A-LEVEL PHYSICS • EXERCISE SHEET

18.2 Uniform electric fields

Name: _____ Class: _____ Date: _____ **Total: 17 marks**

KEY WORDS electric field 电场 • uniform field 匀强场 • field line 场线 • electron 电子 • parabolic 抛物线

Objective

Build the skills to answer exam questions on **uniform electric fields** between parallel plates.

You must be able to:

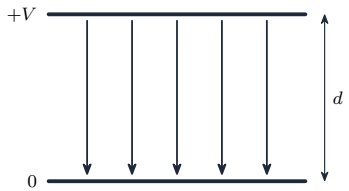
- use $E = V/d$ for the field between parallel plates
- describe the motion of a **charged particle** in a uniform field

1 Worked examples

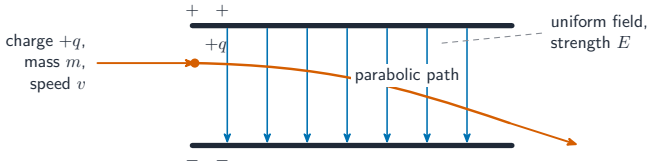
Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ Field between plates

Between parallel plates a distance d apart with p.d. V, the field is **uniform**:



$E = V/d$



A charge follows a parabola in a uniform field

$$E = \frac{V}{d} \quad (\text{V m}^{-1} = \text{N C}^{-1}),$$

pointing from the **higher** to the **lower** potential plate.

■ Charged particle in the field

A charge in the field feels a **constant force** $F = qE$, so it has a **constant acceleration** $a = \dfrac{F}{m} = \dfrac{qE}{m}$. A particle entering **perpendicular** to the field follows a **parabolic** path (like a projectile in gravity); a particle released **from rest** accelerates straight along the field, towards the plate of **opposite** sign to its charge.

Worked example. Plates 5.0 mm apart, 200 V: $E = \dfrac{200}{5.0 \times 10^{-3}} = 4.0 \times 10^{4}$ V m^{-1}; force on an electron $= qE = (1.6 \times 10^{-19})(4.0 \times 10^{4}) = 6.4 \times 10^{-15}$ N; acceleration $a = \dfrac{F}{m} = \dfrac{6.4 \times 10^{-15}}{9.1 \times 10^{-31}} = 7.0 \times 10^{15}$ m s^{-2}.

2 Practice

Now apply the methods above.

2.1 Write the equation for the field strength between **parallel plates**. [1]

2.2 Two plates 5.0 mm apart have a p.d. of 200 V. Find the **field strength**. [2]

2.3 State the **direction** of the field between two charged plates. [1]

2.4 State the unit equal to V m^{-1}. [1]

3 Exam-style questions

3.1 The electric field between two parallel charged plates is: [1]

- **A** radial
- **B** uniform
- **C** zero
- **D** circular

3.2 Two plates 5.0 mm apart have a p.d. of 200 V. Calculate (a) the field strength, (b) the force on an electron in the gap. ($e = 1.6 \times 10^{-19}$ C.) [3]

3.3 Describe the **path** of an electron that enters the uniform field **perpendicular** to the field lines. [2]

3.4 State what happens to the force on a charge if the plate separation is **halved** (same p.d.). [1]

3.5 An electron is released from rest at the negative plate of two plates 8.0 mm apart with a p.d. of 250 V. ($e = 1.6 \times 10^{-19}$ C, $m_e = 9.1 \times 10^{-31}$ kg.)

(a) Calculate the field strength between the plates. [2]

(b) Calculate the **acceleration** of the electron. [3]

Solutions

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

2.1

- $E = V/d$

2.2

- $E = V/d$

$$E = \frac{200\ \text{V}}{5.0 \times 10^{-3}\ \text{m}} = \mathbf{4.0 \times 10^{4}}\ \text{V m}^{\mathbf{-1}}$$

2.3

- from the **higher-potential** plate to the **lower-potential** plate

2.4

- N C^{-1}

3.1 B

- parallel plates a small distance apart give a **uniform** field

3.2

(a) $E = V/d$

$$E = \frac{200\ \text{V}}{5.0 \times 10^{-3}\ \text{m}} = \mathbf{4.0 \times 10^{4}}\ \text{V m}^{\mathbf{-1}}$$

(b) $F = qE$

$$F = (1.6 \times 10^{-19}\ \text{C})(4.0 \times 10^{4}\ \text{V m}^{-1}) = \mathbf{6.4 \times 10^{-15}}\ \text{N}$$

3.3

- it follows a **parabolic** path
- constant velocity along the plates, constant acceleration across the field (like a projectile)

3.4

- the force **doubles** ($E = V/d$, so halving d doubles E and hence $F = qE$)

3.5

(a) $E = V/d$

$$E = \frac{250\ \text{V}}{8.0 \times 10^{-3}\ \text{m}} = \mathbf{3.1 \times 10^{4}}\ \text{V m}^{\mathbf{-1}}$$

(b) $F = qE$

$$F = (1.6 \times 10^{-19}\ \text{C})(3.1 \times 10^{4}\ \text{V m}^{-1}) = 5.0 \times 10^{-15}\ \text{N}$$

- $a = F/m$

$$a = \frac{5.0 \times 10^{-15}\ \text{N}}{9.1 \times 10^{-31}\ \text{kg}} = \mathbf{5.5 \times 10^{15}}\ \text{m s}^{\mathbf{-2}}$$