Electric Potential

Text sections 25.1, 25.2, 25.4

- Potential Energy and Electric Potential
- Field and Potential
- Equipotential surfaces

Practice: Chapter 25,
Objective Questions 4, 6
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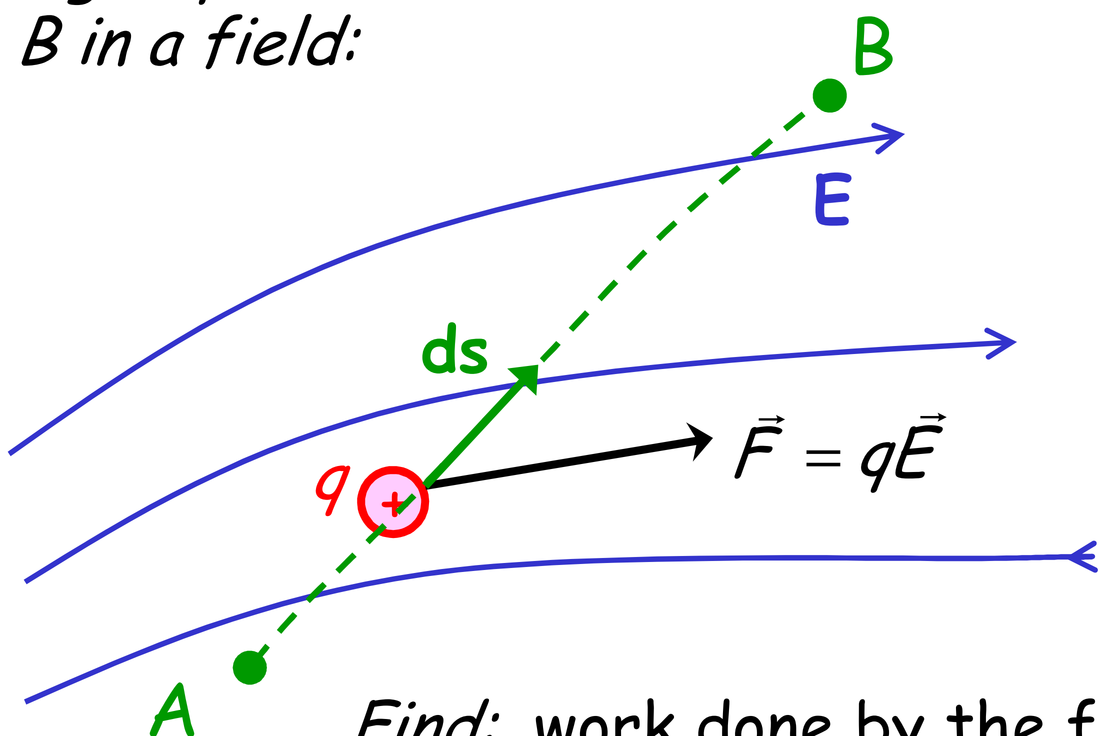
Electric Potential

(Potential energy per unit charge)

A "test charge" q is moved from A to B in a field:



Find: work done by the field.

Recall... $dW = \mathbf{F} \bullet \mathbf{ds} = \underline{\underline{q\mathbf{E} \bullet \mathbf{ds}}}$

or $$W = q\int_A^B \mathbf{E} \bullet \mathbf{ds}$$

The work is proportional to the charge.

The electric force is conservative. *Define an electrostatic potential energy, U, such that:*

$$W_{A\to B} = U_A - U_B = -\Delta U$$

When the field does work on the test charge, electrostatic potential energy is converted to other forms of energy.

$\Delta U \propto$ charge q; so we introduce

Electric Potential: $V \equiv \frac{U}{q}$ or

$$U \equiv qV$$

Units: 1 volt = 1 joule/coulomb (V)

- V is a SCALAR field
- V is produced by other charges Q
- V is a little arbitrary; we can **choose** to set V=0 at any position (often at "infinity")

"Electron Volt" (eV):

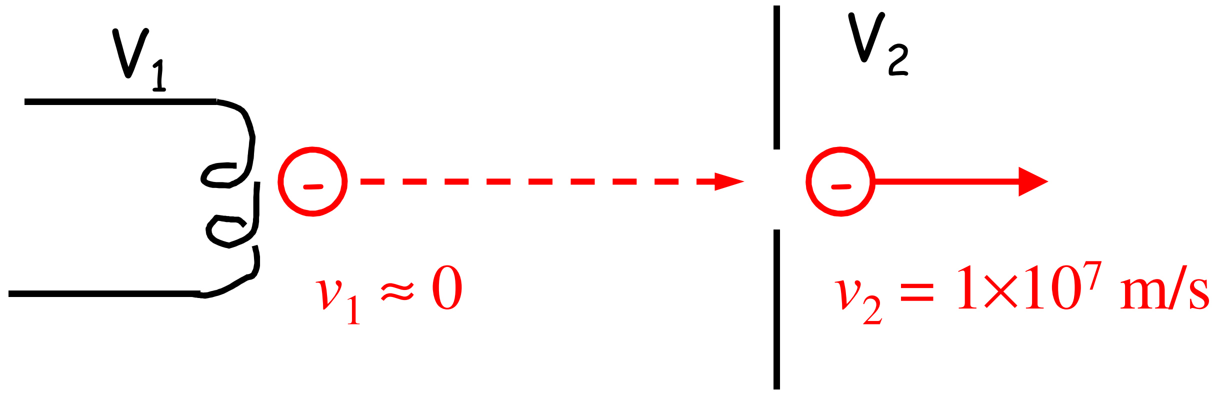
- A unit of energy

$$1 \text{ eV} = e \times (1 \text{ volt}) \approx 1.609 \times 10^{-19} \text{ J}$$

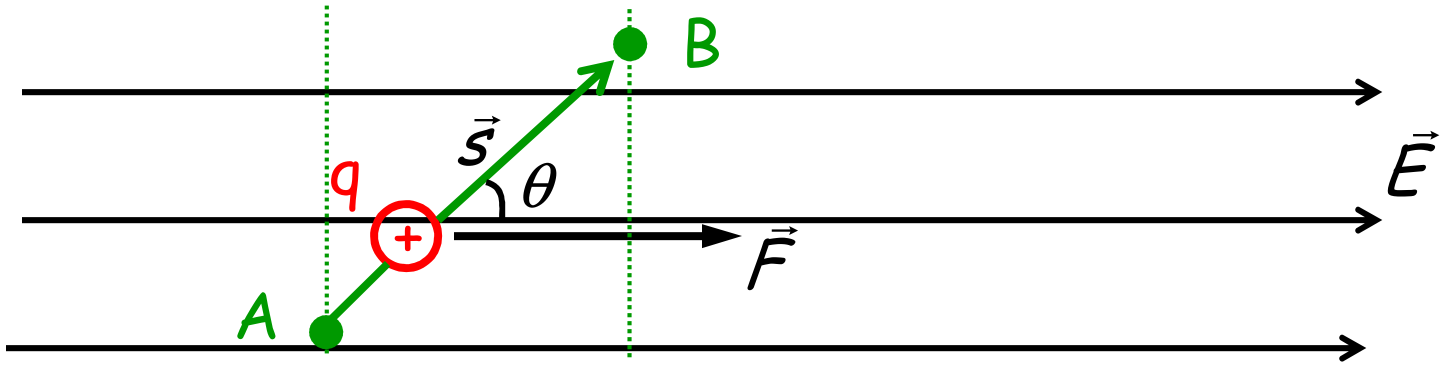
Example:

Find ΔV to accelerate electrons to 10^7 m/s.

$e = 1.60x10^{-19}C$ and $m_e = 9.11x10^{-31}kg$



Uniform Electric Field:



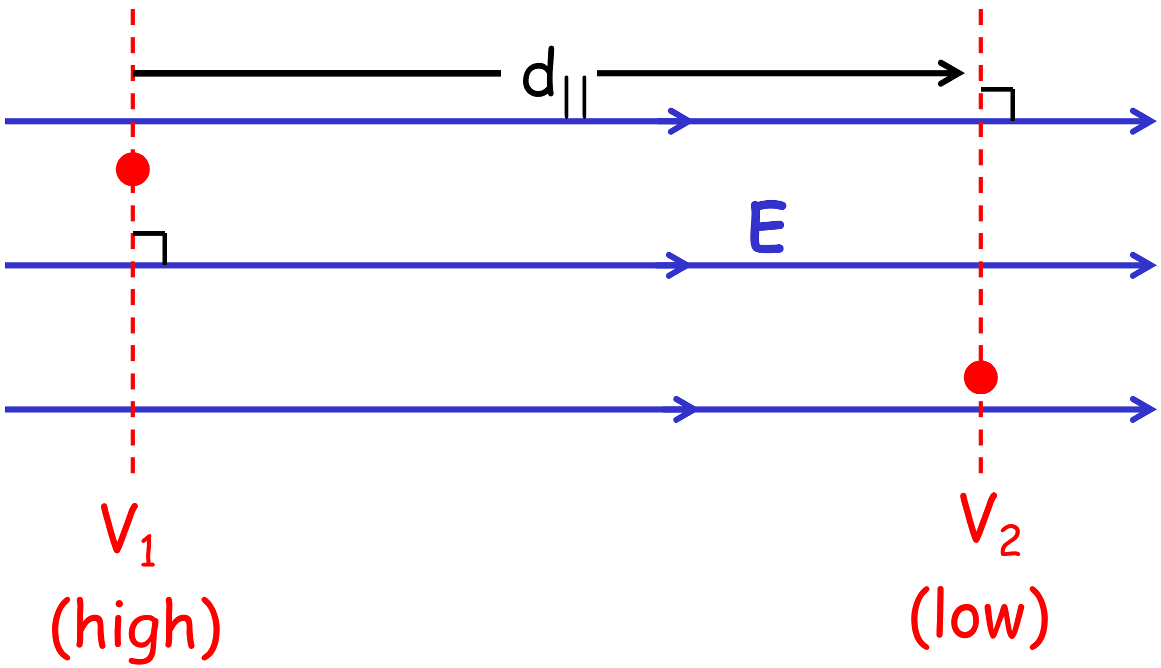
$$\text{Work} = U_A - U_B = q(V_A - V_B) \quad \underline{\text{and}} \quad \text{Work} = \vec{F} \bullet \vec{s}$$

($V_A - V_B$ = -ΔV)

$$\Rightarrow \quad -q\Delta V = q\vec{E} \bullet \vec{s}$$

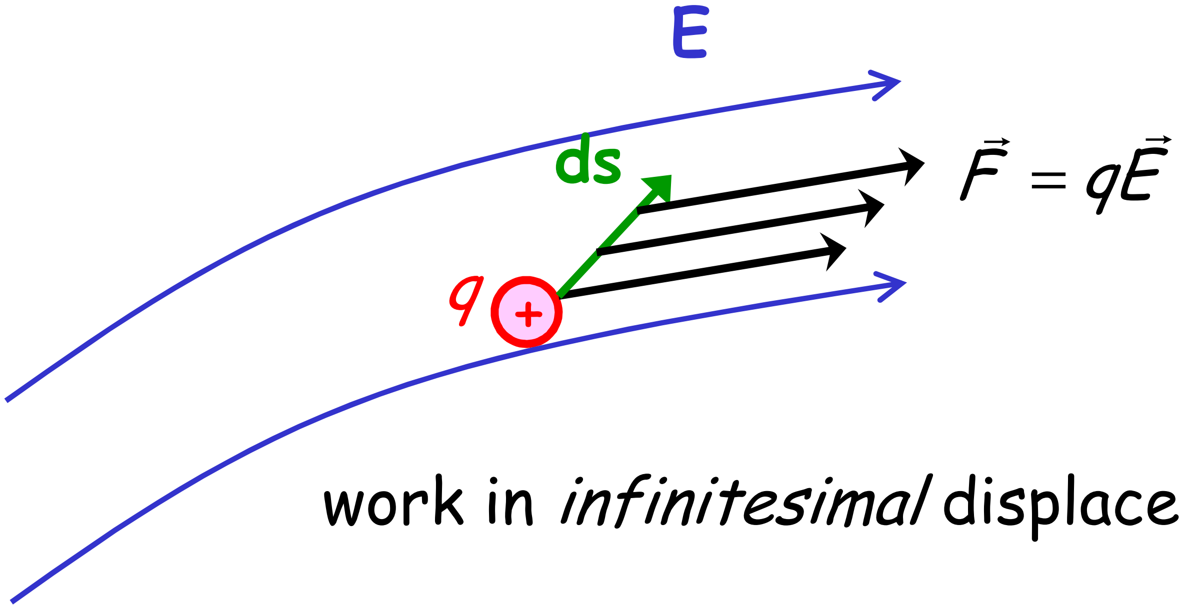
$$\Rightarrow \quad \Delta V = -E \bullet (\text{distance} \parallel \text{field})$$

(distance || field = s cosθ)



Uniform **E**: $\Delta V = -Ed_{||}$

In general: $E_x = -\frac{dV}{dx}$ *(Note Units: 1 N/C = 1 volt/metre)*



work in *infinitesimal* displacement $\mathbf{ds}$,

$$dW = q\mathbf{E}\cdot\mathbf{ds} = -q\,dV$$

so in general,

$$dV = -\,\mathbf{E}\cdot\mathbf{ds}$$

“EQUIPOTENTIALS”

- (Imaginary) surfaces on which V has some uniform value

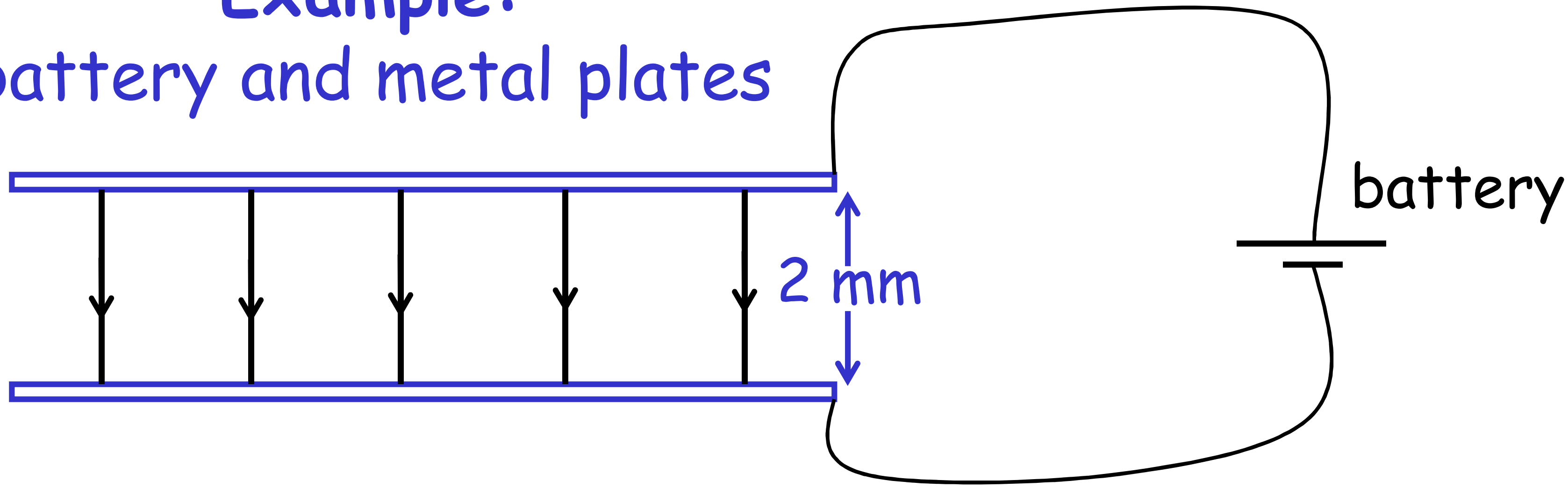
- Equipotential surfaces are $\perp$ field lines

- A conductor is always an equipotential (if no current)

- Closely spaced where |E| is large; widely spaced where |E| is weak.

Example:

battery and metal plates

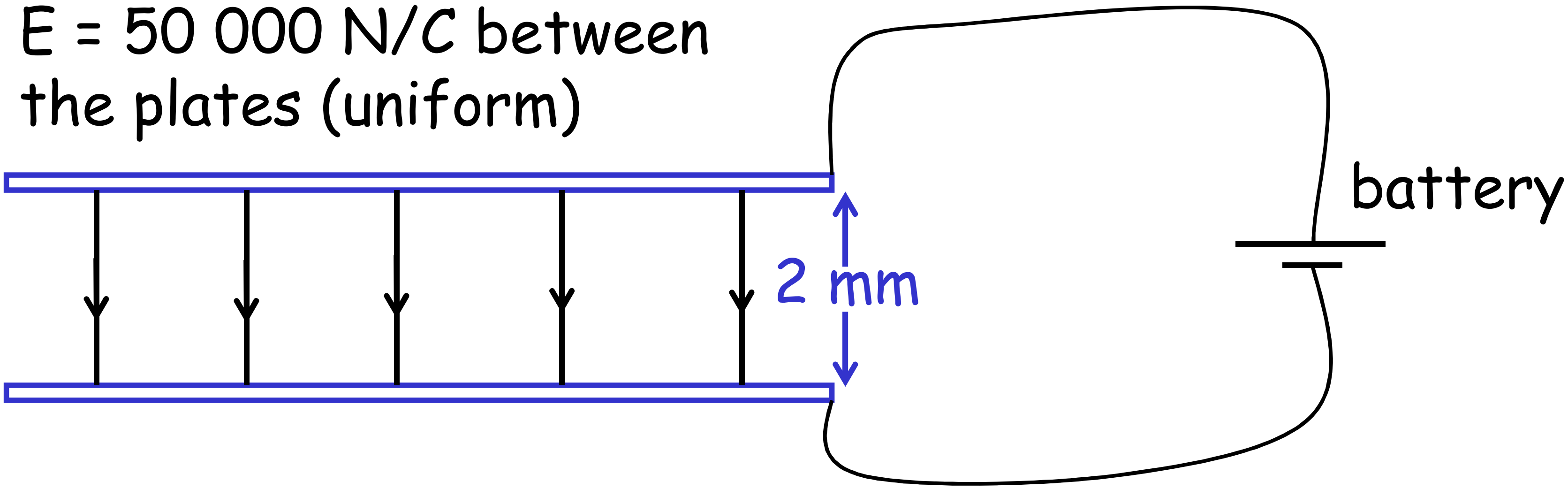


E = 50 000 N/C between the plates (uniform)

a) Find battery voltage
b) Sketch a few equipotentials

Quiz

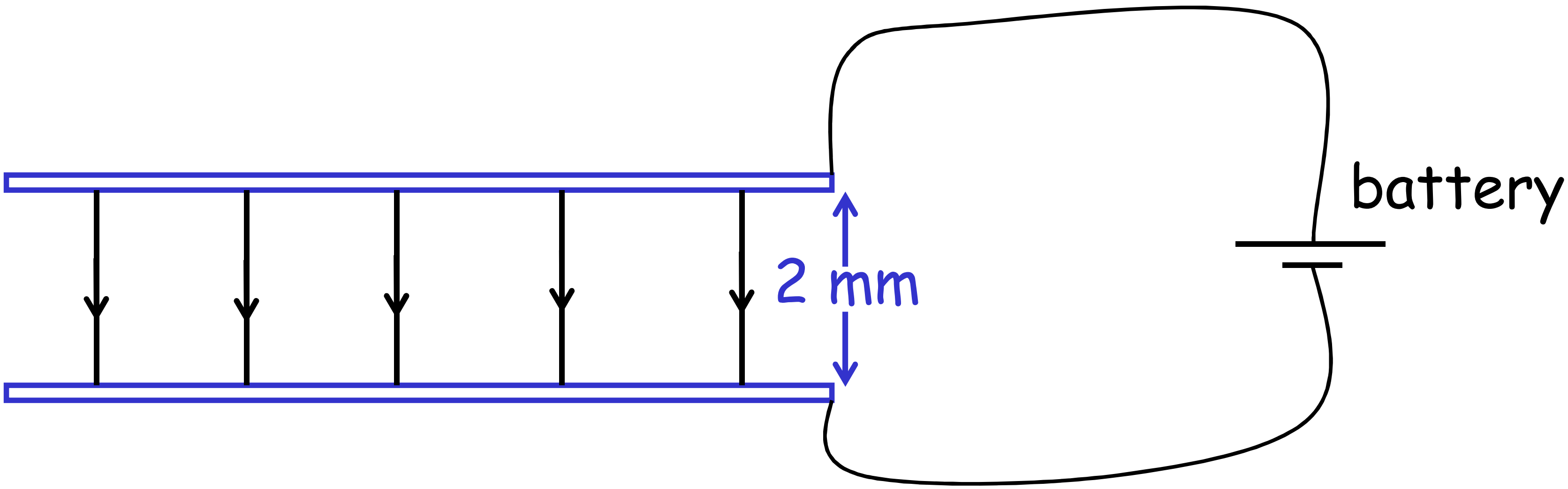
E = 50 000 N/C between the plates (uniform)



The battery voltage is

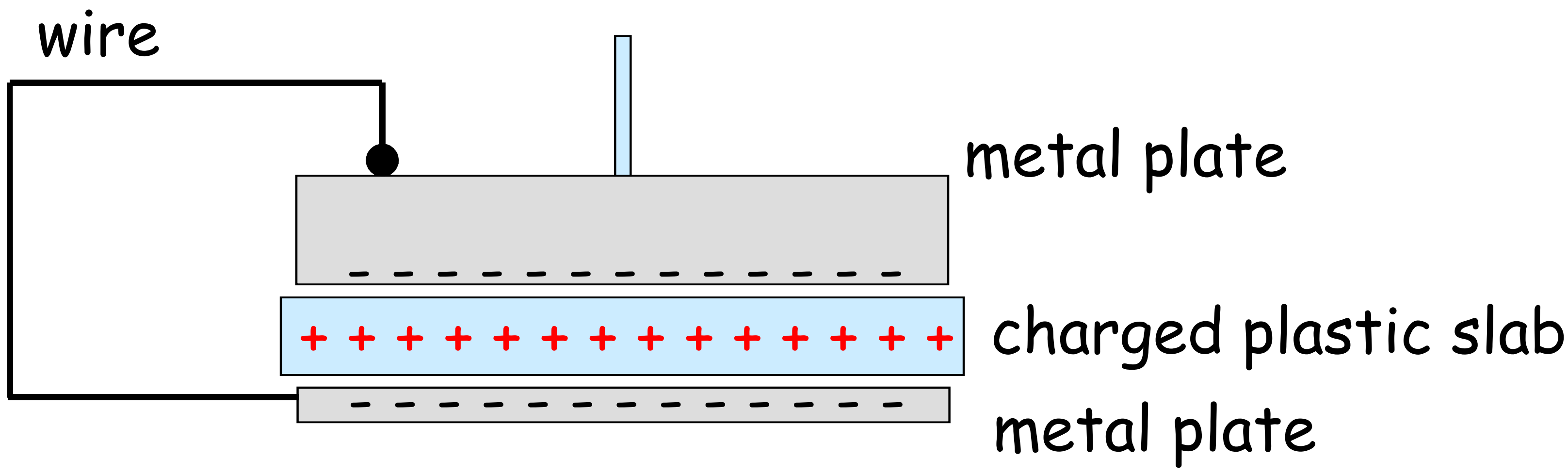
A) 50 000 volts
B) 100 volts
C) 25 volts
D) 1.5 volts

Quiz

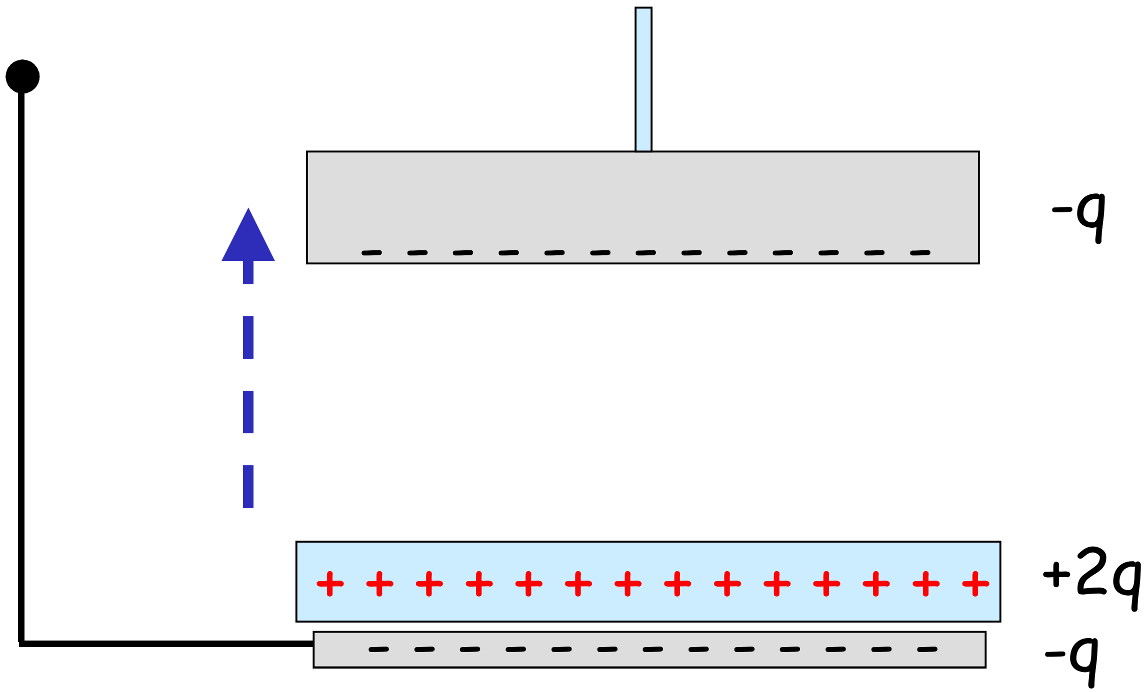


The equipotentials between the plates are

A) vertical planes
B) horizontal planes
C) vertical lines
D) spherical



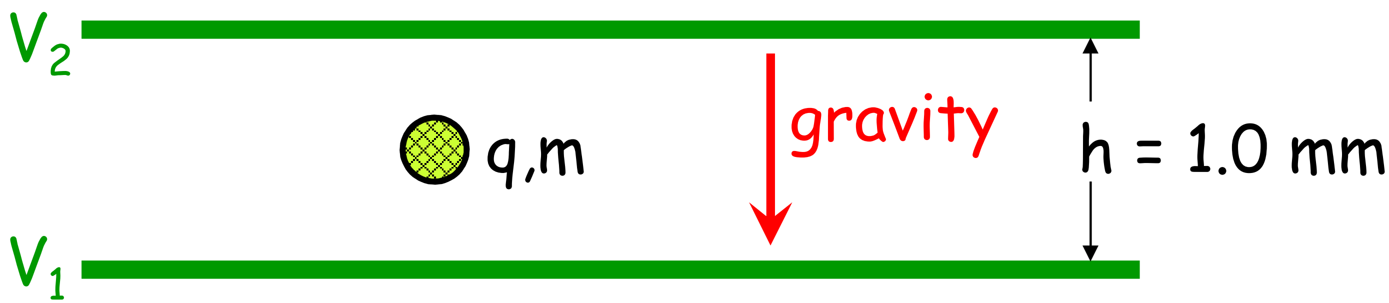
Which plate is at the higher potential?



The wire is removed, and the top plate is lifted up. As the plate is lifted, the potential difference

a) Increases in magnitude
b) Decreases in magnitude
c) Remains constant

Example Problem:



Oil droplet , with charge $q = +3e\ (4.8\times10^{-19}\ \text{C})$

and mass $m = 1\times10^{-15}\ \text{kg})$

Find: Potential Difference V_2-V_1 for equilibrium.

answer: $|\Delta V|$ = 98 volts

Summary: Electric Potential

$$V \equiv \frac{\text{potential energy}}{\text{charge}}$$

and so

$$(\text{electric field}) = -(\Delta V)/(d_{||})$$