Electric Potential

AP Physics C: E&M ▪ Unit 9

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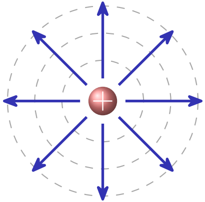
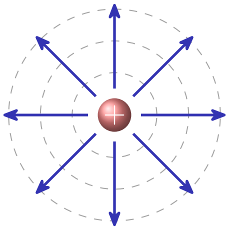


What we will cover

1. Electric potential energy
2. Electric potential (voltage)
3. Potential and field
4. Conservation of electric energy



Electric potential energy

Electric potential energy 电势能 is the work to assemble charges from infinity:

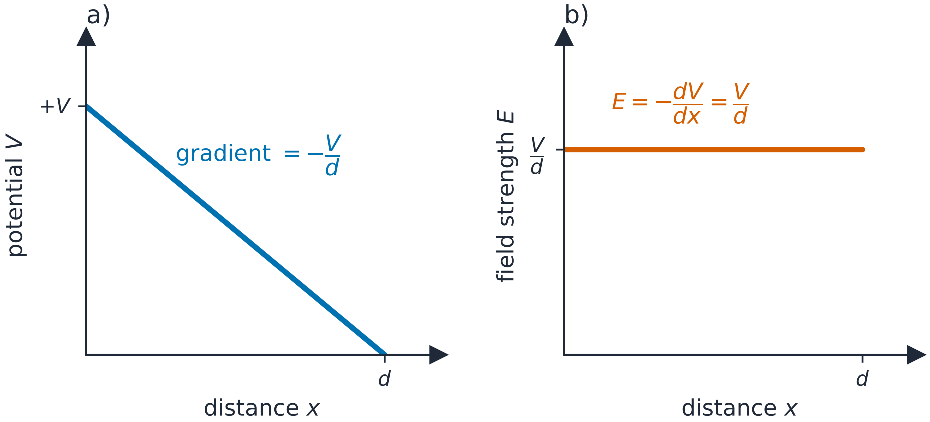
A pair, and a system

$$U = k\frac{q_1 q_2}{r}, \qquad U_{tot} = k\sum_{\text{pairs}} \frac{q_i q_j}{r_{ij}}$$

Like charges: $U > 0$ (fly apart). Unlike: $U < 0$ (a well). Note r, not r^2; $W = -\Delta U$.

power Lines

Electric potential energy



Electric potential (voltage)

Electric potential 电势 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.

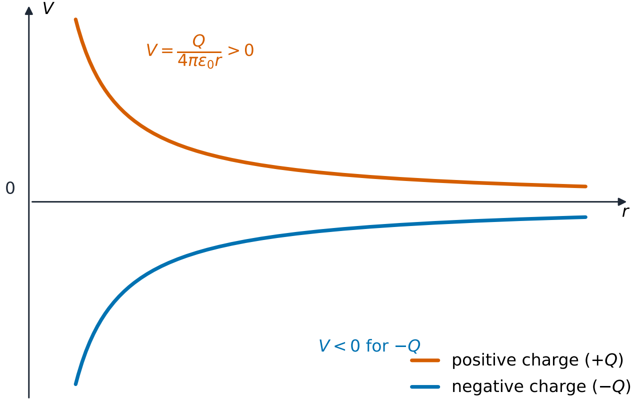
Worked example

$+3\,\mathrm{nC}$ and $-3\,\mathrm{nC}$, each $2\,\mathrm{m}$ away:

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

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

Electric potential (voltage)



Potential and field

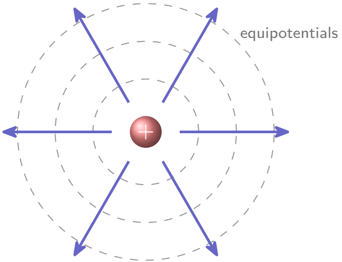
Field and potential are linked by calculus:

Integrate, or take the gradient

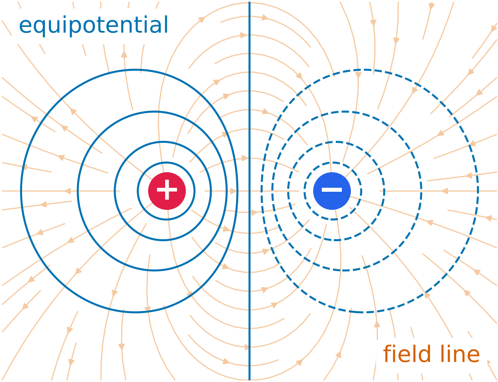
$$V = -\int \vec{E} \cdot d\vec{l}, \qquad \vec{E} = -\nabla V$$

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

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



Potential and field



Conservation of electric energy

Moving a charge through a **potential difference** 电势差 does work:

Work and kinetic energy

$$W = q\,\Delta V, \qquad \Delta K = q\,\Delta V$$

- a + charge speeds up moving to lower V
- 1 **eV** 电子伏特 $= 1.6 \times 10^{-19}\,\mathrm{J}$ (an energy)

Worked example

An electron through $200\,\mathrm{V}$:

$$\Delta K = 200\,\mathrm{eV} = 3.2 \times 10^{-17}\,\mathrm{J}$$

$$v = \sqrt{\frac{2\,\Delta K}{m}} \approx 8.4 \times 10^{6}\,\mathrm{m/s}$$

Unit 9 – key takeaways

1 Energy

$U = kq_1 q_2/r$; sum over distinct pairs; $W = -\Delta U$

2 Potential

$V = kq/r$, a scalar; $V = k\int dq/r$ for distributions

3 Field link

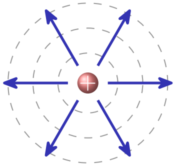
$V = -\int \vec{E} \cdot d\vec{l}$, $\vec{E} = -\nabla V$; equipotentials $\perp$ field

4 Conservation

$\Delta K = q\Delta V$; energy in electron volts

Check yourself

1. Is electric potential a scalar or a vector?
2. How do you get the field from the potential?
3. How much work moves a charge along an equipotential?
4. An electron falls through $50\,\mathrm{V}$ – how much energy in eV?



Answers **1.** a scalar **2.** $\vec{E} = -\nabla V$ **3.** zero **4.** $50\,\mathrm{eV}$