Physics 10164 - Exam 1B

Partial credit will be given provided you show all work and are solving parts of the problem correctly. Points will be deducted if you don't show your work even if you get the right answer. Clearly indicate your answer with a circle or a box and remember to include correct units and significant figures.

#1. (40 pts) A 3.0 μC charge is fixed at the origin. Nearby, at a coordinate x = 2.4 mm, a -5.5 μC charged particle with a mass of 220 grams has a speed of 21 m/s in the +x direction, which is directly away from the origin.

How far away does the 220 gram mass get from the origin before it is stopped by the electric force from the positive charge at the origin, assuming the electric force is the only relevant force in this problem?

$q_1 = +3.0\ \mu C \qquad q_2 = -5.5\ \mu C$

Non-uniform field, so must use work-energy

$\Sigma W_F = W_E = \Delta K$

$-q_2 \Delta V_1 = \Delta K$

$V_{1i} = \frac{kq_1}{r_i} = \frac{(9\times10^9)(3\times10^{-6})}{2.4\times10^{-3}}$

$= 1.125\times10^7$ Volts

$K_f = 0$ (like a max height problem)

$-(-5.5\times10^{-6})(V_f - 1.125\times10^7) = 0 - \frac{1}{2}(.220)(21)^2$

$(5.5\times10^{-6})(V_f - 1.125\times10^7) = -48.5$

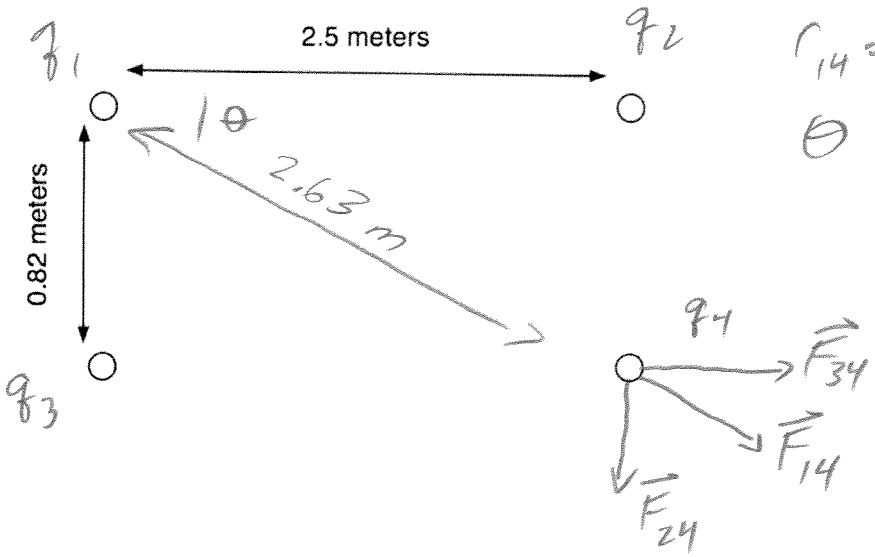
$V_f - 1.125\times10^7 = -8.82\times10^6$

$V_f = 2.43\times10^6 = \frac{kq_1}{r_f}$

$r_f = \frac{(9\times10^9)(3.0\times10^{-6})}{2.43\times10^6} = 11\ mm$

2. (30 pts) Four identical +4.0 nC charges are arranged in a rectangle as shown below. The charge on the top left of the rectangle is located at the origin.

Find the magnitude and direction of the electric force acting on the charge on the bottom right of the rectangle.



$r_{14} = \sqrt{2.5^2 + .82^2} = 2.63\,m$

$\theta = \tan^{-1}\left(\frac{.82}{2.5}\right) = 18.16^\circ$

$\vec{F}_{14} = \frac{k q_1 q_4}{r_{14}^2} = \frac{(9\times10^9)(4\times10^{-9})^2}{2.63^2} = 2.08\times10^{-8}$, 18.16° below $+x$

$\vec{F}_{24} = \frac{(9\times10^9)(4\times10^{-9})^2}{.82^2} = 2.14\times10^{-7}$, $-y$

or 21.4×10^{-8}

$\vec{F}_{34} = \frac{(9\times10^9)(4\times10^{-9})^2}{2.5^2} = 2.3\times10^{-8}$, $+x$

$F_{14,x} = 2.08\cos 18.16^\circ = 1.98\times10^{-8}$

$F_{14,y} = -2.08\sin 18^\circ = -0.648\times10^{-8}$

$F_{24,x} = 0$

$F_{24,y} = -21.4\times10^{-8}$

$F_{34,x} = 2.30\times10^{-8}$

$F_{34,y} = 0$

$F_{TOT,x} = +4.28\times10^{-8}$

$F_{TOT,y} = -22.048\times10^{-8}$

$|F_{TOT}| = \sqrt{4.28^2 + 22^2} = 22\times10^{-8}$ or $2.2\times10^{-7}\,N$

$\theta = \tan^{-1}\left(\frac{22}{4.28}\right) = 79^\circ$ below $+x$

#3. (30 pts) A parallel-plate capacitor has a cross-sectional area of 3.5 cm^2 and a plate separation of 4.4 mm. It is connected to a 12 Volt battery.

a) What is the charge on the positive plate of the capacitor?

b) What is the magnitude of the electric field between the plates?

c) Keeping the capacitor plates connected to the battery, the plates are pulled apart to a new separation of 6.6 mm. What happens to the charge on the positive plate? Justify your answer qualitatively or mathematically.

d) The capacitor is restored to its original 4.4 mm separation. Now a dielectric with K = 3.0 is inserted between the plates, and the system is allowed time to reach a new equilibrium with the plates still connected to the battery. What is the new charge on the positive plate?

e) What is the new electric field between the plates after they have reached equilibrium with the dielectric inserted?

a) $E = \frac{\Delta V}{d} = \frac{12}{4.4\times10^{-3}} = 2730\ V/m$

$2370 = \frac{4\pi k Q}{A}$

$Q = \frac{2370(3.5\times10^{-4} m^2)}{4\pi(9\times10^9)} = 8.4\times10^{-12}\ C$

b) $|\vec{E}| = 2730\ V/m$ (see above)

c) ΔV remains same, $\Delta V = Ed$

d increases, so E decreases

If E decreases, so does Q

Q decreases

d) With K inserted, C goes up, ΔV same

Since $Q = C\Delta V$ and $C_{new} = KC_{old}$

$Q_{new} = KQ_{old} = 2.5\times10^{-11}\ C$

e) ΔV + d same, so $\vec{E} = 2730\ V/m$