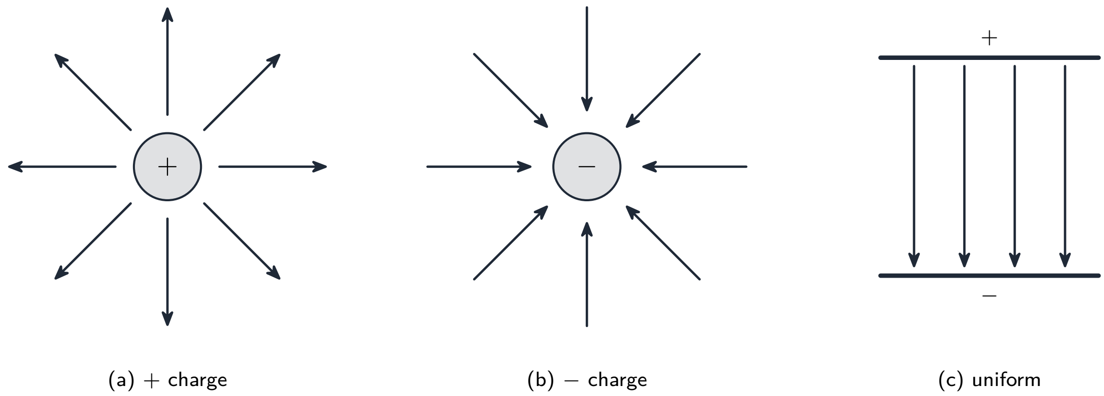
Field strength

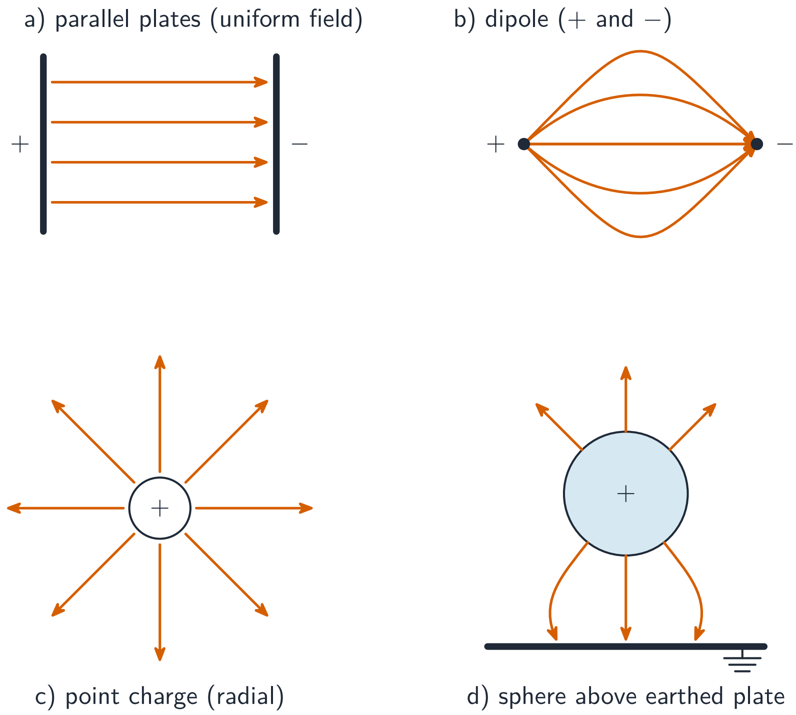
The **electric field strength** is the force per unit **positive** charge:

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

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 $\rightarrow$ 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 2.0×10^{-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 2.6×10^{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

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** — positive charge.

3.2 $E = F/q = 0.10/(2.0 \times 10^{-6}) = 5.0 \times 10^4$ 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) $E = \dfrac{V}{d} = \dfrac{430}{0.067} = 6.4 \times 10^3$ V m^{-1}.
(d) $F = Eq = 6.4 \times 10^3 \times 1.60 \times 10^{-19} = 1.0 \times 10^{-15}$ 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 $B = \dfrac{E}{v} = \dfrac{6.4 \times 10^3}{2.6 \times 10^7} = 2.5 \times 10^{-4}$ T. The magnetic force must be **downwards**, opposite to the electric force on the electron.