Physics 2145 Spring 2022 Test 1 (4 pages)

Name: Solution **February 19, 2022** **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

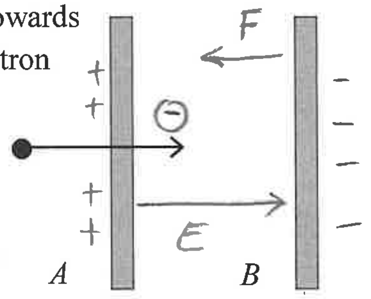
$F = k\frac{|q_1 q_2|}{r^2}$ $E = k\frac{|q\ |}{r^2}$ $\vec{F} = q\vec{E}$ $U = k\frac{q_1 q_2}{r}$ $V = k\frac{q}{r}$ $U = qV$

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

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

C 1.(5) An electron travels through a small hole in plate A and then towards plate B. A uniform electric field between the plates **slows down** the electron without deflecting it. What is the direction of the electric field?

A) up B) down [✓ C) right] D) left

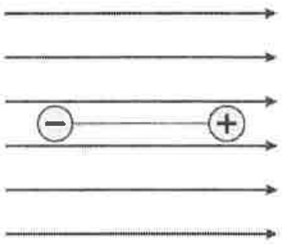


C 2. (5) As the electron in question 1 goes from plate A to plate B, its potential energy ____________________ and it moves towards ___________ electric potential.

A) increases, higher B) decreases, higher

[✓ C) increases, lower] D) decreases, lower

E 3. (5) An electric dipole is placed in a uniform electric field that is directed to the right, as shown in the figure. Which is true?



A) The dipole moves to the right.

B) The dipole moves to the left.

C) The dipole rotates clockwise.

D) The dipole rotates counterclockwise.

[✓ E) The dipole remains motionless.]

B 4.(5) Which of the following is true?

A) Equipotentials are parallel to the electric field vector.

B) The surface of a conductor is an equipotential surface.

C) The electric field vector points towards higher potential.

D) The electric field is smaller where the equipotentials are close together and larger where they are spaced further apart

20/20 points for this page

5. (20) A parallel plate capacitor consists of two square plates of side length 6.0cm that are spaced 2.0mm apart with air between the plates. Each plate stores a charge of 2.0 nC.

a) (5) Calculate the capacitance.

$$C = k\varepsilon_0 \frac{A}{d} = 1 \cdot 8.85\times10^{-12}\frac{C^2}{Nm^2}\cdot\frac{(0.06m)^2}{2\times10^{-3}m} = 1.59\times10^{-11}F$$

$$= 16\,pF$$

b)(5) Calculate the potential difference between the plates.

$$C = \frac{Q}{\Delta V} \qquad \Delta V = \frac{Q}{C} = \frac{2\times10^{-9}C}{1.6\times10^{-11}F} = 125V$$

c) (5) Calculate the electric field between the plates.

$$\Delta V = Ed \qquad E = \frac{\Delta V}{d} = \frac{125V}{2\times10^{-3}m} = 6.25\times10^{4}\frac{V}{m}$$

d) (5) The capacitor is **disconnected** from the battery, and the plates are moved further apart. Which of these quantities **increases**? Circle the correct answer.

charge	capacitance	[✓ potential difference]	electric field
same	↓	$\Delta V = \frac{Q}{C}$	same

6. (20) The potential difference between two plates of a parallel plate capacitor equals 3,000 V. An electron is launched from the negative plate with a speed of 1.5×10^{7}m/s.

a) Derive a **symbolic answer** in terms of system parameters and calculate a **numerical value** for the speed with which the electron strikes the positive plate.

$$\Delta K = -q\Delta V$$

$$\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = -(-e)\Delta V$$

$$\frac{1}{2}mv_f^2 = \frac{1}{2}mv_i^2 + e\Delta V$$

$$v_f = \sqrt{v_i^2 + \frac{2e\Delta V}{m}}$$

$$v_f = 3.6\times10^{7}\frac{m}{s}$$

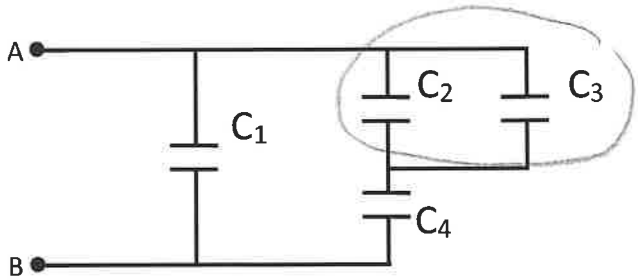
$$v_f = \sqrt{\left(1.5\times10^{7}\frac{m}{s}\right)^2 + \frac{2\cdot1.6\times10^{-19}C\cdot3000V}{9\times10^{-31}kg}}$$

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

3000 eV

____/40 points for this page

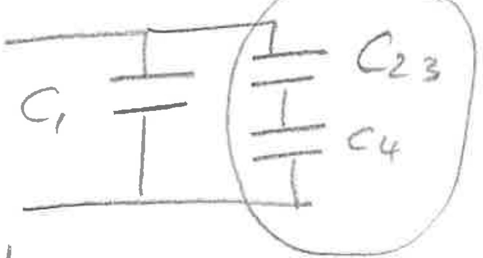
7. (20) For the capacitor circuit in the figure,
$C_1 = 6$ pF, $C_2 = 10$ pF, $C_3 = 30$ pF, and $C_4 = 40$ pF.
a)(15) Find the equivalent capacitance.



Parallel

$C_{23} = C_2 + C_3 = 10pF + 30pF$

$C_{23} = 40pF$

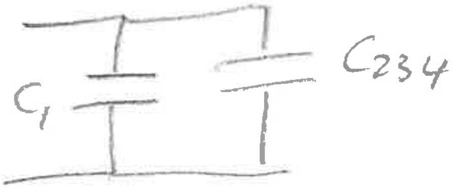


Series:

$$\frac{1}{C_{234}} = \frac{1}{C_{23}} + \frac{1}{C_4}$$

$$= \frac{1}{40pF} + \frac{1}{40pF} = \frac{2}{40pF} = \frac{1}{20pF}$$

$C_{234} = 20pF$



Parallel:

$C_{eq} = C_1 + C_{234} = 6pF + 20pF$

$C_{eq} = 26pF$

b) (5) If the applied voltage between points A and B is $V_{ab} = 20V$, find the total charge on the system.

$C_{eq} = \frac{Q_{net}}{\Delta V}$

$Q_{net} = C_{eq} \Delta V$

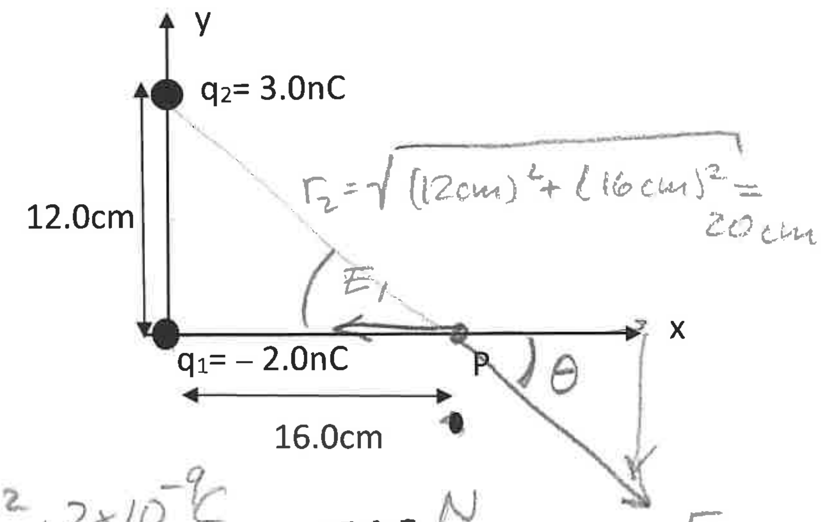
$= 26pF \cdot 20V$

$= 520 \times 10^{-12} C$

$= 0.52 nC$

___/20 points for this page

8. (40) Two charges, q_1= −2.0nC and q_2=+3.0nC, are located as shown in the figure. Charge q_1 is at the origin. Charge q_2 is located on the y-axis at y= 12.0cm. Point P is on the x-axis at x= 16.0cm.



a)(5) At point P, 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 point P.

$E_1 = k\frac{|q_1|}{r_1^2} = 9\times10^9\frac{Nm^2}{C^2}\cdot\frac{2\times10^{-9}C}{(0.16m)^2} = \underline{703\frac{N}{C}}$

$E_2 = k\frac{|q_2|}{r_2^2} = 9\times10^9\frac{Nm^2}{C^2}\frac{3\times10^{-9}}{(0.2m)^2} = \underline{675\frac{N}{C}}$

$\tan\theta = \frac{12cm}{16cm} = \frac{3}{4}$

$\underline{\theta = 37^\circ}$

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

$E_{1x} = -E_1 = -703 N/C$ $\quad E_{2x} = E_2\cos\theta = 540\frac{N}{C}$

$E_{1y} = 0$ $\quad E_{2y} = -E_2\sin\theta = -405 N/C$

$E_{net_x} = E_{1x} + E_{2x} = \underline{-163 N/C}$ $\quad E_{net_y} = E_{1y} + E_{2y} = \underline{-405 N/C}$

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

$E_{net} = \sqrt{E_{net_x}^2 + E_{net_y}^2} = \sqrt{(163\frac{N}{C})^2 + (405\frac{N}{C})^2} = 436 N/C$

e)(10) Calculate the electric **potential** at point P.

$V = k\frac{q_1}{r_1} + k\frac{q_2}{r_2} = 9\times10^9\frac{Nm^2}{C^2}\left(-\frac{2\times10^{-9}C}{0.16m} + \frac{3\times10^{-9}C}{0.2m}\right)$

$\underline{V = 22,5V}$

40/40 points for this page