

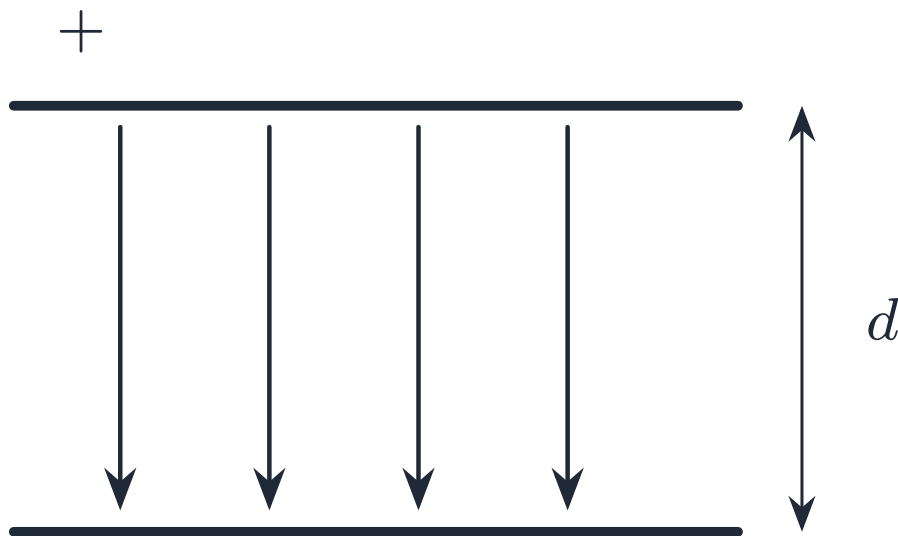
Exercise walk-through

18.2

Uniform electric fields

A-Level Physics

The uniform field between plates



$$E = V/d$$

Plates a distance d apart with p.d. V across them:

$$E = \frac{V}{d}$$

pointing from the **high**-potential plate to the low.

This is where V m^{-1} comes from – and it is the **same unit** as N C^{-1} .

Worked example – plates and an electron

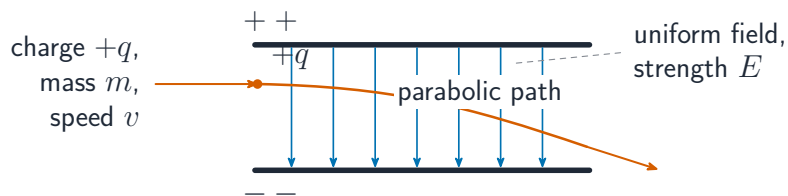
Plates 5.0 mm apart carry a p.d. of 200 V. Find E , and the force on an electron between them. ($e = 1.6 \times 10^{-19} \text{ C}$)

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

$$F = qE = (1.6 \times 10^{-19})(4.0 \times 10^4) = 6.4 \times 10^{-15} \text{ N}$$

Convert **mm to m** first – forgetting it scales E by a thousand. The force is the **same everywhere** in the gap: that is what uniform means.

A charge crossing a uniform field



Constant force $\Rightarrow$ constant acceleration

$$a = qE/m:$$

- released **at rest**: speeds up along the field, gaining KE
- entering **at right angles**: a **parabolic** path

Exactly a **projectile** problem
 – steady velocity across, uniform acceleration down. This is how a **cathode-ray tube** steered its beam.

Two ways a charge is set moving

Released at rest

It accelerates along the field (positive charge) or against it (negative), gaining **kinetic energy** qV after falling through a potential difference V .

Fired across

Constant velocity along the plates, constant acceleration across them – the same parabola as a projectile.

In an atom

An **electron** orbiting a **nucleus** of charge $+Ze$ at radius r : the Coulomb attraction supplies the **centripetal force**

$$, \frac{Ze^2}{4\pi\epsilon_0 r^2} = \frac{mv^2}{r}.$$

Energy method or force method – both work. Use energy when the question gives a potential difference, force when it gives a field.

Exercises 2.1-2.3

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]

Exercises 2.1-2.3

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

2.1

- $E = V/d$

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

2.2

- $E = V/d$

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

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

2.3

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

Exercises 2.4·3.1

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

[1]

3.1 The electric field between two parallel charged plates is:

[1]

☐

A radial

B uniform

C zero

D circular

Exercises 2.4·3.1

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

2.4

- N C^{-1}

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

☐

A radial

B uniform

C zero

D circular

3.1 B

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

Exercises 3.2-3.3

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]

Exercises 3.2·3.3

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]

3.2

(a) $E = V/d$

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

(b) $F = qE$

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

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

3.3

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

Exercise 3.4

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

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3.4

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

Exercise 3.5 (a)

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]

Exercise 3.5 (a)

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]

(a) $E = V/d$

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

Exercise 3.5 (b)

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.)

(b) Calculate the **acceleration** of the electron.

[3]

Exercise 3.5 (b)

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.)

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

(b) $F = qE$

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

• $a = F/m$

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