Recall definition of work:

- Exert a force, and move object in that direction, you have given the object energy called work.

\[
W = \int \overrightarrow{F} \cdot d\overrightarrow{x} = \overrightarrow{F}_{avg} \cdot \Delta \overrightarrow{x}
\]

- For a conservative force, we can store energy as potential energy.

\[
W = F_{push} \Delta y \rightarrow W = \Delta U
\]

Our work of lifting adds to potential energy.

\[
W = F_p \Delta y \rightarrow \Delta U = mg \Delta y
\]

So we say the potential energy change is:

If we stop at the indefinite integral,

\[
U_g = \int F_{app} \cdot d\overrightarrow{x} = -\int F_g \cdot d\overrightarrow{x}
\]

\[
U_g = mg \gamma + C
\]
For an Electric Force

\[ U_E = -\int F_E \cdot dx \]

\[ \vec{F}_E = -\nabla U_E \]

- Force points toward lower potential energy.

With E-Field, we said \( \vec{F}_E = q_0 \vec{E} \)

\[ U_E = -\int q_0 \vec{E} \cdot dx = q_0 \left( -\int \vec{E} \cdot dx \right) \]

- Electric Potential Energy
- Electric Potential

Usually used as: \( \Delta U_E = q_0 \Delta V \)

Because of the def: \( E_x = -\frac{dV}{dx} \)

- \( E \) points "downhill" toward lower \( V \).

Protons are \( + \)
- Pushed with \( E \)
- Repelled from high \( V \)
- Repelled from high \( U_E \)

Elections are \( - \)
- Pulled against \( E \)
- Attracted to high-\( V \)
- Repelled from high \( U_E \)

\[ U_E = q_0 V \]
Capacitor as Voltage Storage.

\[ E = \frac{1}{4\pi k} \frac{Q}{d} \]

\[ \Delta V = - \int E_y \, dy = -E \cdot d \]

Since we know the sign of \( Q \) is at higher \( V \), drop the sign. Since we know only potential differences matter, drop the \( \Delta \).

\[ V = Ed = \frac{1}{4\pi k} \frac{Q}{A} \]

\[ Q = \left( \frac{1}{4\pi k} \frac{A}{d} \right) V \]

\[ Q = CV \]

How much energy does the capacitor store?

\[ \text{Energy} = \frac{1}{2} (\text{Charge})^2 \left( \frac{\text{Energy}}{\text{Charge}} \right) = \frac{1}{2} QV \]
Particle Accelerator

\[ E \rightarrow \Phi \rightarrow \Delta V \]

Energy given = $q \Delta V$

Where does the energy show up?

\[ K = \frac{1}{2}mv^2 \]

Veloctiy
Electric Current - Flow rate of electricity

\[ I = \frac{dQ}{dt} \]

Charge that passes by.

\[ I = \frac{dQ_1}{dt} \quad I = \frac{dQ_2}{dt} \]

Current

Usually, we don't let Q accumulate. No dead ends.

How do we measure current?

- Make charges go thru our ammeter.
- Allow current thru meter easily.