Goals for the Lecture:

1) Continue to solve electric potential problems using:

$$\Delta V = -\int_A^B \vec{E} \cdot \overrightarrow{ds}$$

And

$$V = \int \frac{kdq}{r}$$

2) Start capacitance

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	U_{int}	W_{ON}	W_{By}
1)	=	0	0
2)	=	0	0
3)	>	<	>
4)	<	>	<
5)	>	<	>
6)	>	<	>

For a 3 particle system:

$$U = U_{12} + U_{23} + U_{13}$$

$$= \frac{k q_1 q_2}{r_{12}} + \frac{k q_2 q_3}{r_{23}} + \frac{k q_1 q_3}{r_{13}}$$

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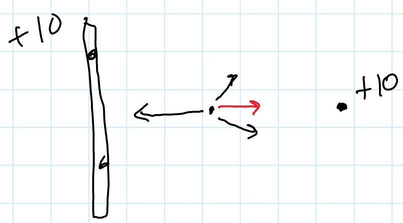
top) To the left



Which direction $\vec{E}$? | will it move? | which direction will it move?

Bottom)

	Particle	Released From	Which direction is $\vec{E}$?	will it move?	which direction will it move?
1	+	A	$+x$	yes	$+x$
2	+	C	$+x$	yes	$+x$
3	+	E	$-x$	yes	$-x$
4	+	F	$-x$	yes	$-x$
5	−	B	$+x$	yes	$-x$
6	−	D	$E=0$	NO	N/A
7	−	E	$-x$	yes	$+x$
8	−	F	$-x$	yes	$+x$

if $\quad \Delta V = -\int \vec{E} \cdot d\vec{s}$

then: $\quad E_x = -\dfrac{\partial V}{\partial x}$

$$E_y = -\frac{\partial V}{\partial y}$$

$$E_z = -\frac{\partial V}{\partial z}$$

in vector notation: $\quad \vec{E} = -\nabla V$

del $\quad \nabla = \hat{\imath}\dfrac{\partial}{\partial x} + \hat{\jmath}\dfrac{\partial}{\partial y} + \hat{k}\dfrac{\partial}{\partial z}$

Book Prob

2 conducting, spherical shells:

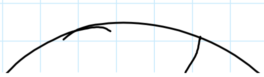
inner shell: $\quad r_1 = 15$ cm

$q_1 = +10$ nC

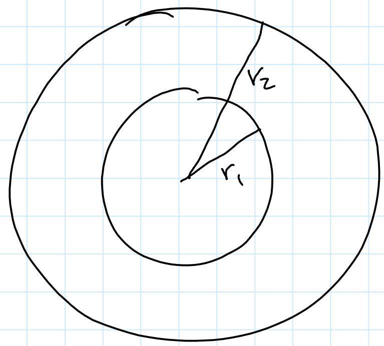
outer shell: $\quad r_2 = 30$ cm

$q_2 = -15$ nC

Find $\vec{E}$ and V everywhere if $V=0$ at $r=\infty$



$\boxed{V = kq \quad \text{For pt charge}}$



$V = \frac{kq}{r}$ for pt charge

$V = \int \frac{k\,dq}{r}$

$V = 0$ at $r = \infty$

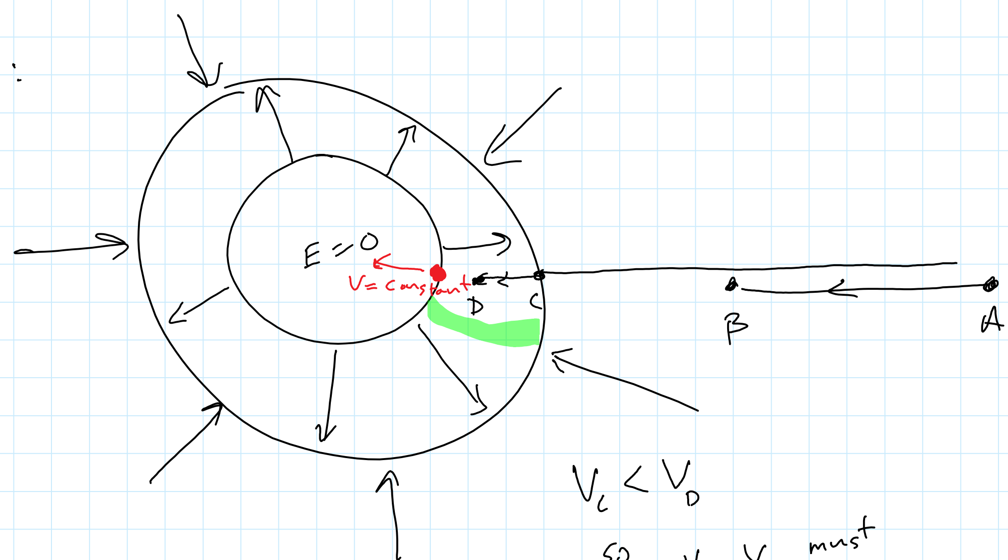
1st) E

$r < r_1 \qquad E = 0$

$r_1 < r < r_2 \qquad E = \frac{k\,q_1}{r^2}\,\hat{r}$

$r > r_2 \qquad E = \frac{k\,(q_1 + q_2)}{r^2} = \frac{k\,(-5\,\mu C)}{r^2}\,\hat{r}$

E fields:



$V_C < V_D$

so, $V_D - V_C$ must be positive

2nd) V

start at $r_A = \infty$

$r > r_2 \qquad V_B - V_A = -\int \vec{E} \cdot d\vec{s}$

$$\underbrace{V_B - \cancel{V_A}^{\,0}}_{\text{must be negative } (V_B < 0)} = -\int_{r_B}^{r_A} \underbrace{\frac{k\,(5\,nC)}{r^2}}_{|\vec{E}|}\,dr\;\underbrace{(\cos 0^\circ)}_{\text{direction is accounted for here}}$$

$$= -k\,(5)\int \frac{dr}{r^2}$$

$(V_B < 0)$

$$= -k(5) \int \frac{dr}{r^2}$$

$$= +k(5) \left. \frac{1}{r} \right|_{r_B}^{r_A}$$

$$= +k(5\,nC)\left(\cancel{\frac{1}{r_A}}^{0} - \frac{1}{r_B}\right)$$

$$V_r = -\frac{k(5\times10^{-9})}{r}$$

$$= -\frac{(8.99\times10^{9})(5\times10^{-9})}{r}$$

$$= -\frac{45}{r}$$

$r_1 < r < r_2$ Find V at $r = r_2$

$$V_{r_2} = -\frac{45}{r_2} = -\frac{45}{0.3} = -150\ V$$

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

$$\underbrace{V_D - V_C}_{\text{positive}} = \underbrace{-\int_{r_D}^{r_C} \frac{kq_1}{r^2}\,dr\,(\cos 180^\circ)}_{\text{should be positive}}$$

$$= kq_1 \int \frac{dr}{r^2}$$

$$= kq_1 \left[\left. -\frac{1}{r} \right|_{r_D}^{r_C} \right]$$

$$= kq_1 \underbrace{\left(-\frac{1}{r_C} + \frac{1}{r_D}\right)}_{\text{positive}}$$

$$V_D = k(10\times10^{-9}\,C)\left(\frac{1}{r_D} - \frac{1}{r_C}\right) + V_C$$

$$= (8.99\times10^{+9})(10\times10^{-9})\left(\frac{1}{} - \frac{1}{}\right) + (-150)$$

$$= (8.99\times 10^{+9})(6\times 10^{-9})\left(\frac{1}{r_D} - \frac{1}{0.3}\right) + (-150)$$

$$V_r = 90\left(\frac{1}{r} - \frac{1}{0.3}\right) - 150$$

for $r_1 < r < r_2$

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for $r < r_1$ Find V at $r = r_1$

$$V_{r_1} = 90\left(\frac{1}{r_1} - \frac{1}{0.3}\right) - 150$$

$$= 90\underbrace{\left(\frac{1}{0.15} - \frac{1}{0.3}\right)}_{\frac{1}{0.3}} - 150$$

$$= 300 - 150$$

$$= 150\ V$$

$V = 150\ V$ for $r < r_1$

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worksheet
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Find E at each location:

$E_A = 0$

$E_B = 0$

$$E_C = \frac{kQ}{\left(\frac{3R}{2}\right)^2} = \frac{4}{9}\frac{kQ}{R^2}$$

$E_D = 0$

$E_E = 0$

$$E_F = \frac{8}{9}\frac{kQ}{R^2}$$

Find V at each location: (if $V = 0$ at $r = \infty$)

Find V at each location: (if $V=0$ at $r=\infty$)

$$V_c = \frac{kQ}{\frac{3R}{2}} = \frac{2}{3}\frac{kQ}{R}$$

$$V_A = V_B = V_{surface} = \frac{kQ}{R}$$

$$V_F = \frac{k(2Q)}{\frac{3R}{2}} = \frac{4}{3}\frac{kQ}{R}$$

$$V_D = V_E = V_{surface} = \frac{k(2Q)}{R} = 2\frac{kQ}{R}$$

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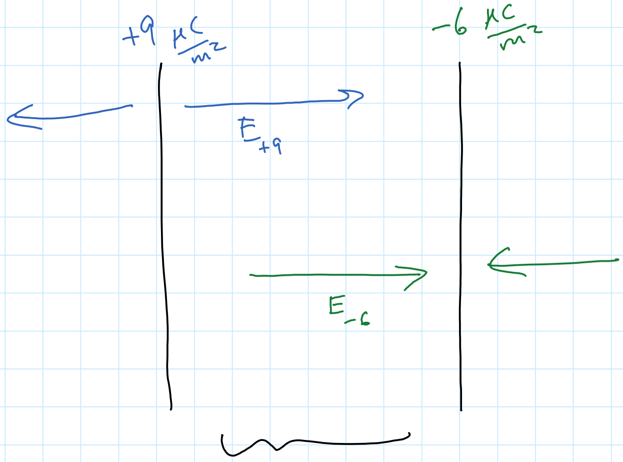
A)



$$E = E_{+9} + E_{-6}$$

$$E_{sheet} = \frac{\sigma}{2\epsilon_0}$$

$$= \left[\frac{9}{2\epsilon_0} + \frac{6}{2\epsilon_0}\right](\times 10^{-6})$$

$$= \frac{15\times 10^{-6}}{2(8.85\times 10^{-12})}$$

$$\approx 1\times 10^{6}\ \frac{V}{m}$$

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

$$= -Ed \qquad \text{if } E \text{ is constant}$$

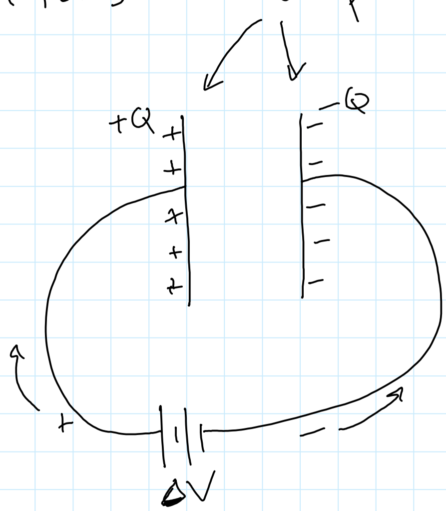
$$\Delta V = (1\times 10^{+6})(0.08\ \text{m})$$

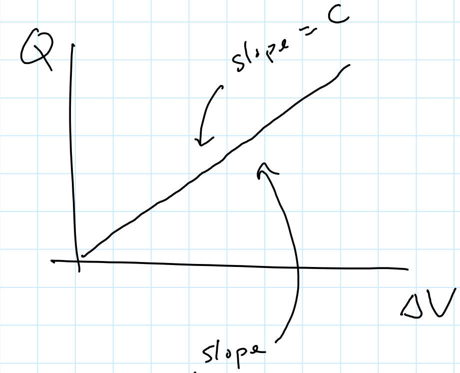
$$\approx 80{,}000\ \text{V}$$

Which plate is at higher potential?

Left ($\vec{E}$ points to Right, E points to lower potential)

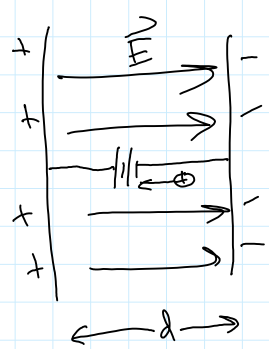
Capacitors:



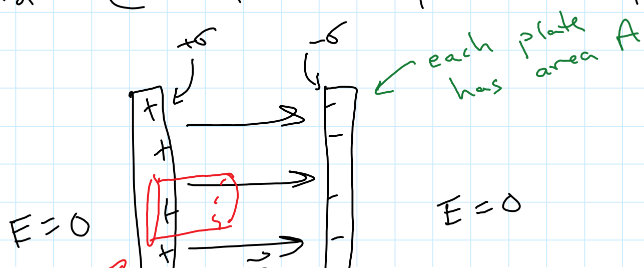


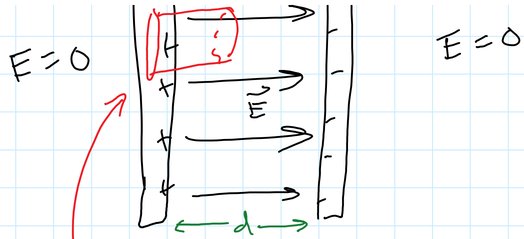
$$Q = C\,\Delta V$$

Capacitance only depends on capacitor
→ shape
→ size
→ spacing



Find C for a parallel plate capacitor:





$$\oint \vec{E}\cdot d\vec{A} = \frac{q_{in}}{\epsilon_0}$$

$$\underbrace{\int_{Left} \vec{E}\cdot d\vec{A}}_{0} + \underbrace{\int_{Side} \vec{E}\cdot d\vec{A}}_{0} + \underbrace{\int_{Right} \vec{E}\cdot d\vec{A}}_{EA} = \frac{q_{in}}{\epsilon_0}$$

$$E\,A = \frac{q_{in}}{\epsilon_0}$$

total charge

$$E = \frac{q_{in}}{\epsilon_0 A} = \frac{\sigma}{\epsilon_0} = \frac{Q}{\epsilon_0 A}$$

total Area

$$|\Delta V| = \left| -\int \vec{E}\cdot d\vec{s} \right|$$

E is constant

$$\Delta V = \frac{Q}{\epsilon_0 A}\, d$$

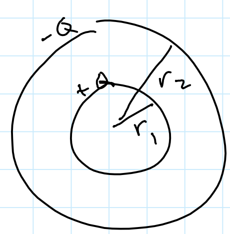
$$Q = C\ \Delta V$$

$$Q = \left(\frac{\epsilon_0 A}{d}\right) \Delta V$$

$$Q = C\ \Delta V$$

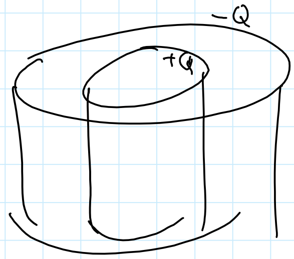
$$C = \frac{\epsilon_0 A}{d}$$ for a parallel plate capacitor

Find the capacitance of this capacitor:



2 concentric spherical shells r_1 and r_2

OR



2 concentric cylindrical shells