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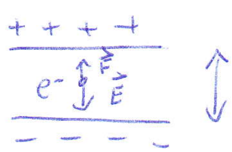
Phys 102 Sec. 002 Assignment 2

February 2011

Print this document and answer the questions in the space provided. Place a box around your final answer. Due Wednesday, Feb. 23 @ 9:30 am.

1. **Electric field and work... (4 marks)**

Oppositely charged conducting parallel plates are separated by 5.33 mm. A potential difference of 600 V exists between the plates. (a) What is the magnitude of the electric field between the plates? (b) What is the magnitude of the force on an electron between the plates? (c) How much work must be done on the electron to move it to the negative plate if it is initially positioned 2.90 mm from the positive plate? (d) What is the surface charge density σ of the plates?



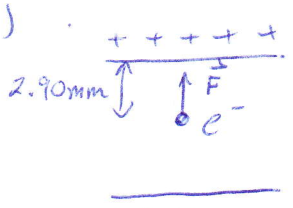
(a) $E = \text{const} \Rightarrow \Delta V = Ed$

$\therefore E = \dfrac{\Delta V}{d} = \boxed{1.13 \times 10^{5}\ \frac{V}{m}}$

(b) $F = qE$

$= (1.6 \times 10^{-19}\ C)E = \boxed{1.80 \times 10^{-14}\ N}$

(c)



$W = \vec{F} \cdot \Delta\vec{S}$

$= -F\Delta S$

$\Delta S = 5.33\ mm - 2.90\ mm$

$= 2.43\ mm$

$\therefore W = \boxed{-4.37 \times 10^{-17}\ J}$

work by $\vec{E}$-field is neg. ∴ have to put energy into system to move e^- to neg. plate.

(d) Between the plate

$E = \dfrac{\sigma}{\varepsilon_0}$

$\therefore \sigma = \varepsilon_0 E$

$= \boxed{1.00 \times 10^{-6}\ \frac{C}{m^2}}$

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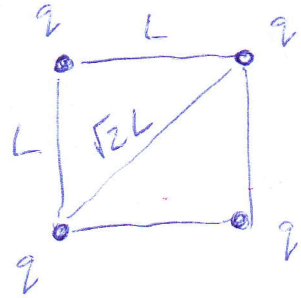
2. **Energy. . . (6 marks)**

Four particles are held in place at the corners of a square with sides of length L. Each particle has a charge q and mass m. (a) What is the potential energy of this system of charges? (b) Starting from the rest, the particles are now released. How fast is each particle moving when their distance from the centre of the square doubles? Give your answers as algebraic expressions.

(a)



There are 6 pairs of charges.
4 separated by L, 2 separated by √2 L

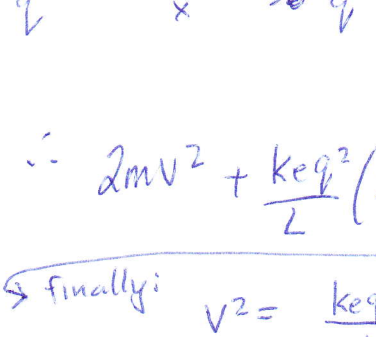
$$U = 4\frac{k_e q^2}{L} + 2\frac{k_e q^2}{\sqrt{2}L} = \boxed{\frac{k_e q^2}{L}\left(4+\sqrt{2}\right)}$$

(b) conservation of energy $U_i + K_i = U_f + K_f$

initial: $U_i = \frac{k_e q^2}{L}\left(4+\sqrt{2}\right)$ $K_i = 0$.

final: $K_f = 4\left(\frac{1}{2}mv^2\right)$ ← four charges

initially each charge is dist $\frac{L}{\sqrt{2}}$ from centre.
find potential energy of system when dist. from centre is $\sqrt{2}L$



$$2x^2 = 8L^2 \therefore x = 2L$$

$$U_f = 4\frac{k_e q^2}{2L} + 2\frac{k_e q^2}{2\sqrt{2}L} = \frac{k_e q^2}{L}\left(2+\frac{1}{\sqrt{2}}\right)$$

$$\therefore 2mv^2 + \frac{k_e q^2}{L}\left(2+\frac{1}{\sqrt{2}}\right) = \frac{k_e q^2}{L}\left(4+\sqrt{2}\right) \quad \therefore 2mv^2 = \frac{k_e q^2}{L}\left(2+\sqrt{2}-\frac{1}{\sqrt{2}}\right)$$

$$= \frac{k_e q^2}{L}\left(\frac{2\sqrt{2}+2-1}{\sqrt{2}}\right)$$

finally: $v^2 = \frac{k_e q^2}{mL}\left(\frac{2\sqrt{2}+1}{2\sqrt{2}}\right) \Rightarrow \boxed{v = \sqrt{\frac{k_e q^2}{mL}}\left(1+\frac{1}{2\sqrt{2}}\right)^{\frac{1}{2}}}$

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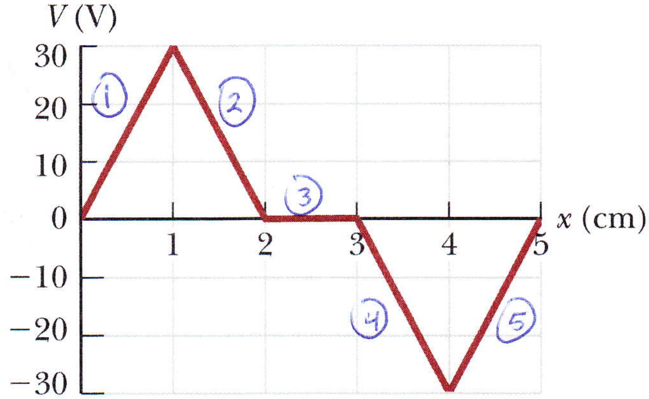
3. E from V... (5 marks)

An electric field in a region of space is parallel to the x-axis. The electric potential varies with position as shown in the figure. Graph the x component of the electric field versus position in this region of space. Label your axes and include a scale with numbers and units!



$E_x = -\frac{dV}{dx}$ ∴ E_x given by −slope$\left(= \frac{\text{rise}}{\text{run}}\right)$ of V vs x graph.

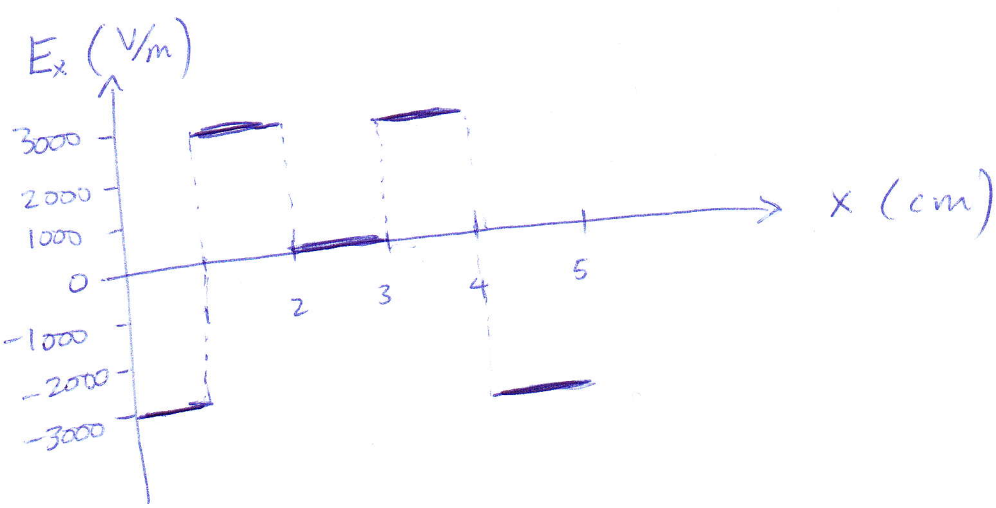
① $E_x = -\frac{30\,V}{.01\,m} = -3000\,\frac{V}{m}$

② $E_x = -\frac{-30\,V}{.01\,m} = +3000\,\frac{V}{m}$

③ $E_x = -\frac{0\,V}{.01\,m} = 0$

④ $E_x = -\frac{-30\,V}{.01\,m} = +3000\,\frac{V}{m}$

⑤ $E_x = -\frac{30\,V}{.01\,m} = -3000\,\frac{V}{m}$



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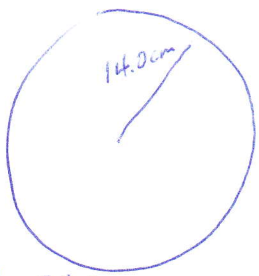
4. **Potential and Conductors... (5 marks)**

A spherical conductor has a radius of 14.0 cm and a charge of 26.0 μC. Calculate the electric field and the electric potential at (a) r = 10.0 cm, (b) r = 20.0 cm, and (c) r = 14.0 cm (for part c assume the point is infinitesimally close to but outside of the conductor surface). Here r is measured from the centre of the sphere.



$Q = 26.0\,\mu C$

Start w/ (b).

$r = 20.0$ cm outside conductor.

$\vec{E}$ & V same as if due to pt. charge Q @ centre of sphere.

$$\vec{E} = \frac{keQ}{r^2}\hat{r} = 5.85\times10^6 \frac{N}{C}\hat{r} \qquad V = \frac{keQ}{r} = 1.17\times10^6 V$$

(c) potential @ conductor surface equal to potential just outside conductor. Since still outside conductor, pt. charge calculations still work (as in (c)).

$\vec{E} = \frac{keQ}{r^2}\hat{r}$ for $r = 14.0$cm

$$\vec{E} = 1.19\times10^7 \frac{N}{C}\hat{r} \qquad V = \frac{keQ}{r} = 1.67\times10^6 V$$

(a) $r = 10.0$ cm is inside conductor.

$\vec{E} = 0$ inside conductor in equilibrium

V = const = V@ surface (part c)

$\therefore V = 1.67\times10^6 V$

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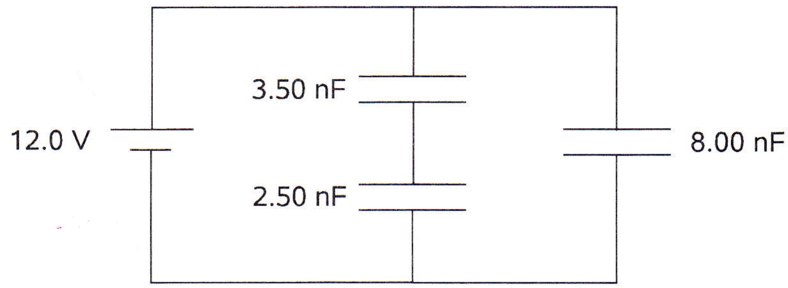
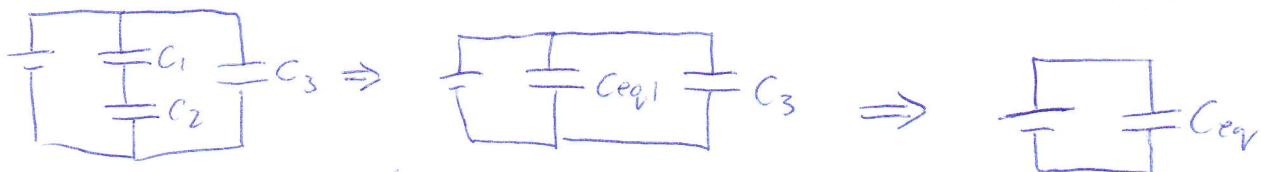
5. **Capacitors... (6 marks)**

Consider the combination of capacitors and a battery shown in the figure. (a) Find the equivalent capacitance. (b) Find the magnitude of the charge associated with each capacitor and the potential difference across each capacitor.



(a)



$$\frac{1}{C_{eq1}} = \frac{1}{C_1} + \frac{1}{C_2} \Rightarrow C_{eq1} = 1.46\,nF$$

$$C_{eq} = C_{eq1} + C_3 = 9.46\,nF$$

(b) C_{eq1} & C_3 in parallel $\therefore \Delta V_{eq1} = \Delta V_3 = 12.0\,V$

$C = \frac{Q}{\Delta V}$ $\therefore$ $Q_3 = C_3 \Delta V_3 = 96.0\,nC$

$Q_{eq1} = C_{eq1} \Delta V_{eq1} = 17.5\,nC$

C_1 & C_2 in series $\therefore$ $Q_1 = Q_2 = Q_{eq1} = 17.5\,nC$

$\Delta V_1 = \frac{Q_1}{C_1} = 5.00\,V$ $\Delta V_2 = \frac{Q_2}{C_2} = 7.00\,V$

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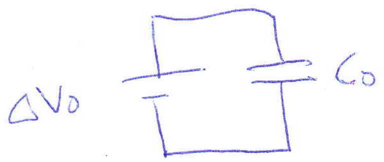
6. **Dielectric... (4 marks)**

A parallel plate capacitor of plate separation d is connected to a battery with a potential difference ΔV_0 across its terminals. With the battery still connected, a dielectric material with dielectric constant κ is inserted between the plates of the capacitor. (a) If the energy stored by the capacitor before the dielectric is inserted is U_0, show that the energy stored after the dielectric is inserted is $U = \kappa U_0$. (b) If the magnitude of the charge on the capacitor plates is Q_0 before the dielectric is inserted, what is the charge after the dielectric is inserted?



$$C_0 = \frac{Q_0}{\Delta V_0} = \varepsilon_0 \frac{A}{d}$$

(a) $$U_0 = \frac{1}{2} Q_0 \Delta V_0 = \frac{1}{2} C_0 (\Delta V_0)^2$$

Dielectric inserted $\Rightarrow$ $C = \kappa C_0$

$\Delta V = \Delta V_0$ doesn't change b/c battery still connected!

$$\therefore U = \frac{1}{2} C (\Delta V)^2 = \frac{1}{2} \kappa C_0 (\Delta V_0)^2 = \kappa \underbrace{\left(\frac{1}{2} C_0 (\Delta V_0)\right)^2}_{U_0}$$

$$\therefore \boxed{U = \kappa U_0}$$

(b) $$C = \frac{Q}{\Delta V} = \frac{Q}{\Delta V_0} \quad \therefore Q = C \Delta V_0 \quad \text{use } C = \kappa C_0$$

$$\therefore Q = \kappa \underbrace{C_0 \Delta V_0}_{Q_0}$$

$$\therefore \boxed{Q = \kappa Q_0}$$