

Exercise walk-through

9.2

Electric Potential

AP Physics C: Electricity and Magnetism

Electric potential (voltage)

Electric potential is energy per unit charge – a **scalar**:

Point charge, sum, integral

$$V = \frac{U}{q} = k \frac{q}{r}$$

$$V = k \sum_i \frac{q_i}{r_i} = k \int \frac{dq}{r}$$

Adding potentials is **easy** – just add numbers with signs, no vectors.

Worked example

+3 nC and -3 nC, each 2 m away:

$$V = k \left(\frac{+3}{2} + \frac{-3}{2} \right) \times 10^{-9} = 0$$

Yet $\vec{E} \neq 0$ there – V and $\vec{E}$ tell different stories.

Potential and field

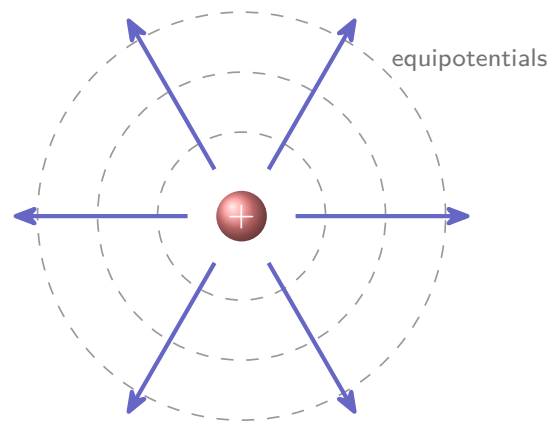
Field and potential are linked by calculus:

Integrate, or take the gradient

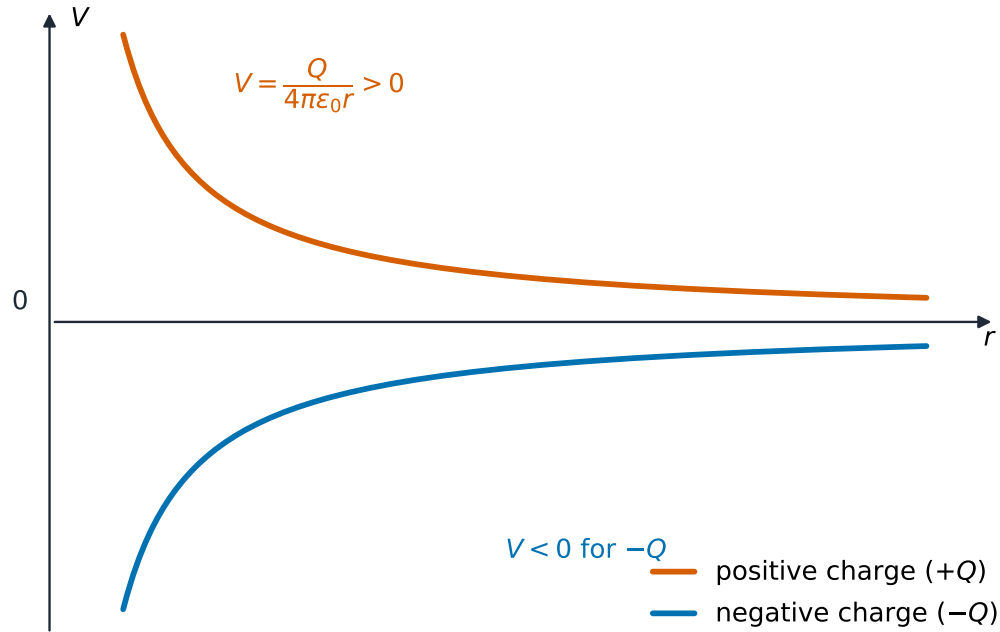
$$V = - \int \vec{E} \cdot d\vec{l}, \quad \vec{E} = -\nabla V$$

In 1-D, $E_x = -\frac{dV}{dx}$: the field points **downhill** in V .

Equipotentials are **always** perpendicular to field lines; no work moving along one.

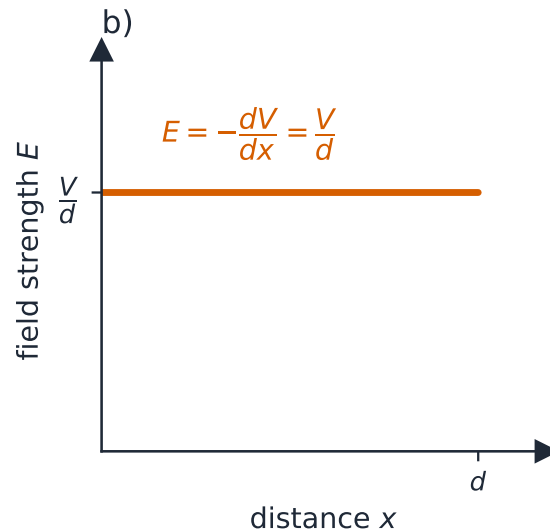
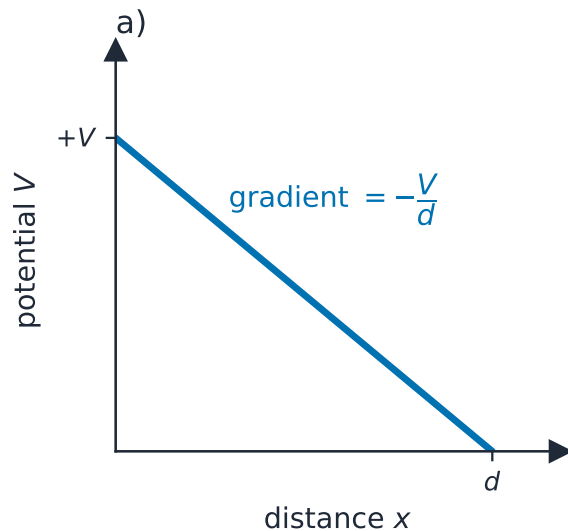


The potential near a point charge varies as – one



The potential near a point charge varies as $1/r$

The potential near a point charge varies as – two



In a uniform field the potential falls steadily with distance

Equipotential maps

- Isolines are **perpendicular** to field lines everywhere they cross.
- $\vec{E}$ points from high V to low V – never along an isoline. Moving a charge along an isoline takes no work.
- Closely spaced isolines mean a strong field: $E \approx -\Delta V/\Delta x$.
- You can sketch the field map from an isoline map, and the isoline map from a field map.

Exercises 2.1-2.3

2.1 Find the potential 0.30 m from a $+6.0 \mu\text{C}$ charge ($k = 8.99 \times 10^9$). [2]

2.2 State the relationship between equipotential surfaces and field lines. [1]

2.3 State whether electric potential is a scalar or a vector. [1]

Exercises 2.1-2.3

2.1 Find the potential 0.30 m from a $+6.0 \mu\text{C}$ charge ($k = 8.99 \times 10^9$). [2]

2.1

- $$V = k \frac{q}{r} = 8.99 \times 10^9 \times \frac{6.0 \times 10^{-6}}{0.30} = 1.8 \times 10^5 \text{ V}$$

2.2 State the relationship between equipotential surfaces and field lines. [1]

2.2

- they are perpendicular to each other
-

2.3 State whether electric potential is a scalar or a vector. [1]

2.3

- a scalar

Exercise 3.1

3.1 The electric potential of a point charge is

[1]

- ☐ **A** $k \frac{q}{r^2}$
- B** $k \frac{q}{r}$
- C** $k \frac{q^2}{r}$
- D** qE

Exercise 3.1

3.1 The electric potential of a point charge is

[1]

☐

A $k \frac{q}{r^2}$

B $k \frac{q}{r}$

C $k \frac{q^2}{r}$

D qE

3.1 B

- $k \frac{q}{r}$.

Exercise 3.2

3.2 Equipotential surfaces are always _____ to the electric field.

[1]

☐

A parallel

B perpendicular

C at 45°

D unrelated

Exercise 3.2

3.2 Equipotential surfaces are always _____ to the electric field.

[1]

☐

A parallel

B perpendicular

C at 45°

D unrelated

3.2 B

- perpendicular.

Exercise 3.3 (a)

3.3 Two $+4.0 \mu\text{C}$ charges are 0.40 m apart.

(a) Find the potential at the midpoint between them.

[3]

Exercise 3.3 (a)

3.3 Two $+4.0 \mu\text{C}$ charges are 0.40 m apart.

(a) Find the potential at the midpoint between them. [3]

(a)

- each charge is 0.20 m from the midpoint: $V = 2 \times k \frac{q}{r} = 2 \times 8.99 \times 10^9 \times \frac{4.0 \times 10^{-6}}{0.20} = 3.6 \times 10^5 \text{ V}$

Exercise 3.3 (b)

3.3 Two $+4.0 \mu\text{C}$ charges are 0.40 m apart.

(b) State why the two potentials can simply be added.

[1]

Exercise 3.3 (b)

3.3 Two $+4.0 \mu\text{C}$ charges are 0.40 m apart.

(b) State why the two potentials can simply be added.

[1]

(b)

- potential is a scalar, so contributions add directly (no direction)