______ ________ ~ "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

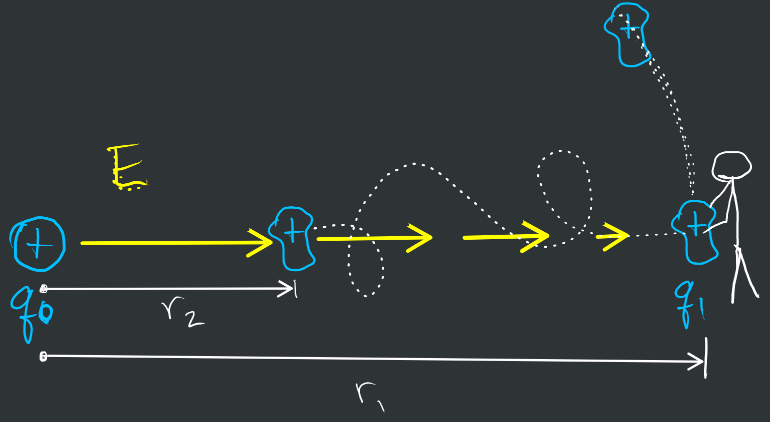
$F_e = q \cdot E$ → pt. source

→ 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



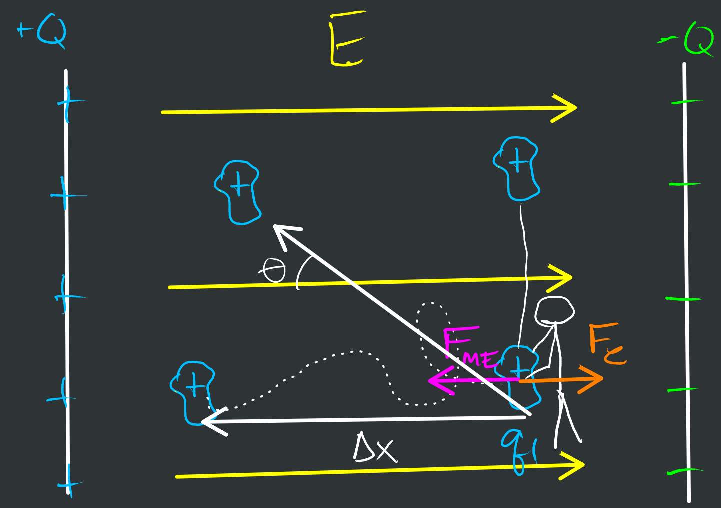
$$W_{ME} = \Delta U_e$$

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

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

$$\boxed{\begin{aligned} \Delta V &= \frac{\Delta U_e}{q_1} \\ \Delta V &= \frac{kq_0}{r_2} - \frac{kq_0}{r_1} \\ V(r) &= \frac{kq_0}{r} \end{aligned}}$$

} implies a reference point of infinity

point charge electric field

$$\boxed{\begin{aligned} \Delta V &= \frac{\Delta U_e}{q_1} \\ \Delta V &= E \cdot \Delta x \end{aligned}}$$

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

$$F_e = q_1 E$$

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

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

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

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

gradient

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

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

$k = 9 \cdot 10^9 \, N \frac{m^2}{C^2}$

$q_0 = 10^{-6} C$

r

500V

400V

300V

200V

100V

equipotential surfaces

$\Delta V = 100V$

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

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

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

$r = 90m$

200V

$r = 45m$

$300V \rightarrow 30m$

$400V \rightarrow 22.5m$

$500V \rightarrow 18m$

$600V \rightarrow 15m$

$700V \rightarrow 12.8m$

⋮

$1000V \rightarrow 10m$