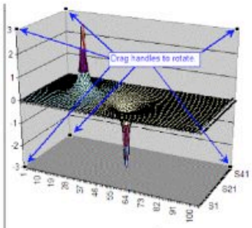
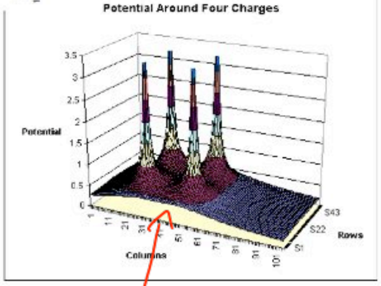
Feb 6

Get Clickers and Whiteboards

Tangible: Making mountains

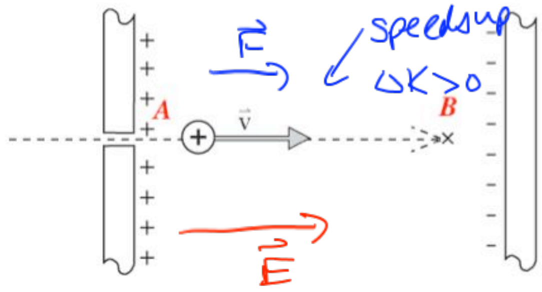




$V \neq 0, \ \vec{E} = 0$ at center point

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 $\Delta U > 0$

[✓ C) $\Delta K > 0$ and $\Delta U < 0$]

D) $\Delta K > 0$ and $\Delta U > 0$

E) $\Delta K < 0$ and $\Delta U < 0$

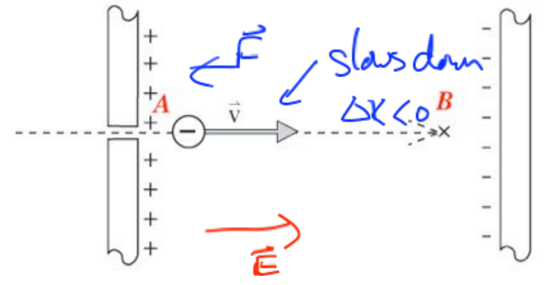
$\Delta V = -\vec{E}\cdot\Delta\vec{r} < 0$

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) ΔK = 0 and ΔU =0

[✓ B) ΔK < 0 and ΔU > 0]

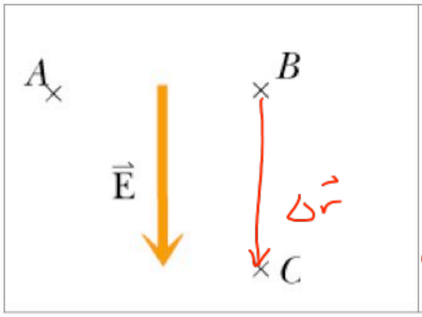
C) ΔK > 0 and ΔU < 0

D) ΔK > 0 and ΔU > 0

E) ΔK < 0 and ΔU< 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 < 2, 2, 0> m. C is at < 2, 0, 0> m. $\vec{E}$ = < 0, –300, 0> N/C



What is ΔV along a path from B to C?

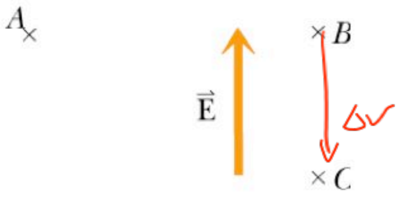
- A) +150 V
- B) –150 V
- C) 0 V
- D) +600 V
- [✓ E) –600 V]

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

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

$$= -600V$$

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



What is ΔV along a path from B to C?

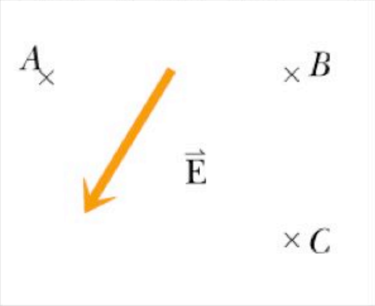
A) +200 V
B) –200 V
C) 0 V
[✓ D) +800 V]
E) –800 V

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

$$= -\langle 0, 400, 0 \rangle \frac{N}{C} \cdot \langle 0, -2, 0 \rangle m$$

$$= +800V$$

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



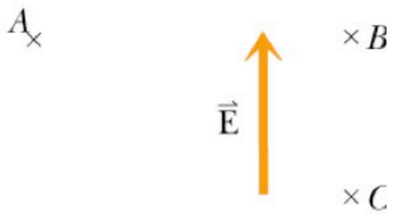
What is ΔV along a path from B to C?

A) 0 V
B) –300 V
C) –500 V
[✓ D) –600 V]
E) –1000 V

$$\Delta V = -\langle -200, -300, 0\rangle \tfrac{N}{C} \cdot \langle 0, -2, 0\rangle m$$

$$= -(-300)\cdot(-2) = -600V$$

6 The electric field is uniform in this region. B is at < 0, 0, 0> m. C is at < 0, –2, 0> 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

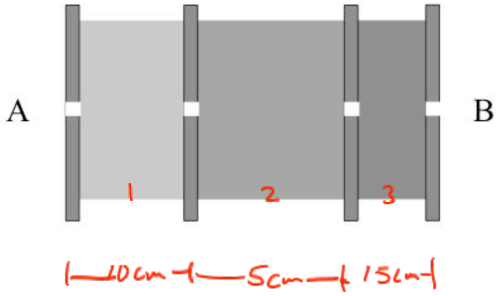
$$\Delta V = -500V = -\langle 0, E_y, 0\rangle \circ \langle 0, -2, 0\rangle m$$

$$= 2E_y$$

$$E_y = -250V/m$$

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

Ponderable: Non-uniform fields



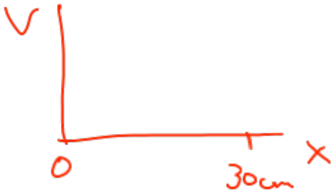
$\vec{E}_1 = \langle 10,0,0 \rangle$ N/C

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

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

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

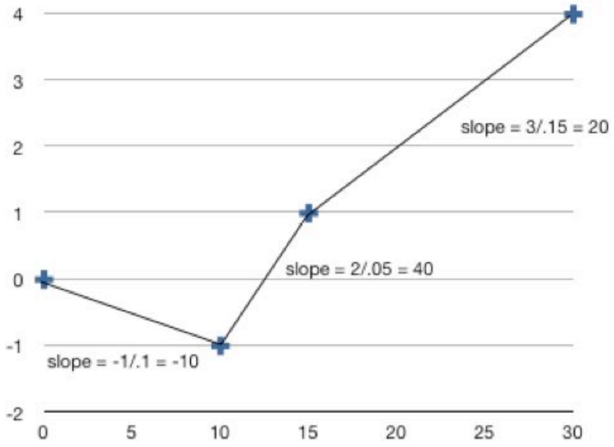
Graph V as function of x



$$\Delta V = -\int \vec{E} \cdot \vec{dl} = -\vec{E}_1 \cdot \Delta\vec{r}_1 - \vec{E}_2 \cdot \Delta\vec{r}_2 - \vec{E}_3 \cdot \Delta\vec{r}_3$$

$$= -\langle 10,0,0 \rangle \cdot \langle 0.1,0,0 \rangle - \langle -40,0,0 \rangle \cdot \langle 0.05,0,0 \rangle - \langle -20,0,0 \rangle \cdot \langle 0.15,0,0 \rangle$$

$$= -1V + 2V + 3V = \boxed{+4V}$$



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

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

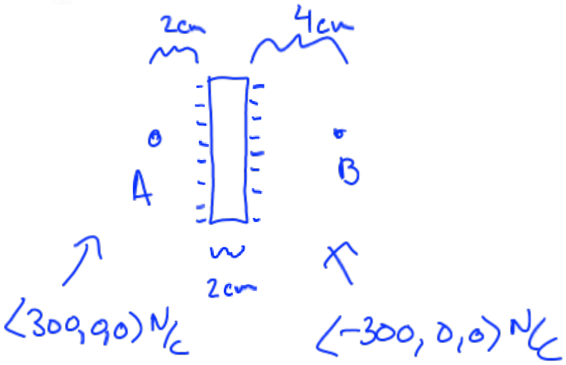
$\vec{E}_3 = \langle -20,0,0 \rangle$ N/C

slope = − electric field

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

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

Tangible: Non-uniform fields



$$\Delta V = V_B - V_A$$

Potential constant inside conductor since $\vec{E} = 0$ (V not nec. 0)

$$\Delta V = V_B - V_A$$

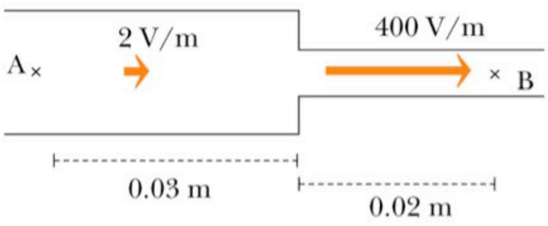
$$= (V_B - V_{right}) + (V_{righ} - V_{left}) + (V_{left} - V_A)$$

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

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

Clickers: Non-uniform fields

1

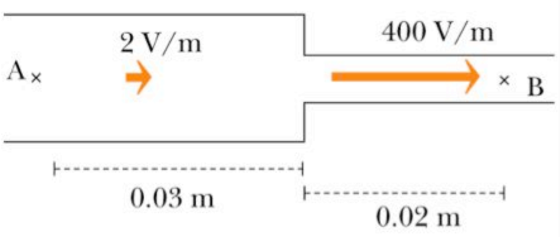


Without doing any calculations, what is the sign of $V_B - V_A$?

A) positive
[✓ B) negative]
C) 0

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

2



What is $V_B - V_A$?

A) –20 V

B) –10.05 V

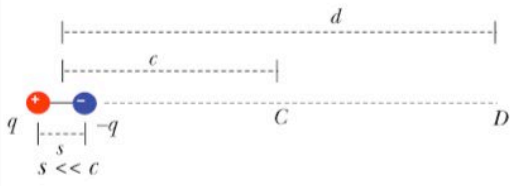
[✓ C) –8.06 V]

D) –0.1 V

E) none of the above

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

3



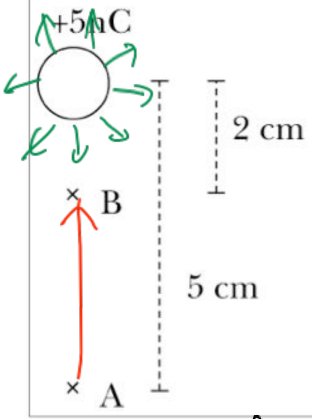
To calculate $V_D - V_C$ we should use:

A) 1 path segment
B) 2 path segments
C) 3 path segments
[✓ D) An integral]

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

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

4



What is $V_B - V_A$?

[✓ A) +1350 V]
B) –1350 V
C) +3375 V
D) –3375 V
E) none of the above

$$\Delta V = -\int_A^B \vec{E}\cdot\vec{dl} = -\frac{q}{4\pi\epsilon_0}\int_A^B \frac{1}{r^2}\,dr = \frac{q}{4\pi\epsilon_0}\frac{1}{r}\Big|_{0.05}^{0.02}$$

$$= 9\times10^9\,\frac{N\cdot m^2}{C^2}\times 5\times10^{-9}\,C\times\left(\frac{1}{0.02m}-\frac{1}{0.05m}\right) = 1350\,\frac{Nm}{C}$$

Discussion: Potential at a point

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

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

Measure potential at a point relative to ∞

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

$$V = -\int_\infty^{r_f} \vec{E}\cdot d\vec{l}$$

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

$$= \frac{1}{4\pi\epsilon_0}\frac{q}{r_f} \leftarrow$$

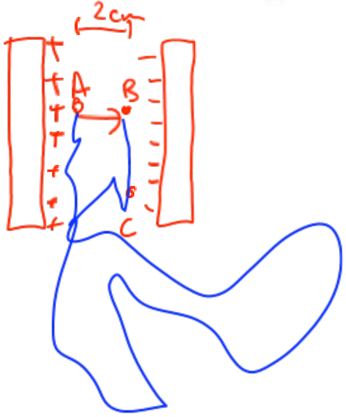
potential at distance r_f from point charge q

Ponderable: Unit games

$$\underset{\overset{\nearrow}{\text{volts}}}{\Delta V} = -\underset{\overset{\uparrow}{N/C}}{\vec{E}} \cdot \underset{\overset{\uparrow}{m}}{\Delta \vec{r}}$$

$$\underset{\overset{\uparrow}{\text{energy/charge}}}{V} = J/C \qquad \frac{V}{m} = \frac{J}{Cm} = \frac{N\cdot\cancel{m}}{C\cdot\cancel{m}} = \frac{N}{C}$$

Ponderable: Field in a capacitor



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

ΔV from A to B

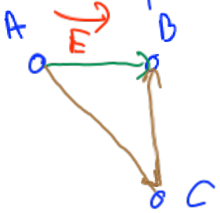
$\Delta V = V_B - V_A$

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

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

$= -6V$

Potential is path independent



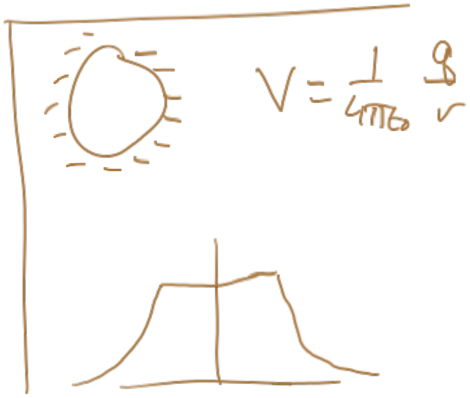
$\Delta V = V_B - V_C = 0$ since $\vec{E} \perp \Delta\vec{r}$

Tangible: Charged spheres

Don't Touch

$|\vec{E}| = 3e6\ N/C$ 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



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