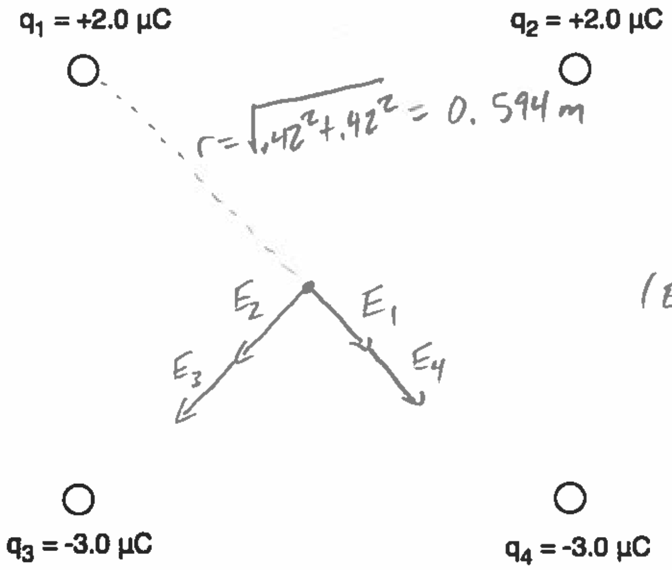
Physics 10164 - Spring 2019 Exam 1A

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. (35 pts) Four charges are arranged in a square as shown below. The length of each side of the square is 84 cm.

(a) Find the magnitude and direction of the electric field at the center of the square.
(b) Find the magnitude and direction of the acceleration that would be felt by an electron at the center of the square.



$|E_1| = |E_2| = \frac{(9\times10^9)(2\times10^{-6})}{.594^2} = 5.10\times10^4\ N/C$

$|E_3| = |E_4| = \frac{(9\times10^9)(3.0\times10^{-6})}{.594^2} = 7.65\times10^4\ N/C$

$E_{1x} + E_{2x}$ cancel

$E_{3x} + E_{4x}$ cancel

$E_{1y} = E_{2y} = -5.10\times10^4 \sin 45° = -3.61\times10^4$

$E_{3y} = E_{4y} = -7.65\times10^4 \sin 45° = -5.41\times10^4$

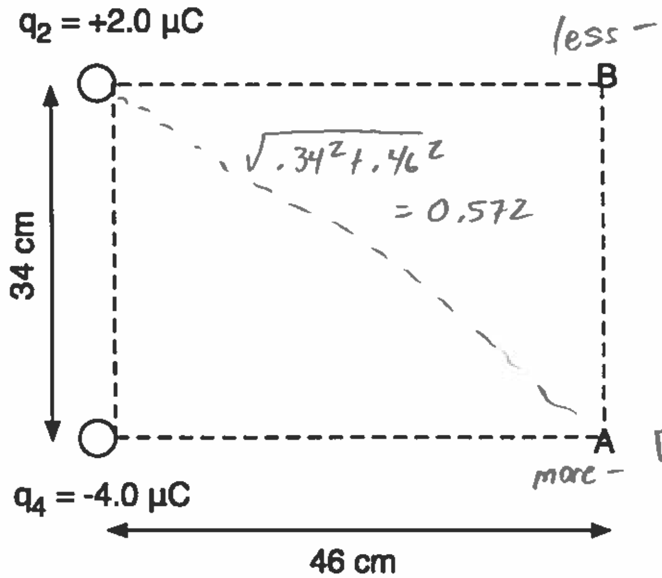
$E_{x,TOT} = 0$

$E_{y,TOT} = 2(-3.61\times10^4) + 2(-5.41\times10^4) =$ $\boxed{1.8\times10^5\ N/C,\ -y\ dir}$

b) Since $\vec{E}\downarrow$, F_E on $\ominus$ points $\uparrow$

$|F_E| = \frac{qE}{m} = \frac{(1.6\times10^{-19})(1.8\times10^5)}{9.11\times10^{-31}} =$ $\boxed{3.2\times10^{16}\ m/s^2,\ +y\ dir}$

2. (35 pts) Two charges are fixed in place as shown below. A third charge of $Q_5 = -5.0\ \mu C$ moves from point A to point B. How much work is done by the electric force during this motion?



$$V_A = \frac{k_c q_2}{.572} + \frac{k_c q_4}{.46}$$

$$= 3.147 \times 10^4 - 7.826 \times 10^4$$

$$= -4.68 \times 10^4$$

$$V_B = \frac{k_c q_2}{.46} + \frac{k_c q_4}{.572}$$

$$= 3.913 \times 10^4 - 6.294 \times 10^4$$

$$= -2.38 \times 10^4$$

$$W_E = -q_5 (V_B - V_A)$$

$$= -(-5.0 \times 10^{-6})(-2.38 \times 10^4 - (-4.68 \times 10^4))$$

$$= \boxed{0.11\ J}$$

makes sense, $\vec{E}$ points generally from $B \to A$

so F_E on q_5 points $A \to B$, same dir as motion

3. (30 pts) A parallel plate capacitor is connected to a 240-Volt battery, and the positive plate is fully charged to +0.17 nC. The plate has a surface area of 13 cm².

a) What is the separation between the plates?

$$E = \frac{4\pi(9\times10^9)(.17\times10^{-9})}{13\times10^{-4}\,m^2} = 1.48\times10^4\ N/C = \frac{\Delta V}{d}$$

$$d = \frac{\Delta V}{E} = \frac{240}{1.48\times10^4} = \boxed{1.6\times10^{-2}\,m} \text{ or } 1.6\,cm$$

Suppose the battery is disconnected. After a K = 4.4 dielectric is inserted in between the plates…

b) What is the voltage difference between the plates?
c) What is the charge on the positive plate?
d) What is the capacitance of the capacitor?

b) $E \downarrow$ by 4.4, so ΔV drops by 4.4 $\rightarrow \Delta V = \frac{240}{4.4} = \boxed{54\ Volts}$

c) Q unchanged, nowhere to go $\rightarrow \boxed{Q = 0.17\,nC}$

d) $$C_{orig} = \frac{13\times10^{-4}}{4\pi(9\times10^9)(.016)} = 7.2\times10^{-13}\,F$$

$$C_{new} = (4.4)\,C_{orig} = \boxed{3.2\times10^{-12}\,F}$$

The dielectric remains in place. After the 240-Volt battery is reconnected…

e) What is the charge on the positive plate?
f) What is the magnitude of the electric field between the plates?

c) ΔV same as original, $C \uparrow$ by 4.4, so $Q \uparrow$ by 4.4

$$Q_{new} = (4.4)(0.17) = \boxed{0.75\,nC}$$

f) E same (ΔV, d have original values) $= \boxed{1.5\times10^4\ N/C}$