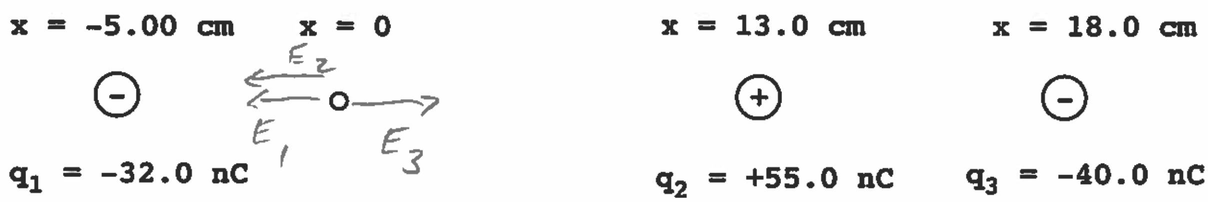
Physics 10164 - Exam 1A

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. (30 pts) Three charges are arranged in a straight line as shown below and fixed in place.

a) Determine the magnitude and direction of the electric field at the origin (x = 0).

b) Determine the magnitude and direction of the acceleration felt by an electron at the origin.



a) $|E_1| = \frac{k_c q_1}{r_1^2} = \frac{(9\times10^9)(32\times10^{-9})}{.05^2} = 115,200$

$|E_2| = \frac{k_c q_2}{r_2^2} = \frac{(9\times10^9)(55\times10^{-9})}{.13^2} = 29,300$

$|E_3| = \frac{k_c q_3}{r_3^2} = \frac{(9\times10^9)(40\times10^{-9})}{.18^2} = 11,100$

$\vec{E}_{TOT} = -E_1 - E_2 + E_3 = -133,400$

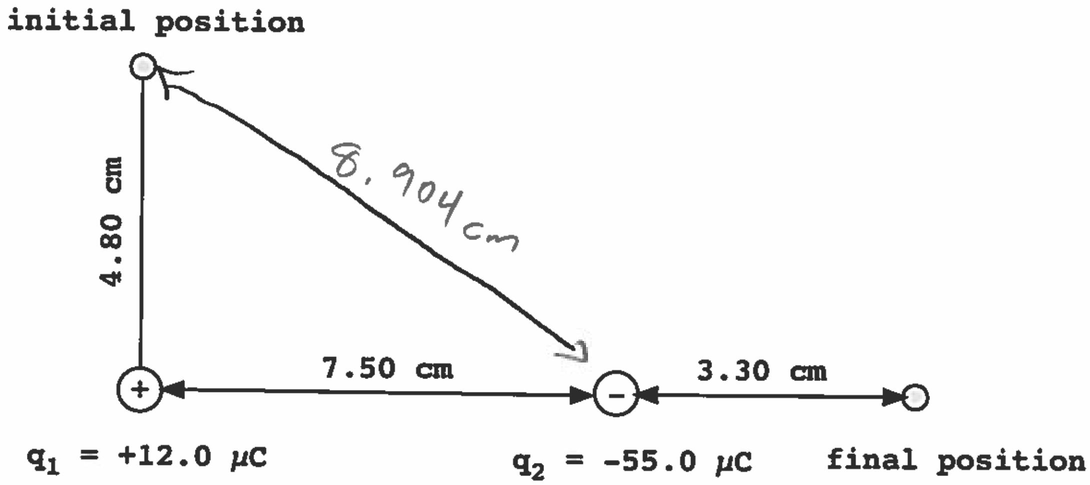
or $\boxed{+133,000\ N/C, \leftarrow}$

b) Since $\vec{E}$ points $\leftarrow$ + q is negative, F_E points $\rightarrow$

$|\vec{F}_E| = qE = (1.60\times10^{-19})(133,000) = 2.13\times10^{-14}\ N/C$

$\Sigma F = F_E = ma \quad a = \frac{2.13\times10^{-14}}{9.11\times10^{-31}} = \boxed{2.3\times10^{16}\ m/s^2, \rightarrow}$

2. (35 pts) Charge q_1 (+12.0 μC) is at the origin. Charge q_2 (-55.0 μC) is at x = 7.50 cm. An applied force moves a 28.0 gram mass with a +125 μC charge from its initial position (at y = 4.80 cm) to its final position (at x = 10.8 cm). If the mass begins and ends its journey at rest, how much work does the applied force do?



$$V_i = \frac{k_c q_1}{r_1} + \frac{k_c q_2}{r_2}$$

$$= \frac{(9\times10^9)(12\times10^{-6})}{.048} + \frac{(9\times10^9)(-55\times10^{-6})}{.08904} = -3.31\times10^6 V$$

$$V_f = \frac{(9\times10^9)(12\times10^{-6})}{.108} + \frac{(9\times10^9)(-55\times10^{-6})}{.033} = -1.40\times10^7 V$$

$$W_E = -q\Delta V$$

$$= -(125\times10^{-6})(-1.4\times10^7 - (-3.31\times10^6))$$

$$= -(125\times10^{-6})(-1.07\times10^7) = 1340 J$$

$$\Sigma W_F = W_E + W_{App} = 0$$

$$W_{App} = -W_E = \boxed{-1340 J}$$

#3. (35 pts) An empty 25 μF capacitor is connected to a 12.0-Volt battery and allowed to reach full charge. The capacitor is then disconnected from the battery, and a slab of dielectric material (K = 2.4) is inserted between the plates.

a) What is the new potential difference across the plates of the capacitor? Be sure to show your work/explain your answer.
b) What is the original charge on the positive plate of the capacitor before the slab is inserted?
c) What is the charge after the slab is inserted? Explain.
d) If the empty 25 μF capacitor is connected to the 12.0 Volt battery and in series with a 5.0 Ohm resistor, how long does it take after the circuit is completed for the capacitor to reach 75% of its maximum possible charge?

a) If C disconnected, Q = constant, ΔV can change

Since dielectric reduces $\vec{E}$ by factor 2.4, ΔV also reduced. $\Delta V_{new} = \frac{12}{2.4} = \boxed{5.0 \text{ Volts}}$

b) $Q = C\Delta V = (25 \times 10^{-6})(12) = \boxed{3.0 \times 10^{-4} \text{ C}}$

c) Q is still $\boxed{3.0 \times 10^{-4} \text{ C}}$ Q must remain constant. If C disconnected, there is no way to add or subtract charge from plate.

d) $Q(t) = Q_{max}(1 - e^{-t/RC})$

$0.75 Q_{max} = Q_{max}(1 - e^{-t/RC})$

$0.75 = 1 - e^{-t/RC}$

$-0.25 = -e^{-t/RC}$

$\ln 0.25 = -\frac{t}{RC}$

$-1.386 = -\frac{t}{RC}$

$t = 1.386 RC$

$= \boxed{1.7 \times 10^{-4} \text{ s}}$