

18.5 Electric potential

Name: _____ Class: _____ Date: _____

Total: 27 marks

KEY WORDS electric potential 电势 • electric potential energy 电势能
• potential gradient 电势梯度 • point charge 点电荷 • test charge 检验电荷

Objective

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

You must be able to:

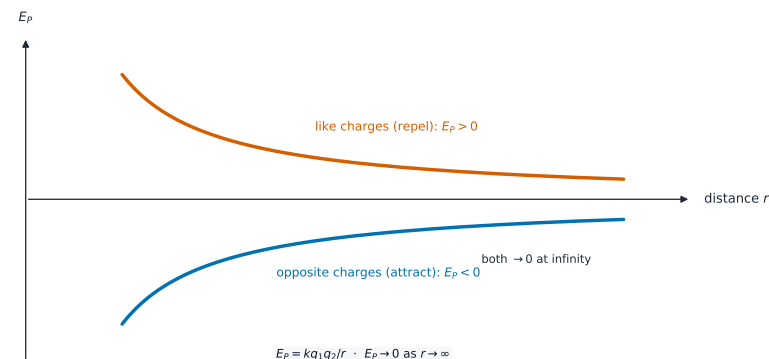
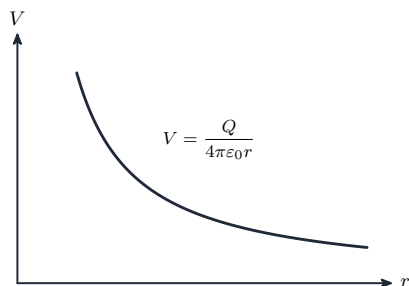
- define **electric potential** and use $V = \frac{Q}{4\pi\epsilon_0 r}$
- use $E_P = \frac{Qq}{4\pi\epsilon_0 r}$ and $E = -\text{potential gradient}$

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 | B |
| C | D |
- 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]

3.6 Two point charges are fixed on a straight line. Charge A, of +4.0 pC, is at the origin; charge B, of −1.0 pC, is at $x = +40$ pm. Take $\frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ m F}^{-1}$.

(a) **Define** the **electric potential** at a point. [2]

(b) **Show that** the electric potential due to charge A alone, at $x = 10$ pm, is about 3.6 V. [2]

(c) **Calculate**, to two significant figures, the **total** potential at $x = 10$ pm due to both charges. [3]

(d) **Determine** the position on the line **between** the two charges at which the total electric potential is **zero**. [3]

(e) **State and explain** whether the electric **field** is also zero at that position. [2]