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- Parallel Plate Capacitors
- Electric Potential Energy
- Electric Potential
- Voltage, the “Volt”
- Electric Potential of a point charge

The Parallel-Plate Capacitor
- The figure shows two electrodes, one with charge \(+Q\) and the other with \(-Q\) placed face-to-face a distance \(d\) apart.
- This arrangement of two electrodes, charged equally but oppositely, is called a parallel-plate capacitor.
- Capacitors play important roles in many electric circuits.

Motion of a Charged Particle in an Electric Field
The electric field exerts a force
\[ \vec{F}_{\text{on } q} = q\vec{E} \]
on a charged particle. If this is the only force acting on \(q\), it causes the charged particle to accelerate with
\[ \vec{a} = \frac{\vec{F}_{\text{on } q}}{m} = \frac{q}{m} \vec{E} \]
In a uniform field, the acceleration is constant:
\[ a = \frac{qE}{m} = \text{constant} \]

Electric Potential Energy
The electric potential energy of charge \(q\) in a uniform electric field is
\[ U_{\text{elec}} = U_0 + qEs \]
where \(s\) is measured from the negative plate and \(U_0\) is the potential energy at the negative plate \((s = 0)\). It will often be convenient to choose \(U_0 = 0\), but the choice has no physical consequences because it doesn’t affect \(\Delta U_{\text{elec}}\), the change in the electric potential energy. Only the change is significant.
The Potential Energy of Point Charges

Consider two point charges, \(q_1\) and \(q_2\), separated by a distance \(r\). The electric potential energy is

\[
U_{\text{elec}} = \frac{k q_1 q_2}{r} = \frac{q_1 q_2}{4\pi \epsilon_0 r} \quad \text{(two point charges)}
\]

This is explicitly 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 \(r \to \infty\).

Ranked in order, from largest to smallest, the potential energies \(U_a\) to \(U_d\) of these four pairs of charges. Each + symbol represents the same amount of charge.

\[\begin{align*}
\text{(a)} & : U_c = U_b > U_d = U_a \\
\text{(b)} & : U_b = U_d > U_a = U_c \\
\text{(c)} & : U_a = U_c > U_b = U_d \\
\text{(d)} & : U_d > U_c > U_b > U_a
\end{align*}\]

A. Positive  
B. Negative  
C. Zero

The Electric Potential

We define the electric potential \(V\) (or, for brevity, just the potential) as

\[V \equiv \frac{U_{\text{q+sources}}}{q}\]

Charge \(q\) is used as a probe to determine the electric potential, but the value of \(V\) is independent of \(q\). The electric potential, like the electric field, is a property of the source charges.

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 Inside a Parallel-Plate Capacitor

The electric potential inside a parallel-plate capacitor is

\[V = Es\]

where \(s\) is the distance from the negative electrode.

The electric potential, like the electric field, exists at all points inside the capacitor.

The electric potential is created by the source charges on the capacitor plates and exists whether or not charge \(q\) is inside the capacitor.

A proton is released from rest at point B, where the potential is 0 V. Afterward, the proton

\[\begin{align*}
-100 \text{ V} & \quad 0 \text{ V} & \quad +100 \text{ V} \\
\text{A} \bullet & \quad \text{B} \bullet & \quad \text{C} \bullet
\end{align*}\]

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.