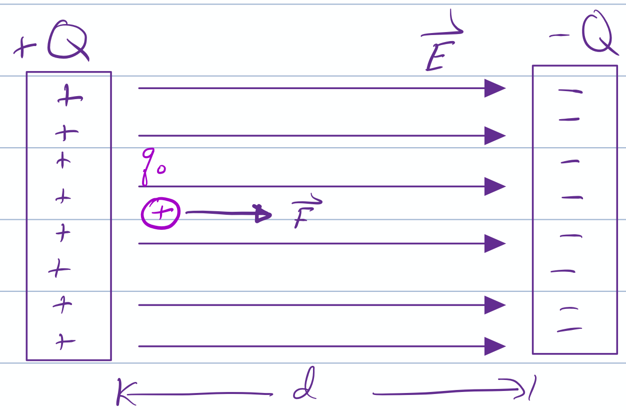
Plan: Calculate ΔU, then $\Delta V = \frac{\Delta U}{q_0}$.

We will consider 2 basic settings, the parallel plate capacitor and a point charge.

Parallel Plates:



area A

$$E = \frac{\sigma}{\epsilon_0}$$

$$\vec{F} = q_0 \vec{E}$$

$$Q = 1.6 \times 10^{-10}\ C$$

Problem: Consider two square plates, 10 cm on a side, separated by a distance of 5 mm. Imagine a proton is released from rest at the + plate. How quickly is it moving when it reaches the − plate?

Way #1 $\quad F = ma$

$$qE = ma \Rightarrow a = \frac{qE}{m}$$

$$E = \frac{\sigma}{\epsilon_0} = \frac{Q/A}{\epsilon_0} = \frac{(1.6 \times 10^{-10}\,C)/(0.10\,m)^2}{8.85 \times 10^{-12}\,C^2/Nm^2}$$

$$E = 1807\ N/C$$

Then $a = \dfrac{(1.602\times10^{-19}C)(1807\,N/C)}{1.6726\times10^{-27}kg}$

$a = 1.731\times10^{11}\,m/s^2$ (huge!)

Kinematics: $v_f^2 = v_i^2 + 2ad$

$v_f^2 = 0 + 2ad$

$v = \sqrt{2ad} = \sqrt{2(1.731\times10^{11}m/s^2)(0.005m)}$

$v = 41,600\,m/s.$

Way #2 Work/Energy

$K_i + W = K_f$

$\frac{1}{2}mv_i^2 + F\cdot d = \frac{1}{2}mv_f^2$

$\frac{1}{2}mv_i^2 + (qE)\cdot d = \frac{1}{2}mv_f^2$

$0 + qEd = \frac{1}{2}mv_f^2$

$v_f = \sqrt{\dfrac{2(qEd)}{m}} =$

$v_f = \sqrt{\dfrac{2(1.602\times10^{-19}c)(1807\,N/c)(0.005m)}{1.6726\times10^{-27}kg}}$

$v_f \simeq 41,600\,m/s.$

Way #3 Conservation of Energy

$K_i + U_i = K_f + U_f$

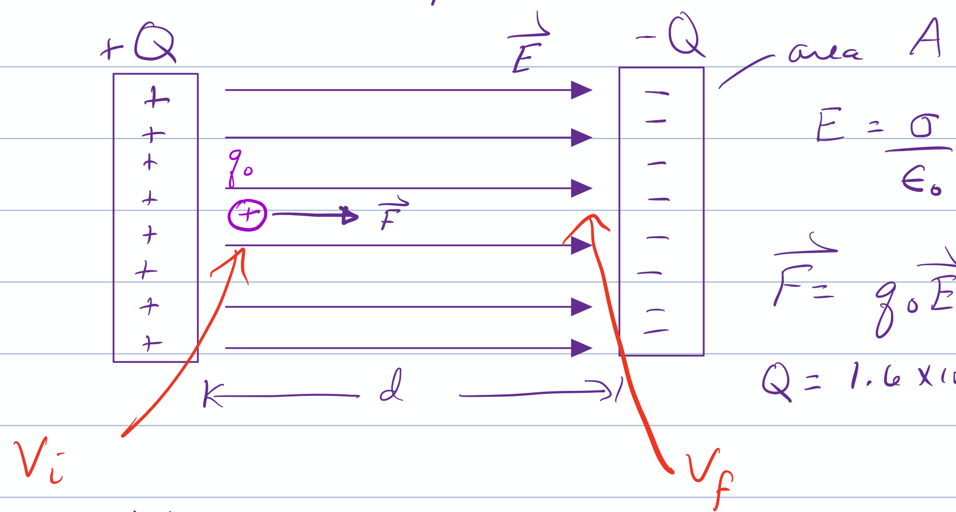
$K_i + qV_i = K_f + qV_f$

$K_i - q(V_f - V_i) = K_f$ compare to last

approach $K_i + q(Ed) = K_f$

This suggests $-\Delta V = E d$. in this problem.

$$-(V_f - V_i) = (1807\ N/C)\cdot(0.005\ m)$$
$$-(V_f - V_i) = 9.04\ V$$
$$V_f - V_i = -9.04\ V$$
$$V_f = V_i - 9.04\ V$$



$E = \dfrac{\sigma}{\epsilon_0}$

$\vec{F} = q_0 \vec{E}$

$Q = 1.6 \times 10^{-10}\ C$

	V_i	V_f
	9.04 V	0
OR	109.04 V	100.0 V

only the <u>difference</u> matters

SO: For the parallel plate

$$|\Delta V| = E \cdot d \quad .\ \text{Sign?}$$

$\vec{E}$ points from high V to low V.

So how to solve the problem?

$$K_i + U_i = K_f + U_f$$

$$K_i + qV_i = K_f + qV_f$$

$$K_i + q_i(V_i - V_f) = K_f$$

$$-\Delta V = E \cdot d = \frac{\sigma}{\epsilon_0} \cdot d = \frac{Q/A}{\epsilon_0} \cdot d$$

$$-\Delta V = \frac{(1.6 \times 10^{-10}\,C)/0.01\,m^2}{8.85 \times 10^{-12}\,C^2/Nm^2} \cdot 0.005\,m$$

$$-\Delta V = 9.04\ V$$

$$-(V_f - V_i) = 9.04\,V$$

$V_i - V_f = 9.04\,V$. $Q+$ starts at higher voltage, and travels to lower voltage.

$$\therefore \quad K_i + q\,(9.04\,V) = K_f$$

$$0 + \underbrace{(e)(9.04\,V)}_{9.04\,eV} = \frac{1}{2} m v_f^2$$

$$\text{or } (1.602 \times 10^{-19}\,C)(9.04\,V)$$

$$= 1.448 \times 10^{-18}\,J = \frac{1}{2} m v_f^2$$

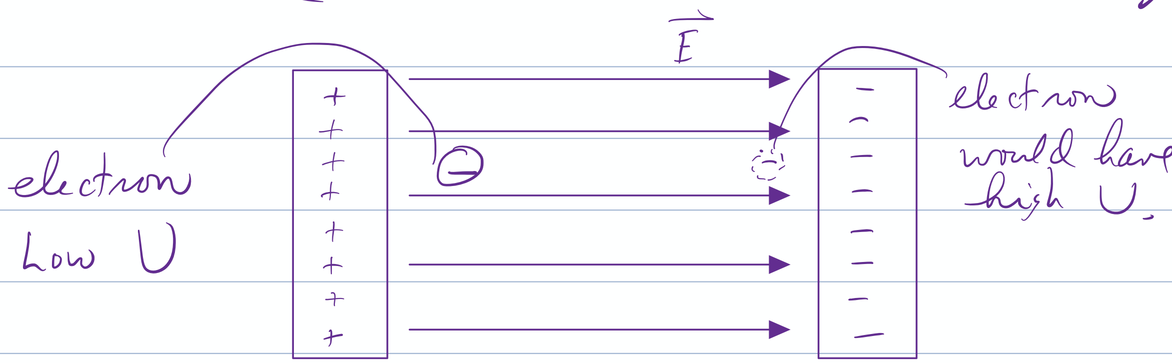
$$v_f = \sqrt{\frac{2e(9.04\,V)}{1.6726 \times 10^{-27}\,kg}} = \underline{41{,}600\ m/s}$$

Summary: for parallel plate

$$|\Delta V| = Ed.$$

What if you have an electron?

$U = (-e)V$. otherwise do the same thing.



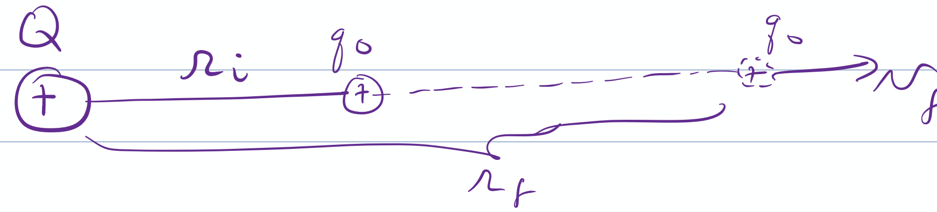
$$K_i + U_i = K_f + U_f$$

$$U = (-e)(V)$$

See examples Ch21-Energy-2 and Ch21-Energy-3.

Next: Calculating ΔV for a point charge

e.g. have a test charge q_0 near a point charge Q:



If you release q_0 from rest it will be repelled from Q. The electric force will do work and give the particle kinetic energy at r_f.

How much work? (Not just $F \cdot d = qE \cdot d$, since the force is not constant.)

Result for a point charge Q.

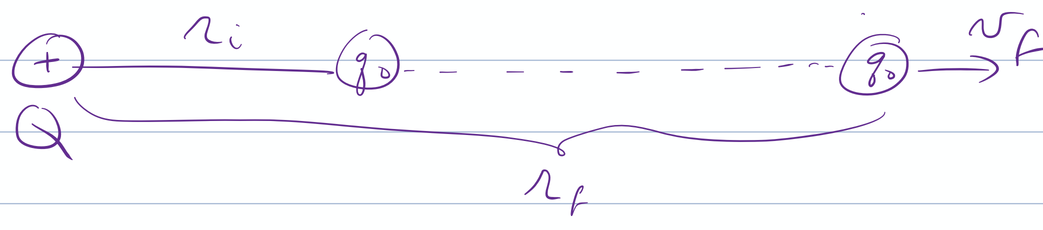
$\vec{E} = \frac{K|Q|}{r^2}$, away from + charge, towards − charge.

get $V = \frac{KQ}{r}$. Not a vector; include the sign.

~~Convention~~: take $V = 0$ when charge q_0 is ∞ far away. ($V \to 0$ as $r \to \infty$).

and $\boxed{U = q_0 V = \frac{KQq_0}{r}}$.

∴ Basic structure of the problem:

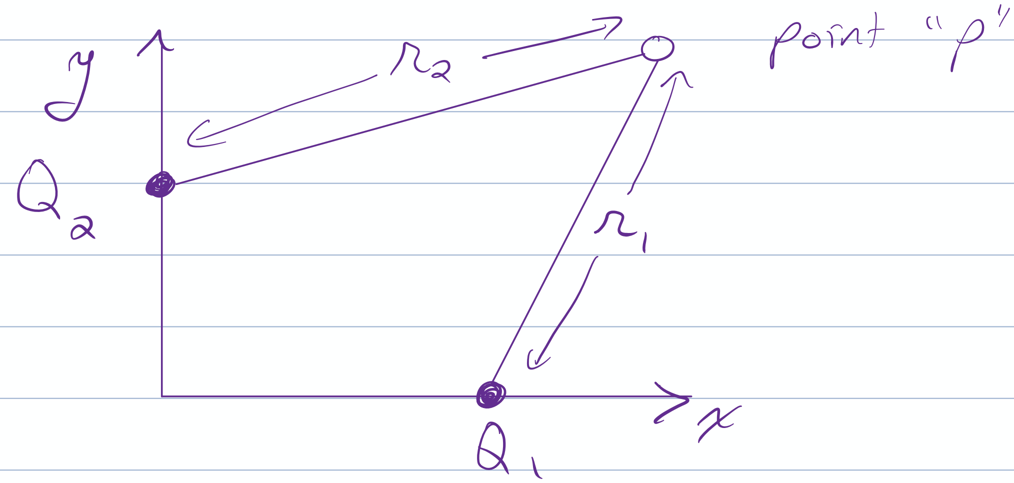


$$K_i + U_i = K_f + U_f$$

$$\frac{1}{2}mv_i^2 + q_0\left(\frac{KQ}{r_i}\right) = \frac{1}{2}mv_f^2 + q_0\left(\frac{KQ}{r_f}\right)$$

See example Ch21-Energy-1

Superposition



$$V = \frac{KQ_1}{r_1} + \frac{KQ_2}{r_2}$$

No vectors!
Include signs!

put a charge q_0 down at "p" and

$$U = q_0 V = \frac{KQ_1 q_0}{r_1} + \frac{KQ_2 q_0}{r_2}$$

See Ch21-superposition-1.pdf.