EXAM I

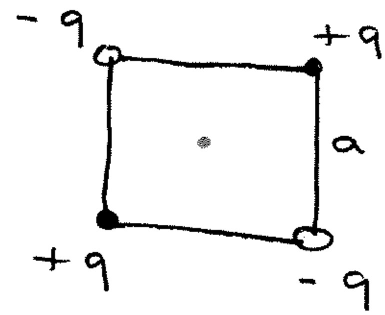
Physics 122 **October 5, 2005**

1. Four charges are fixed at the corners of a square of side a as shown. The charges all have magnitude q, but two are positive and two are negative.

(9) a. Find the E-field (magnitude and direction) at the center of the square.

(8) b. Find the potential at the center of the square. (take the potential to vanish at infinity).

(8) c. Find the total potential energy of the system.



a) $E = \sum_i \frac{k_e q_i}{r_i^2} = 0$ since the q's cancel

that is the E-fields from the two "+q" charges cancel
" " " "-q" " "

b) $V = \sum_i \frac{k_e q}{r_i} = 0$ likewise

c) Potential energy from a pair of charges

$PE = k_e \frac{q_1 q_2}{r}$, there are 6 pairs of charges in the problem

→ there are 4 pairs of oppositely charged particles a distance "a" apart $PE = \frac{-k_e q^2}{a}$

→ there are 2 pairs of like charged particles a distance "$\sqrt{2}a$" apart $PE = \frac{k_e q^2}{\sqrt{2}a}$

$PE = -4k_e \frac{q^2}{a} + 2\frac{k_e q^2}{\sqrt{2}a} = \boxed{k_e \frac{q^2}{a}(\sqrt{2} - 4)}$

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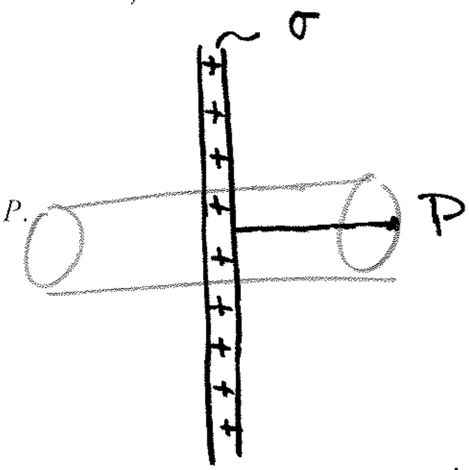
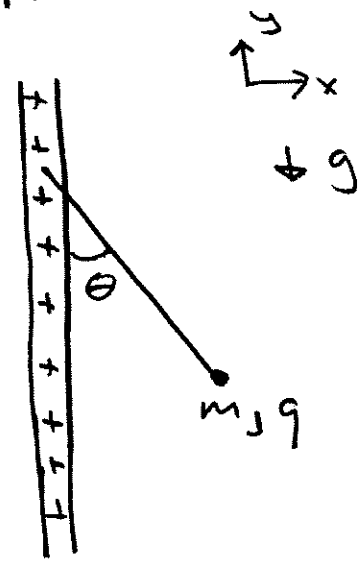
2. Shown is an infinite sheet of charge, turned edgewise, with charge density σ.



a. What is the electric field at the observation point P.

A massless string is attached to a charged mass ($q = 19.7\mu C, m = 1.12\,mg$). The string makes an angle $\theta = 27.4^{\circ}$ with the charged plate, and the apparatus is in the earth's gravitational field, $g = 9.8\ m/s^2$.



b. What forces act on the mass? Write equations expressing the mass is stationary using (b).

c. What is the numerical value of σ?

a) by gauss's law $2EA = \sigma A/\epsilon_0$

$$E = \frac{\sigma}{2\epsilon_0}$$

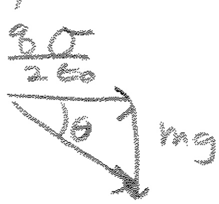
b) tension, electric, gravitational

$$\vec{F}_T = \vec{F}_g + \vec{F}_e$$

x direction $F_T \sin\theta = F_g = mg$

y direction $F_T \cos\theta = F_e = \frac{q\sigma}{2\epsilon_0}$

c)



$$\tan\theta = \frac{mg}{\frac{q\sigma}{2\epsilon_0}}$$

$$\sigma = \frac{2mg\epsilon_0}{q\tan\theta} = \frac{2 \cdot 1.12\times10^{-6}\,kg \cdot 9.8\frac{m}{s^2} \cdot 8.85\times10^{-12}\frac{C^2}{Nm^2}}{19.7\times10^{-6}\,C\ \tan 27.4}$$

 $= 1.9\times10^{-11}\ \frac{C}{m^2}$

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3. Shown is a capacita half-filled with a dielectric constant $K = 2$. The potential of its negative plate is taken to be zero, and the potential of the positive plate is V_0. The separation between plates is d.

   a. Call the field on the empty gap E_0. What is the field inside the dielectric slab.

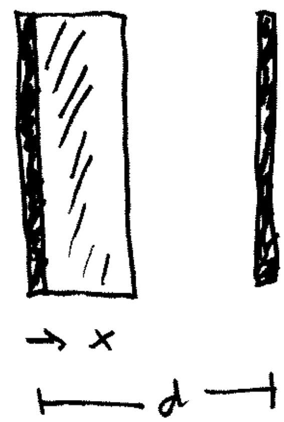
   b. Express E_0 in terms of V_0 and d.

   c. Draw a graph of V versus x, where $x = 0$ at the negative plate.

lets call E-field in dielectric E_d

$$V_0 = E_d \frac{d}{2} + E_0 \frac{d}{2}$$

$$E_d = \frac{2V_0}{d} - E_0$$



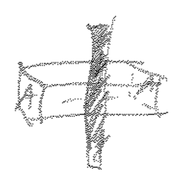
b] first lets find the capacitance, we can consider this set up 2 capacitors in series

$$\frac{1}{C_{eq}} = \frac{1}{2\epsilon_0 \frac{A}{d/2}} + \frac{1}{\epsilon_0 \frac{A}{d/2}} = \frac{3}{4} \frac{1}{\epsilon_0 \frac{A}{d}}$$

$$C_{eq} = \frac{4}{3} \frac{\epsilon_0 A}{d}$$ ← therefore we know C + V

find $Q = VC = \frac{4}{3} \frac{\epsilon_0 A}{d} V_0$

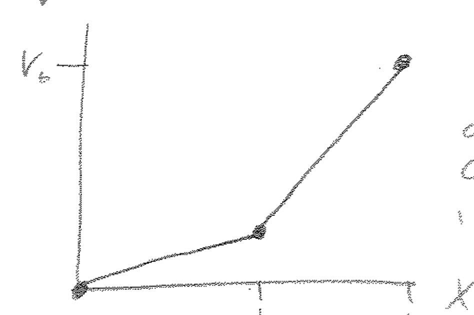
now use gausse law on 1 plate



$$2AE = \frac{4}{3} \frac{\epsilon_0 A}{d} V_0$$ but since we are in a capacitor contribution from each plate

$$E_0 = 2E = \frac{4}{3} \frac{\epsilon_0}{d} V_0$$

c]



note abrupt change in slope

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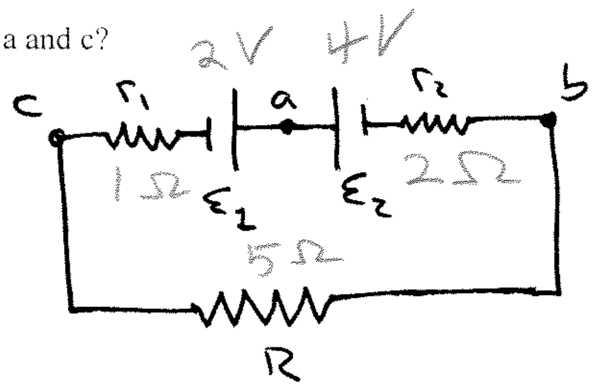
4. In the figure let ε_1 and ε_2 be 2.0 volts and 4.0 volts, respectively. Let the resistances r_1, r_2 and R be 1.0 *ohm*, 2.0 *ohms*, 5.0 *ohms*, respectively.

a. What is the current I?

b. What is the potential difference between points b and a?

c. What is the potential difference between points a and c?



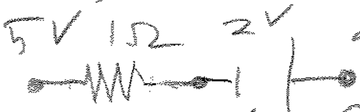
a] reduce the circuit

2V = 4V − 2V

8Ω = 1Ω + 2Ω + 5Ω

$I = \frac{2V}{8\Omega} = .25\ A$

b] let pt a be at V = 0



potential change across resistor

$\Delta V = IR = .25A \cdot 1\Omega = .25\ V$

$V_{ab} = 2.25\ V$ these are added since the current is in the same direction we are going

c] again

potential change across $R_2 = IR_2 = .25A \cdot 2\Omega = .5V$

$V_{ac} = 3.5V$ subtract since current is going in the opposite direction