Establish the relationship between \( E \) and \( V \).
- Determine the properties of conductors in electrostatic equilibrium.
- Introduce batteries as a practical source of potential difference.
- Connect current and potential difference for a conductor.
- Connect charge and potential difference for a capacitor.
- Analyze simple capacitor circuits.

\[ V = \int E \, ds \]

We’ve seen previously that we can get the electrical potential difference by integrating the electric field component along a path.

\[ \Delta V = -\int_a^b E \cdot ds \]

Now let’s go the other way and get the field component from the potential.

\[ E = -\frac{dV}{ds} \]

We’ve seen the general relationship between a conservative force and potential energy:

Subbing in electrical force and electrical potential energy:

We now have a relationship between electric fields and potentials.
Given the graph of the x-component of the electric field below, sketch the corresponding graph of the potential.

An equipotential surface is a locus of points in an electric field that are all at the same electrical potential. An example is the locus of points equidistant from an isolated point charge (a sphere).

Notice that the equipotential surfaces are perpendicular to the electric field lines everywhere!

Remember the electric field only performs work on a charge when the charge moves parallel to the electric field lines.

So no work is done by the electric field as a charge moves along an equipotential surface. This is just like GRAVITY, right?

By definition, the potential difference between any two points on an equipotential surface $(V_a - V_b)$ must be...

$$W = -q\Delta V$$
When in electrostatic equilibrium (i.e., no charges are moving around), all points on and inside of a conductor are at the same electrical potential!

Remember that the electric field is everywhere perpendicular to the surface of a conductor, and is zero inside of a conductor.

From the surface of a conductor throughout its entire interior, the electric field is 0 when the conductor is in electrostatic equilibrium.

A common type of capacitor consists of a pair of parallel conducting plates, one charged positively, one charged negatively. A device for storing charge (and energy).

Therefore... An electric field exists between the plates of a capacitor.

On what could capacitance possibly depend?

Think geometrically....

The area of the plates: the larger the area, the more charge it can hold. \( \sim A \)

The separation distance of the plates: the closer the plates, the more charge it can hold (the attractive force of the charges from the opposite plate). \( \sim 1/d \)

\[
C = \varepsilon_0 A / d
\]

\[
\text{units!} \quad [C] = \left[ \varepsilon_0 \right] \left[ \frac{A}{d} \right] = \frac{C^2}{N \cdot m} = \frac{C^2}{J} = \frac{C}{V}
\]

1 Farad = \( C / V \)
What happens when you connect a capacitor to a battery?

In this circuit, the battery pulls electrons off the top plate of the capacitor and pushes them onto the lower plate of the capacitor until the capacity of the capacitor is reached.

Each plate then holds a charge \( |Q| \), which is said to be the charge on the capacitor.

What’s a battery?

The battery converts internal chemical energy to electrical energy, maintaining a constant potential difference between its terminals.

What’s the potential difference between the 2 plates of the capacitor when the capacitor is fully charged?

The battery maintains a constant potential difference across its terminals (and hence, the capacitor as well) of \( V \).

Capacitance, \( II \)

\[ C = \frac{Q}{V} \]

A VERY useful definition of capacitance!

Does not require us to have any knowledge about the geometry of the capacitor.

Capacitance can be determined solely from the behavior of the electrical circuit.

Notice this has the same units as the quantity we derived earlier!

1 Farad = \( \frac{C}{V} \)
Parallel Circuits

So, what happens when the battery is connected to this circuit?

Charge of $Q_1 = C_1 V$ accumulates on $C_1$.
Charge of $Q_2 = C_2 V$ accumulates on $C_2$.

Capacitors in parallel ADD.

We can construct an equivalent circuit with a single capacitor...

$\frac{C_{eq}}{V} = (Q_1 + Q_2) / V = C_1 + C_2$

Series Circuits

So, what happens after the battery is connected to this circuit?

$Q_1 = Q_2$, conservation of charge!

$V_1 + V_2 = V$

$V_1 = Q / C_1$
$V_2 = Q / C_2$
$V = V_1 + V_2$

$C_{eq} = Q / V$
Series capacitor combination:

\[ C_{eq} = Q / V \]

\[ V = V_1 + V_2 \]

\[ V_1 = Q / C_1 \]

\[ V_2 = Q / C_2 \]

Series capacitors “ADD INVERSELY.”

What is the effective capacitance of this circuit?

1) 0.28 μF
2) 0.61 μF
3) 0.93 μF
4) 1.00 μF
5) 1.50 μF
6) 3.00 μF
7) 6.00 μF
8) None of the above