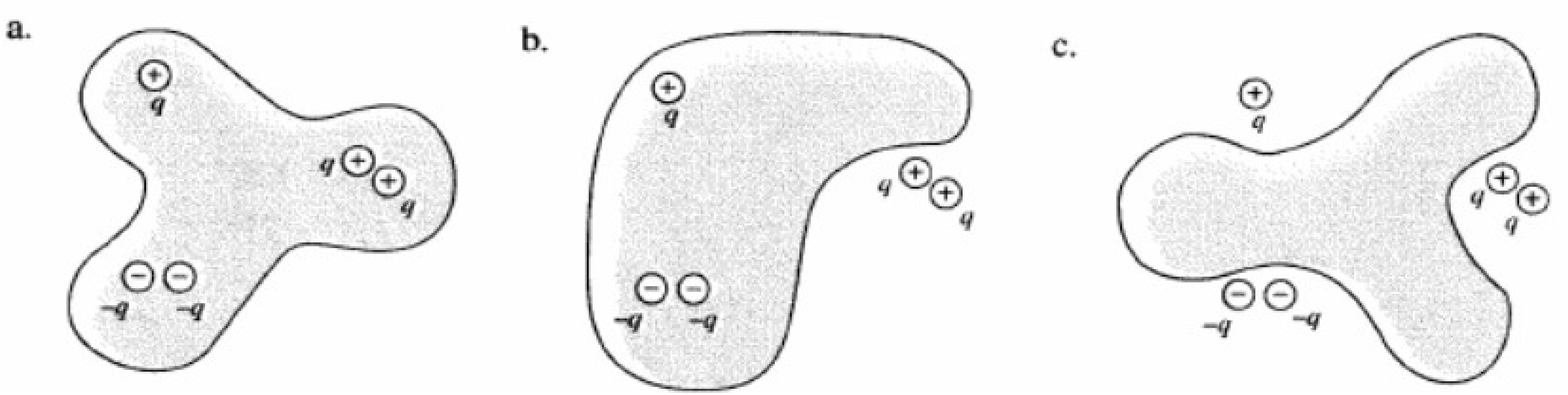
Conductors & Electric Fields

Consider the Gaussian surfaces and point charges shown.
Which has the greatest total flux?

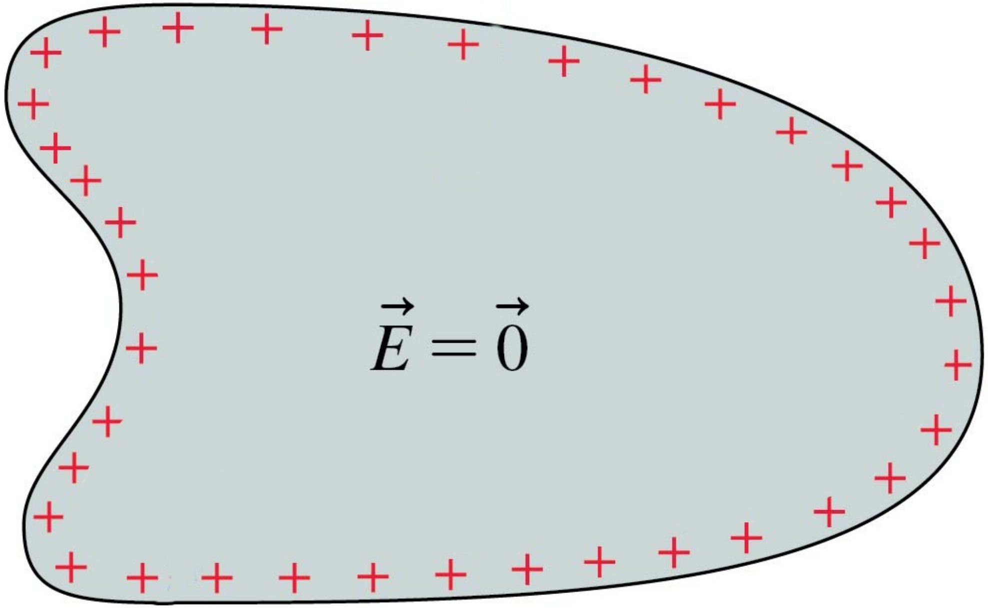


d. a and b has the same flux, which is greater than c

e. they all have equal flux

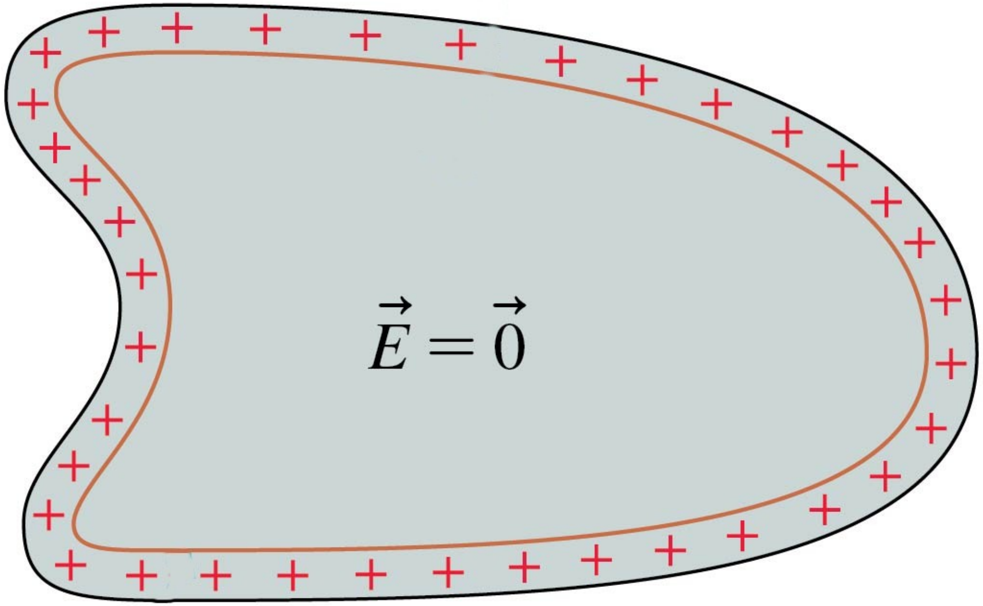
Conductors & Electric Fields

- suppose you have a conductor (that may have charge on it)
- any electric field in the bulk of it would cause charges to move
- therefore: **electric field is zero inside a conductor in equilibrium**



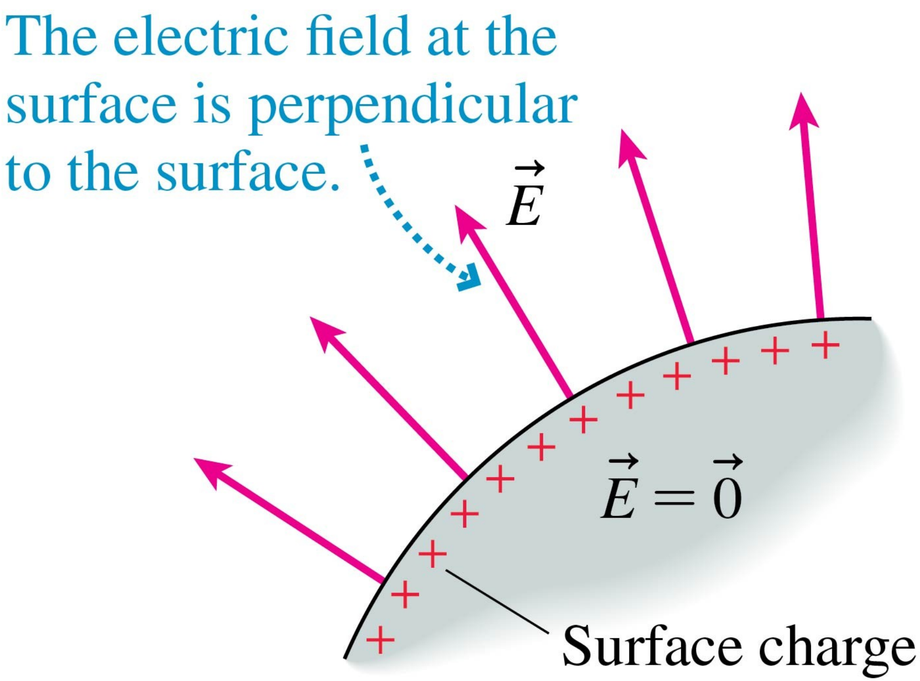
Conductors & Electric Fields

- suppose you have a conductor (that may have charge on it)
- any electric field in the bulk of it would cause charges to move
- therefore: **electric field is zero inside a conductor in equilibrium**
- consider a Gaussian surface just inside the surface of the conductor
- zero E means $$\oint \vec{E} \cdot d\vec{A} = 0$$
- by Gauss's Law $Q_{\rm in} = 0$ therefore: **all charge resides on the surface**



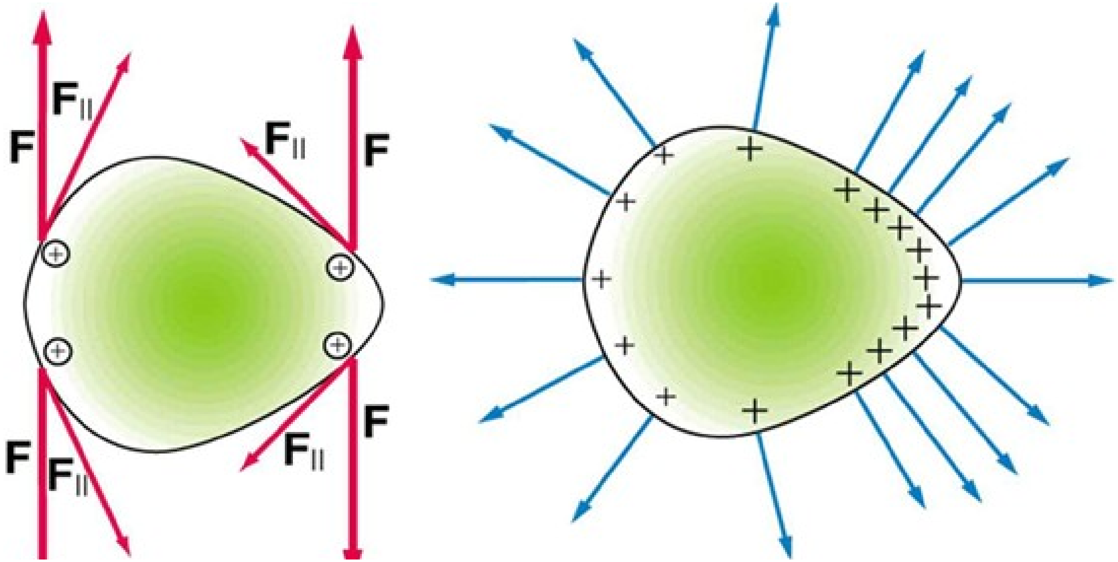
Conductors & Electric Fields

- there is an electric field outside of a charged conducting surface
- but if it had any component parallel to the surface, charges would move
- therefore: **electric fields just outside the surface of a conductor must be perpendicular to the surface**

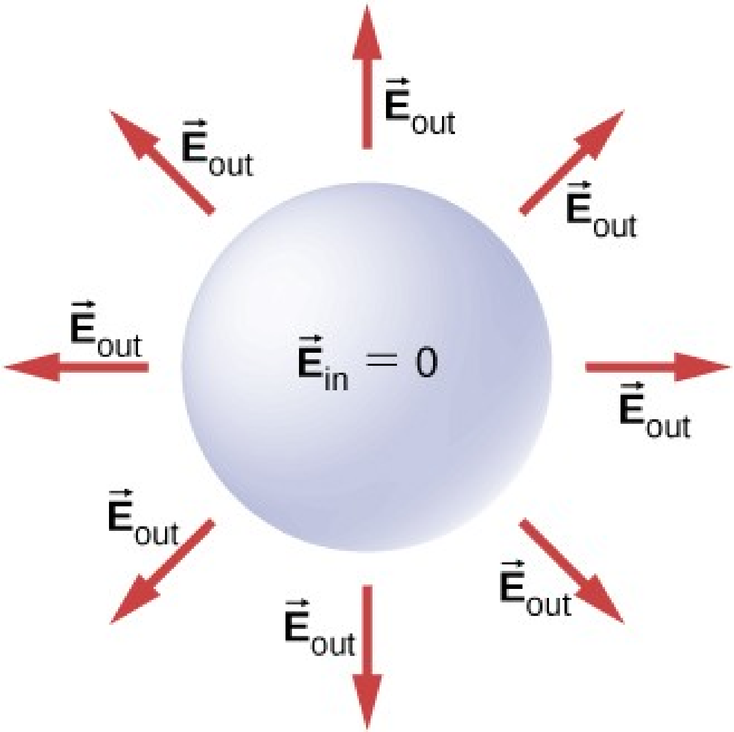


Conductors & Electric Fields

If the electric field had any component parallel to the surface, charges would move.



Conductors & Electric Fields



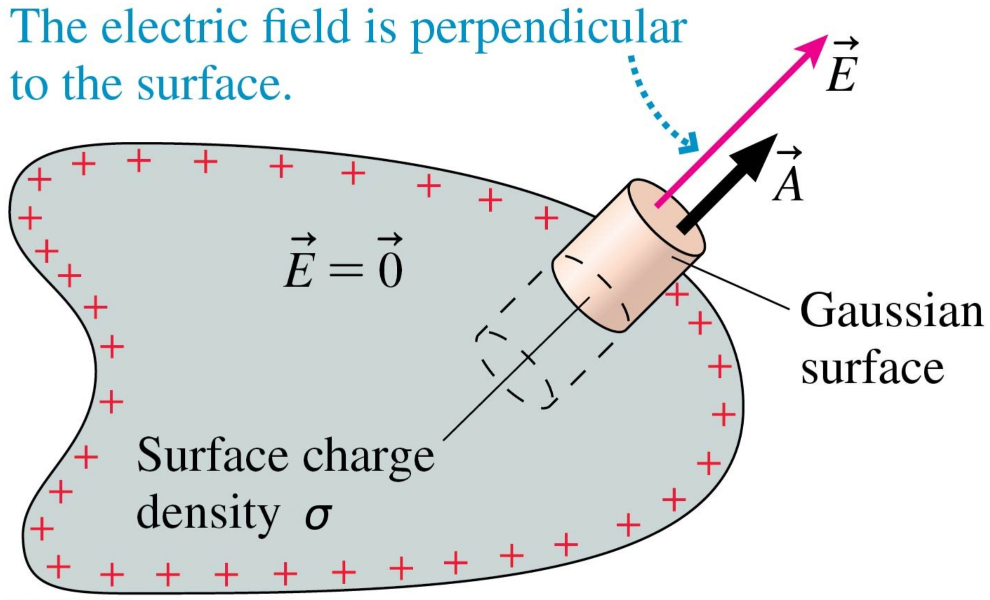
Conductors & Electric Fields

Determine the electric field outside the surface of a charged conductor.

$$\Phi_e = AE_{surface} = Q_{in}/\epsilon_0$$

$$Q_{in} = \sigma A$$

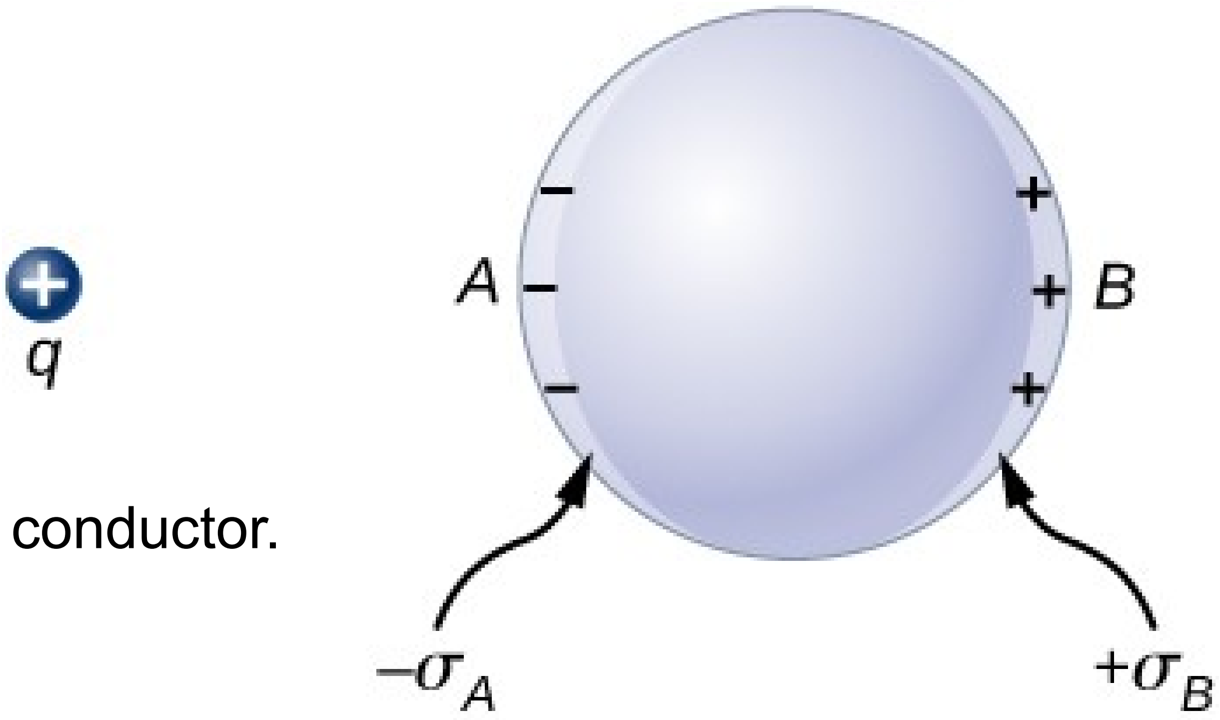
$$\vec{E}_{surface} = \frac{\sigma}{\epsilon_0}\hat{n}$$



where σ is the surface charge density of the conductor.

Conductors & Electric Fields

What happens when you bring an external charge near a conductor?

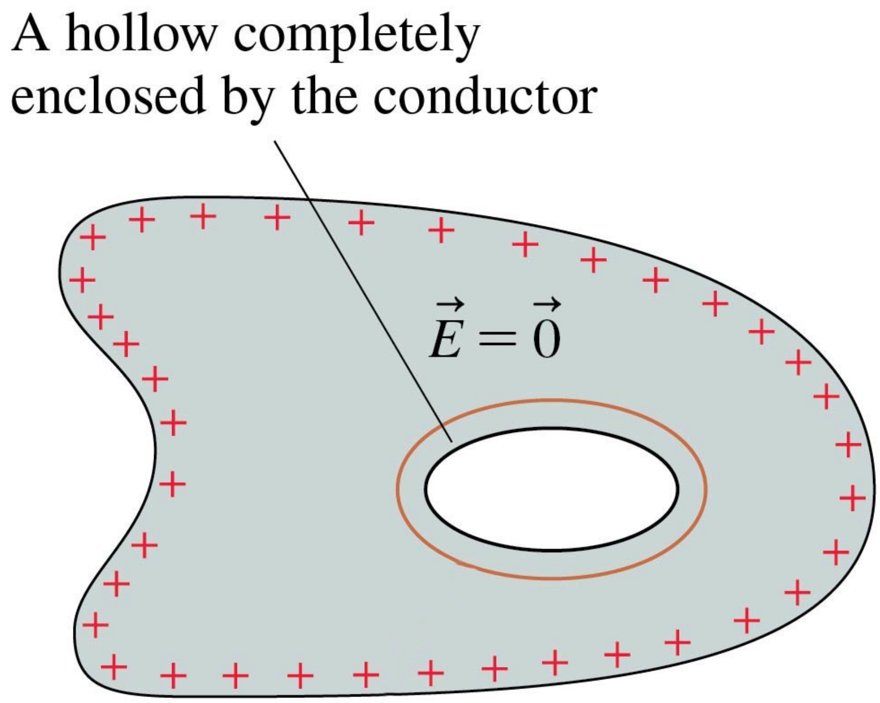


Electric field is zero inside the conductor.

Conductors & Electric Fields

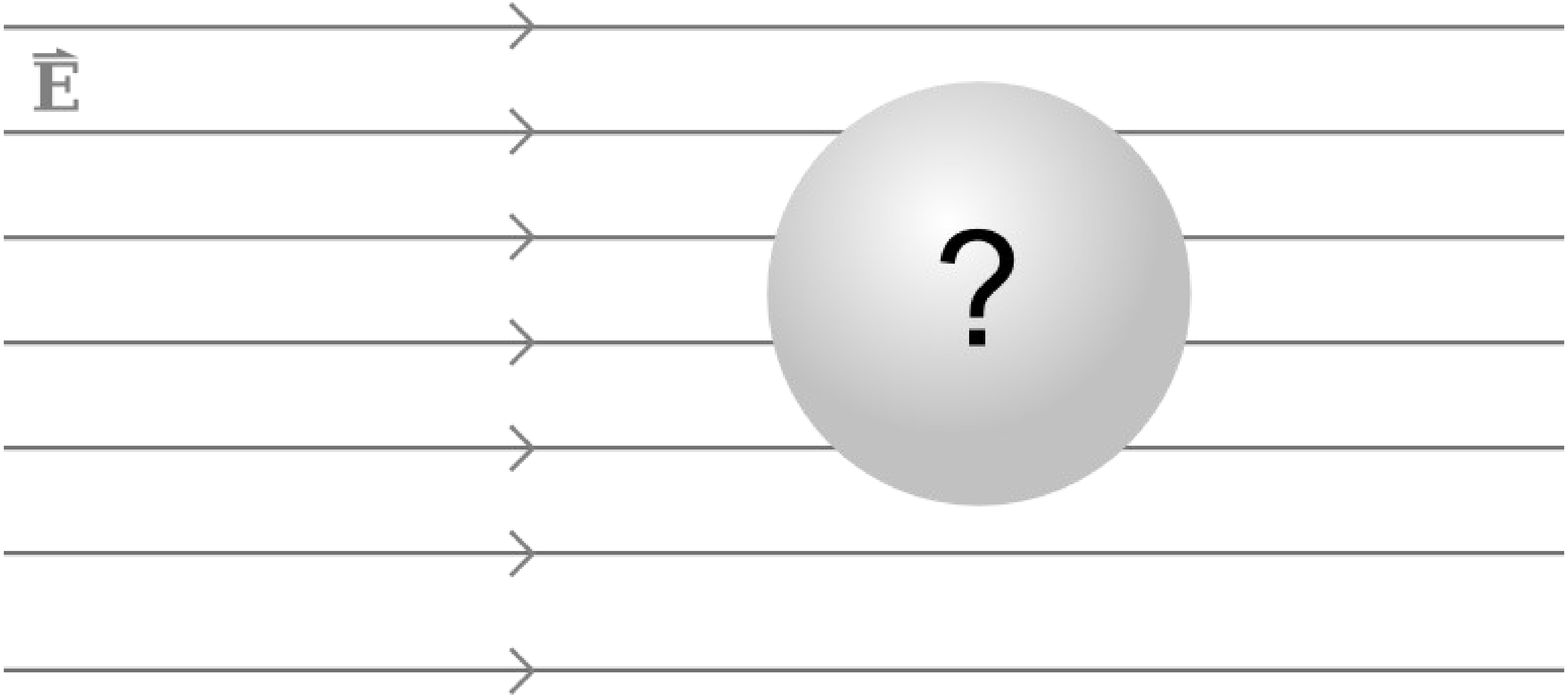
- consider a charged conductor with a hole inside.
- *E*=0 inside the conductor,

  so $Q_{\text{in}} = 0$ for the interior surface.
- therefore *E*=0 in the hole as well



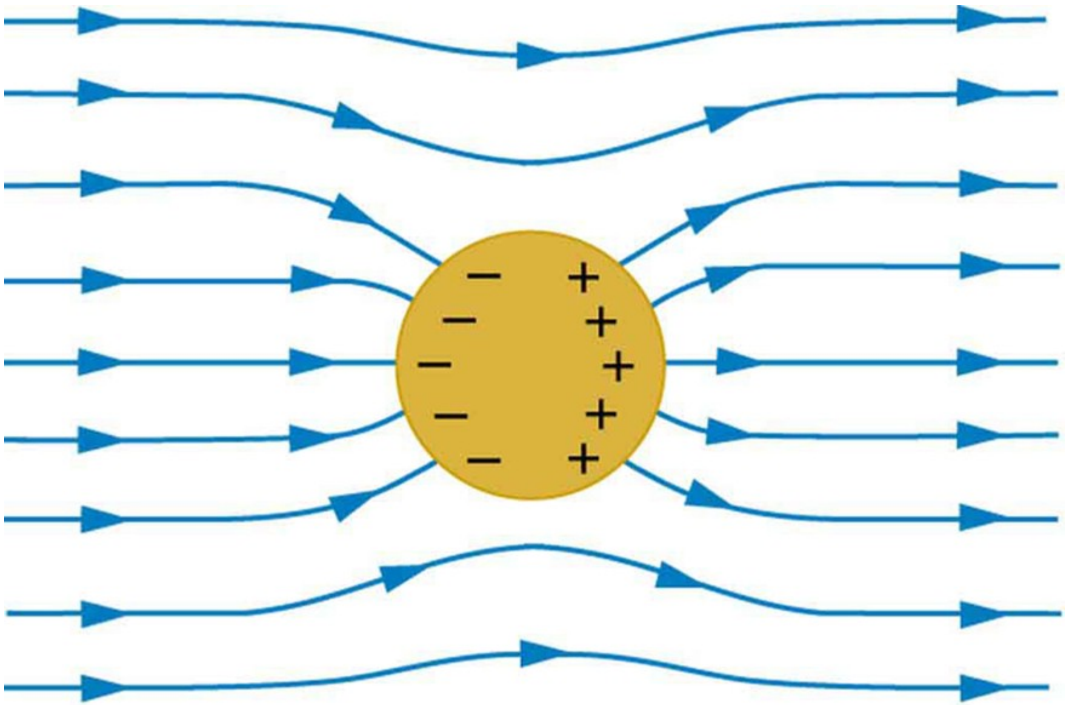
Conductors & Electric Fields

A conducting sphere is placed in a uniform electric field. What will happen to charges in the sphere?



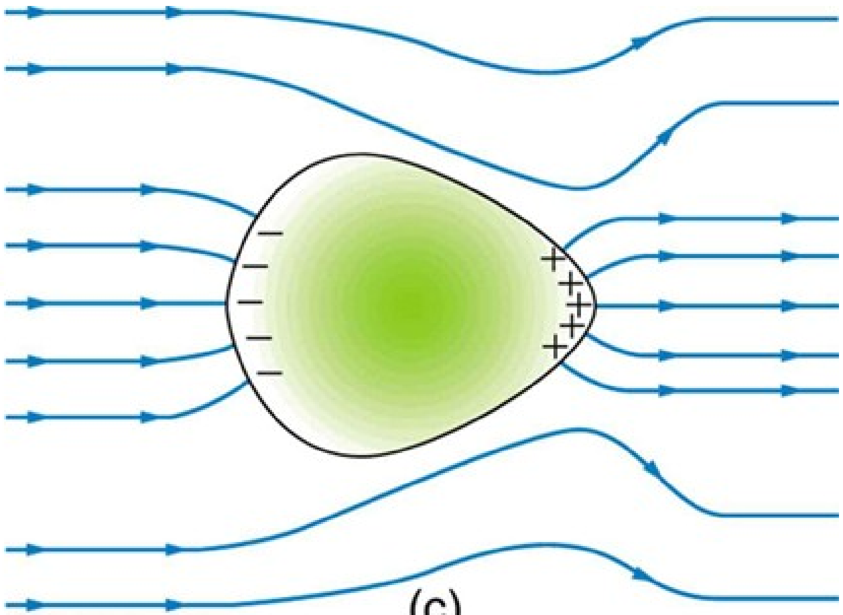
Conductors & Electric Fields

The charges move until the interior field is zero.



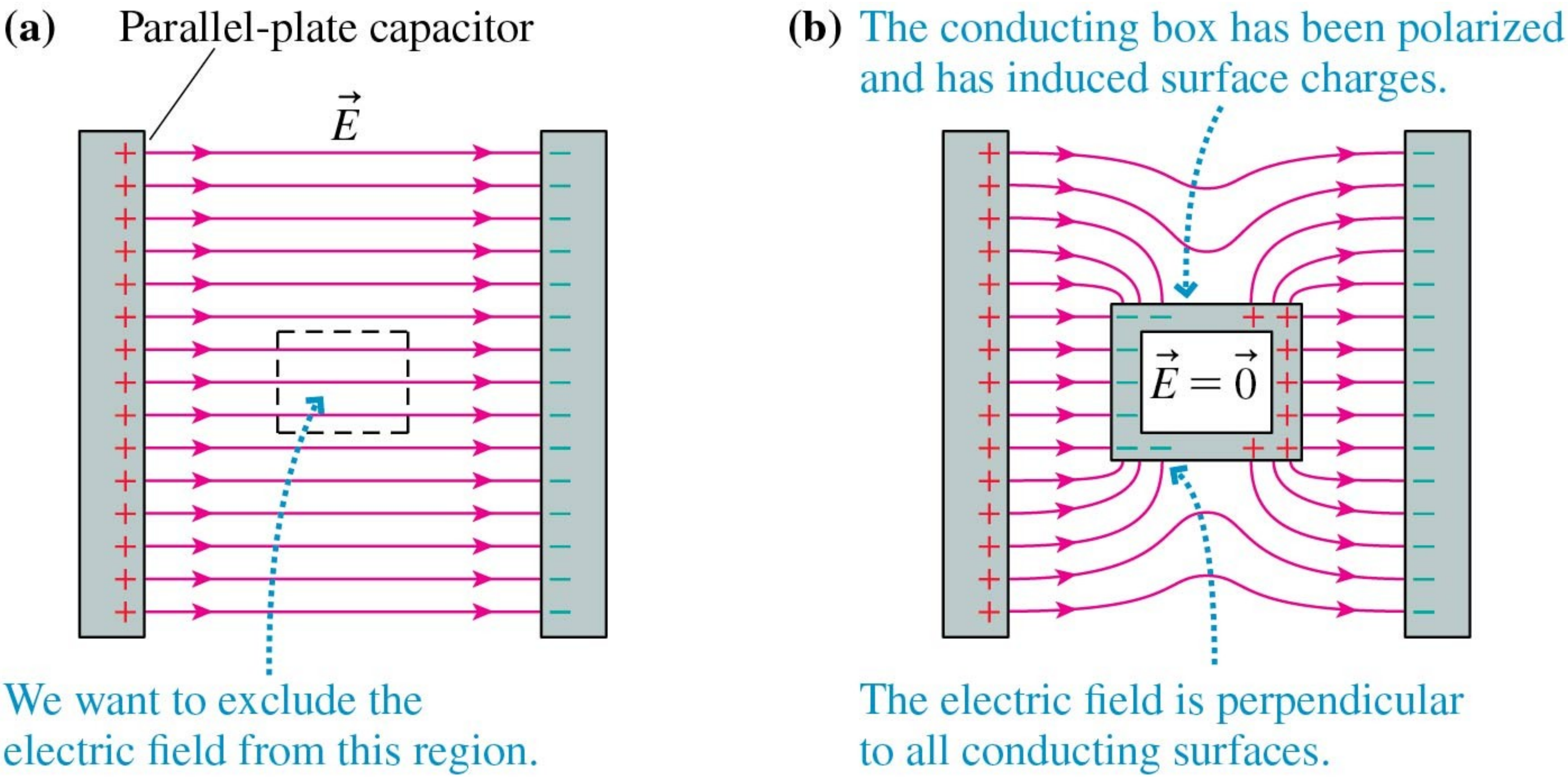
Conductors & Electric Fields

The charges move until the interior field is zero.



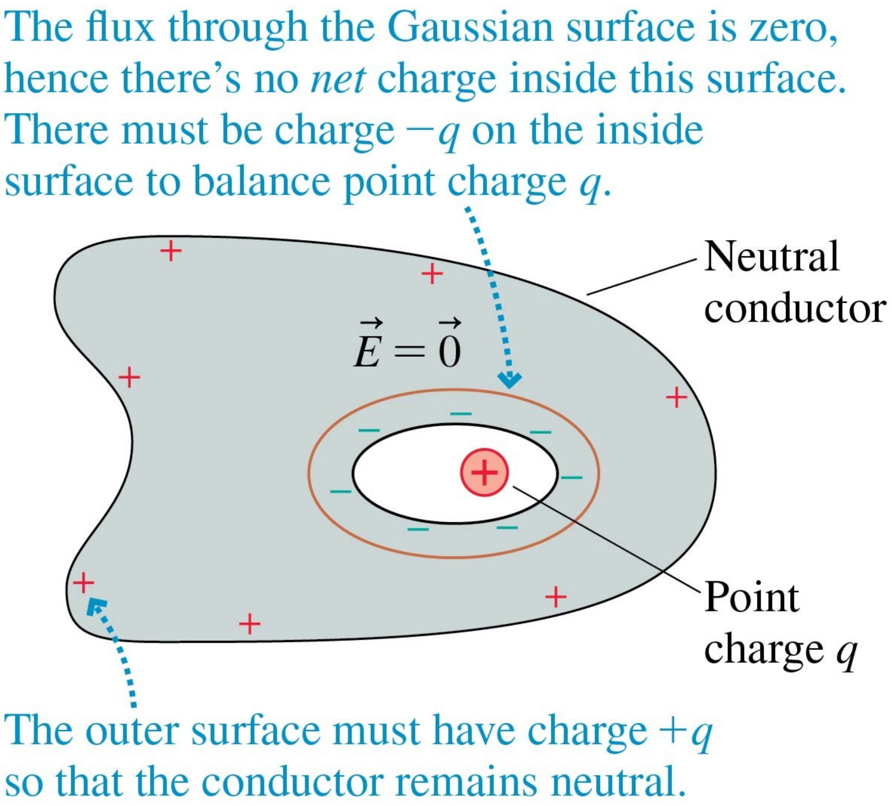
(c)

Conductors & Electric Fields

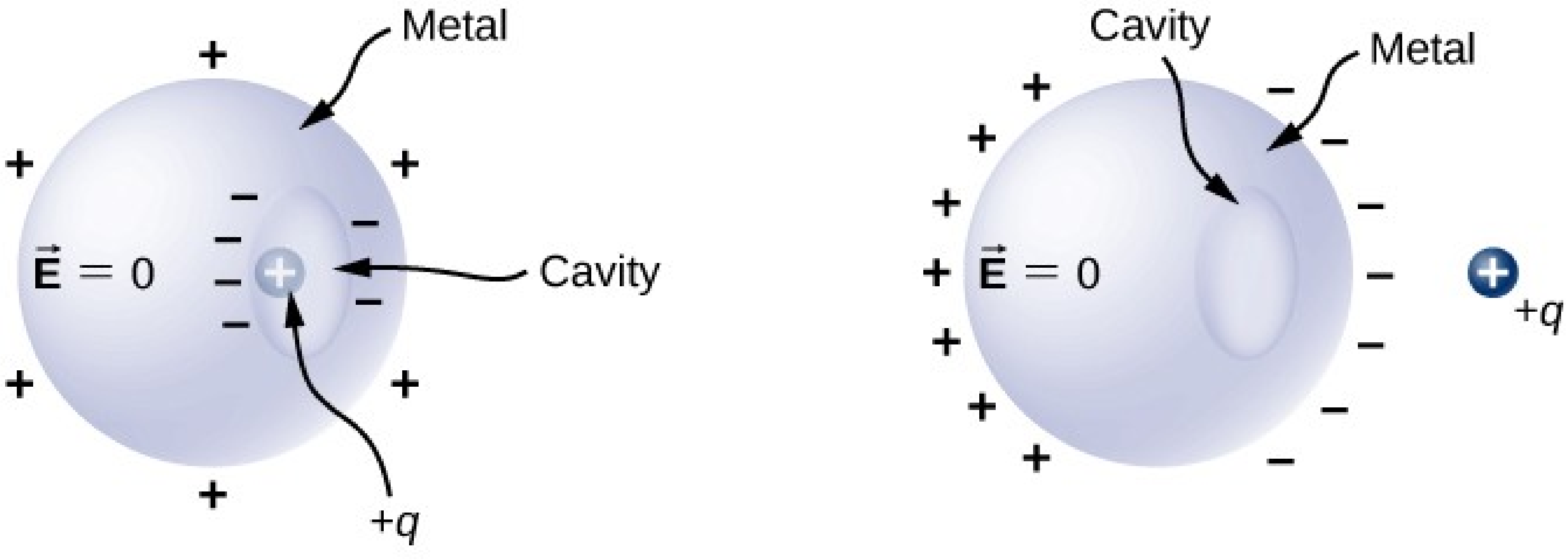


Conductors & Electric Fields

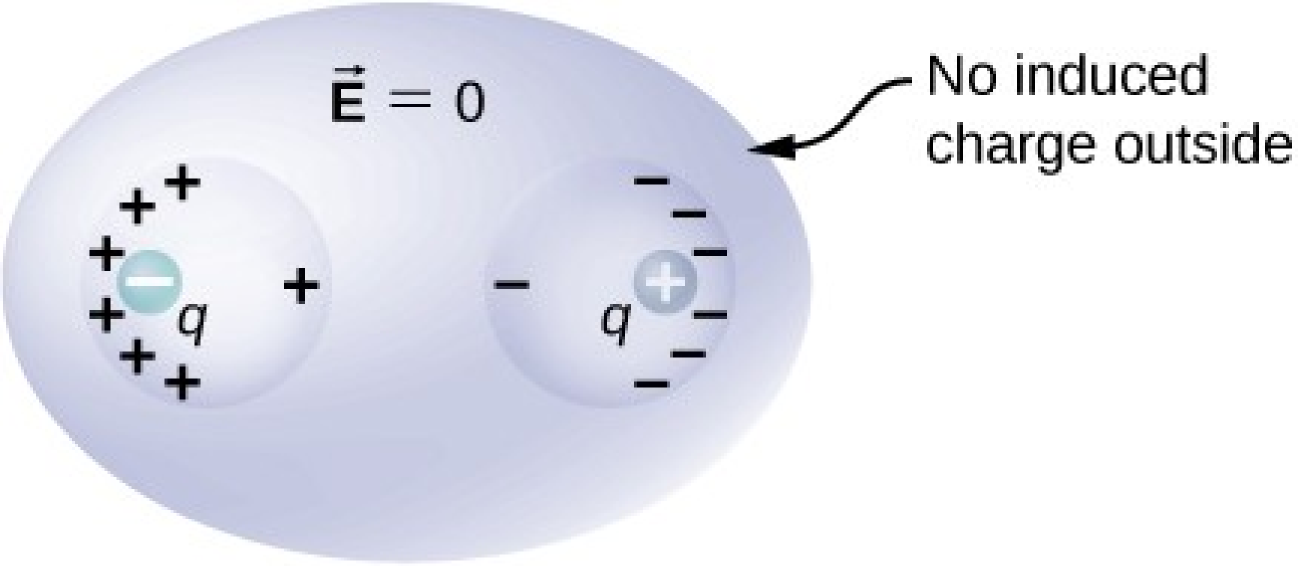
Consider a charged conductor with a hole inside, and a charge in the hole:



Conductors & Electric Fields

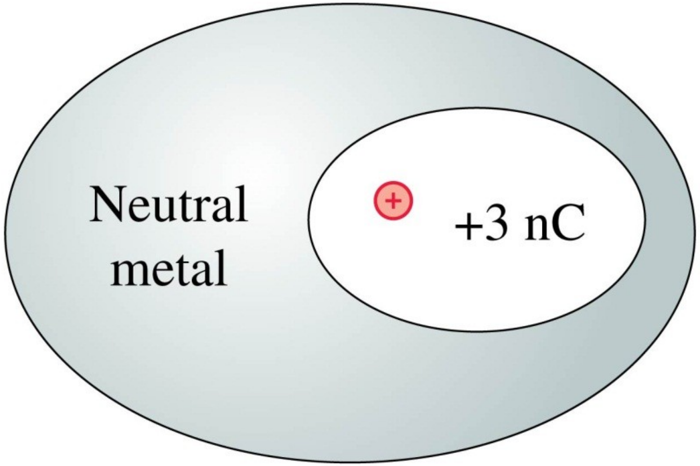


Conductors & Electric Fields



Conductors & Electric Fields

Charge +3 nC is in a hollow cavity inside a large chunk of metal that is electrically neutral. The total charge on the exterior surface of the metal is



A. 0 nC

B. +3 nC ✔

C. –3 nC

D. Can’t say without knowing the shape and location of the hollow cavity.

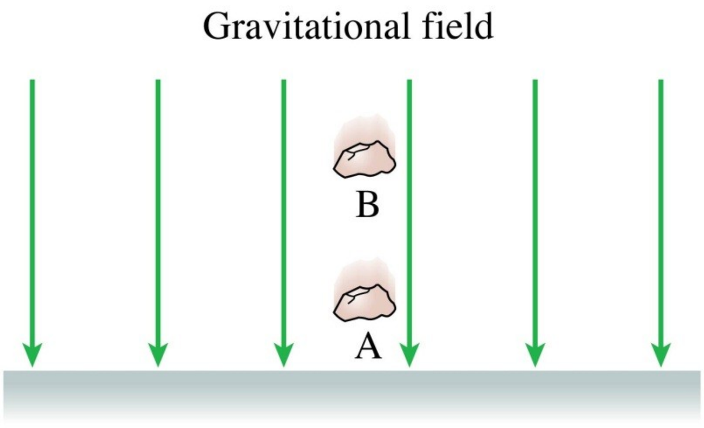
Chapter 7: Electric Potential

1 Electric Potential Energy
2 Electric Potential
3 Calculations of Electric Potential
4 Determining Field from Potential
5 Equipotential Surfaces & Conductors
6 Applications of Electrostatics

lecture 3.2.18

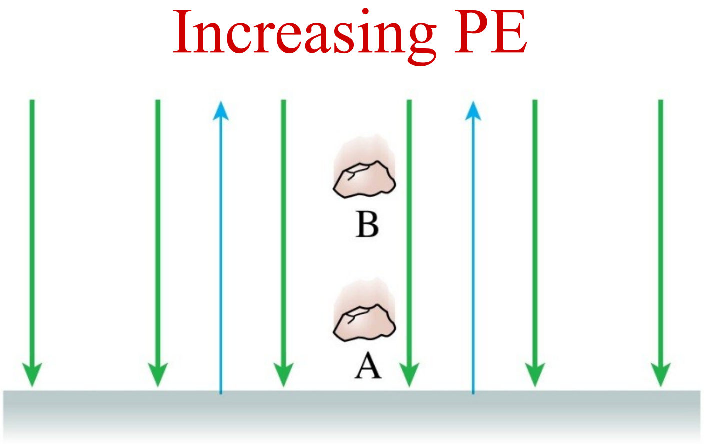
Work and Energy

Two rocks have equal mass. Which has more gravitational potential energy?



A. Rock A
B. Rock B
C. They have the same potential energy.
D. Both have zero potential energy.

Two rocks have equal mass. Which has more gravitational potential energy?



A. Rock A

✔ **B. Rock B**

C. They have the same potential energy.

D. Both have zero potential energy.

Work and Energy

- kinetic energy of a system:

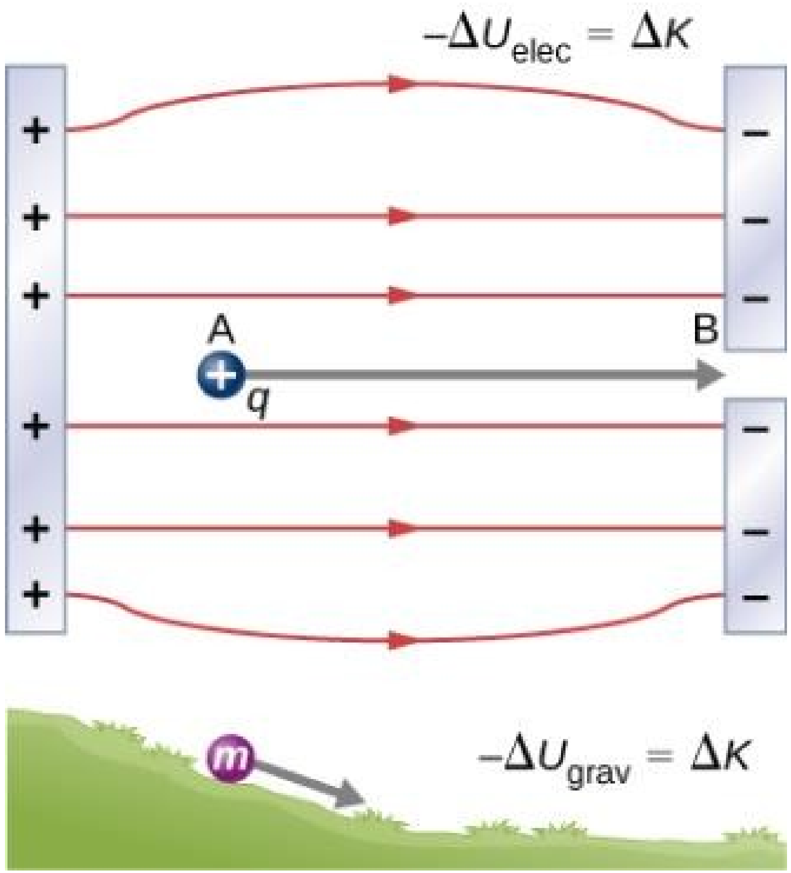
$$K = \sum_i \frac{1}{2} m_i v_i^2$$

- a system's change in potential energy, ΔU, is the negative of the work done by all internal (interaction) forces:

$$\Delta U = -W_{\text{interaction}}(\mathrm{i} \rightarrow \mathrm{f})$$

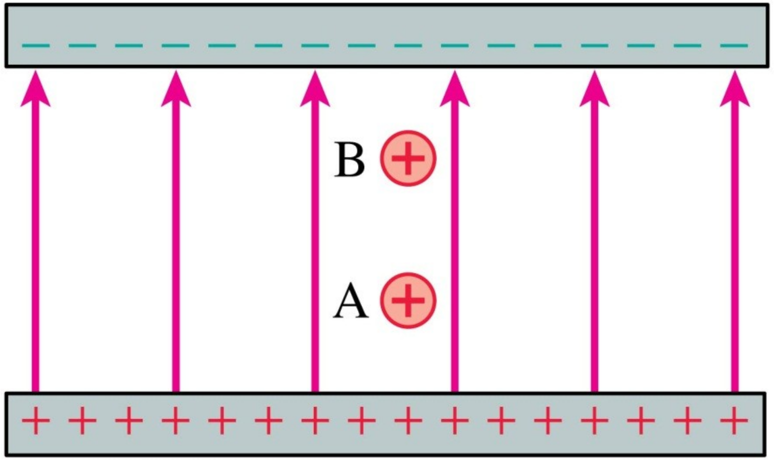
- with *conservative forces* the total energy $E_{\text{mech}} = K + U$ is *conserved*

Work and Energy



Work and Energy

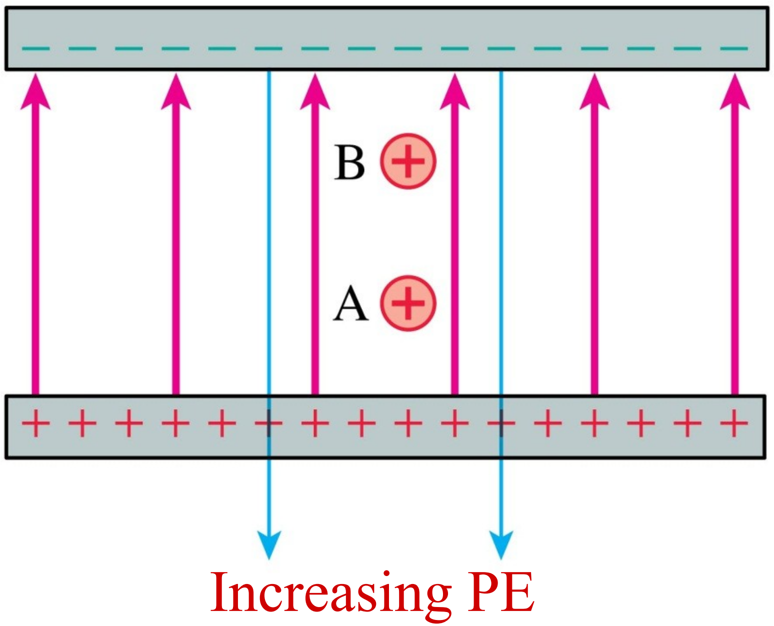
Two positive charges are equal. Which has more electric potential energy?



A. Charge A
B. Charge B
C. They have the same potential energy.
D. Both have zero potential energy.

Work and Energy

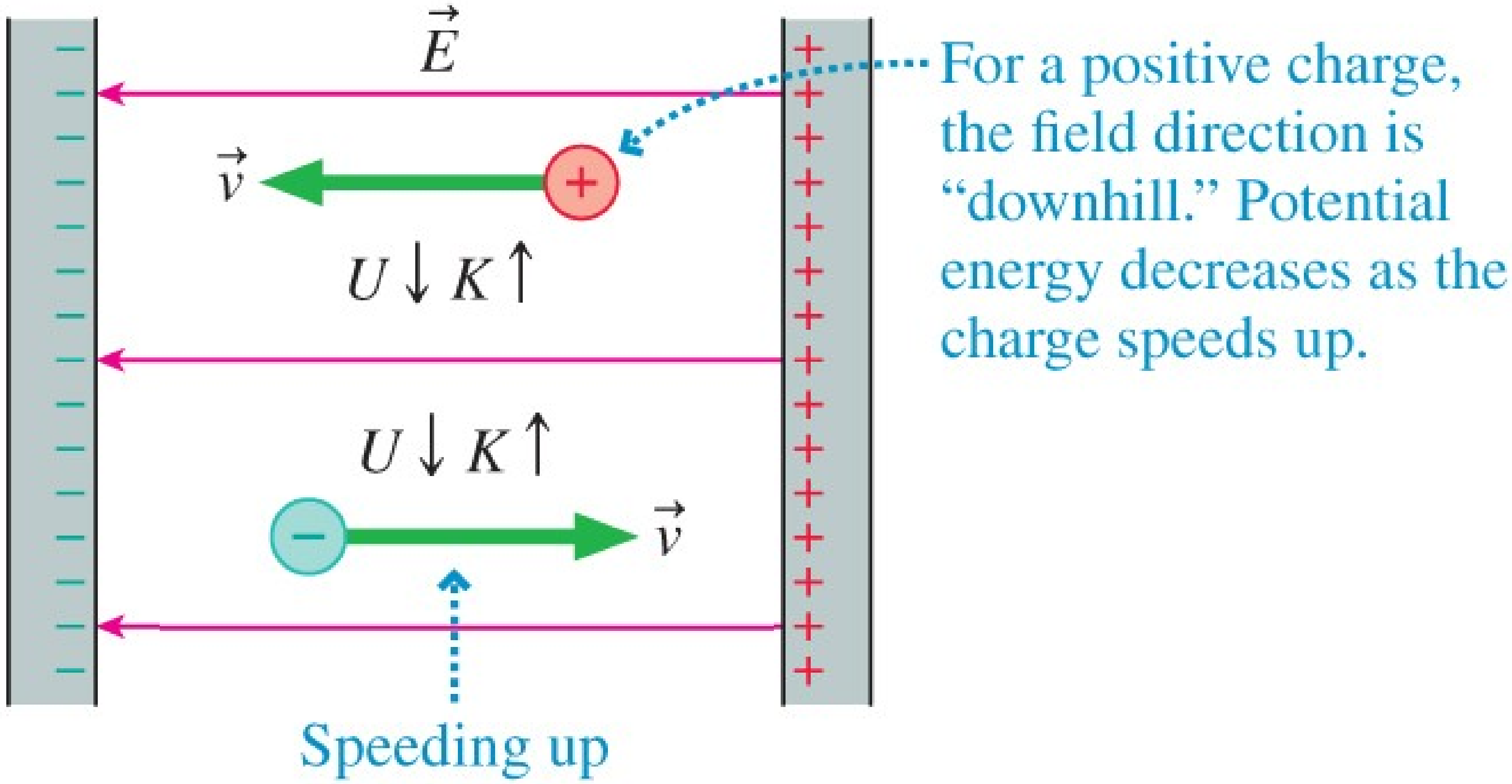
Two positive charges are equal. Which has more electric potential energy?



✔ **A. Charge A**
B. Charge B
C. They have the same potential energy.
D. Both have zero potential energy.

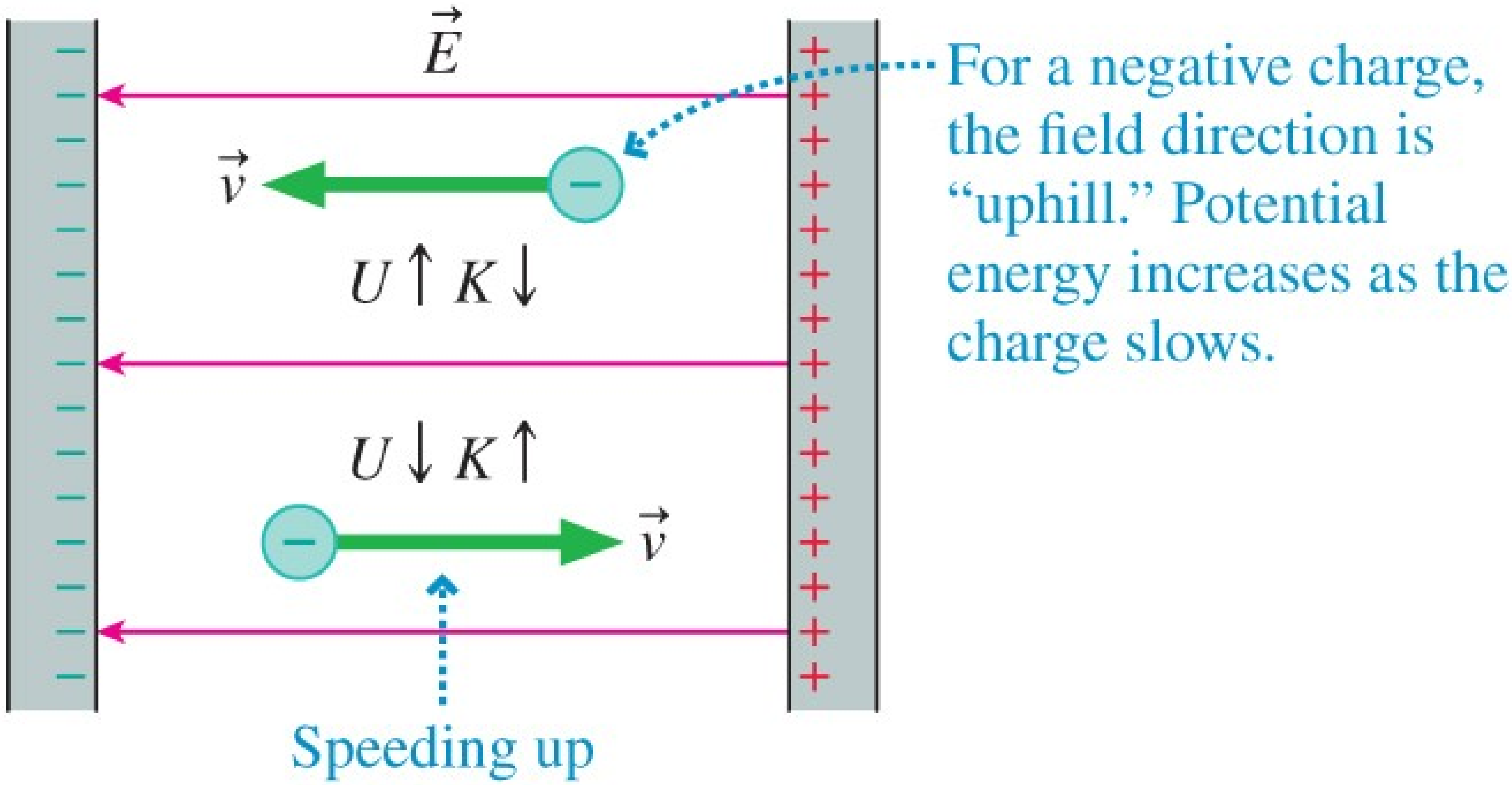
Work and Energy

Objects always “fall” toward lower potential energy.



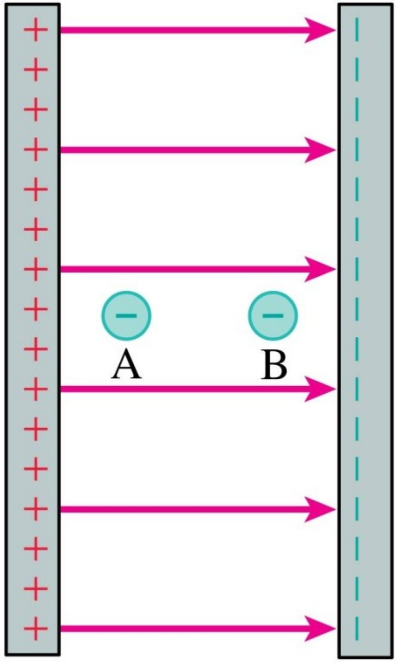
Work and Energy

Objects always "fall" toward lower potential energy.



Work and Energy

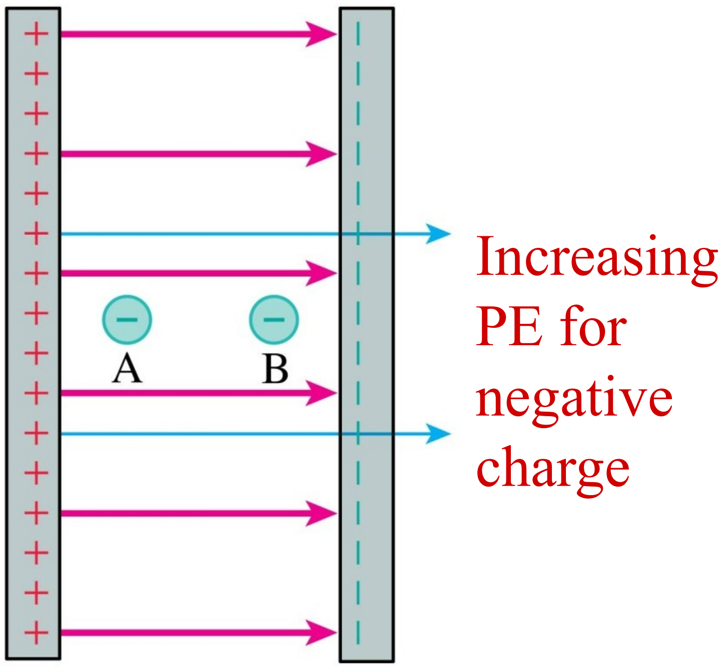
Two negative charges are equal. Which has more electric potential energy?



A. Charge A
B. Charge B
C. They have the same potential energy.
D. Both have zero potential energy.

Work and Energy

Two negative charges are equal. Which has more electric potential energy?



A. Charge A

✔ **B. Charge B**

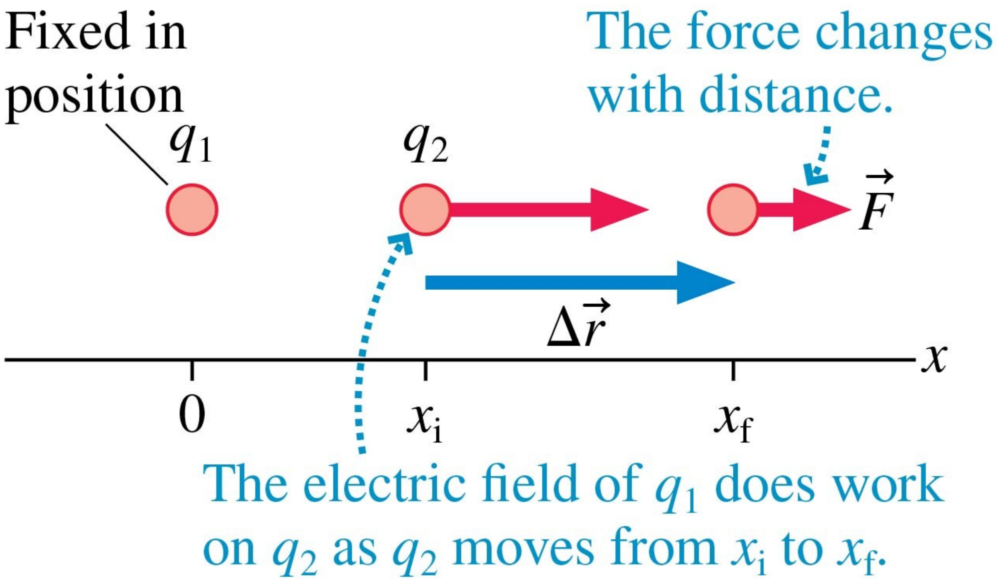
C. They have the same potential energy.

D. Both have zero potential energy.

Work and Energy

For a non-uniform field...

Find the work done to move charge q_2 from x_i to x_f :



$$W = F_1 \Delta x_1 + F_2 \Delta x_2 + \ldots$$

$$W = \int_{x_i}^{x_f} F(x)\, dx$$

$$W = \int_{x_i}^{x_f} \frac{kq_1 q_2}{x^2}\, dx = -kq_1 q_2 \left[\frac{1}{x}\right]_{x_i}^{x_f} = -\frac{kq_1 q_2}{x_f} + \frac{kq_1 q_2}{x_i}$$

Work and Energy

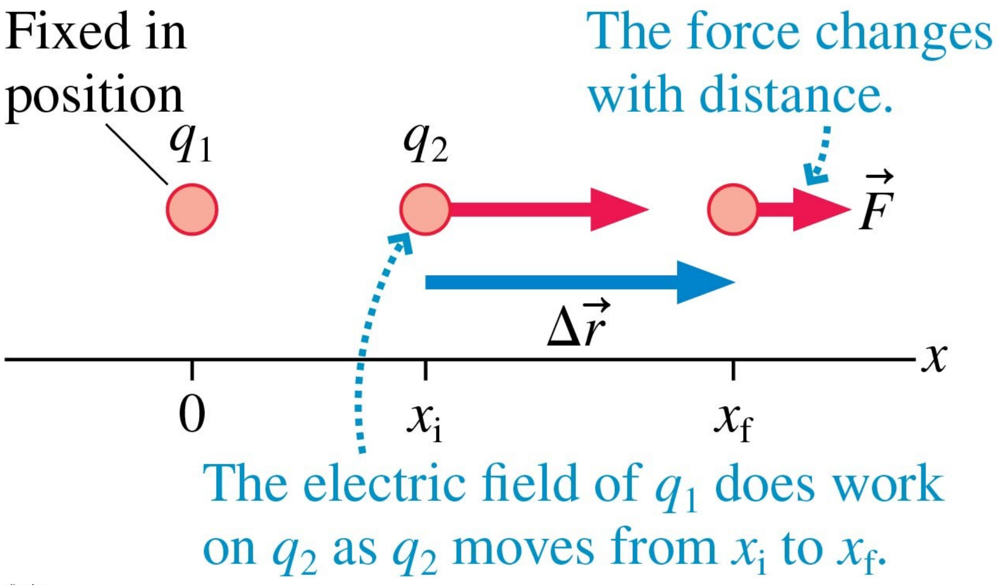
For a non-uniform field...

Find the work done to move charge q_2 from x_i to x_f:

$$W = -\frac{kq_1q_2}{x_f} + \frac{kq_1q_2}{x_i}$$

$$\Delta U = -W_{\text{internal}}$$

$$\Delta U = U_f - U_i = \frac{kq_1q_2}{x_f} - \frac{kq_1q_2}{x_i}$$



Electric Potential Energy

- Two point charges, q_1 and q_2, separated by a distance r store an electric potential energy of

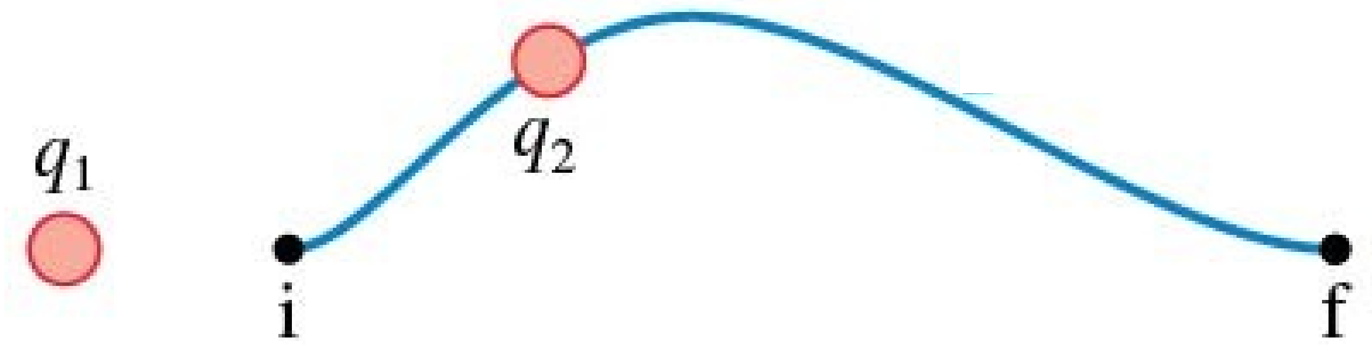
$$U = \frac{kq_1q_2}{r} = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r}$$

- This is the energy of *the system*, not the energy of just q_1 or q_2.

- Note that the potential energy of two charged particles approaches zero as $r \rightarrow \infty$.

Electric Potential Energy

The work done on q_2 (and the change in potential energy) is **path independent**.



$$U = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r}$$

Electric Potential Energy

- for more than two point charges, add up the potential energies due to all pairs of charges:

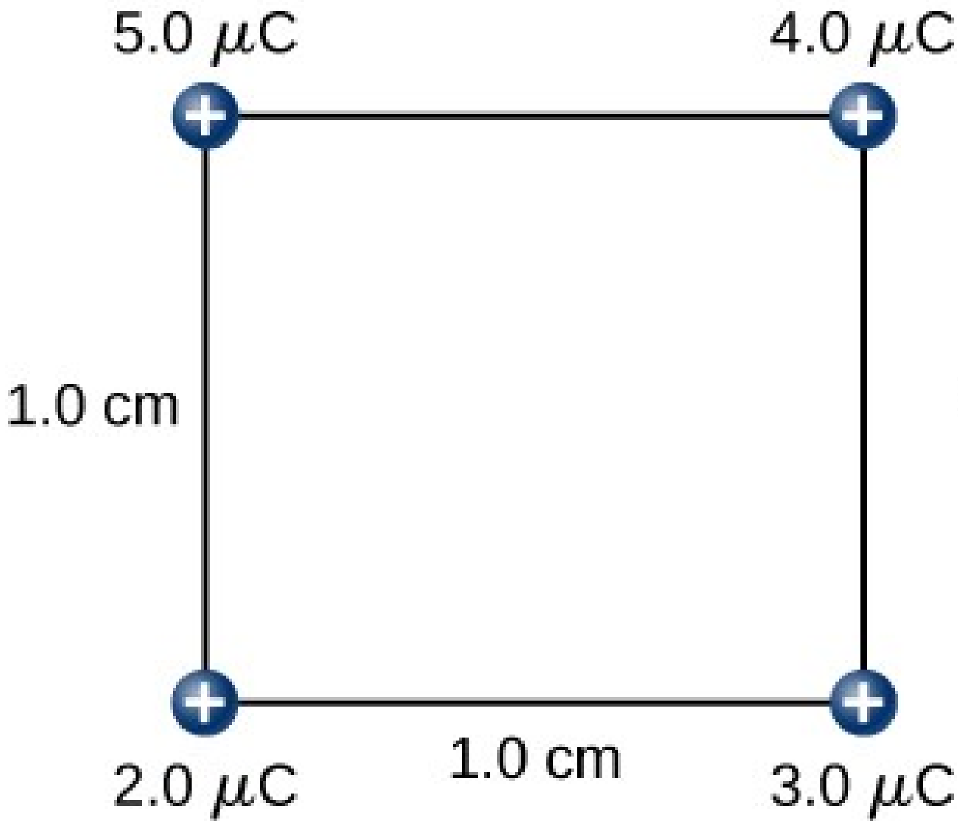
$$U = \sum_{i<j} \frac{1}{4\pi\epsilon_0} \frac{q_i q_j}{r_{ij}}$$

where r_{ij} is the distance between q_i and q_j.

- The summation contains the $i < j$ restriction to ensure that each pair of charges is counted only once.

Electric Potential Energy

$$U = \sum_{i<j} \frac{1}{4\pi\epsilon_0} \frac{q_i q_j}{r_{ij}}$$



The Electric Potential

- We define the electric potential V (or just "*the potential*") as

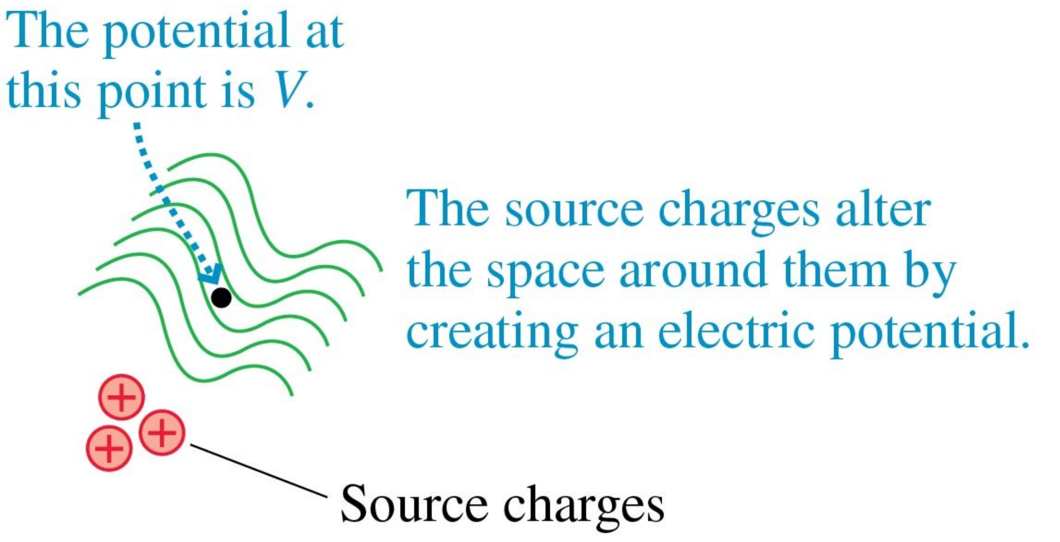
$$V \equiv \frac{U_{q+\text{sources}}}{q}$$

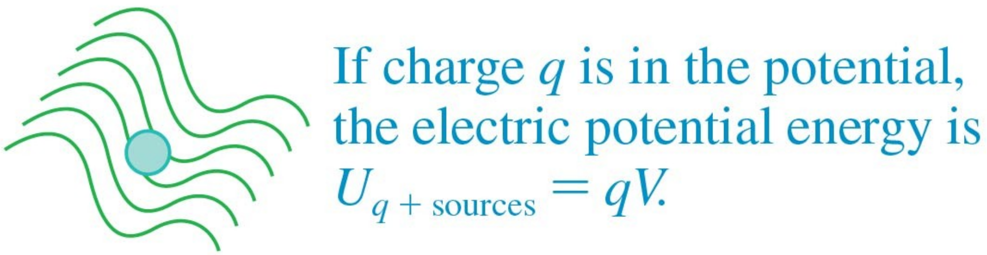
- The unit of electric potential is the joule per coulomb, which is called the **volt V**:

$$1 \text{ volt} = 1 \text{ V} \equiv 1 \text{ J/C}$$

The Electric Potential

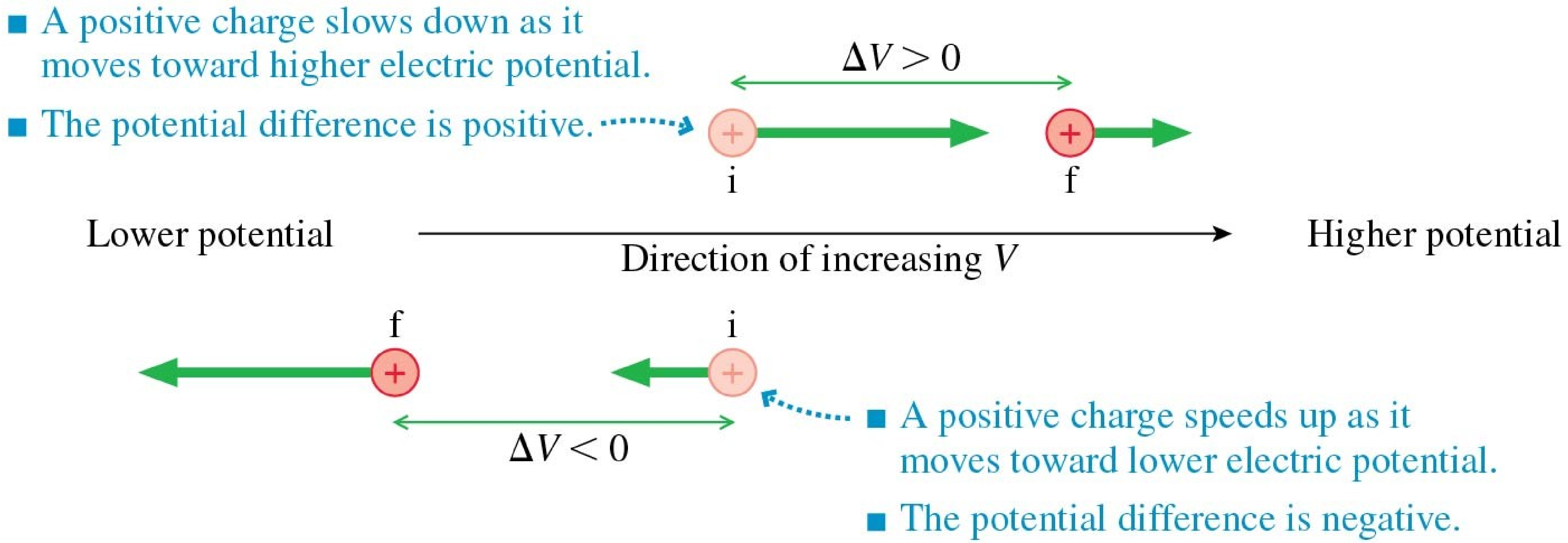
The electric potential, like the electric field, is a property of the source charges.





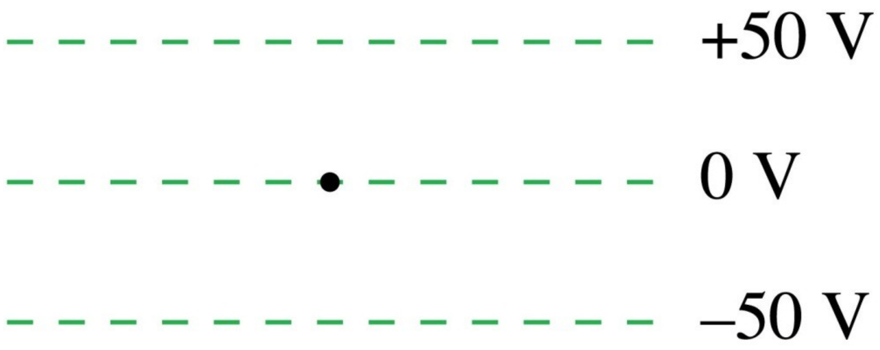
Using the Electric Potential

$$K_f + qV_f = K_i + qV_i$$



Electric Potential

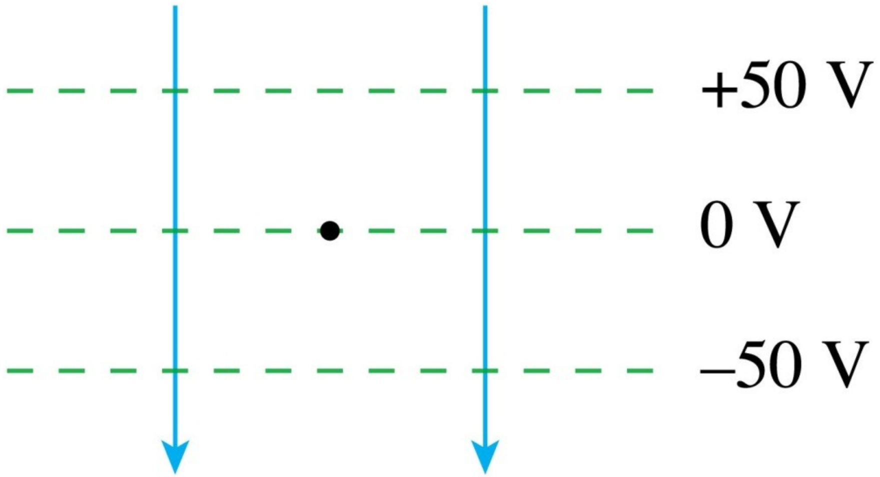
A proton is released from rest at the dot. Afterward, the proton



A. Remains at the dot.
B. Moves upward with steady speed.
C. Moves upward with an increasing speed.
D. Moves downward with a steady speed.
E. Moves downward with an increasing speed.

Electric Potential

A proton is released from rest at the dot. Afterward, the proton



Decreasing PE
Increasing KE

A. Remains at the dot.
B. Moves upward with steady speed.
C. Moves upward with an increasing speed.
D. Moves downward with a steady speed.
✔E. **Moves downward with an increasing speed.**

Electric Potential

If a positive charge is released from rest, it moves in the direction of

A. A stronger electric field.

B. A weaker electric field.

C. Higher electric potential.

✔ **D. Lower electric potential.**

E. Both B and D.

Using the Electric Potential

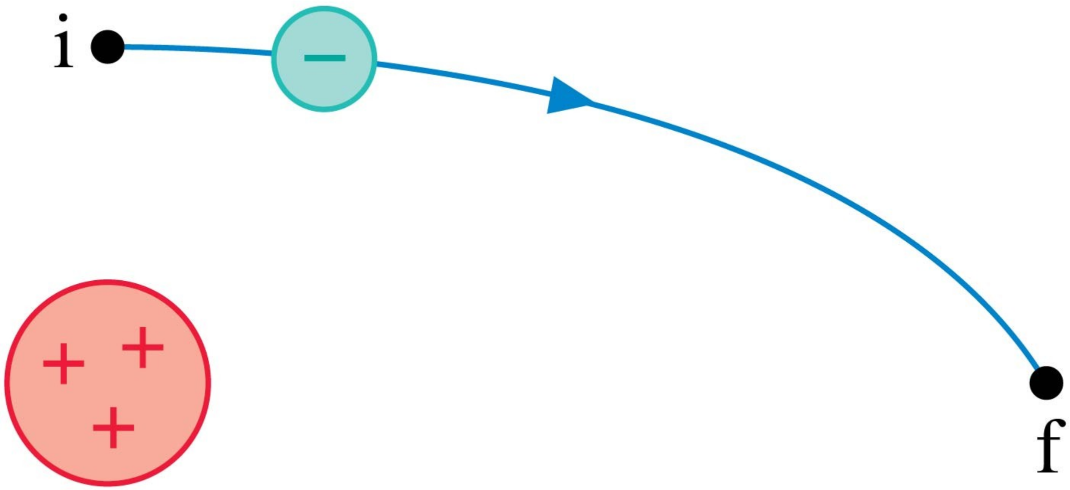
- As a charged particle moves through a changing electric potential, energy is conserved:

$$K_f + qV_f = K_i + qV_i$$

	Electric potential	
	Increasing ($\Delta V > 0$)	Decreasing ($\Delta V < 0$)
+ charge	Slows down	Speeds up
− charge	Speeds up	Slows down

Electric Potential (Voltage)

An electron follows the trajectory shown from i to f. At point f,



A. $v_f > v_i$

B. $v_f = v_i$

C. $v_f < v_i$

D. Not enough information to compare the speeds at these points.

Electric Potential (Voltage)

An electron follows the trajectory shown from i to f. At point f,

A. $v_f > v_i$

B. $v_f = v_i$

✔ C. $\boldsymbol{v_f < v_i}$

D. Not enough information to compare the speeds at these points.

Increasing PE (becoming less negative) so decreasing KE