

Exercise walk-through

9.1

Electric Potential Energy

AP Physics C: Electricity and Magnetism

Electric potential energy

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

A pair, and a system

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

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



Power lines

The electric force is conservative

conservative force

the work it does depends only on the **start and end points**, never the path taken

so

$W_{\text{elec}} = -\Delta U_E$ – a potential energy exists at all only because of this

a group of charges

add the **superposition**

of every **pair**, counting each pair once: $U_{\text{tot}} =$

$$k \left(\frac{q_1 q_2}{r_{12}} + \frac{q_1 q_3}{r_{13}} + \frac{q_2 q_3}{r_{23}} \right)$$

signs matter

U is a **scalar** with a sign – carry the sign of each q into the sum, do not take magnitudes

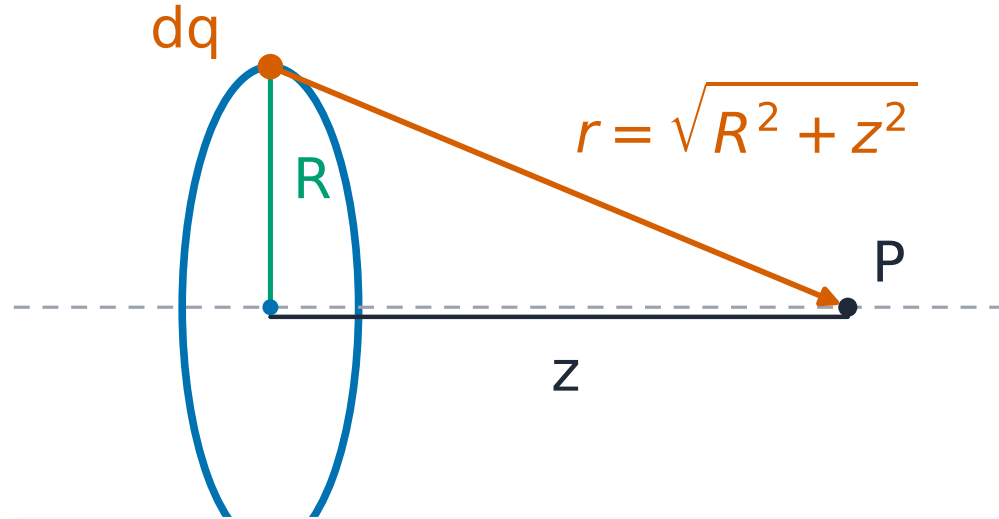
Three charges give **three** pairs, four give six. Count the pairs before you write the sum and you will not lose a term.

Continuous charge distributions

For a **continuous charge distribution**, cut it into small pieces dq , treat each piece as a point charge, and **integrate** :

AP expects you to handle four shapes with calculus: a thin ring (at a point on its axis), an arc (at its centre), a finite line or wire (collinear, or on its perpendicular bisector).

Continuous charge distributions, in detail



$$V = \frac{1}{4\pi\epsilon_0} \frac{Q}{\sqrt{R^2 + z^2}} \quad (\text{all } dq \text{ share the same } r)$$

A ring of charge: every element dq is the same distance from an axis point

Potential is easier than field, and here is why

V is a scalar

no components, no cancellation – just add $\frac{k dq}{r}$ over the distribution

a ring or arc

every element sits the **same** distance r from the centre, so $V = \frac{kQ}{R}$ whatever the arc's shape

say it

“ r is the same for every element” is the **marked step** on the FRQ – write the sentence, not just the answer

potential difference

$\Delta V = \Delta U_E / q$: the energy change per unit charge moved. A battery is a device that maintains one

When a question asks for a *field*, you must handle direction. When it asks for a *potential*, you never do – so reach for V whenever the question lets you.

Exercises 2.1-2.3

2.1 Find the potential energy of a $+3.0 \mu\text{C}$ and a $-2.0 \mu\text{C}$ charge 0.40 m apart ($k = 8.99 \times 10^9$). [2]

2.2 State the sign of the potential energy of two like charges. [1]

2.3 The electric force does $+6.0 \text{ J}$ of work on a charge. State the change in its potential energy. [1]

Exercises 2.1-2.3

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2.1

- $$U = k \frac{q_1 q_2}{r} = 8.99 \times 10^9 \times \frac{(3.0 \times 10^{-6})(-2.0 \times 10^{-6})}{0.40} = -0.13 \text{ J}$$

2.2 State the sign of the potential energy of two like charges. [1]

2.2

- positive

2.3 The electric force does $+6.0 \text{ J}$ of work on a charge. State the change in its potential energy. [1]

2.3

- $$\Delta U = -6.0 \text{ J}$$

Exercise 3.1

3.1 The electric potential energy of two point charges is

[1]

☐

A $k \frac{q_1 q_2}{r^2}$

B $k \frac{q_1 q_2}{r}$

C qE

D $\frac{1}{2}CV^2$

Exercise 3.1

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3.1 B

• $k \frac{q_1 q_2}{r}$.

Exercise 3.2

3.2 The work done by the electric force equals

[1]

☐

A $+\Delta U$

B $-\Delta U$

C ΔU^2

D zero always

Exercise 3.2

3.2 The work done by the electric force equals

[1]

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A $+\Delta U$

B $-\Delta U$

C ΔU^2

D zero always

3.2 B

- $-\Delta U$.

Exercise 3.3 (a)

3.3 Three $+2.0 \mu\text{C}$ charges sit at the corners of an equilateral triangle of side 0.30 m.

(a) Find the potential energy of **one** pair.

[2]

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(a) Find the potential energy of **one** pair. [2]

(a)

- $$U = k \frac{q^2}{r} = 8.99 \times 10^9 \times \frac{(2.0 \times 10^{-6})^2}{0.30} = 0.12 \text{ J}$$

Exercise 3.3 (b)

3.3 Three $+2.0 \mu\text{C}$ charges sit at the corners of an equilateral triangle of side 0.30 m .

(b) State the total potential energy of the system.

[2]

Exercise 3.3 (b)

3.3 Three $+2.0 \mu\text{C}$ charges sit at the corners of an equilateral triangle of side 0.30 m .

(b) State the total potential energy of the system. [2]

(b)

- three identical pairs, so $U_{\text{total}} = 3 \times 0.12 = 0.36 \text{ J}$