Physics 2145 Spring 2023 Test 1 (4 pages)

Name: Solution **February 17, 2023** **Total Score:** 120 /120

Constants: electron mass $m_e = 9.11 \times 10^{-31}$ kg proton mass $m_p = 1.67 \times 10^{-27}$ kg

$e = 1.602 \times 10^{-19}$ C $\varepsilon_0 = 8.85 \times 10^{-12}$ C²/N•m² $k = 9.0 \times 10^9$ N•m²/C²

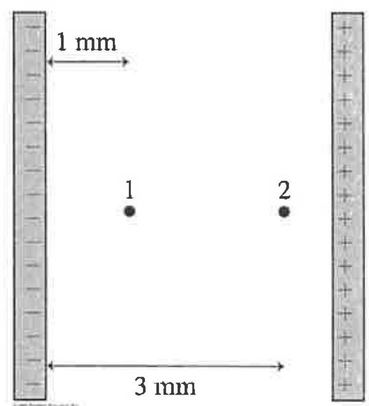
$F = k\frac{|q_1 q_2|}{r^2}$ $E = k\frac{|q|}{r^2}$ $\vec{F} = q\vec{E}$ $U = k\frac{q_1 q_2}{r}$ $V = k\frac{q}{r}$ $U = qV$

$C = \frac{Q}{\Delta V}$ $C = \kappa\varepsilon_0\frac{A}{d}$ $\Delta V = Ed$ $U = ½Q\Delta V = ½C(\Delta V)^2 = ½\frac{Q^2}{C}$

$K = ½mv^2$ $\Delta K = -q\Delta V$ parallel: $C_{eq} = \sum_i C_i$ series: $\frac{1}{C_{eq}} = \sum_i \frac{1}{C_i}$

D 1. (5) An electron is moving in a uniform electric field and slowing down. Its potential energy ____________________ and it moves towards __________ electric potential.

A) increases, higher B) decreases, higher
C) decreases, lower D) increases, lower



C 3.(5) The figure shows a parallel plate capacitor. Let V=0 be the electric potential at the negative plate. Which of the following is true about the of the electric potential V_1 and V_2 and the electric field strengths E_1 and E_2 at the two points, respectively?

A) $V_1 = V_2$ and $E_1 = E_2$ B) $V_1 = ⅓V_2$ and $E_1 = ⅓ E_2$
C) $V_1 = ⅓V_2$ and $E_1 = E_2$ D) $V_1 = V_2$ and $E_1 = ⅓ E_2$

A 3. (5) Which of the following is **FALSE**?
A) The electric field vector points towards higher potential.
B) The surface of a conductor is an equipotential surface.
C)) Equipotentials are perpendicular to the electric field vector.
D) The electric field inside a conductor in electrostatic equilibrium is zero.

B 4. (5) If the potential difference across a capacitor in doubled, the capacitance
A) doubles B) remains unchanged C) halves D) decreases by a factor of four

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5. A parallel plate capacitor consists of two circular plates of radius 10cm that are spaced 2mm apart with air between the plates. The electric field between the plates is 1.6×10^5 V/m.

a) (5) Calculate the voltage drop across the capacitor.

$\Delta V = Ed = 1.6\times10^5 \frac{V}{m} \cdot 2\times10^{-3} m = 3.2\times10^2 V = 320V$

b) (5) Calculate the capacitance.

$C = \frac{k\varepsilon_0 A}{d} = 1 \cdot 8.85\times10^{-12} \frac{C^2}{Nm^2} \cdot \frac{\pi(0.1m)^2}{2\times10^{-3}m} = 1.39\times10^{-10} F$

c) (5) Calculate the amount of charge store on each plate.

$Q = C\Delta V = 4.4\times10^{-8} C$

d)(5) The capacitor is remains connected to the battery, and the plates are moved further apart. Which of these quantities remains unchanged? Circle the correct answer.

charge capacitance potential difference electric field

$Q\downarrow$ $C\downarrow$

$\Delta V = Ed$

$E = \frac{\Delta V}{d} \downarrow$

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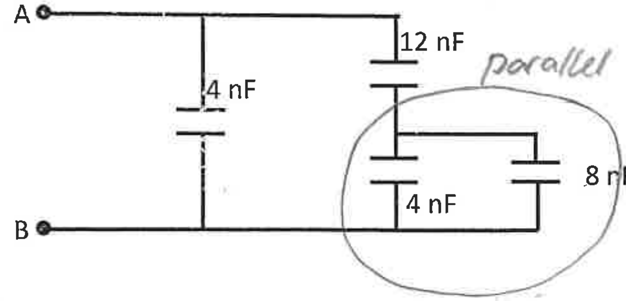
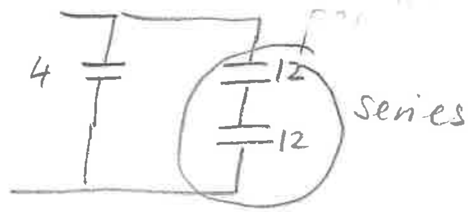
6. (20) For the capacitor circuit in the figure,
$C_1 = 4$ nF, $C_2 = 12$ nF, $C_3 = 4$ nF, and $C_4 = 8$ nF.
a)(15) Find the equivalent capacitance.



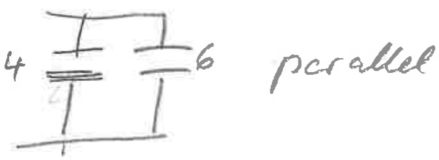
Parallel $C_{34} = 4nF + 8nF = 12nF$

Series: $\frac{1}{C_{234}} = \frac{1}{C_2} + \frac{1}{C_{34}} = \frac{1}{12nF} + \frac{1}{12nF}$

$= \frac{2}{12nF} \Rightarrow C_{234} = 6nF$



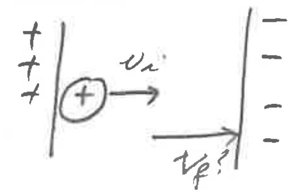
Parallel $C_{eq} = 4nF + 6nF = 10nF$



b) (5) If the applied voltage $V_{ab} = 36$V, find the total charge on the system.

$Q = C\Delta V = 10nF \cdot 36V = 360nC$

7) a)(15) The potential difference between two plates of a parallel plate capacitor equals 1,500 V. A proton is launched from the positive plate with a speed of 1×10^5m/s. Derive a symbolic answer in terms of system parameters and calculate a numerical value for the speed with which the proton strikes the negative plate.



$K_i + U_i = K_f + U_f$

$\Delta K = -q\Delta V$

$\frac{1}{2}m(v_f^2 - v_i^2) = -e(V_f - V_i)$

$v_f = \sqrt{v_i^2 - \frac{2e}{m}(V_f - V_i)} = \sqrt{(1\times10^5 \frac{m}{s})^2 - \frac{2\cdot1.6\times10^{-19}C}{1.67\times10^{-27}kg}\cdot(-1{,}500V)}$

$v_f = 5.5\times10^5 \frac{m}{s}$

b)(5) During this process, what is the proton's change in kinetic energy in electron volt?

1500 eV

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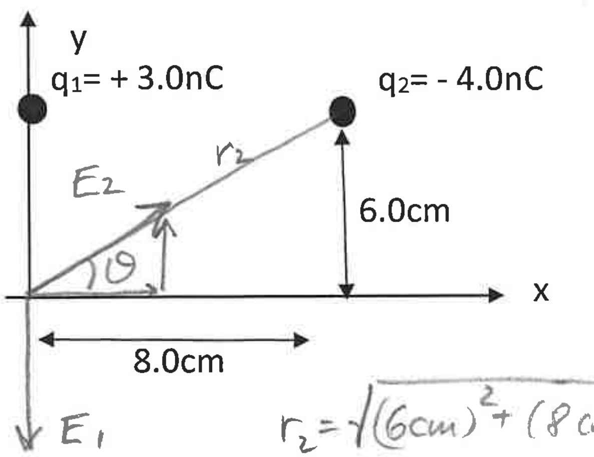
8. (40) Two charges, q_1=+3.0nC and q_2=–4.0nC, are located as shown in the figure. Charge q_1 is located on the *y*-axis at *y*= 6.0cm. Charge q_2 is at *x*= 8.0cm, *y*=6.0cm.



a) (5) At the origin, draw the electric field vectors created by each of the charges.

b) (10) Calculate the magnitudes of the electric fields created by each of the charges at the origin.

$$E_1 = \frac{kq_1}{r_1^2} = 9\times10^9\frac{Nm^2}{C^2}\frac{3\times10^{-9}C}{(6\times10^{-2}m)^2}$$

$$E_1 = 7{,}500\ \frac{N}{C}$$

$$r_2 = \sqrt{(6cm)^2 + (8cm)^2}$$

$$r_2 = 10\,cm = 0.1m$$

$$E_2 = \frac{k|q_2|}{r_2^2} = 9\times10^9\frac{Nm^2}{C^2}\frac{4\times10^{-9}C}{(0.1m)^2} = 3{,}600\frac{N}{C}$$

c)(10) Calculate the *x*- and *y*- components of the net electric field at the origin.

$$E_{1x} = 0 \qquad E_{1y} = -E_1 = -7500\frac{N}{C}$$

$$E_{2x} = E_2\cos\theta = 2880\frac{N}{C}$$

$$E_{2y} = E_2\sin\theta = 2160\frac{N}{C}$$

$$\cos\theta = \frac{8}{10} = 0.8$$

$$\sin\theta = \frac{6}{10} = 0.6$$

$$E_{netx} = E_{1x} + E_{2x} = 2880\,N/C \qquad E_{nety} = E_{1y} + E_{2y} = -5340\,N/C$$

d)(5) Calculate the magnitude of the net electric field at the origin.

$$E_{net} = \sqrt{E_{netx}^2 + E_{nety}^2} = 6070\frac{N}{C}$$

e)(10) Calculate the electric **potential** at the origin.

$$V = \frac{kq_1}{r_1} + \frac{kq_2}{r_2} = 9\times10^9\frac{Nm^2}{C^2}\left(\frac{3\times10^{-9}C}{0.06m} - \frac{4\times10^{-9}C}{0.1m}\right)$$

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$$V = 450V - 360V = 90V$$