

18.5 Electric potential

Name: _____ Class: _____ Date: _____

Total: 17 marks

Objective

Build the skills to answer exam questions on **electric potential** and electric potential energy.

You must be able to:

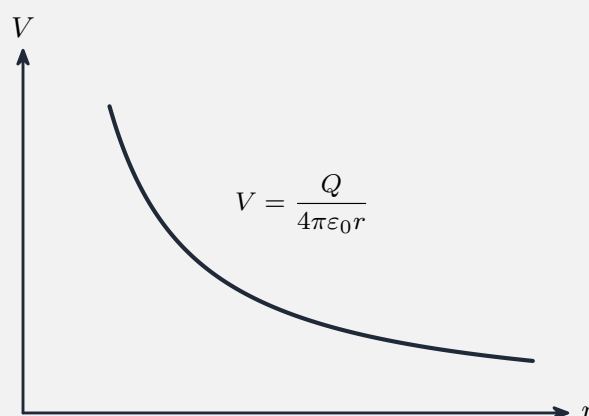
- define **electric potential** and use $V = \frac{Q}{4\pi\epsilon_0 r}$
- use $E_P = \frac{Qq}{4\pi\epsilon_0 r}$ and $E = -\text{potential gradient}$

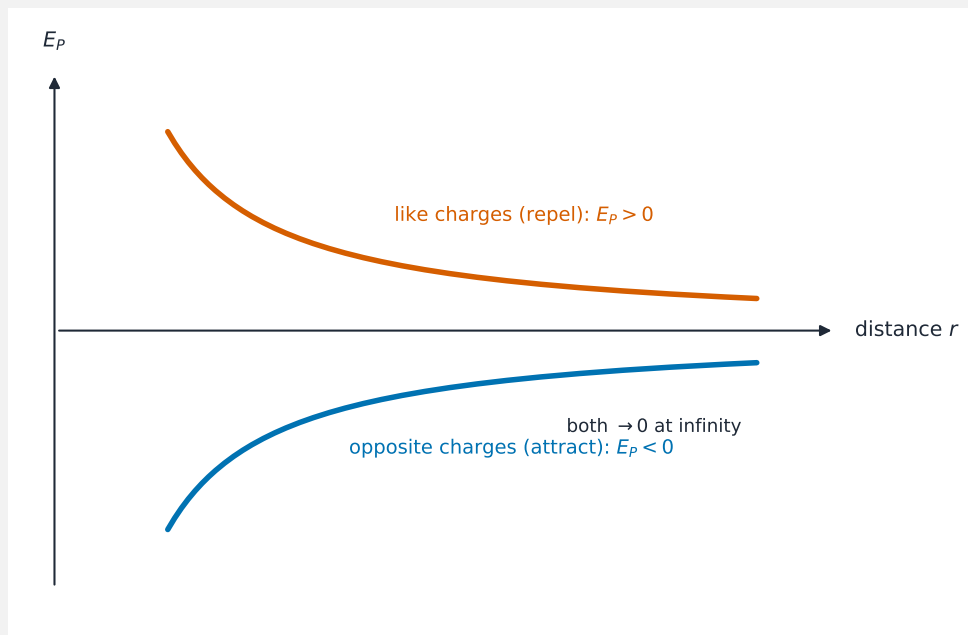
1 Worked examples

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.

■ Electric potential

Electric potential at a point is the **work done per unit positive charge** to bring a small test charge from **infinity** to that point (zero at infinity):





Electric potential energy near a charge

$$V = \frac{Q}{4\pi\epsilon_0 r}, \quad E_P = \frac{Qq}{4\pi\epsilon_0 r}, \quad E = -\frac{\Delta V}{\Delta r}.$$

For a **positive** charge $V > 0$ (falling to zero); for a **negative** charge $V < 0$.

■ Adding potentials (a scalar)

Potential is a **scalar**, so the total potential from several charges is the **algebraic sum** (keep the signs) —no directions or vectors:

$$V = \sum \frac{Q_i}{4\pi\epsilon_0 r_i}.$$

Worked example. Point P is 0.10 m from a +4.0 nC charge and 0.20 m from a +6.0 nC charge: $V = \frac{(9.0 \times 10^9)(4.0 \times 10^{-9})}{0.10} + \frac{(9.0 \times 10^9)(6.0 \times 10^{-9})}{0.20} = 360 + 270 = 630 \text{ V}.$

Between a **positive** and a **negative** charge, the potentials have opposite sign, so there is a point where they **cancel** ($V = 0$): where $\frac{|Q_1|}{r_1} = \frac{|Q_2|}{r_2}.$

2 Practice

Now apply the methods above.

2.1 Define electric potential.

[1]

2.2 Write the equation for the potential V due to a point charge. [1]

2.3 Write the equation for the **electric potential energy** of two point charges. [1]

2.4 State the relationship between the **field** E and the **potential gradient**. [1]

3 Exam-style questions

3.1 The electric potential at **infinity** is: [1]

- **A** a maximum
 - **B** zero
 - **C** always negative
 - **D** infinite
-

3.2 Calculate the electric potential at 0.050 m from a +3.0 nC point charge. ($\frac{1}{4\pi\epsilon_0} = 9.0 \times 10^9$.) [3]

3.3 Calculate the electric potential energy of a +2.0 nC and a +3.0 nC charge placed 4.0 cm apart. [2]

3.4 State **one** difference between the electric potential near a **positive** charge and near a **negative** charge. [1]

3.5 A +5.0 nC charge is at point A and a −2.0 nC charge is at point B, 0.21 m away on

the line AB.

(a) Explain why the total potential is found by **adding** the two potentials, including their signs. [1]

(b) Find the distance from A, on the line AB, where the total potential is **zero**. [3]

4 Go further

You are now ready for the real exam questions on this subtopic. Open the **18.5 Electric potential** past-paper sheet in the Library, or try these in **Practice mode**:

- 9702/41 N25 —Q5 (electric potential, two charges)
- 9702/43 N25 —Q5 (potential and potential energy)
- 9702/44 N25 —Q5 (electric potential)
- 9702/44 J25 —Q5 (potential, structured)
- 9702/42 M25 —Q2 (electric potential)

Solutions

2.1 The **work done per unit positive charge** in bringing a small test charge from **infinity** to that point.

2.2 $V = \frac{Q}{4\pi\epsilon_0 r}$.

2.3 $E_P = \frac{Qq}{4\pi\epsilon_0 r}$.

2.4 The field is the **negative of the potential gradient**: $E = -\frac{\Delta V}{\Delta r}$.

3.1 B —zero.

3.2 $V = \frac{(9.0 \times 10^9)(3.0 \times 10^{-9})}{0.050} = 540 \text{ V}$.

3.3 $E_P = \frac{(9.0 \times 10^9)(2.0 \times 10^{-9})(3.0 \times 10^{-9})}{0.040} = 1.35 \times 10^{-6} \text{ J}$.

3.4 Near a **positive** charge the potential is **positive**; near a **negative** charge it is **negative**.

3.5 (a) Potential is a **scalar**, so the contributions simply add (algebraically, keeping their signs) —there are no directions to resolve.

3.5 (b) $V = 0$ where the magnitudes cancel: $\frac{5.0}{x} = \frac{2.0}{0.21 - x}$; $5.0(0.21 - x) = 2.0x \Rightarrow 1.05 = 7.0x$; $x = 0.15 \text{ m}$ from A.