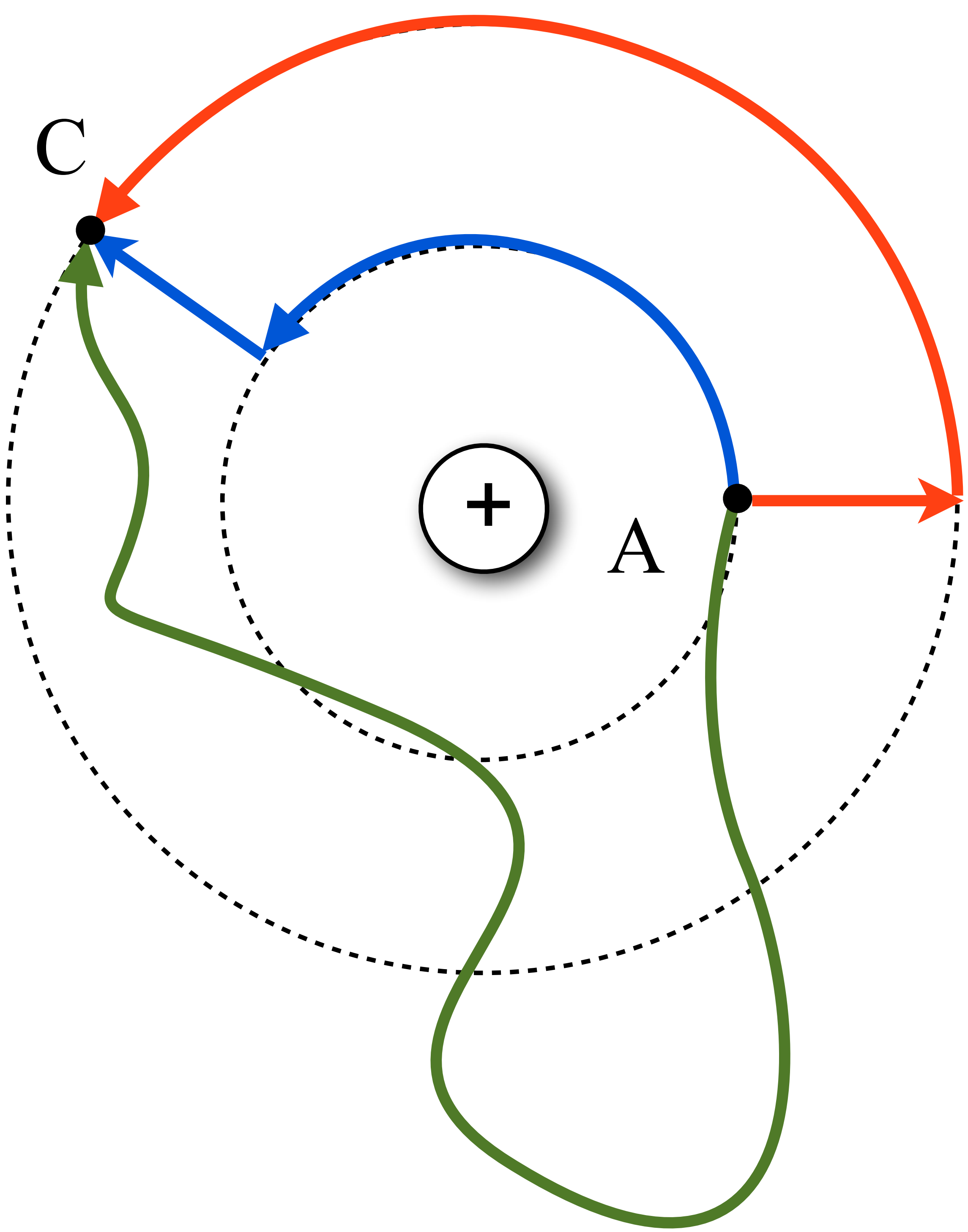
Path Independence

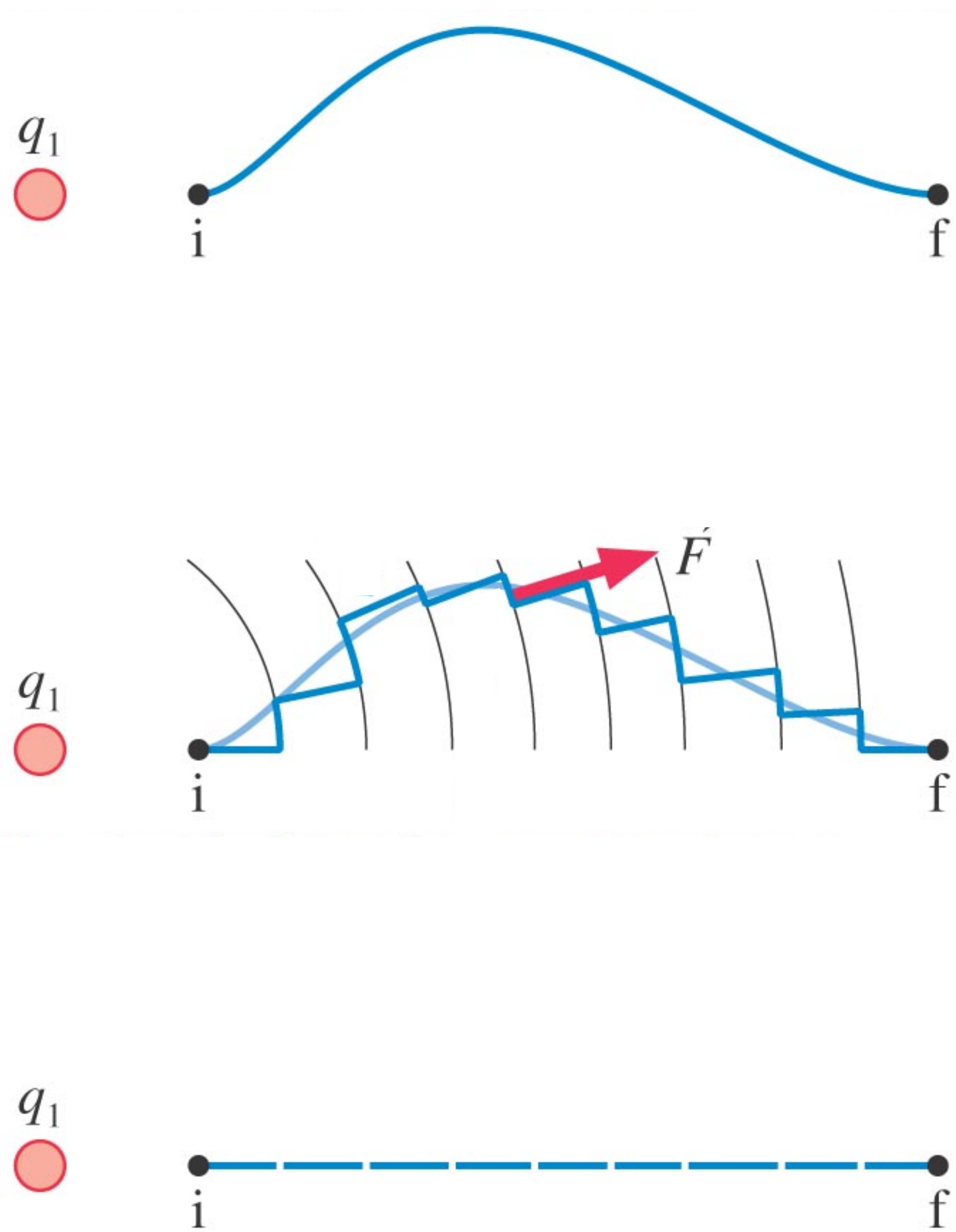


$$\Delta U = -\int_s \vec{F} \cdot \vec{ds}$$

The Blue Path, the Red Path, and the Green Path all have the same change in potential energy. The path does not matter.

Conservative Force

The work done along this path can be simplified to a straight line. This is called path independence.



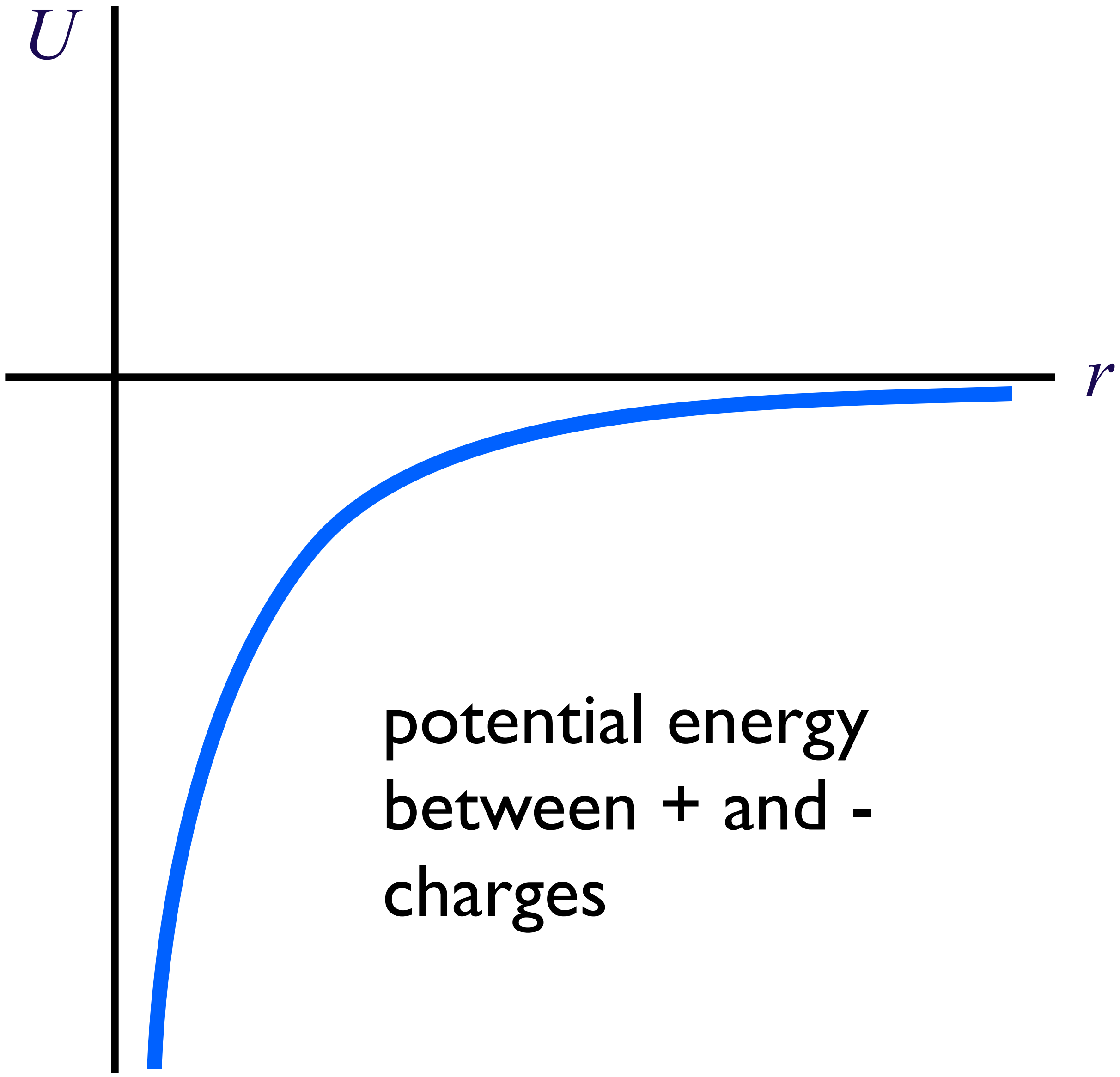
Path independence is a quality of conservative forces.

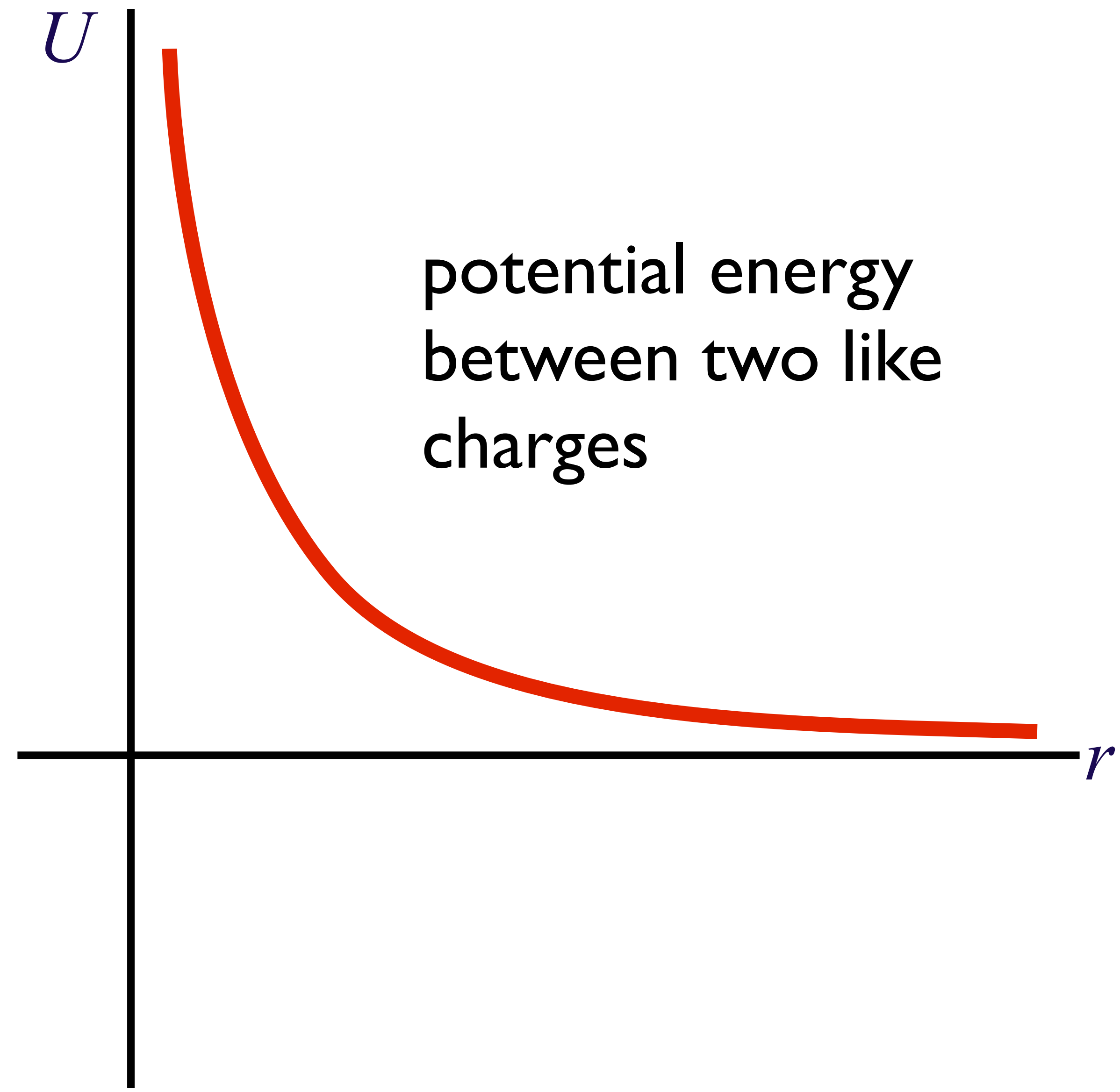
Conservative forces can always be written in terms of a potential.

$$F_s = -\frac{dU}{ds}$$

U for two charges?

The Coulomb Potential Energy





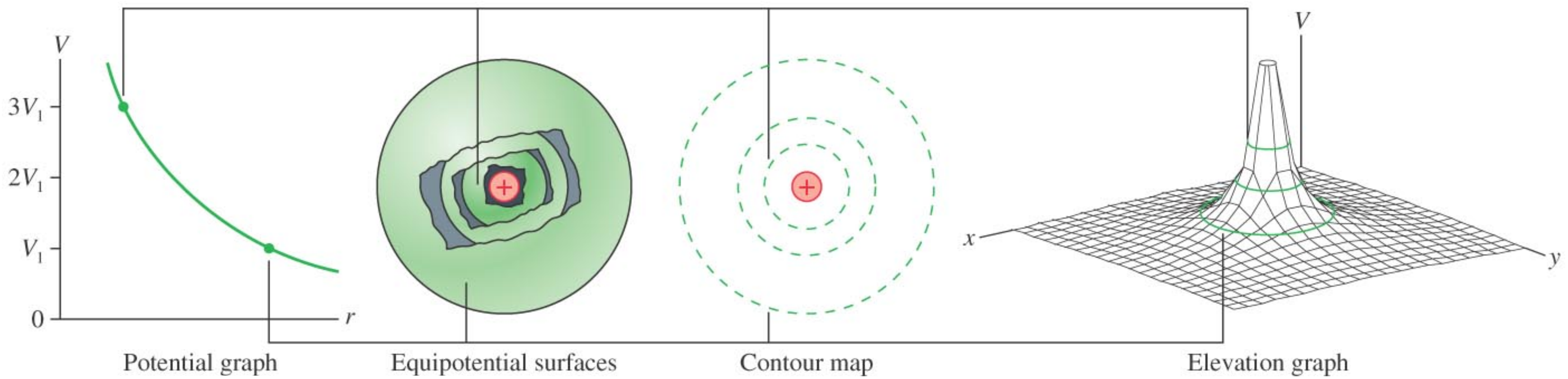
$$U = k\frac{q_1 q_2}{r}$$

One of these should look familiar from chemistry...

Potential of a point charge

The potential of a point charge is a quality of the charge, **similar to the electric field**. Mysteriously permeates all space.

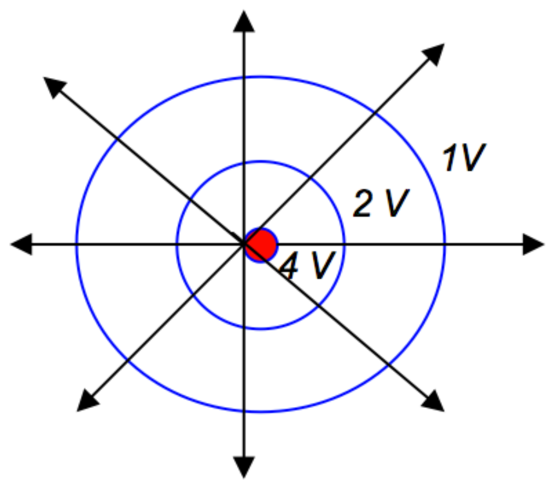
$$V_{q_1} = \frac{U_{q_1 \text{ and } q_2}}{q_2} = k\frac{q_1}{r}$$

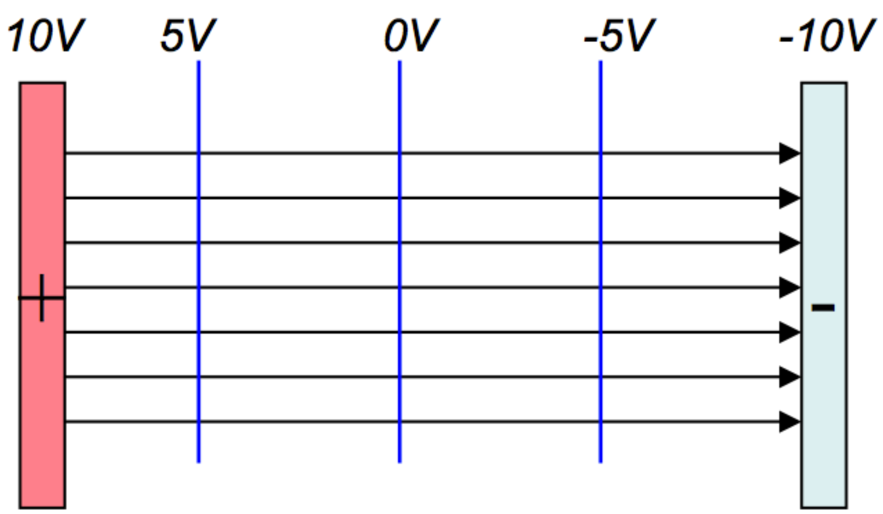


Charges and Fields PhET

Equipotential Surfaces

- All points on an equipotential surface have the same electric potential.
- Surfaces can be imaginary or real surfaces (as in a conductor).
- Electric field lines and are **perpendicular to** the equipotential surfaces at all points.

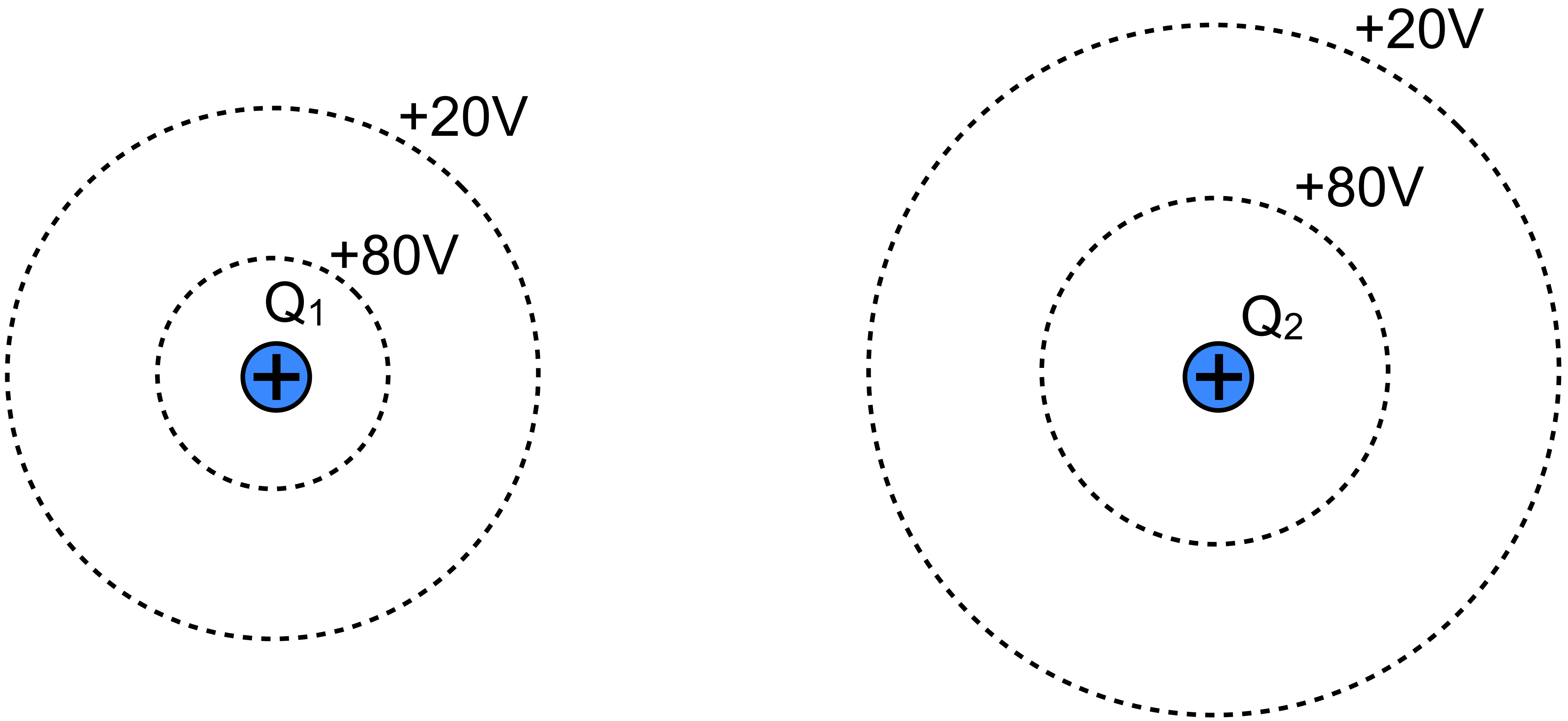




Charges and Fields PhET

Clicker Question

Equipotentials are plotted around two charges. What can you conclude about Q_1 and Q_2?



A) $Q_1 > Q_2 > 0$
B) $Q_2 > Q_1 > 0$
C) $Q_1 < Q_2 < 0$
D) $Q_2 < Q_1 < 0$
E) Can't Determine

Clicker Question

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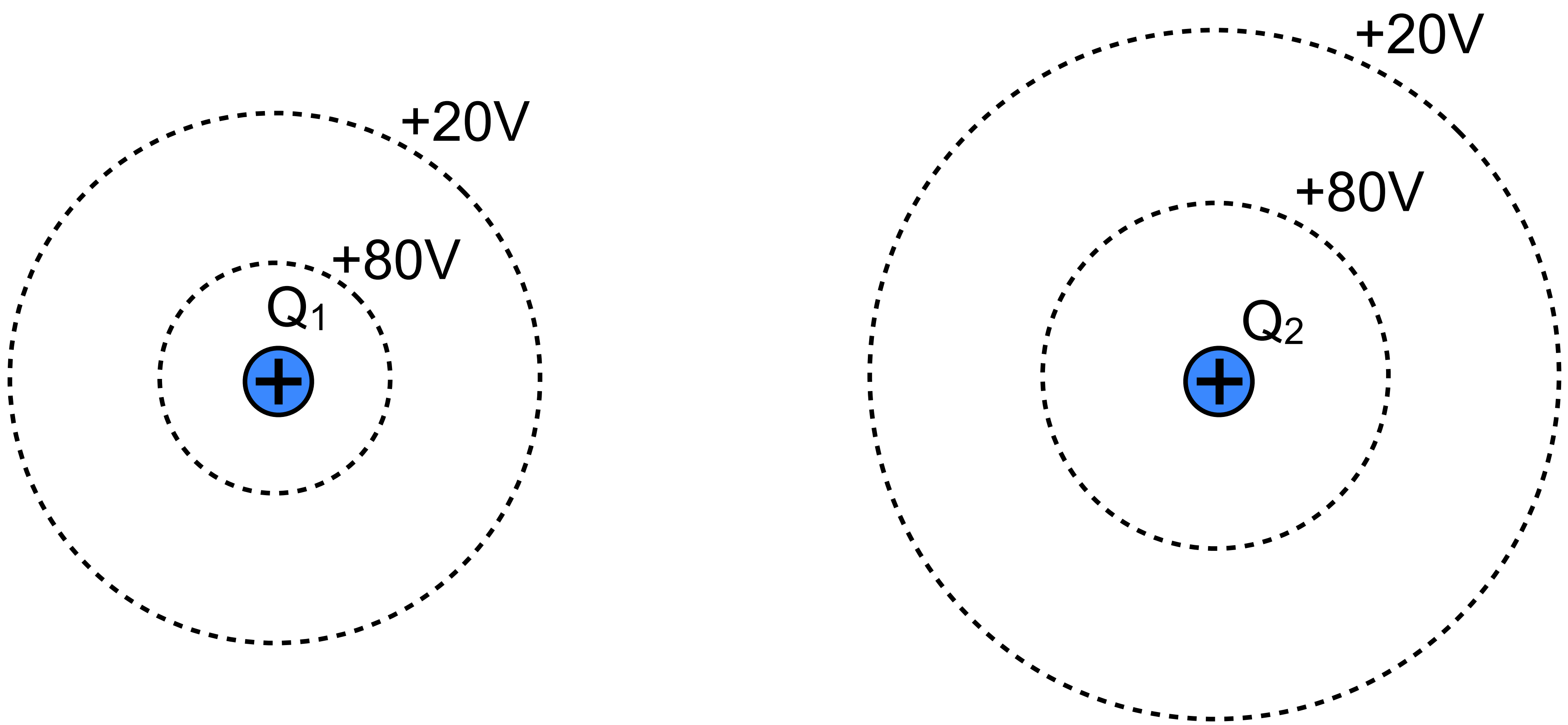

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The potential is stronger further away, so the charge must be bigger. The charge is positive, so the potential must be positive.

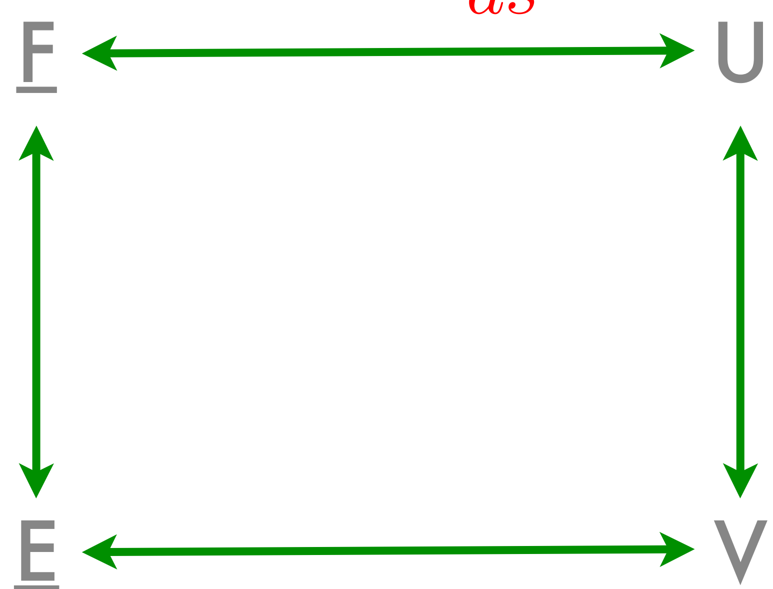
4 Electric Quantities

$$dU = -\vec{F} \cdot \vec{ds}$$

$$F_s = -\frac{dU}{ds}$$

Force

Energy



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

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

$$U = qV$$

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

Field

Potential

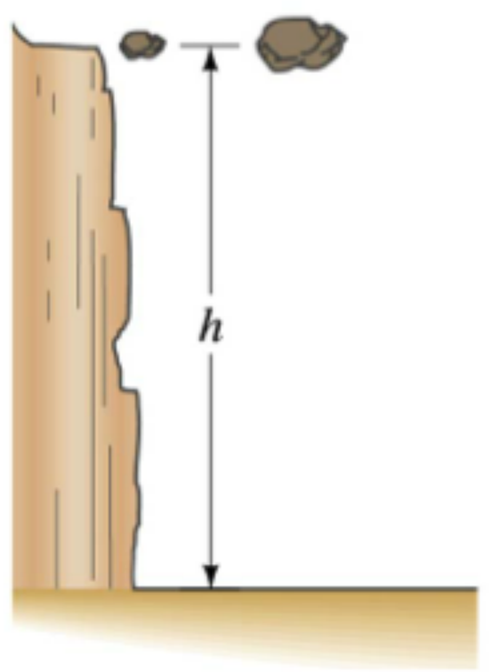
$$dV = -\vec{E} \cdot \vec{ds}$$

$$E_s = -\frac{dV}{ds}$$

Electric Potential

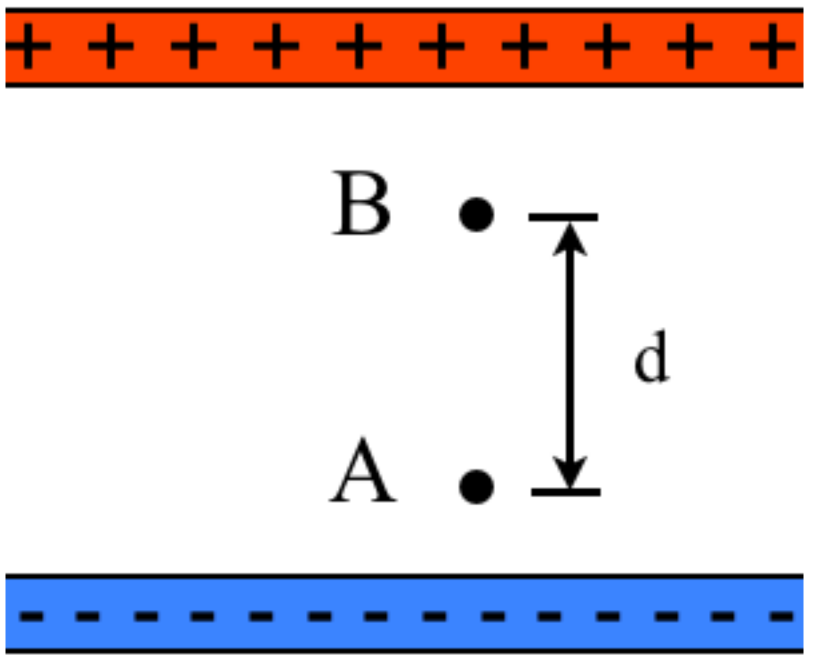
Ability to do work on a charge.

Higher potential = larger energy per charge.



Gravitational Potential Energy:
$U = mgh$

Gravitational Potential:
$V = gh$



Electrical potential Energy:
$U = qEd$

Electrical potential:
$V = Ed$

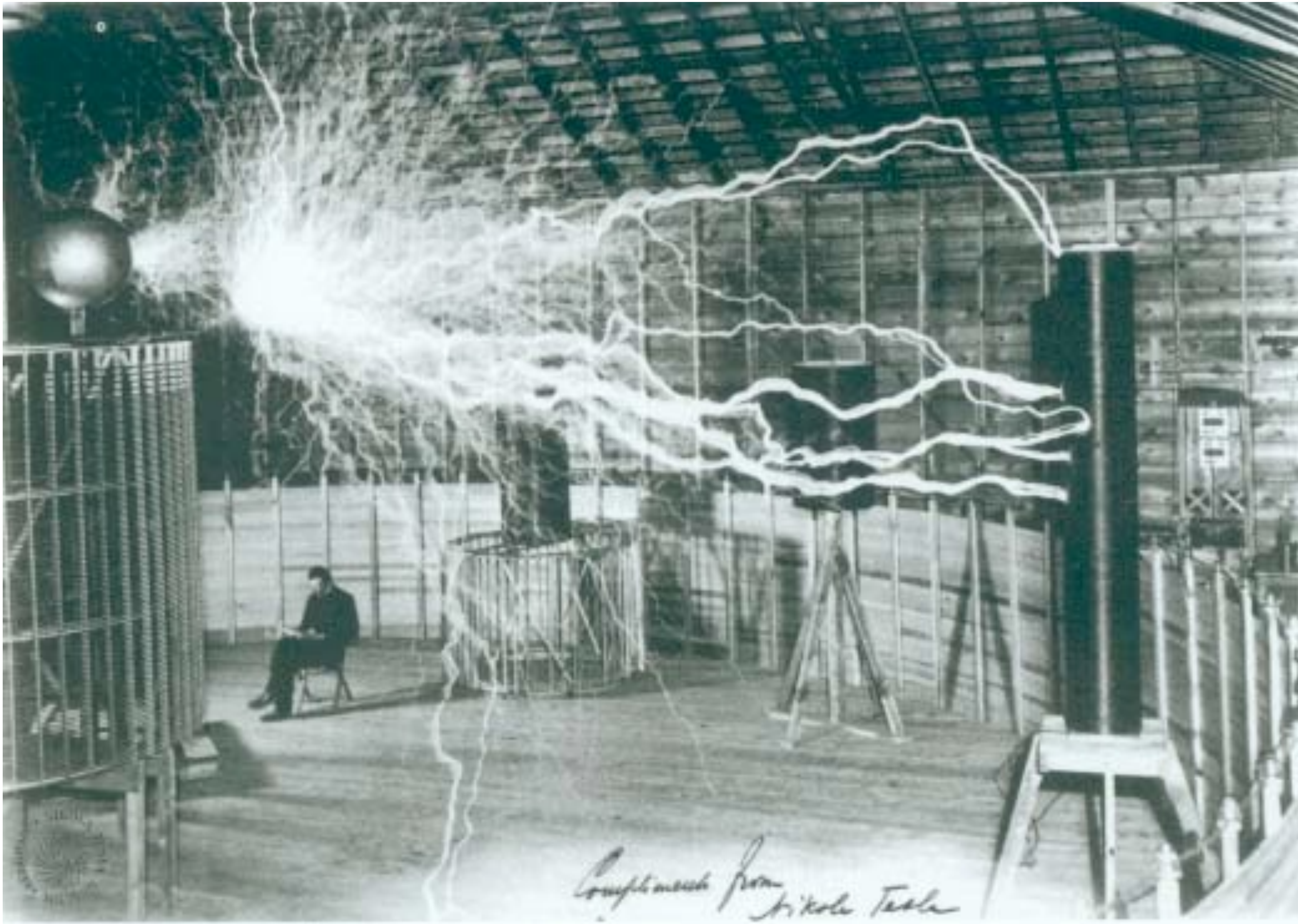
Alessandro Volta

Discovered methane (1776), invented the battery (to prove Galvani wrong) and capacitance (early 1800s).

Where Does Potential Appear?

Jacob's Ladder Demo

Tesla Coil

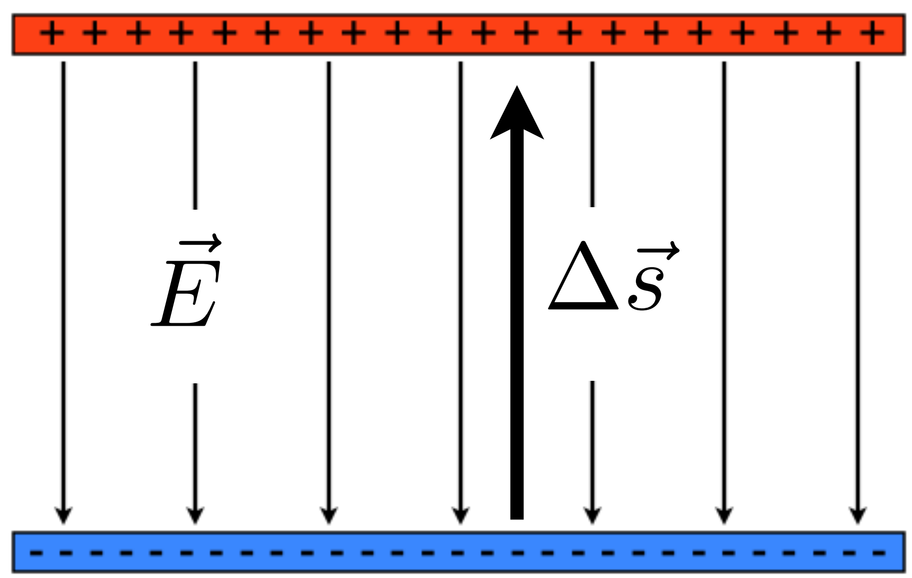

Compliments from
Nikola Tesla

The potential of the Capacitor

The potential and field of a capacitor with plates a **distance s apart**.

$$\Delta V = -\vec{E} \cdot \Delta \vec{s}$$

$$\Delta V = Es = \frac{\eta}{\epsilon_0} s$$



$$\vec{E} = -\frac{\eta}{\epsilon_0} \hat{y}$$

$$E_s = -\frac{dV}{ds}$$

Equipotentials and Fields

Consider the relationship: $dV = -\vec{E} \cdot \vec{ds}$

What happens if we choose the path *ds* to follow an equipotential?

The change in voltage *dV* along the path is:

A) positive
B) negative
C) zero
D) can't determine

Which from the equation above means that the angle between ***E*** and ***ds*** is:

A) 0^o
B) 90^o
C) 180^o
D) can't determine

Charges and Fields PhET

Equipotentials and Fields

Consider the relationship: $dV = -\vec{E} \cdot \vec{ds}$

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The change in voltage *dV* along the path is:

A) positive
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C) zero
D) can't determine

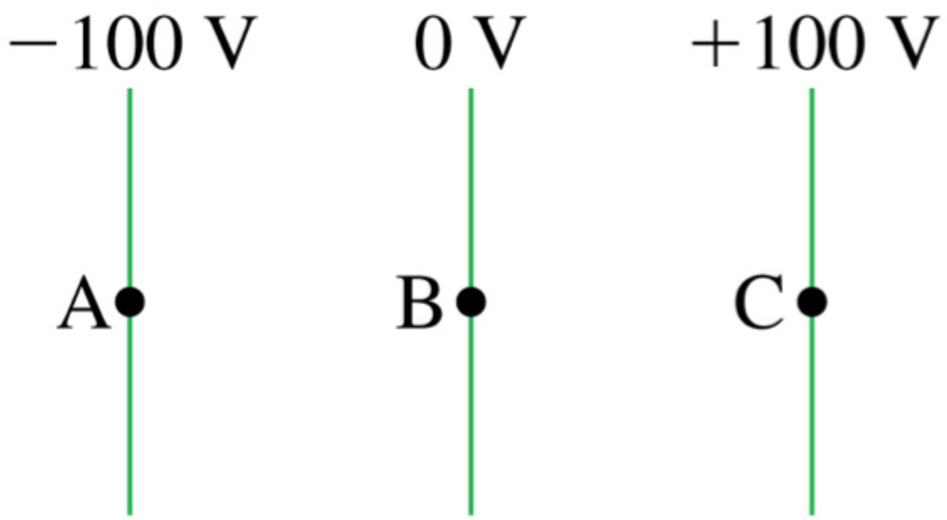
Which from the equation above means that the angle between ***E*** and ***ds*** is:

A) 0°
B) 90°
C) 180°
D) can't determine

The electric field runs downhill perpendicular to equipotential lines.

Charges and Fields PhET

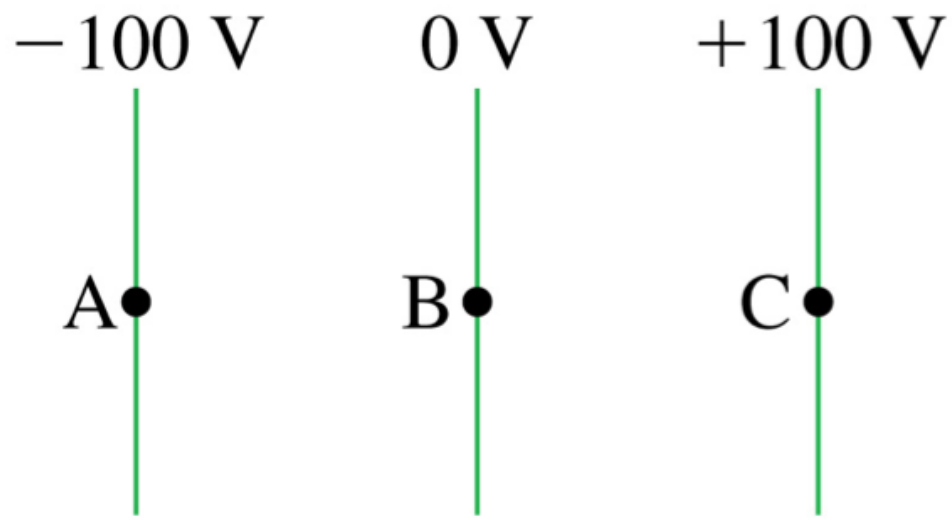
Clicker Question



An electron is released from rest at point B, where the potential is 0 V. Afterward, the electron

A) moves toward A with a steady speed.
B) moves toward A with an increasing speed.
C) moves toward C with a steady speed.
D) moves toward C with an increasing speed.
E) remains at rest at B.

Clicker Question



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E) remains at rest at B.

The **electric field** is in the **direction of decreasing potential**. Negative charges move *against electric fields* and *up potential gradient.s* That's the opposite of positively charged particles.

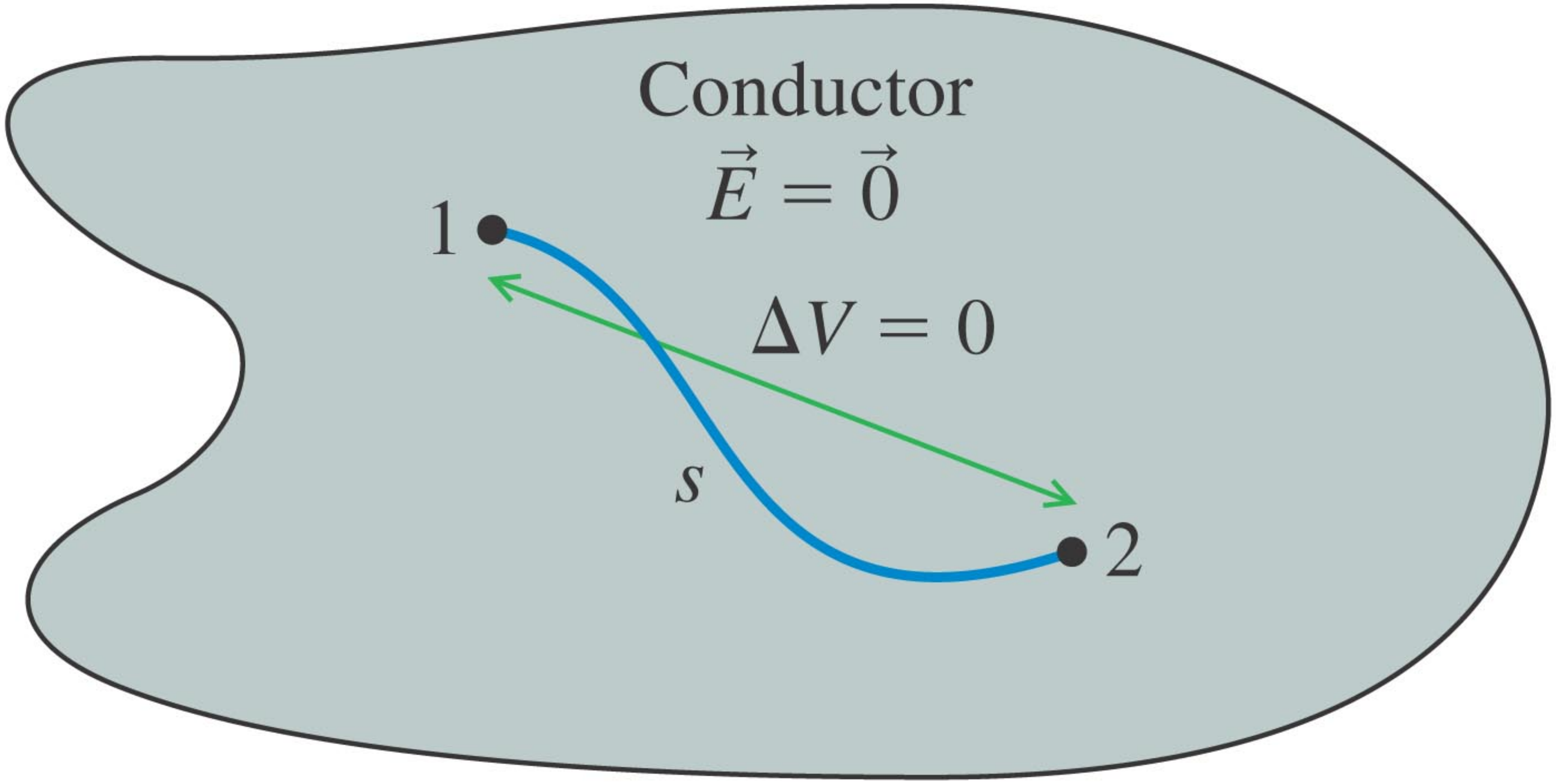
$$E_s = -\frac{dV}{ds}$$

Potential and Conductors

E = 0 in a conductor implies that the **entire conductor is an equipotential**.

$$dV = -\vec{E} \cdot \vec{ds} = 0$$

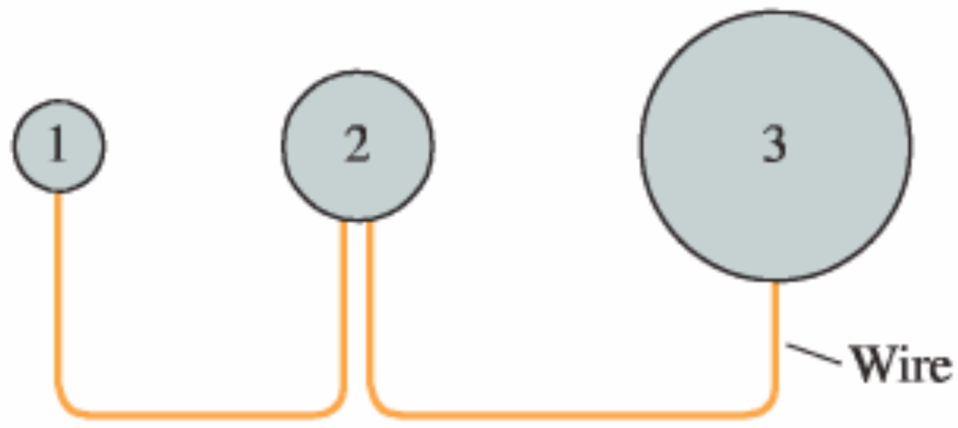
Thus, the surface must be an equipotential and **E-field must be perpendicular to the surface**.



Clicker Question

Three charged metal spheres are connected by a thin metal wire. The potential and electric field on the surface of each sphere are V and E. Which of the following is true?

A) $V_1 = V_2 = V_3$ and $E_1 = E_2 = E_3$
B) $V_1 = V_2 = V_3$ and $E_1 > E_2 > E_3$
C) $V_1 > V_2 > V_3$ and $E_1 = E_2 = E_3$
D) $V_1 > V_2 > V_3$ and $E_1 > E_2 > E_3$
E) $V_3 > V_2 > V_1$ and $E_1 = E_2 = E_3$
F) $V_3 > V_2 > V_1$ and $E_3 > E_2 > E_1$



The the potential is the same everywhere in a conductor.

The electric field is related by E=V/r, so the field is bigger for the smaller surface.

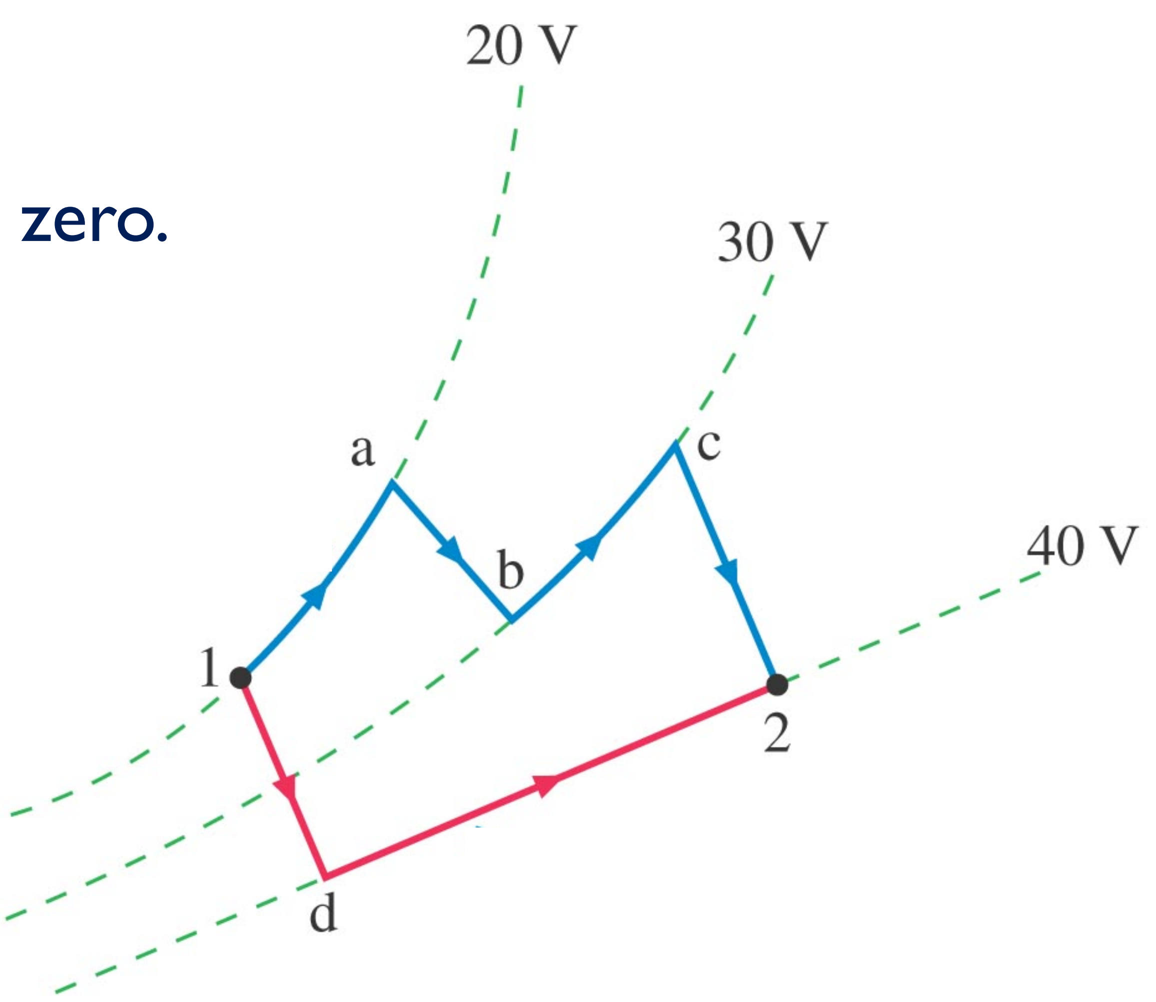
Kirchhoff's Loop law

A foundation of circuit analysis.

The loop law comes from path independence:

$$\Delta U = -\oint \vec{F}\cdot d\vec{s} = -q\oint \vec{E}\cdot d\vec{s} = 0$$

The change in energy around a closed path is zero.



We then know that *U* = *qV* gives

$$\Delta V_{\text{loop}} = 0$$

Which is the loop law.

It's Alive!

Frankenstein 1931

Pierre's Slide from last term!

Intermolecular Interactions

Interaction type	Typical stabilization energies (kJ/mol)	Distance dependence
ion-ion	200-400	r^{-1}
ion-dipole	5-20	r^{-2}
dipole-dipole	2-10	r^{-3}
VdW	0.3-1	r^{-4} - r^{-6}