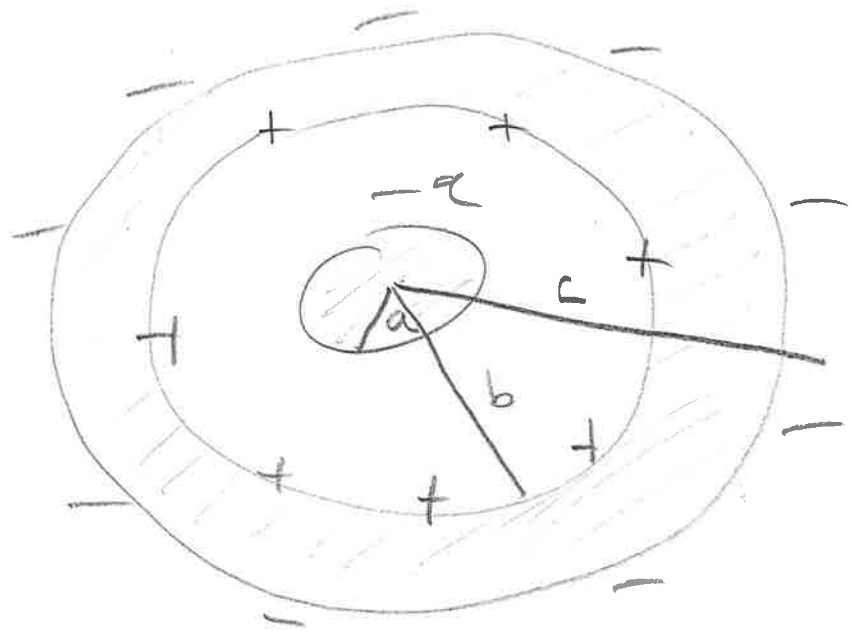
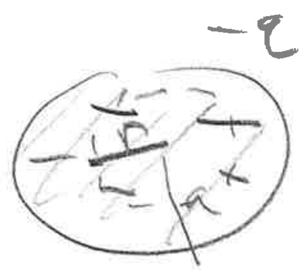
Warm up problem



a) $0 < r < a$



$$\rho = \frac{-q}{\frac{4}{3}\pi a^3}$$

$$\Phi_E = \frac{q_{encl}}{\varepsilon_0}$$

$$E\,\cancel{4\pi r^2} = \frac{\frac{4}{3}\pi r^{\cancel{3}}\rho}{\varepsilon_0}$$

$$\boxed{E = \frac{\rho r}{3\varepsilon_0}}$$

b) $a < r < b$

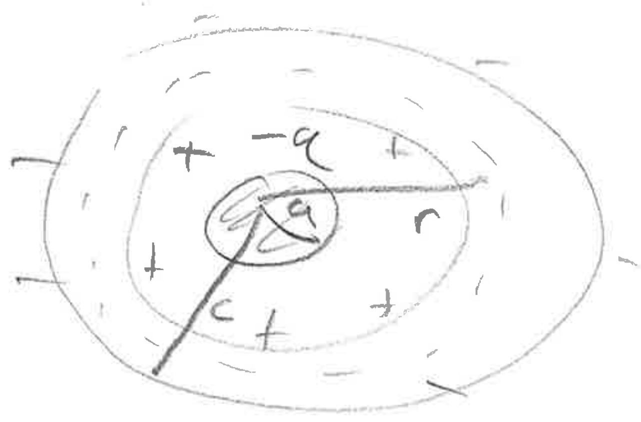
$$\Phi_E = \frac{q_{enc}}{\varepsilon_0}$$

$$q_{enc} = -q$$

$$E\, 4\pi r^2 = \frac{-q}{\varepsilon_0}$$

$$\boxed{E = \frac{-q}{4\pi\varepsilon_0 r^2}}$$

c) $b < r < c$



Inside conductor

$\boxed{\vec{E} = 0}$ ($q_{enc} = 0$)

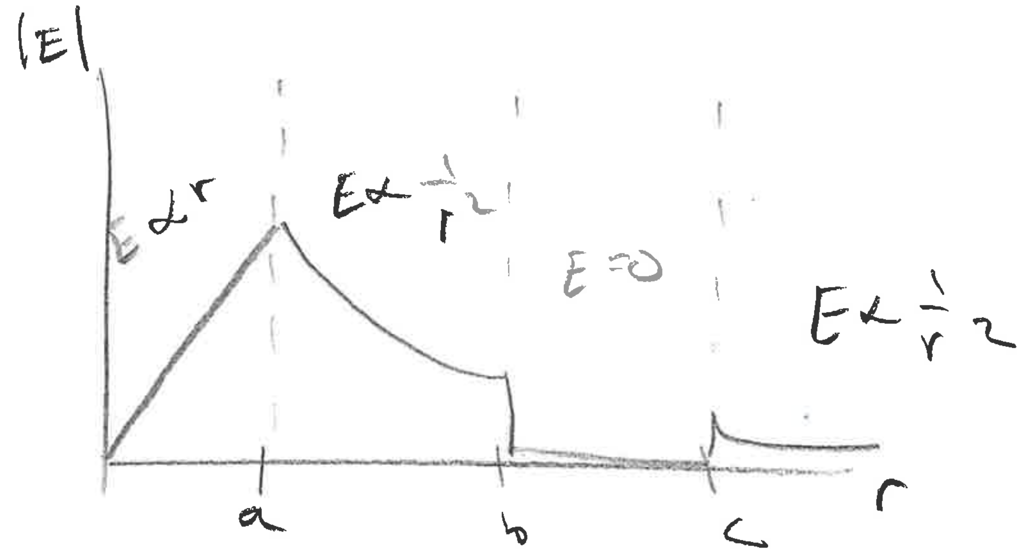
Charges move in conductor such that the enclosed charge is 0.

d) $r > c$

$$q_{enc} = -q$$

$$E\, 4\pi r^2 = \frac{q_{enc}}{\varepsilon_0}$$

$$\boxed{E = \frac{\pm q}{4\pi\varepsilon_0 r^2}}$$



Electric Potential

- charged particles accelerate along or against electric field lines.
- acceleration changes speed → change in energy.
- when a particle moves in an electric field, its potential energy is changing.

$$U = qV$$

V – Electric Potential

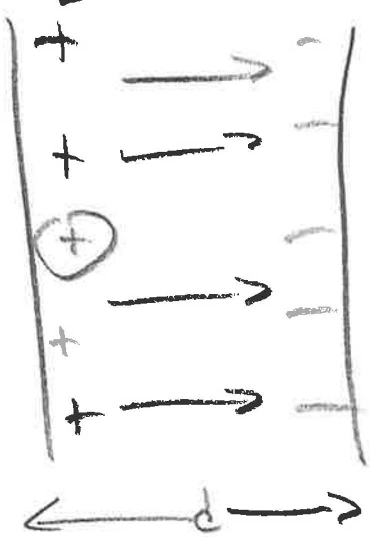
$\Delta V = V_B - V_A$

units – Volts (V)

$1\,V = 1\,J/C$

Potential difference in uniform $\vec{E}$ field.

$\vec{E}$ = const.



$\Delta V = -\vec{E} \cdot \vec{d}$

(V) (N/C) (m)

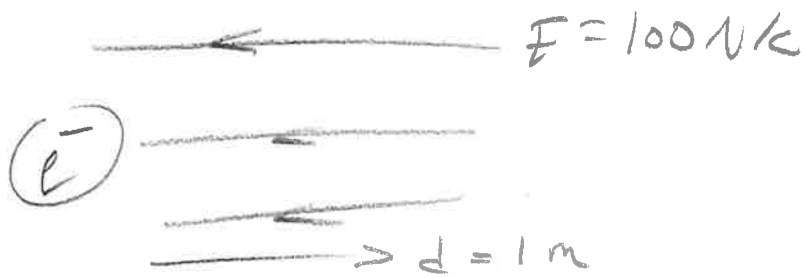
$1\,N/C = 1\,V/m$

alternative units for $\vec{E}$ field.

- Positive charges move from high electric potential to low electric potential ($\Delta V < 0V$).
- Negative charges move from low to high electric potential ($\Delta V > 0V$).

Electric Potential Example

An electron is released from rest in an electric field $\vec{E} = 100\,N/C$. Calculate the speed of the electron after it has moved 1m.



$$-\Delta V = \vec{E}\cdot\vec{d}$$

$$\Delta V = -\vec{E}\cdot\vec{d}$$

$$\Delta V = -(100\,N/C)(-1m)$$

$$\Delta V = 100\,V$$

$$E_1 = E_2$$

$$qV_1 = qV_2 + \frac{1}{2}mv^2$$

$$qV_1 - qV_2 = \frac{1}{2}mv^2$$

$$q(V_1 - V_2) = \frac{1}{2}mv^2$$

$$-q\Delta V = \frac{1}{2}mv^2$$

$$\sqrt{\frac{-2q\Delta V}{m}} = v$$

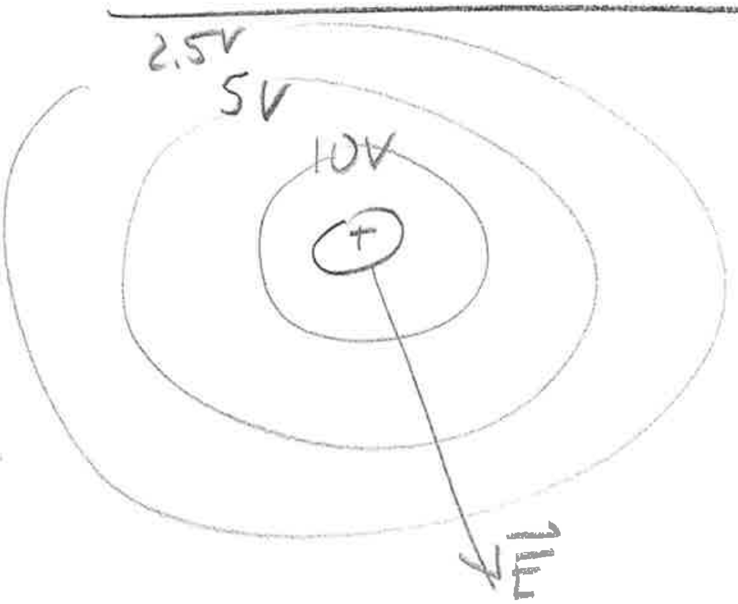
$q = -1.6 \times 10^{-19}\,C$

$m = 9.11 \times 10^{-31}\,kg$

$\Delta V = 100V$

$$\boxed{v = 5.93 \times 10^{6}\,m/s}$$

Electric Potential from a Point charge



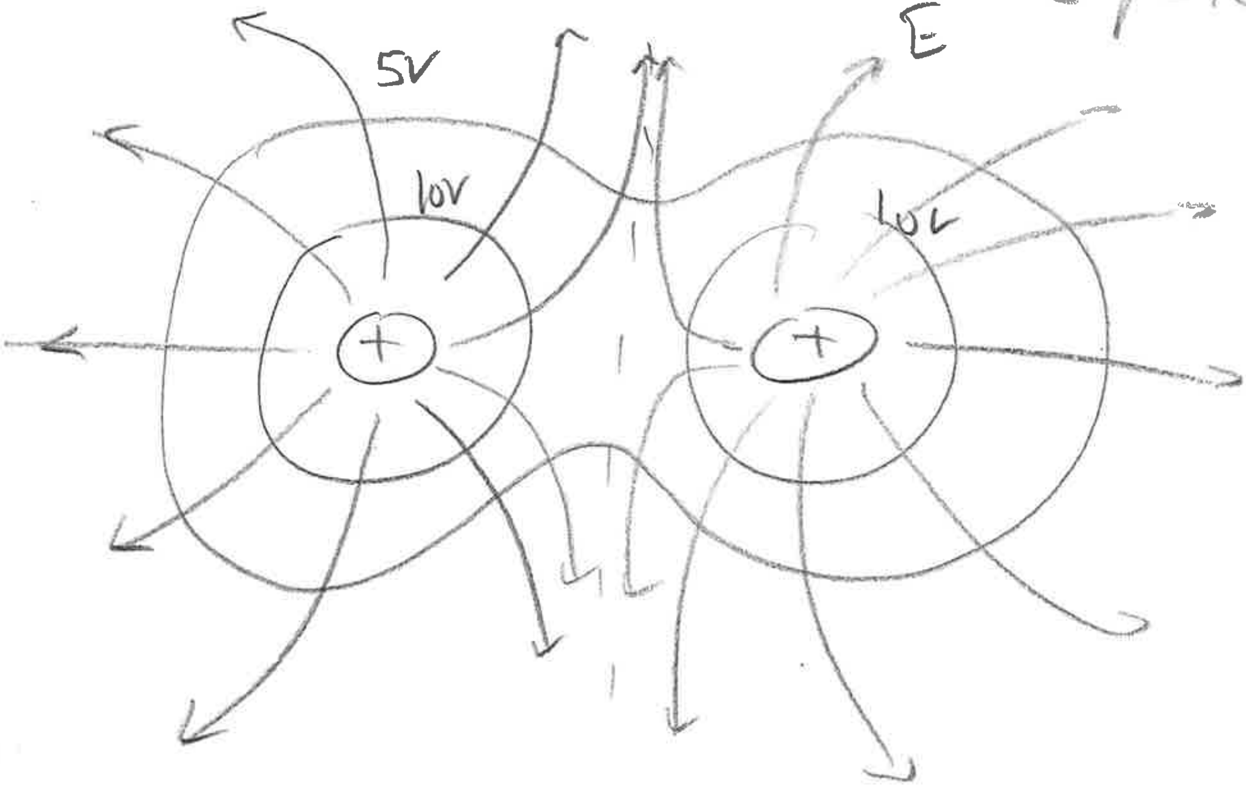
$$V = \frac{kQ}{r}$$

— $\vec{E}$ points in the direction of the fastest decrease of electric potential (negative gradient).

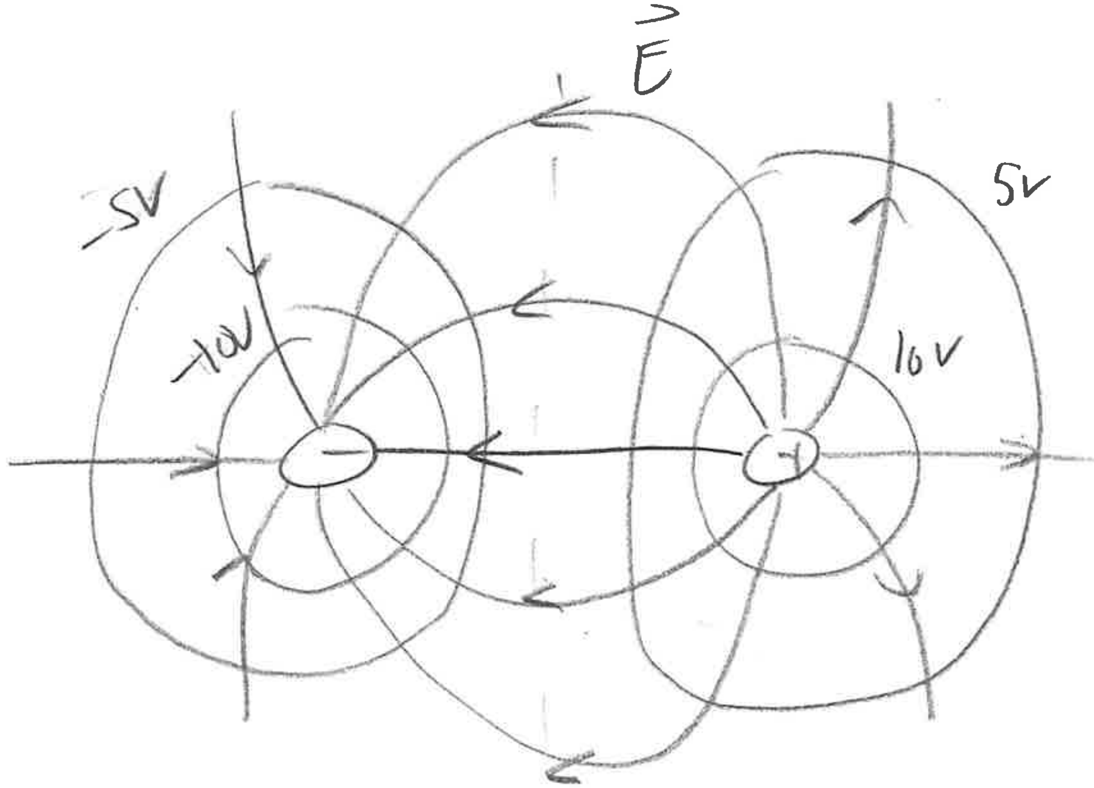
- $\vec{E}$ field is always 90° to equipotential lines.

Equipotential Lines

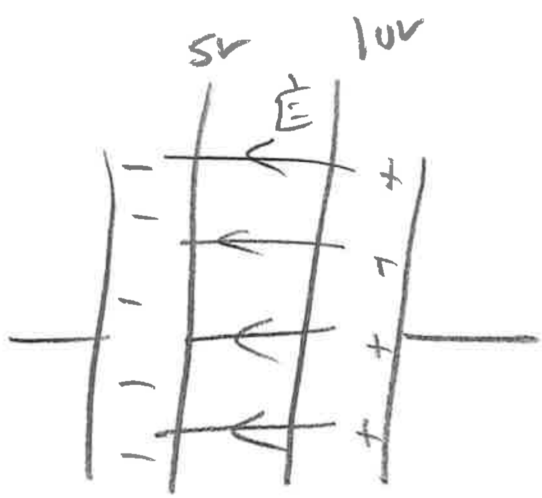
- Lines of constant electric potential



Same charges



opposite charge



parallel plates

Electron volt (eV)

- unit of energy

$$U = eV$$

- 1eV is the energy required to move an electron through 1V of potential difference.

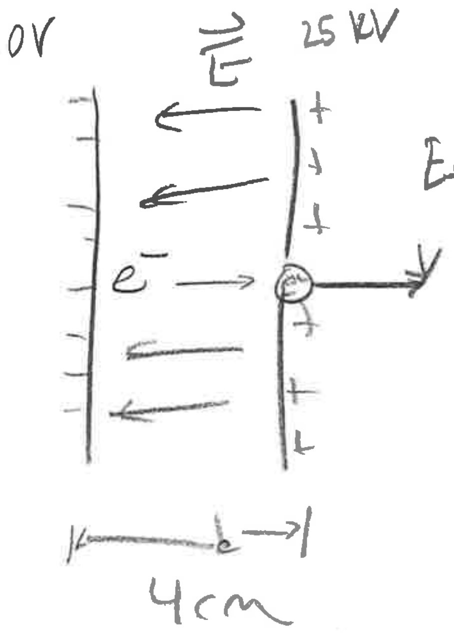
$$1eV = 1.6 \times 10^{-19} J$$

Potential difference problem

2. Parallel plates separated by 4cm give an electron 25 keV of energy.

a) what is the strength of the $\vec{E}$-field between the plates?

b). what is the velocity of the e^-?



$E_f = 25$ keV

$\Delta V = 25$ kV

a) $-\Delta V = \vec{E} \cdot \vec{d}$

because $\vec{d}$ is opposite of $\vec{E}$, $\cos\theta = -1$

$-25000 = |\vec{E}|(0.04)(-1)$

$\boxed{|\vec{E}| = 625{,}000 \text{ V/m}}$

b) $E_1 = E_2$

$qV_1 = qV_2 + \frac{1}{2}mv^2$

$\frac{1}{2}mv^2 = q(V_1 - V_2)$

$\frac{1}{2}mv^2 = -q\Delta V$

$v = \sqrt{\frac{-2q\Delta V}{m}}$

$\boxed{v = 9.37 \times 10^7 \text{ m/s}}$