Chapter 17 - Electric Potential ~ "Voltage"

After this you can
- define electric potential energy
- define electric potential
- discuss the difference between them

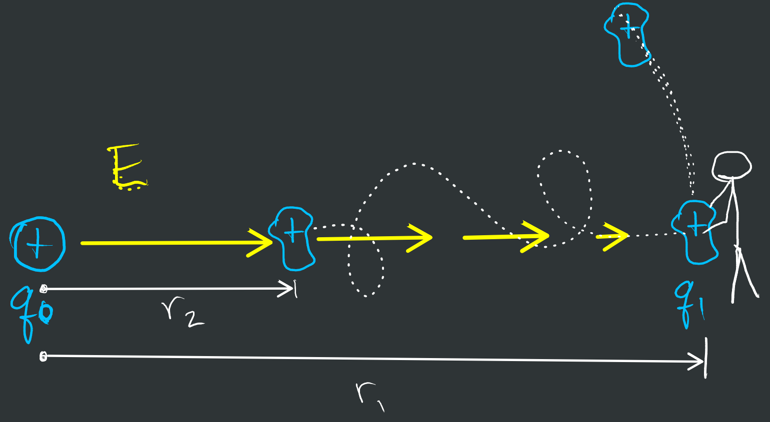
Work - transfer of energy
- outside the system
- increases the energy of system

$W = F \cdot \Delta x \cdot \cos\theta$ ← limited to constant force

$F_e = q \cdot E$ → pt. source

→ sheet/capacitor → $E = \frac{Q}{\epsilon_0 A} = \frac{\sigma}{\epsilon_0}$

→ work done by conservative forces → potential energy
- → path independent
- → converted to kinetic energy



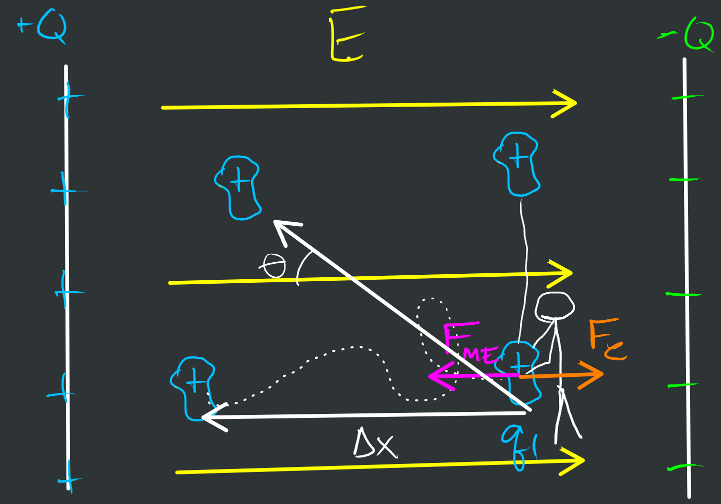
$$W_{ME} = \Delta U_e$$

$$W_{ME} = \Delta U_e = \underbrace{\frac{k q_0 q_1}{r_2}}_{U(r_2)} - \underbrace{\frac{k q_0 q_1}{r_1}}_{U(r_1)}$$

So for $r \to \infty$

$\to U(r \to \infty) = 0$

$$U(r) = \frac{k q_0 q_1}{r}$$ } implies a reference point of infinity



$$W_{ME} = \Delta U$$

$$W_{ME} = \Delta U_e = F_{ME} \cdot \Delta x \cdot \underbrace{\cos\theta}_{1}$$

$$|F_{ME}| = |F_e| = q_1 E$$

$$\Delta U_e = q_1 \cdot E \cdot \Delta x$$

electric potential $\to \dfrac{\Delta U_e}{q_1}$ $\quad \dfrac{[\text{Joule}]}{[\text{Coulomb}]} = [\text{Volt}]$

↓

voltage → work/(Δ potential energy) per unit of moving charge

↓

potential difference

$$\Delta V = \frac{\Delta U_e}{q_1}$$

$$\Delta V = \frac{kq_0}{r_2} - \frac{kq_0}{r_1}$$

$$V(r) = \frac{kq_0}{r}$$ } implies a reference point of infinity

point charge electric field

$$\Delta V = \frac{\Delta U_e}{q_1}$$

$$\Delta V = E \cdot \Delta x$$

uniform electric field

After this you can

- discuss the relationships between electric field, voltage, force, and potential energy
- determine the equipotential surfaces in the space around a charge distribution

charge distribution

$F_e = q_1 E$

$$\begin{tikzcd}[column sep=huge, row sep=huge]
\boxed{\text{electric field}} \arrow[r, shift left, "\times q_1"] \arrow[d, shift left, "\times \Delta x"] & \boxed{\text{electric force}} \arrow[l, shift left, "\div q_1"] \arrow[d, shift left, "\times \Delta x"] \\
\boxed{\text{voltage (potential diff)}} \arrow[u, shift left, "\div \Delta x"] \arrow[r, shift left, "\times q_1"] & \boxed{\text{work/change in potential energy}} \arrow[l, shift left, "\div q_1"] \arrow[u, shift left, "\div \Delta x"]
\end{tikzcd}$$

(uniform)

$W = \Delta U = F_e \cdot \Delta x$

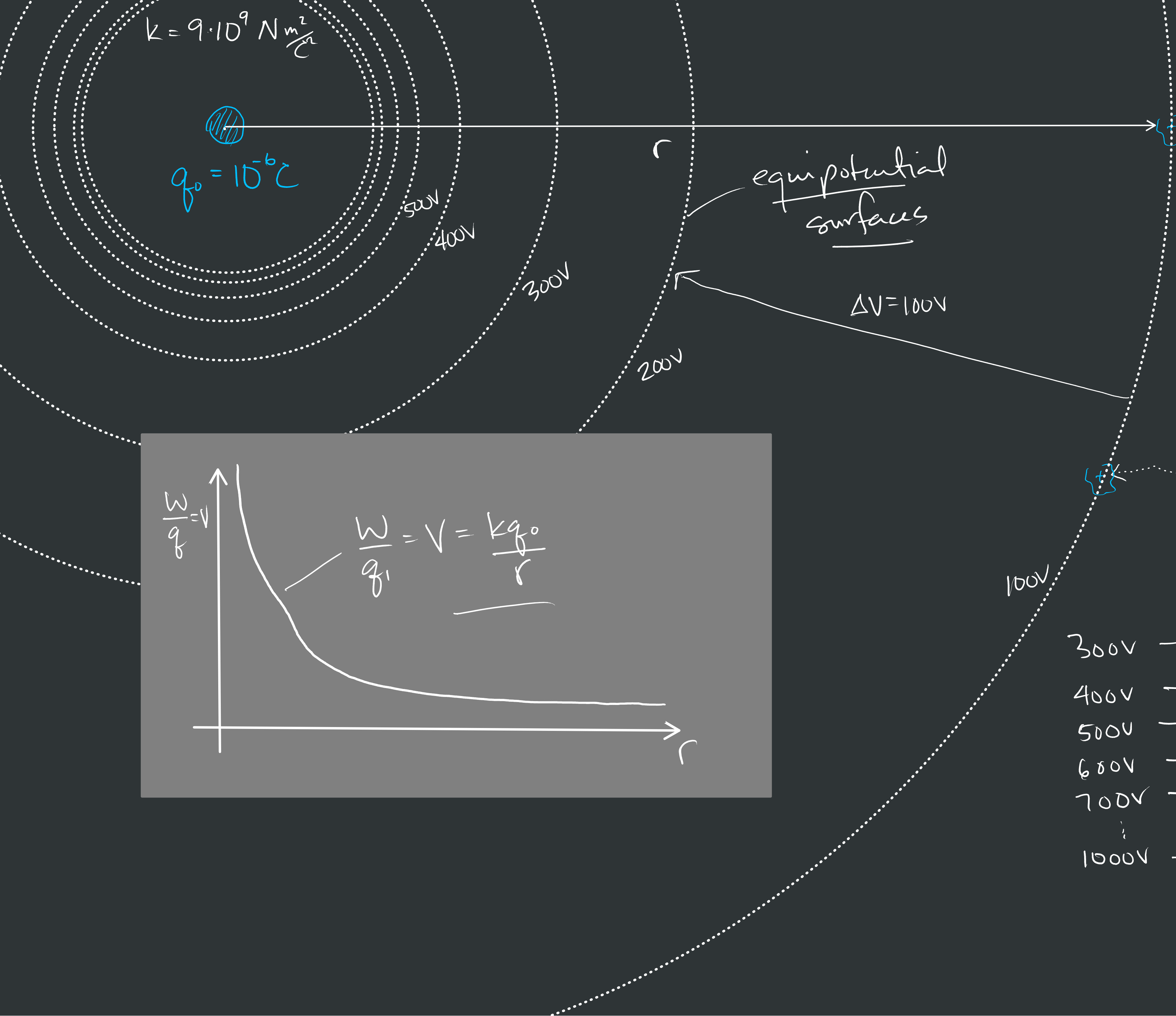
$\Delta V = E \cdot \Delta x$

$E = \frac{\Delta V}{\Delta x}$

gradient

$\Delta V = \frac{\Delta U_e}{q_1}$

$$\left.\begin{aligned} \text{velocity} &= \frac{\Delta x}{\Delta t} \\ \text{acc} &= \frac{\Delta v}{\Delta t} \end{aligned}\right\} \text{rates of change}$$



$\frac{100 J}{C} = 100V$

$V = \frac{kq_0}{r}$

$r = \frac{kq_0}{V}$

$r = 90m$

200V

$r = 45m$

$300V \rightarrow 30m$

$400V \rightarrow 22.5m$

$500V \rightarrow 18m$

$600V \rightarrow 15m$

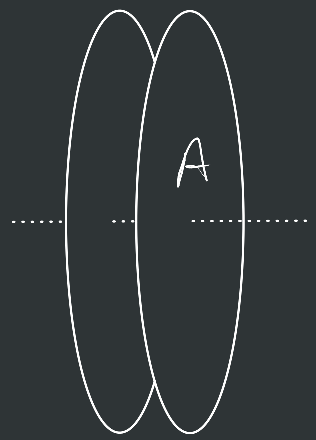
$700V \rightarrow 12.8m$

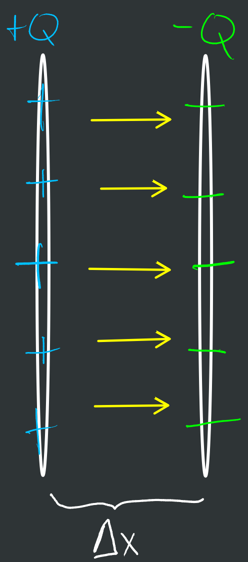
⋮

$1000V \rightarrow 10m$

After this you can

- use the new quantity of capacitance to relate the charge stored on a capacitor to the voltage between the plates
- use the physical properites of a capacitor to predict how much charge can be stored
- discuss energy storage in a capacitor





$\Delta V = E \cdot \Delta x$

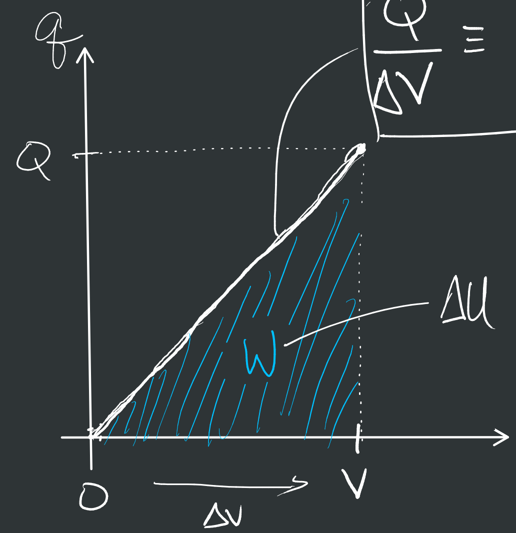
$\Delta x \cdot E = \dfrac{Q}{\epsilon_0 A} \cdot \Delta x$

$\Delta V = \dfrac{Q}{\epsilon_0 A} \cdot \Delta x$

$\dfrac{\epsilon_0 A}{\Delta x} = \dfrac{Q}{\Delta V} = C$

parallel plate capacitor

$$\boxed{C = \frac{\epsilon_0 A}{\Delta x}}$$



$$\boxed{\frac{Q}{\Delta V} \equiv \text{Capacitance}}$$

Units

$\dfrac{[\text{Coulomb}]}{[\text{Volt}]} = \left[\dfrac{C \cdot s}{J}\right] = [\text{Farad}]$

$\mu F \to 10^{-6} F$

$nF \to 10^{-9} F$

$pF \to 10^{-12} F$

$$\boxed{\Delta U = \frac{1}{2} \Delta V \, Q}$$

$C = \dfrac{Q}{\Delta V}$

energy stored in a capacitor