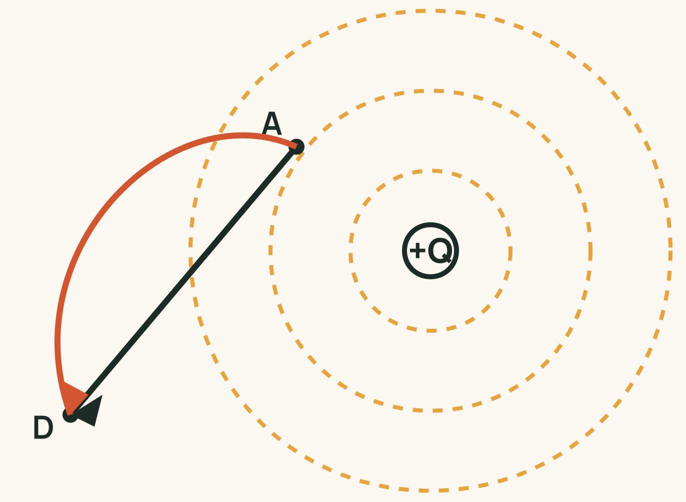
ELECTROSTATICS

Electric Potential Energy & Electric Potential

From the energy of one charge to a property of the field itself.



ESSENTIAL QUESTION

What is electric potential — and how is it different from potential energy and field strength?

Build potential in four moves.

01

STORE

The electric force is conservative, so a charge has potential energy.

02

DEPEND

That energy grows with the charge — it isn't the field alone.

03

DIVIDE

Divide energy by charge to get potential, a field property.

04

READ

Use potential to compare points and tell it from E.

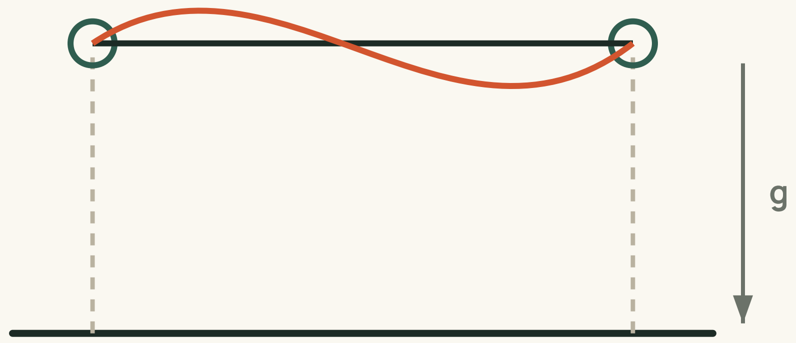
KEEP THIS IN MIND

Potential energy belongs to a charge. Potential belongs to the field.

RECALL

Gravity already taught us this idea.

Lift a ball and gravity stores energy you can get back — no matter which path you take.



Because gravity is conservative

PE depends only on height
not on the path taken

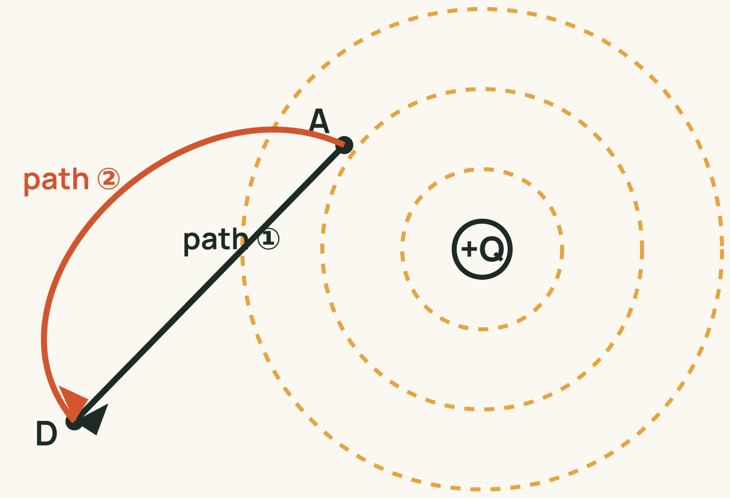
W work done sets the energy change
$W = E_{p1} - E_{p2}$

The electric force behaves the same way. Let's see why.

OBSERVE

Moving a charge: the path doesn’t matter.

Around a source charge $+Q$, the work to carry a charge from A to D is the same for every path.



WHAT THIS MEANS

The electric force is conservative. Work depends only on the start and end points.

So we can give each point an **electric potential energy** E_p — the energy stored by a charge sitting there.

MODEL

Work done by the field = drop in potential energy.

Exactly like gravity: when the field does positive work, stored energy falls.

$$W_{AB} = E_{pA} - E_{pB}$$

POSITIVE WORK · $W_{AB} > 0$

The field pushes the charge along. Potential energy **decreases**.

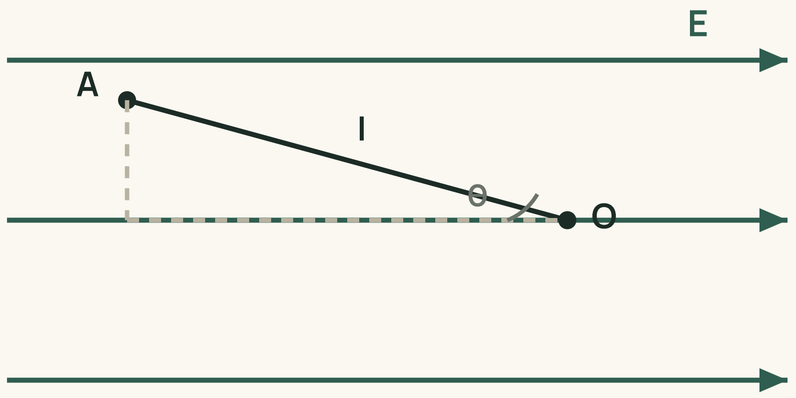
NEGATIVE WORK · $W_{AB} < 0$

You push against the field. Potential energy **increases**.

THE CATCH

But this energy depends on the charge.

In a uniform field E, a charge at point A (distance l, angle θ) stores:



$$E_p = qEl\cos\theta$$

q	energy $Eql\cos\theta$
$2q$	energy $2Eql\cos\theta$ — twice as much

Double the charge → double the energy. So E_p describes the charge, not just the field.

KEY INSIGHT

Divide out the charge — what’s left is the field's.

For every test charge at the same point, the ratio E_p/q comes out the same.

$$\frac{E_p}{q} = \text{the same value for any charge} \quad \Longrightarrow \quad \varphi = \frac{E_p}{q}$$

This ratio is a property of the point in the field — the electric potential φ.

THE PARALLEL

Two field properties, built the same way.

Each one divides a charge's experience by the charge itself.

FIELD STRENGTH · FORCE PER CHARGE

$$E = \frac{F}{q}$$

Vector. How hard the field pushes one unit of charge.

Units: $\mathrm{N/C}$

POTENTIAL · ENERGY PER CHARGE

$$\varphi = \frac{E_p}{q}$$

Scalar. How much potential energy one unit of charge has.

Units: $\mathrm{V = J/C}$

PROPERTIES

What potential tells you about a point.

It is a scalar attached to the field, fixed once you choose a zero.

+

SIGN

Take zero at infinity: potential is positive near $+Q$, negative near $-Q$.

↓

FALLS ALONG FIELD LINES

Move along a field line and potential **drops** — the field points "downhill".

0

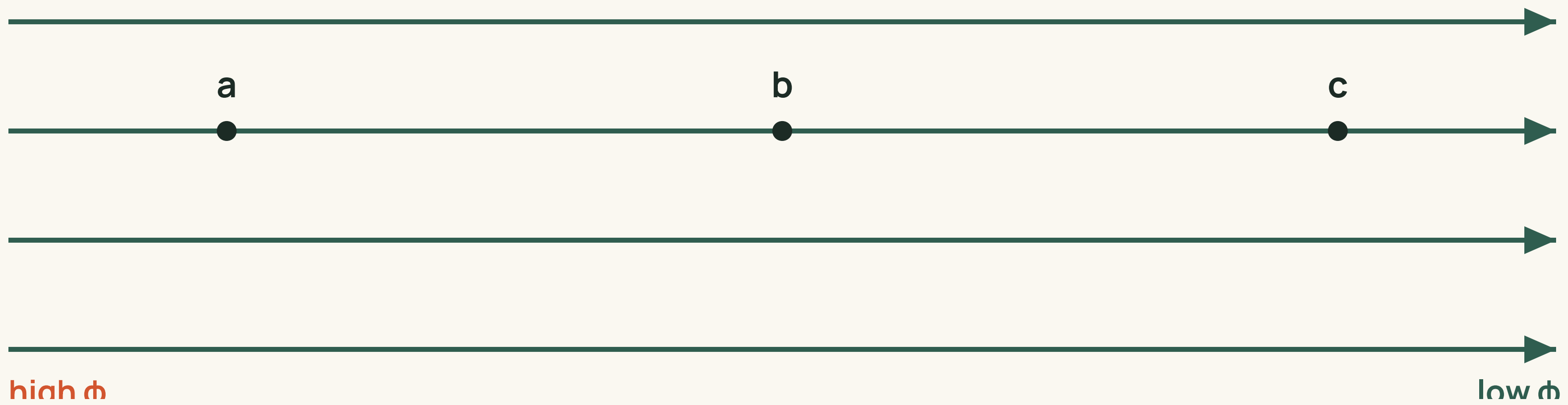
REFERENCE

Only differences matter; the zero point is a choice (often infinity or earth).

READ IT

Field lines point from high to low potential.

Denser lines mean a stronger field E; following a line, the potential φ always decreases.



$$\varphi_a > \varphi_b > \varphi_c$$

DON'T CONFUSE THEM

Three quantities, three questions.

Two belong to the field; one belongs to a particular charge.

FIELD STRENGTH

$$E = \frac{F}{q}$$

Field · vector. Force per unit charge — how strong the push is.

POTENTIAL

$$\varphi = \frac{E_p}{q}$$

Field · scalar. Energy per unit charge at a point.

POTENTIAL ENERGY

$$E_p = q\varphi$$

The charge. Energy this particular charge stores.

SUMMARY

Potential energy E_p belongs to a charge; divide it by the charge and you get electric potential $\varphi = E_p/q$ — a scalar map of the field itself, just as $E = F/q$ maps the force. Follow a field line and φ always falls.