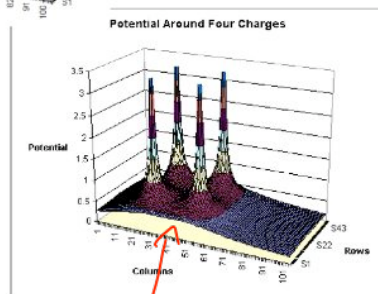
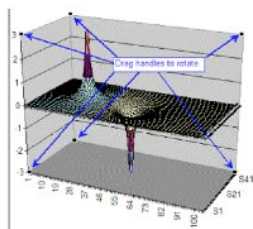


Feb 6

Get Clickers and Whiteboards

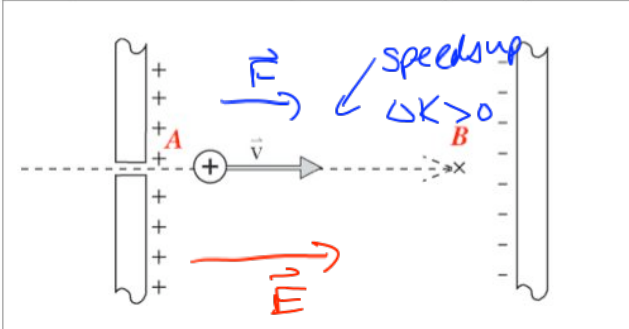
Tangible: Making mountains



$V \neq 0, \vec{E} = 0$ at center point

Clickers

1. A proton enters a capacitor through a tiny hole. System: everything

	Which is true? A) $\Delta K = 0$ and $\Delta U = 0$ B) $\Delta K < 0$ and $\Delta U > 0$ <u>C) $\Delta K > 0$ and $\Delta U < 0$</u> D) $\Delta K > 0$ and $\Delta U > 0$ E) $\Delta K < 0$ and $\Delta U < 0$
--	--

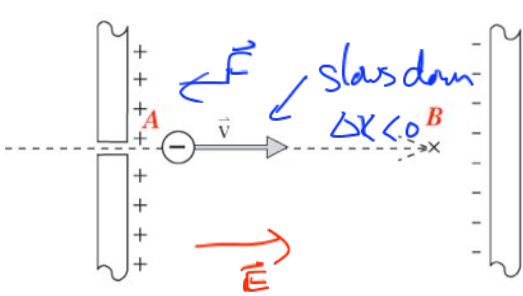
$$\Delta U = -\vec{E} \cdot \Delta \vec{r} < 0$$

↑ ↑
Same direction

$$\Delta U = q \Delta V < 0$$

$$\Delta K + \Delta U = 0$$

2 An electron enters a capacitor through a tiny hole. System: everything



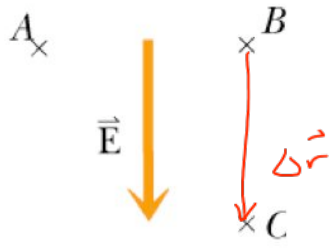
Which is true?

- A) $\Delta K = 0$ and $\Delta U = 0$
- B) $\Delta K < 0$ and $\Delta U > 0$
- C) $\Delta K > 0$ and $\Delta U < 0$
- D) $\Delta K > 0$ and $\Delta U > 0$
- E) $\Delta K < 0$ and $\Delta U < 0$

$$\Delta V = -\vec{E} \cdot \Delta \vec{r} < 0$$

$$\Delta U = q \Delta V = (-e) \Delta V > 0$$

3 The electric field is uniform in this region. B is at $\langle 2, 2, 0 \rangle$ m.
C is at $\langle 2, 0, 0 \rangle$ m. $\vec{E} = \langle 0, -300, 0 \rangle$ N/C

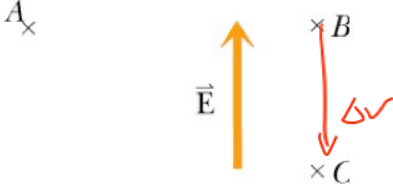
	What is ΔV along a path from B to C? A) +150 V B) -150 V C) 0 V D) +600 V E) -600 V
--	--

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

$$= - \langle 0, -300, 0 \rangle \frac{\text{N}}{\text{C}} \cdot \langle 0, -2, 0 \rangle \text{m}$$

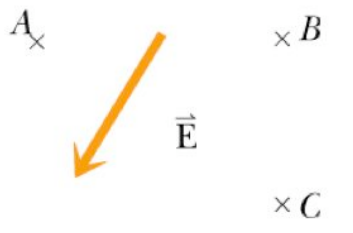
$$= -600 \text{ V}$$

4 The electric field is uniform in this region. B is at $\langle 0, 0, 0 \rangle$ m. C is at $\langle 0, -2, 0 \rangle$ m. $\vec{E} = \langle 0, 400, 0 \rangle$ N/C

	What is ΔV along a path from B to C? A) +200 V B) -200 V C) 0 V <u>D) +800 V</u> E) -800 V
--	---

$$\begin{aligned}
 \Delta V &= - \int \vec{E} \cdot d\vec{\ell} \\
 &= - \langle 0, 400, 0 \rangle \frac{\text{N}}{\text{C}} \cdot \langle 0, -2, 0 \rangle \text{ m} \\
 &= +800 \text{ V}
 \end{aligned}$$

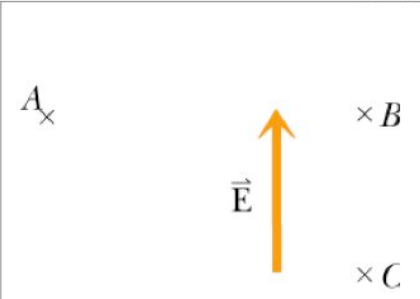
5 The electric field is uniform in this region. B is at $\langle 0, 0, 0 \rangle$ m.
 C is at $\langle 0, -2, 0 \rangle$ m. $\vec{E} = \langle -200, -300, 0 \rangle$ N/C

	What is ΔV along a path from B to C? A) 0 V B) -300 V C) -500 V D) -600 V E) -1000 V
--	---

$$\Delta V = - \langle -200, -300, 0 \rangle \cdot \langle 0, -2, 0 \rangle$$

$$= - (-300) \cdot (-2) = -600 \text{ V}$$

6 The electric field is uniform in this region. B is at $\langle 0, 0, 0 \rangle$ m.
C is at $\langle 0, -2, 0 \rangle$ m. ΔV along a path from B to C is -500 volts.

	What is the magnitude of the electric field in this region? A) 250 V/m B) 500 V/m C) 750 V/m D) 1000 V/m
--	---

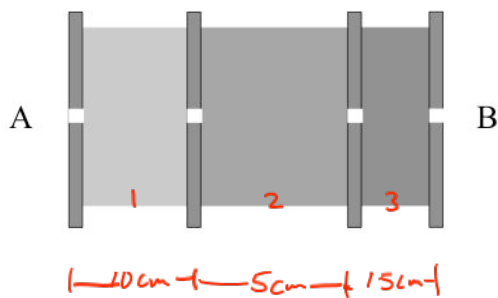
$$\Delta V = -500 \text{ V} = -\langle 0, E_y, 0 \rangle \cdot \langle 0, -2, 0 \rangle \text{ m}$$

$$= 2E_y$$

$$E_y = -250 \text{ V/m}$$

$$\text{mag } E = |\vec{E}| = 250 \text{ V/m}$$

Ponderable: Non-uniform fields



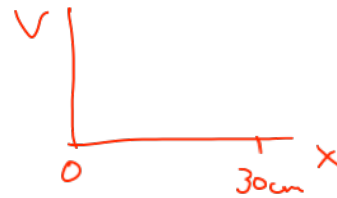
$$\vec{E}_1 = \langle 10, 0, 0 \rangle \text{ N/C}$$

$$\vec{E}_2 = \langle -40, 0, 0 \rangle \text{ N/C}$$

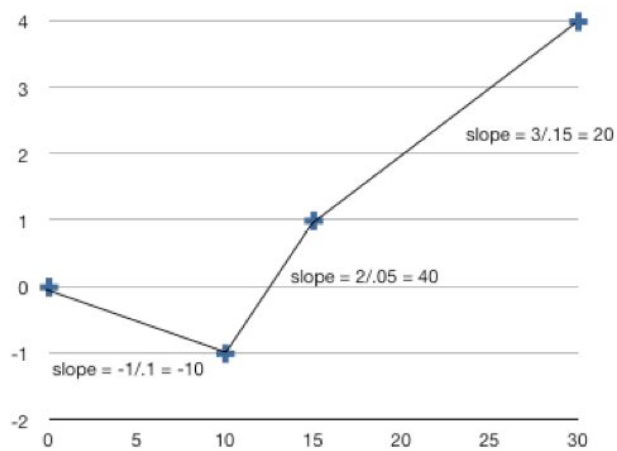
$$\vec{E}_3 = \langle -20, 0, 0 \rangle \text{ N/C}$$

What is $\Delta V = V_B - V_A$?

Graph V as function of x



$$\begin{aligned} \Delta V &= -\int \vec{E} \cdot d\vec{l} = -\vec{E}_1 \cdot \Delta \vec{r}_1 - \vec{E}_2 \cdot \Delta \vec{r}_2 - \vec{E}_3 \cdot \Delta \vec{r}_3 \\ &= -\langle 10, 0, 0 \rangle \cdot \langle 0.1, 0, 0 \rangle - \langle -40, 0, 0 \rangle \cdot \langle 0.05, 0, 0 \rangle - \langle -20, 0, 0 \rangle \cdot \langle 0.15, 0, 0 \rangle \\ &= -1\text{V} + 2\text{V} + 3\text{V} = \boxed{+4\text{V}} \end{aligned}$$



$$\vec{E}_1 = (10, 0, 0) \text{ N/C}$$

$$\vec{E}_2 = (-40, 0, 0) \text{ N/C}$$

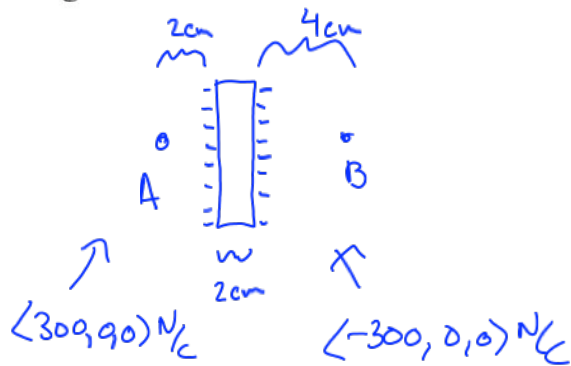
$$\vec{E}_3 = (-20, 0, 0) \text{ N/C}$$

Slope = - electric field

$$\vec{E} = -\vec{\nabla} V$$

$$\hookrightarrow \vec{\nabla} = \hat{x} \frac{\partial}{\partial x} + \hat{y} \frac{\partial}{\partial y} + \hat{z} \frac{\partial}{\partial z}$$

Tangible: Non-uniform fields



$$\Delta V = V_B - V_A$$

Potential constant

inside conductor

Since $\vec{E} = 0$

(V not nec. 0)

$$\Delta V = V_B - V_A$$

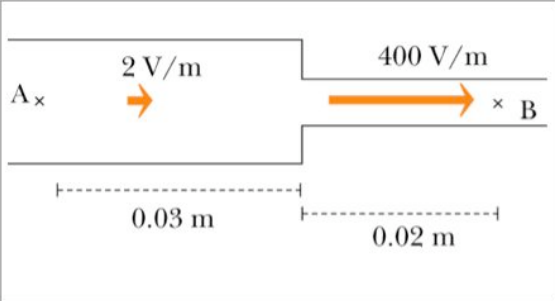
$$= (V_B - V_{\text{right}}) + (V_{\text{right}} - V_{\text{left}}) + (V_{\text{left}} - V_A)$$

$$= -\langle 300, 0, 0 \rangle \cdot \langle 0.02, 0, 0 \rangle + 0 - \langle -300, 0, 0 \rangle \cdot \langle 0.04, 0, 0 \rangle$$

$$= -6V + 0 + 12V = +6V$$

Clickers: Non-uniform fields

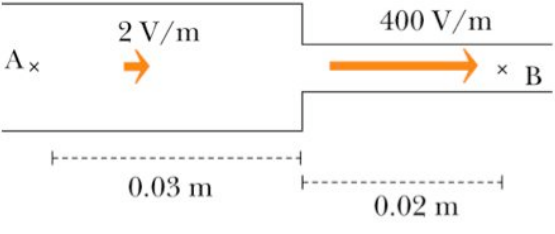
1

 Diagram showing a non-uniform electric field between two parallel plates. The field is divided into two regions: - Region 1 (Left): Width 0.03 m, Electric field 2 V/m (indicated by an orange arrow pointing right). - Region 2 (Right): Width 0.02 m, Electric field 400 V/m (indicated by an orange arrow pointing right). Point A is at the left edge of the first region, and Point B is at the right edge of the second region.	Without doing any calculations, what is the sign of $V_B - V_A$? A) positive B) negative C) 0
--	--

ΔV

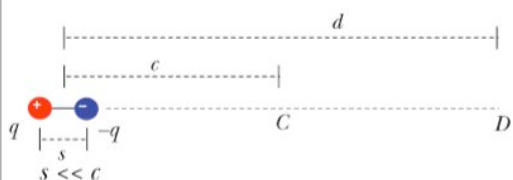
$$\vec{E} \cdot \vec{\Delta r} > 0 \Rightarrow \Delta V < 0$$

2

 The diagram shows two adjacent regions of uniform electric field. The first region, on the left, has a width of 0.03 m and a field of 2 V/m. The second region, on the right, has a width of 0.02 m and a field of 400 V/m. Points A and B are marked at the ends of the regions. The field direction is indicated by an orange arrow pointing to the right.	What is $V_B - V_A$? A) -20 V B) -10.05 V C) -8.06 V D) -0.1 V E) none of the above
--	--

$$\Delta V = -2 \times 0.03 - 400 \times 0.02 = -8.06 \text{ V}$$

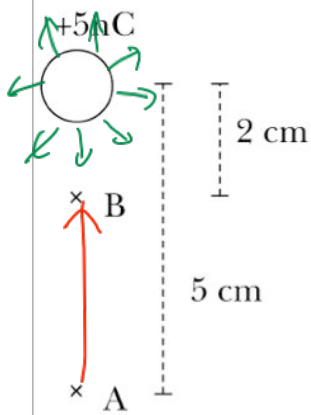
3

 The diagram shows two point charges, $+q$ (red) and $-q$ (blue), separated by a distance c. A horizontal line passes through both charges. Point C is located to the right of $+q$ at a distance d from it. Point D is located to the right of $-q$ at a distance c from it. The distance between points C and D is labeled s. Below the charges, it is noted that $s \ll c$.	To calculate $V_D - V_C$ we should use: A) 1 path segment B) 2 path segments C) 3 path segments <u>D) An integral</u>
--	--

$\vec{E}$ not const. must use integral

$$\vec{E} \cdot d\vec{r} < 0 \Rightarrow \Delta V > 0$$

4



What is $V_B - V_A$?

- A) $+1350 \text{ V}$
- B) -1350 V
- C) $+3375 \text{ V}$
- D) -3375 V
- E) none of the above

$$\Delta V = - \int_A^B \vec{E} \cdot d\vec{r} = - \frac{q}{4\pi\epsilon_0} \int_A^B \frac{1}{r^2} dr = \frac{q}{4\pi\epsilon_0} \left. \frac{1}{r} \right|_{0.05}^{0.02}$$

$$= 9 \times 10^9 \frac{\text{N} \cdot \text{m}^2}{\text{C}^2} \times 5 \times 10^{-9} \text{ C} \times \left(\frac{1}{0.02 \text{ m}} - \frac{1}{0.05 \text{ m}} \right) = 1350 \frac{\text{Nm}}{\text{C}}$$

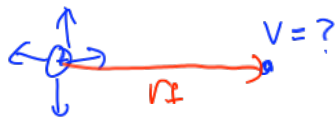
Discussion: Potential at a point

$$\Delta V = - \int_i^f \vec{E} \cdot d\vec{u} = V_f - V_i$$

We define V to be 0 when very far apart (i.e. at ∞)

Measure potential at a point relative to ∞

$$\Delta V = V_f - V_i \xrightarrow{0 \text{ at } \infty} V_f - 0 = V_f$$



$$V = - \int_{\infty}^r \vec{E} \cdot d\vec{u}$$

$$= - \int_{\infty}^r \frac{1}{4\pi\epsilon_0} \frac{q}{x^2} dx$$

$$= \frac{1}{4\pi\epsilon_0} \frac{q}{r}$$

← potential at distance r from point charge q

Ponderable: Unit games

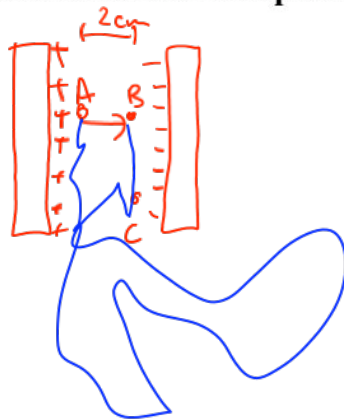
$$\Delta V = - \vec{E} \cdot \Delta \vec{r}$$

$\nearrow \quad \quad \quad \uparrow \quad \nearrow$
volts N/C m

$$V = \frac{J}{C} \qquad \frac{V}{m} = \frac{J}{C \cdot m} = \frac{N \cdot m}{C \cdot m} = \frac{N}{C}$$

$\uparrow$
energy/charge

Ponderable: Field in a capacitor



$$\vec{E} = \langle 300, 0, 0 \rangle \frac{N}{C}$$

ΔV from A to B

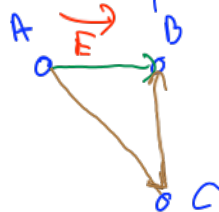
$$\Delta V = V_B - V_A$$

$$= - \int_A^B \vec{E} \cdot d\vec{l}$$

$$= - 300 \frac{N}{C} \times 0.02 m$$

$$= -6 V$$

Potential is path independent



$$\Delta V = V_B - V_C = 0 \quad \text{since } \vec{E} \perp \Delta \vec{r}$$

Tangible: Charged spheres

Don't Touch

$|\vec{E}| = 3 \times 10^6 \text{ N/C}$ air breaks down, get spark

0.12 m	basket ball
0.0484 m	softball
0.0363 m	baseball
0.0326 m	tennis ball
0.0213 m	golf ball
0.00229 m	bb

