Physics 152, HW #3

Mastering Physics: 8 problems from Chapter 21

One written Problem

21.1 $\overset{C}{\underset{q}{\circ}} \longrightarrow \overset{D}{\circ}$

AN EXTERNAL Agent does $6\mu J$ of work moving $q = -2\mu C$ FROM points C to point D (at a constant speed).

a) What is $\Delta V = V_D - V_C$?

$$W_{C\to D} = q \underbrace{\Delta V}_{V_D - V_C} \Rightarrow \Delta V = \frac{W_{C\to D}}{q}$$

NO ABS. VALue

$$\Delta V = \frac{6\times10^{-6} J}{-2\times10^{-6} J} = -3V$$

b) What direction is $\vec{E}$? $V_D - V_C = -3V \Rightarrow$ Point D is 3V lower in potential than point C. Going with Electric field causes potential to decrease $\Rightarrow$ Field must point from C to D $\overset{C}{\circ} \xrightarrow{\vec{E}} \overset{D}{}$

THIS CAN Also be EXPLAINED by looking at the force. The electric force is opposite to $\vec{E}$ for a Negative charge $\Rightarrow$ EXTERNAL Agent Must Make q move from C to D $\underset{\vec{F}_E}{\longleftarrow} \overset{C}{\circ} \xrightarrow{\vec{F}_{Agent}}$ $\quad \circ \xrightarrow{\vec{F}_{Agent}}$ $\underset{\text{motion}}{\longrightarrow}$ Force in SAME DIRECTION AS motion Does positive work.

c) if q starts with No potential Energy, how much does it have at D?

THE EASIest way to answer this is to remember that $W_{C\to D} = \Delta U$

$\Rightarrow \Delta U = 6\mu J \quad \Delta U = U_D - U_C. \quad U_C = 0 \Rightarrow U_D = 6\mu J$

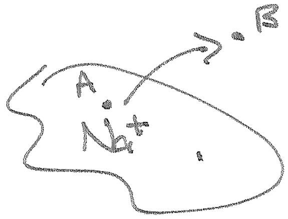
d) How much work to move a $+3\mu C$ charge from C to D?

ΔV stays the same since it depends only on the electric field $\Rightarrow \Delta V = -3V$

$$W_{C \to D} = q\Delta V = (3\times10^{-6}C)(-3V) = -9\times10^{-6} J = -9\mu J$$

Here external agent has to keep the positive charge, which feels an electric force in the same direction as $\vec{E}$, from speeding up $\Rightarrow$ Negative work.

21.66



$V_A = -70\,mV$, $V_B = 0$

a) what is ΔU_{elec} in eV?

$$\Delta U_{elec} = q\Delta V = q(V_B - V_A) = q(0-(-70\,mV)) = q(0+70\,mV)$$

$$\Rightarrow \Delta U_{elec} = q(70\times10^{-3}\,V) = q(.07\,V)$$

Na^+ HAS SAME CHARGE AS proton (AND electron) $\Rightarrow$

$$\Delta U_{elec} = e(.07\,V) = .07\,eV$$

b) The Potential Energy increased because A positive charge moving in the direction of increasing Potential (0 is bigger than $-70\,mV$)

c) What is ΔU_{elec} for a Na^{++} ion?

Na^{++} has twice as much charge as Na^+. $\Delta U = q\Delta V \Rightarrow$ Doubling charge also doubles the amount of potential energy $\Rightarrow$ $\Delta U_{elec} = 2(0.07\,eV) = 0.14\,eV$.

21.74

Want $E_{TOT} = 0.1\,J$

bit misleading all protons have is

Kinetic Energy $\Rightarrow K_{TOT} = 0.1\,J$

Protons accelerated through $24\,MV = 24\times10^{6}\,V = 2.4\times10^{7}\,V$

Proton has charge $+e \Rightarrow K = 2.4\times10^{7}\,eV$ per proton

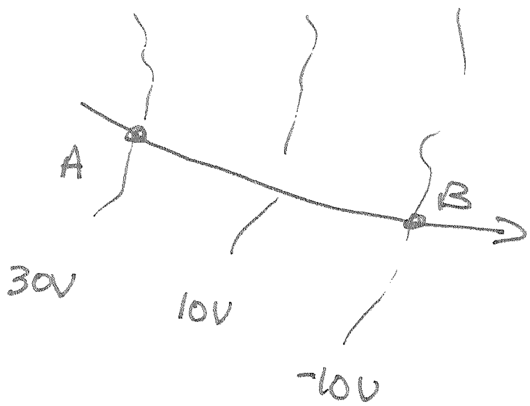
$$2.4\times10^{7}\,eV \times \frac{1.6\times10^{-19}\,J}{eV} = 3.84\times10^{-12}\,J/\text{proton}$$

$$\therefore \quad \frac{K_{TOT}}{K} = \frac{0.1\,J}{3.84\times10^{-12}\,J/\text{proton}} = 2.6\times10^{10}\text{ protons}$$

Each proton has charge $e \Rightarrow 2.6\times10^{10}\,\text{proton}\left(\frac{1.6\times10^{-19}\,C}{\text{proton}}\right) = 4.1667\times10^{-9}\,C$

$= 4.2\,nC$

21.62



Proton with $v_A = 5\times10^4\,\text{m/s}$

How fast at B?

Energy Conservation: $\frac{1}{2}mv_A^2 + qV_A = \frac{1}{2}mv_B^2 + qV_B$

proton $\Rightarrow$ $q = 1.6\times10^{-19}\,\text{C}$, $V_A = 30\,\text{V}$, $V_B = -10\,\text{V}$

$m = 1.67\times10^{-27}\,\text{kg}$

$$\frac{1}{2}(1.67\times10^{-27}\,\text{kg})(5\times10^4\,\text{m/s})^2 + (1.6\times10^{-19}\,\text{C})(30\,\text{V}) = \frac{1}{2}(1.67\times10^{-27}\,\text{kg})v_B^2 + (1.6\times10^{-19}\,\text{C})(-10\,\text{V})$$

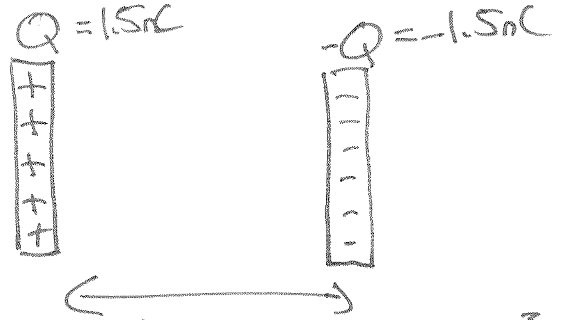
$$\Rightarrow 2.0875\times10^{-18}\,\text{J} + 4.8\times10^{-18}\,\text{J} = \frac{1}{2}(1.67\times10^{-27}\,\text{kg})v_B^2 - 1.6\times10^{-18}\,\text{J}$$

$$\therefore \frac{1}{2}(1.67\times10^{-27}\,\text{kg})v_B^2 = 2.0875\times10^{-18}\,\text{J} + 4.8\times10^{-18}\,\text{J} + 1.6\times10^{-18}\,\text{J}$$

$$= 8.4875\times10^{-18}\,\text{J}$$

$$\Rightarrow v_B = \sqrt{\frac{2(8.4875\times10^{-18}\,\text{J})}{1.67\times10^{-27}\,\text{kg}}} = 1.008\times10^5\,\text{m/s} = 1\times10^5\,\text{m/s}$$

21.73



$d = 1.9\text{mm} = 1.9 \times 10^{-3}\text{m}$
$= 0.0019\text{m}$

Disks ⇒ Circles of Diameter 2.2cm

⇒ Radius, $r = 1.1\text{cm} = 0.011\text{m}$

$Q = 1.5 \times 10^{-9}\,C$ (1.5nC)

a) What is Voltage Between plates of Capacitor?

Voltage of Capacitor, $\Delta V_c = Ed$

⇒ have to find electric field

Uniform Electric field of parallel-plate Capacitor

is $E = \dfrac{Q}{\varepsilon_0 A}$ (From chapter 20)

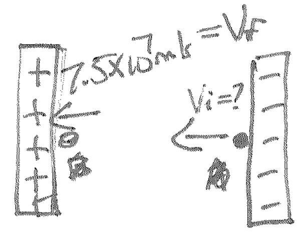
A = Area of Plate ⇒ Area of Circle ⇒ $A = \pi r^2$

So $E = \dfrac{1.5 \times 10^{-9}\,C}{\left(8.85 \times 10^{-12}\,\frac{C^2}{N \cdot m^2}\right)\pi (0.011\text{m})^2} = 4.46 \times 10^5\,\text{V/m}$

Unit: $\dfrac{C}{\frac{C^2}{N \cdot m^2} \cdot m^2} = \dfrac{N}{C} = \dfrac{N \cdot m}{C \cdot m} = \dfrac{J}{C \cdot m} = \dfrac{J/C}{m} = \dfrac{V}{m}$ (E&M Units Kind of Suck!)

So $\Delta V_c = Ed = (4.46\times 10^{5}\,V/m)(0.0019\,m) = \underline{847\,V}$

b) AN ELECTRON LAUNCHED FROM Negative plate, Reaches positive plate with A speed of 7.5×10^{7} m/s.
What ~~is~~ WAS speed at Negative plate?

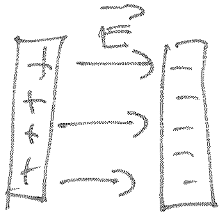


Electron Attracted to positive plate ⇒ speeds up ⇒ INitiAL velocity must be SMALLER THAN FINAL

CONSERVATION OF ENERGY: $\frac{1}{2}mv_i^2 + qV_i = \frac{1}{2}mv_f^2 + qV_f$

$\vec{E}$ points in direction of decreasing Potential

$\Delta V_c = 847\,V$ ⇒ Positive plate at higher Potential (847V higher)



Electron starts at Negative plate AND ENDS at positive ⇒ $V_i = 0$

$V_f = 847\,V$

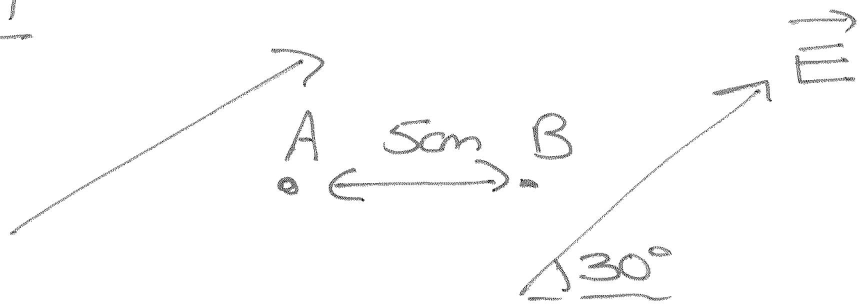
So $\frac{1}{2}mv_i^2 + 0 = \frac{1}{2}mv_f^2 + qV_f$. No Absolute Value!

$\Rightarrow \frac{1}{2}(9.11\times10^{-31}\,kg)v_i^2 = \frac{1}{2}(9.11\times10^{-31}\,kg)(7.5\times10^{7}\,m/s)^2 + (-1.6\times10^{-19}\,C)(847\,V)$

$\Rightarrow \frac{1}{2}(9.11\times10^{-31}\,kg)v_i^2 = 2.56\times10^{-15}\,J - 1.19\times10^{-16}\,J = 2.441\times10^{-15}\,J$

$\therefore v_i = \sqrt{\frac{2(2.441\times10^{-15}\,J)}{9.11\times10^{-31}\,kg}} = \underline{7.32\times10^{7}\,m/s}$

21.21

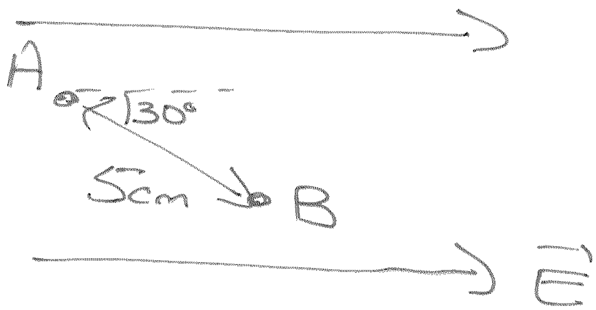


$E = 1200\ V/m$

$V_A = -300V$

$V_B = ?$

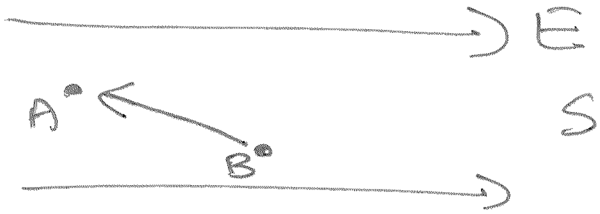
REDRAW PICTURE BY ROTATING EVERYTHING BY 30°
(THIS MAKES IT LOOK LIKE WHAT WE DREW IN CLASS.)



FROM A TO B IS WITH FIELD ⇒ POTENTIAL DECREASES, ⇒ SO V_B WILL BE SMALLER THAN V_A, i.e., IT WILL BE MORE NEGATIVE

UNIFORM FIELD ⇒ $\Delta V = EX$ BUT!!

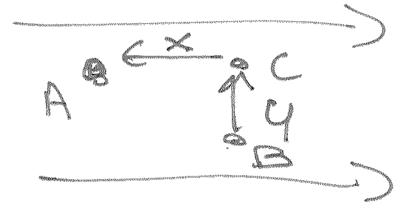
① WE HAVE TO GO AGAINST FIELD ⇒ START AT B AND GO TO A ⇒



SO $\Delta V = V_A - V_B$

② X IS JUST THE DISTANCE DIRECTLY OPPOSITE TO FIELD if you prefer: ΔV is independent of ~~path~~ path

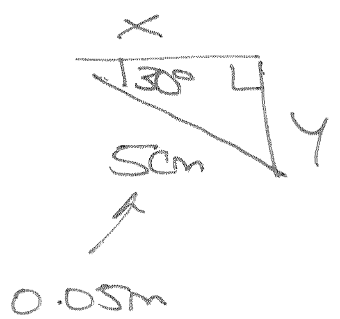
⇒



Since from B to C is 90° to field, potential is constant

⇒ $V_B = V_C$ AND $V_A - V_C = Ex$

⇒ $V_A - V_B = Ex$



$\cos 30° = \frac{x}{0.05m}$ ⇒ $x = 0.05m \cos 30°$

$= 0.0433m$

So $V_A - V_B = Ex$ ⇒ $-300V - V_B = (1200V/m)(0.0433m)$

⇒ $-300V - V_B = 51.96V$ ⇒ $-300V - 51.96V = V_B$

⇒ $V_B = -351.96V = \underline{\underline{-352V}}$

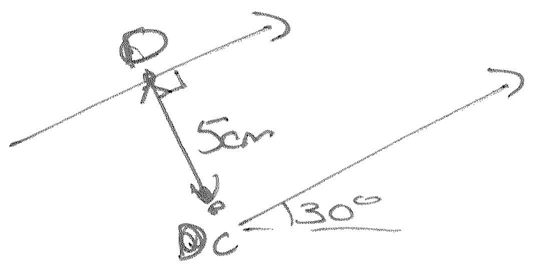
b.) What is V_A if $V_B = 0$?

Remember that ΔV has the same value regardless of where we set $V = 0$

$\Delta V = Ex$ ⇒ $\Delta V = 51.96V$. ⇒ $\Delta V = V_A - V_B$ ⇒ $V_A - V_B = 51.96V$

⇒ A is 51.96V higher than B ⇒ if $V_B = 0$, $V_A = +51.96V = \underline{\underline{+52V}}$

c)

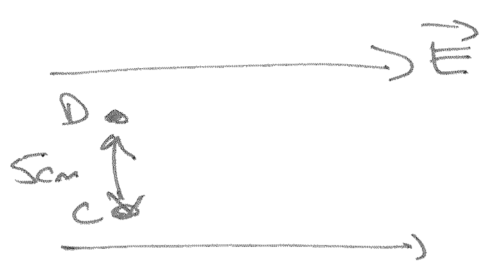


$E = 1200\,V/m$

$V_C = 100V$

$V_D = ?$

As show on figure from D to C is perpendicular to field, i.e. it looks like this when rotated

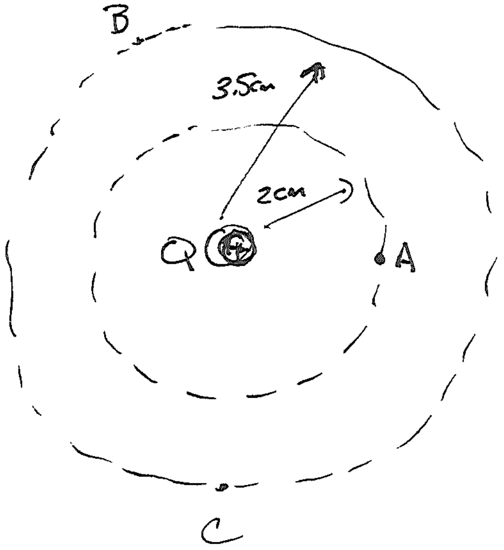


As we used before, there is no change in potential 90° to field $\Rightarrow$ $\underline{V_D = V_C = 100V}$

More mathy: $\Delta V = Ex$ but $x = 0$ ($y = 5cm$ but that is irrelevant) $\Rightarrow \Delta V = 0$. $\Delta V = V_D - V_C$

So $V_D - V_C = 0 \Rightarrow V_D = V_C$

21.16



$Q = 7nC = 7\times10^{-9}C$

a.) What is V_A, V_B, V_c if $V=0$ at INFINITY?

$V = \frac{KQ}{r}$ gives value of potential WHEN $V=0$ at INFINITY

$K = 9\times10^9 N\cdot m^2/C^2 \Rightarrow r_A = 0.02m,\ r_B = r_c = 0.035m$

$$\therefore\ V_A = \frac{(9\times10^9 N\cdot m^2/C^2)(7\times10^{-9}C)}{0.02m} = 3150V \quad \left(\text{unit: } \frac{\frac{N\cdot m^2}{C^2}\cdot C}{m} = \frac{N\cdot m}{C} = J/C = V\right)$$

$$V_B = V_c = \frac{(9\times10^9 N\cdot m^2/C^2)(7\times10^{-9}C)}{0.035m} = 1800V$$

b.) if we set $V=0$ at point A, what is V_A, V_B, V_c?

Obviously $V_A = 0$ Now.

To find V_B & V_c, We use the fact that ΔV is the SAME for any choice of $V=0$.

When $V=0$ at infinity $V_A = 3150V$ and $V_B = 1800V$

$\Rightarrow \Delta V = V_B - V_A = 1800V - 3150V = -1350V$

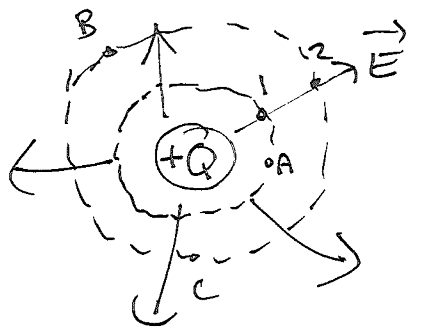
$\Rightarrow$ Regardless of where $V=0$, Point B is 1350V lower than Point A.

So if $V_A = 0$ then V_B must be 1350V lower than zero $\Rightarrow V_B = -1350V$

Since C is at the same distance as B, it must also be 1350V lower than A

$\Rightarrow V_C = -1350V$ when $V_A = 0$.

Notice (and this will help for part c) that we could have immediately guessed that B and C's values were going to be negative.

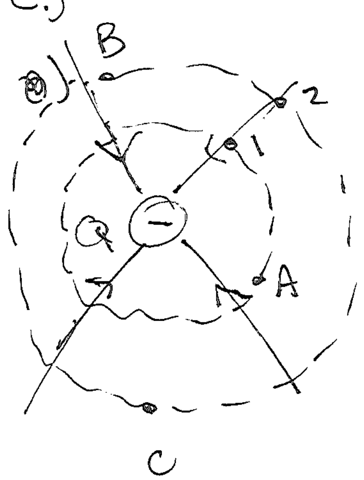


the field created by A positive charge points outward

going with the field, i.e., outwards causes potential to decrease $\Rightarrow V_2$ must be smaller than V_1 $\Rightarrow$ if $V_1 = 0$, $V_2 < 0$

Going at 90° to $\vec{E}$ causes no change in potential $\Rightarrow V_A = V_1$ and $V_C = V_B = V_2$.

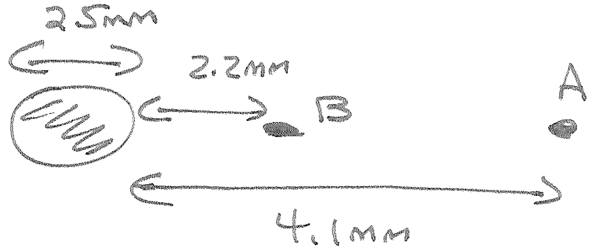
c.)



If source is negative then $\vec{E}$ points inward $\Rightarrow$ going outward from 1 to 2 is against the field.

Going against the field causes potential to increase $\Rightarrow V_2$ must be larger than V_1 $\Rightarrow$ V_B & V_C are larger than V_A $\Rightarrow$ if $V_A = 0$ then V_B & V_C would be positive. By the same reasoning if $V=0$ is closer to the source than A then V_A would be positive and V_B & V_C would ~~also~~ be even more positive.

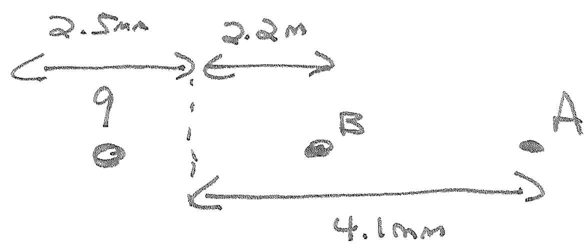
21.58 A 2.5mm diameter glass bead



B is 500V higher than A

$\Rightarrow V_B - V_A = 500V$

Outside of any charged object which is spherical, the electric field and potential values are the same as a point charge located at the center of the sphere. (Did you read this part of the book?) $\Rightarrow$



Point charge: $V = \frac{kq}{r}$

$\Rightarrow V_A = \frac{kq}{r_A}$ $\quad r_A = \frac{2.5mm}{2} + 4.1mm = 5.35mm = 5.35 \times 10^{-3} m$

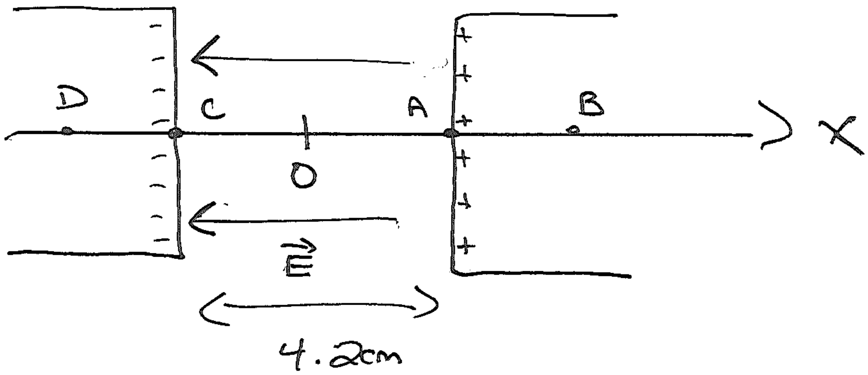
$V_B = \frac{kq}{r_B} = \frac{2.5mm}{2} + 2.2mm = 3.45mm = 3.45 \times 10^{-3} m$

$V_B - V_A = \frac{kq}{r_B} - \frac{kq}{r_A} = kq\left(\frac{1}{r_B} - \frac{1}{r_A}\right) = kq\left(\frac{1}{3.45 \times 10^{-3} m} - \frac{1}{5.35 \times 10^{-3} m}\right) = kq\,(102.9/m)$

$V_B - V_A = 500V \Rightarrow kq\,(102.9/m) = 500V \Rightarrow q = \frac{500V}{(102.9/m)k} = \frac{500V}{(102.9/m)(9 \times 10^9 N\cdot m^2/C^2)} = \underline{5.4 \times 10^{-10} C}$

Unit: $\frac{V}{\frac{1}{m}\cdot\frac{N\cdot m^2}{C^2}} = \frac{V}{J}\cdot C^2 = \frac{J/C}{J}\cdot C^2 = C$

Written Question #1



$E = 400\,V/m$ between plates

$V = 0$ is at Halfway point, $x = 0$

a.) what is Electric ~~PO~~ POTENTIAL AT THE POSITIVE plate?

IN A UNIFORM ELECTRIC FIELD* $\Delta V = Ex$

IF we ~~let~~ start at O to go to A: $x = 2.1\,cm$, O, A, $\vec{E}$

*WE ARE going ~~[illegible]~~ Against the electric Field $\Rightarrow$ potential INCREASES

$\Rightarrow V_A - V_O = Ex$ where $x = \frac{1}{2}(4.2cm) = 2.1cm \times \frac{m}{100cm} = 0.021m$

$V_O = 0 \Rightarrow V_A - 0 = (400V/m)(0.021m) \Rightarrow \boxed{V_A = 8.4V}$

b.) What is potential at point B?

INSIDE A CONDUCTOR $E = 0$ (which is a type of uniform field), so $\Delta V = Ex$ applies but if $E = 0$ THEN $\Delta V = 0 \Rightarrow$ NO change IN POTENTIAL FROM point A to Point B (the Region over which $E = 0$)

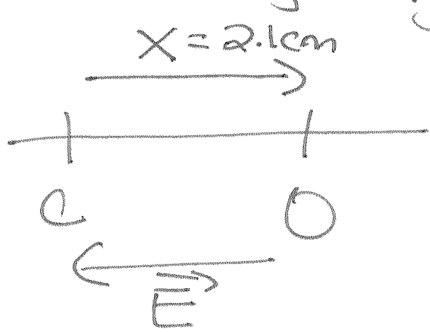
So $\boxed{V_B = 8.4V}$ too

if you prefer: FROM A to B $\Rightarrow \Delta V = V_B - V_A$.

$\Delta V = 0 \Rightarrow V_B - V_A = 0 \Rightarrow V_B = V_A$.

c.) what is potential at point C?

OUR EQUATION, $\Delta V = Ex$, REQUIRES US TO GO AGAINST THE FIELD. $\vec{E}$ is to the left AT All points Between plates $\Rightarrow$ Must go to the right (just Like in Part a)



Going to Right $\Rightarrow \Delta V = V_O - V_C$,

$Ex = 400V/m(0.021m) = 8.4V$

So $\Delta V = Ex \Rightarrow 0 - V_C = 8.4V \Rightarrow \boxed{V_C = -8.4V}$

(WE KNEW V_C HAD to be Negative, BECAUSE going Against FIELD $\Rightarrow$ INCREASING POTENTIAL $\Rightarrow$ V_C HAD to be SMALLER THAN V_O.
$\Rightarrow$ V_C SMALLER THAN ZERO.)

d.) What is potential at point D?

Again we are inside a conductor $\Rightarrow E=0 \Rightarrow \Delta V=0$

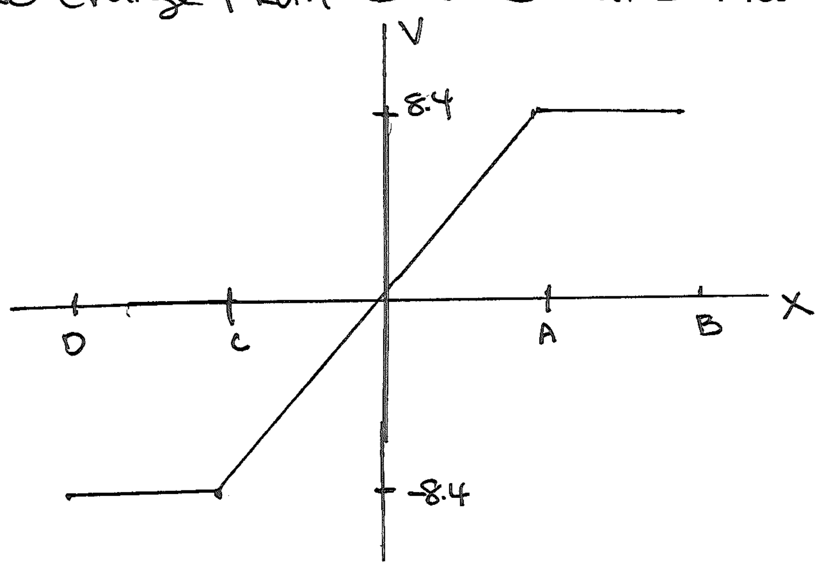
but now $E=0$ from point C to point D

$\Rightarrow V_D = V_C \Rightarrow \boxed{V_D = -8.4V}$

e.) Draw a graph of $V(x)$.

The potential only changes from C to A. Over that range, $\Delta V = Ex \Rightarrow$ graph is a straight line from $V=-8.4V$ at C ($X=-2.1$cm to be mathy) to $V=+8.4V$ at A ($X=+2.1$cm). Point B is at $X=2.1$cm$+2$cm $\Rightarrow X=4.1$cm and D is at $X=-2.1$cm -2cm $=-4.1$cm.

Finally no change from D to C and from A to B $\Rightarrow$ horizontal lines.



f. REDRAW graph if $V=0$ at Negative plate.

~~The~~ WE DON'T have to REDO all of OUR calculations!

Remember that ΔV is the SAME for any choice of ZERO. $V_A - V_C = 8.4V - (-8.4V) = 8.4V + 8.4V = 16.8V$

$\Rightarrow$ A is 16.8V higher than C. $\Rightarrow$ if $V_C = 0$ then $V_A = 16.8V$

$V_D - V_C = 0$ still $\Rightarrow$ $V_D = 0$ when $V_C = 0$

$V_B - V_A = 0$ still $\Rightarrow$ $V_B = 16.8V$ when $V_A = 16.8V$

$\Rightarrow$ SAME shape graph, it's just moved upward to be positive