Kuwait University — Physics Department

General Physics II — PHY 102

جامعة الكويت
KUWAIT UNIVERSITY

Second Midterm Examination
Summer Semester 2023 – 2024

July 20, 2024
Time: 11:30 – 1:00 PM

Name: …… Student No: ……

Section No: …… Serial No: ……

Instructors: Drs. Alfailakawi, Lajko, and Vagenas

Fundamental constants

$k = \frac{1}{4\pi\varepsilon_o} = 9.0\times10^{9}\ \text{N.m}^2/\text{C}^2$ (Coulomb constant)

$\varepsilon_o = 8.85 \times 10^{-12}\ \text{C}^2/(\text{N}\cdot\text{m}^2)$ (Permittivity of free space)

$\mu_0 = 4\pi \times 10^{-7}\ \text{T.m/A}$ (Permeability of free space)

$|e| = 1.60 \times 10^{-19}\ \text{C}$ (Elementary unit of charge)

$N_A = 6.02 \times 10^{23}$ (Avogadro's number)

$g = 9.8\ \text{m/s}^2$ (Acceleration due to gravity)

$m_e = 9.11 \times 10^{-31}\ \text{kg}$ (Electron mass)

$m_p = 1.67 \times 10^{-27}\ \text{kg}$ (Proton mass)

Prefixes of units

$m = 10^{-3}$	$\mu = 10^{-6}$	$n = 10^{-9}$	$p = 10^{-12}$
$k = 10^{3}$	$M = 10^{6}$	$G = 10^{9}$	$T = 10^{12}$

For use by Instructors only

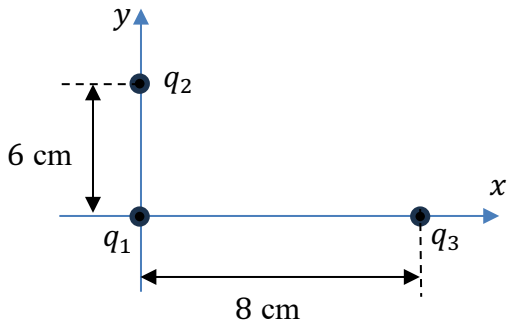
Problems	1	2	3	4	5	6	7	8	**Questions**	**Total**
Marks										

Instructions to the Students:

1. Mobile or other electronic devices are **strictly prohibited** during the exam.
2. Programmable calculators, which can store equations, are not allowed.
3. **Cheating incidents will be processed according to the university rules.**

PART I: Solve the following problems. Show your solutions in detail.

1. Three point charges $q_1 = q_2 = 10$ nC, and q_3 are placed on the x and y-axis as shown. The total potential energy of the system is 20 μJ. Find the electric charge q_3. **[4 points]**



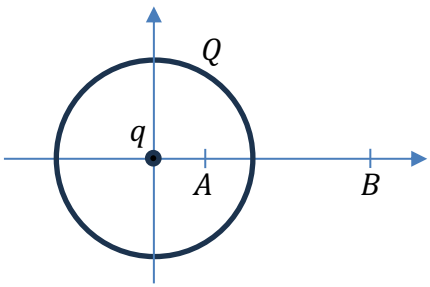
$d = \sqrt{(0.06)^2 + (0.08)^2}$ m $\Rightarrow d = 0.10$ m

$U_{total} = k\frac{q_1 q_2}{0.06} + k\frac{q_1 q_3}{0.08} + k\frac{q_2 q_3}{0.10}$

$20 \times 10^{-6} = 15 \times 10^{-6} J + 1125 q_3 + 900 q_3$

$q_3 = 2.47$ nC

2. A conducting sphere of radius $R = 0.4$ m is uniformly charged with electric charge $Q = 30$ nC. A point charge $q = 5$ nC is placed at the center of the sphere. Find the potential difference $V_A - V_B$. Given: $x_A = 0.2$ m and $x_B = 0.9$ m. **[3 points]**

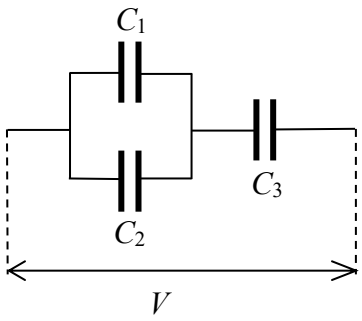


$V_A = k\frac{Q}{R} + k\frac{q}{x_A} \Rightarrow V_A = 900$ V

$V_B = k\frac{Q}{x_B} + k\frac{q}{x_B} \Rightarrow V_B = 350$ V

$V_A - V_B = 550$ V

3. In the capacitor network shown, $C_1 = C_2 = 5\ \mu\text{F}$, $C_3 = 30\ \mu\text{F}$, and the applied potential difference is $V = 4.8$ V. Find the electric potential energy stored in capacitor C_1. **[5 points]**



C_1 and C_2 are in parallel:

$C_{12} = C_1 + C_2 \Longrightarrow C_{12} = 10\ \mu\text{F}$

C_{12} and C_3 are in series:

$C_{123} = \frac{C_{12}C_3}{C_{12}+C_3} \Longrightarrow C_{123} = 7.5\ \mu\text{F}$

The total charge of C_{123} is $Q_{123} = Q_{12} = Q_3$

$C_{123} = \frac{Q_{12}}{V} \Longrightarrow Q_{12} = C_{123}V \Longrightarrow Q_{12} = 36\ \mu\text{C}$

$C_{12} = \frac{Q_{12}}{V_{12}} \Longrightarrow V_{12} = 3.6\ \text{V}$

$U_1 = \frac{1}{2}C_1{V_{12}}^2 \Longrightarrow U_1 = 32.4\ \mu\text{J}$

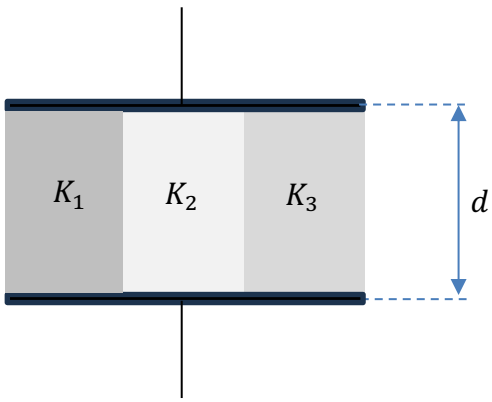
4. An air-filled parallel-plate capacitor with a plate area A and separation d, has capacitance C_0. Then, the capacitor is partially filled with three dielectric slabs with constants $K_1 = 4,\ K_2 = 5,\ K_3 = 6$, as shown. Each dielectric slab fills 1/3 of the space between the capacitor plates. If the equivalent capacitance is 200 μF, find the initial capacitance C_0. **[5 points]**

$C_0 = \varepsilon_0 \frac{A}{d}$

$C_1 = K_1\varepsilon_0 \frac{A/3}{d} \Longrightarrow C_1 = \frac{K_1}{3}\varepsilon_0 \frac{A}{d} \Longrightarrow C_1 = \frac{4}{3}C_0$

$C_2 = K_2\,\varepsilon_0 \frac{A/3}{d} \Longrightarrow C_1 = \frac{K_2}{3}\varepsilon_0 \frac{A}{d} \Longrightarrow C_2 = \frac{5}{3}C_0$

$C_3 = K_3\,\varepsilon_0 \frac{A/3}{d} \Longrightarrow C_3 = \frac{K_3}{3}\varepsilon_0 \frac{A}{d} \Longrightarrow C_3 = \frac{6}{3}C_0$



C_1,C_2, and C_3 are in parallel:

$C_{eq} = C_1 + C_2 + C_3 \Longrightarrow C_{eq} = \frac{4}{3}C_0 + \frac{5}{3}C_0\frac{6}{3}C_0 \Longrightarrow C_{eq} = \frac{15}{3}C_0 \Longrightarrow C_0 = 40\ \mu\text{F}$

5. A gold wire of length $L = 3$ m has resistivity $\rho = 2.44 \times 10^{-8}$ Ω·m and concentration of free electrons $n = 5.90 \times 10^{28}$ m^{-3}. When a potential difference V is applied, the electrons run the full length of the gold wire in time 2×10^4 s. Find the potential difference V. **[4 points]**

$v_d = \frac{L}{t} \Longrightarrow v_d = \frac{3\ m}{2\times10^4 s} \Longrightarrow v_d = 1.5 \times 10^{-4}$ m/s

$J = n|e|\ v_d \Longrightarrow J = 14.16 \times 10^5$ A/m^2

$E = \rho J \Longrightarrow E = 0.0346$ N/C

$E = \frac{V}{L} \Longrightarrow V = EL \Longrightarrow V = 0.104$ V

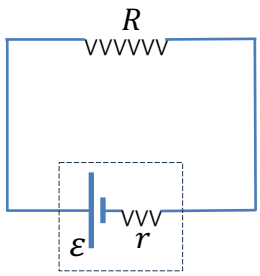
6. In the electric circuit below, the power dissipated on the resistor $R = 3\ \Omega$ is $P_R = 15$ W. The internal resistance of the battery is $r = 1\ \Omega$. Find the emf Ɛ of the battery. **[3 points]**

$P_R = I^2\ R \Rightarrow I = \sqrt{\frac{P_R}{R}} \Rightarrow I = 2.24$ A

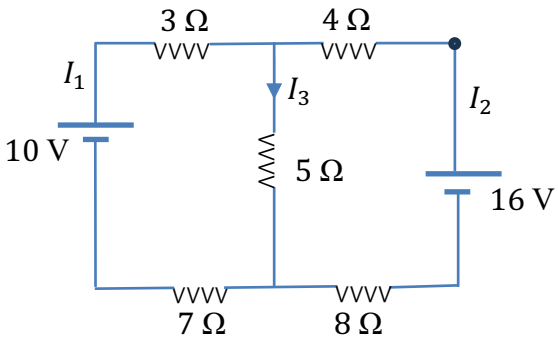
$P_R = \frac{V_R^2}{R} \Rightarrow V_R = \sqrt{P_R R} \Rightarrow V_R = 6.71$ V

Since $V_R = V_{terminal}$

$V_{terminal} = \mathcal{E} - Ir \Rightarrow \mathcal{E} = V_R + Ir \Rightarrow \mathcal{E} = 8.95$ V



7. Find the electric currents I_1, I_2, and I_3 in the electric circuit below. **[5 points]**



Junction rule: $I_3 = I_1 + I_2$

Loop rule:

- **Left loop**

$10 - 3I_1 - 5I_3 - 7I_1 = 0 \Rightarrow 10 - 15I_1 - 5I_2 = 0$

- **Right loop**

$16 - 4I_2 - 5I_3 - 8I_2 = 0 \Rightarrow 16 - 5I_1 - 17I_2 = 0$

Multiply 2nd loop rule equation with (-3):

$-48 + 15I_1 + 51I_2 = 0$

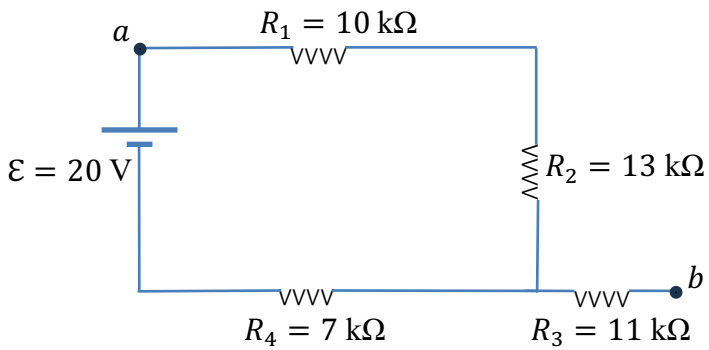
and then add it to the 1st loop rule. We get:

$-38 + 46I_2 = 0 \Rightarrow I_2 = 0.826$ A

$10 - 15I_1 - 5 \times 0.862 = 0 \Rightarrow I_1 = 0.391$ A

$I_3 = (0.391 + 0.826)$ A $\Rightarrow I_3 = 1.217$ A

8. Find the potential difference between points a and b in the electric circuit below. **[3 Points]**



Loop rule:

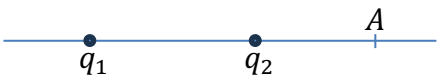
$\mathcal{E} - IR_1 - IR_2 - IR_4 = 0 \Longrightarrow I = \frac{\mathcal{E}}{R_1+R_2+R_4} \Longrightarrow I = 0.67 \times 10^{-3}$ A

$V_a - IR_1 - IR_2 = V_b \Longrightarrow V_a - V_b = I(R_1 + R_2)$

$V_a - V_b = 15.3$ V

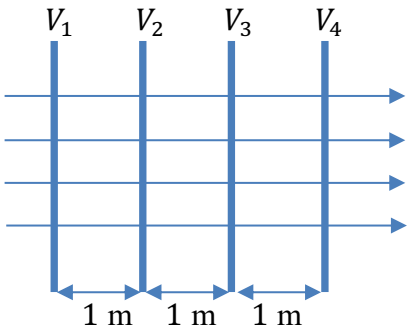
PART II: Conceptual Questions (each carries 1 point). Tick the best answer:

1. Two negative point charges, $q_1 < 0$ and $q_2 < 0$, are placed on the x-axis as shown. We bring a positive charge, $Q > 0$, from infinity to point A. The electric potential at infinity is zero. The work of the electric force to move charge Q from infinity to point A is:



a) zero.
b) positive. ⟵
c) negative.
d) indetermined.

2. In a uniform electric field of magnitude $E = 10$ V/m, the horizontal lines are the electric field lines while the vertical lines are the equipotential surfaces. If the potential of the first equipotential surface is $V_1 = 95$ V, then



a) $V_2 = 95$ V, $V_3 = 95$ V, $V_4 = 95$ V.
b) $V_2 = 95$ V, $V_3 = 85$ V, $V_4 = 75$ V.
c) $V_2 = 85$ V, $V_3 = 75$ V, $V_4 = 65$ V. ⟵
d) $V_2 = 85$ V, $V_3 = 65$ V, $V_4 = 45$ V.

3. An air-filled parallel-plate capacitor is charged by a battery, then the battery is disconnected and the space between the plates of the capacitor is fully filled with a dielectric slab of constant K. Which statement is correct?

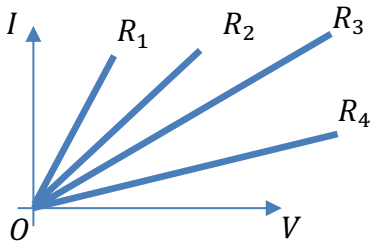
a) The stored electric potential energy will decrease by a factor K. ⟵
b) The stored electric potential energy will decrease by a factor $2K$.
c) The stored electric potential energy will increase by a factor K.
d) The stored electric potential energy will increase by a factor $2K$.

4. An air-filled parallel-plate capacitor is charged by a battery. While the battery remains connected, the separation between the plates of the capacitor is doubled. Which statement is correct?

a) The electric energy density increases by a factor of 2.
b) The electric energy density increases by a factor of 4.
c) The electric energy density decreases by a factor of 2.
d) The electric energy density decreases by a factor of 4. ⟵

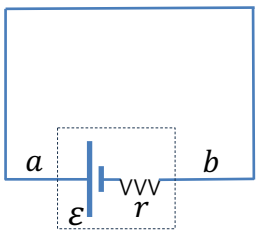
5. In the current-voltage diagram below, the characteristic curves of 4 resistors are given. Which relation is correct?

a) $R_1 > R_2 > R_3 > R_4$
b) $R_2 > R_1 > R_4 > R_3$
c) $R_3 > R_4 > R_2 > R_1$
d) $R_4 > R_3 > R_2 > R_1$



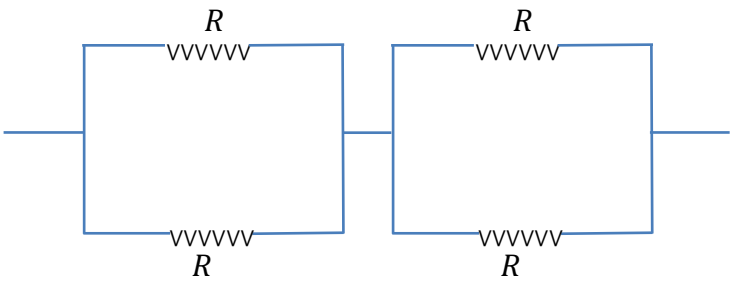
6. The current between points a and b in the electric circuit below is:

a) $I = \frac{\mathcal{E}}{R}$.
b) $I = \frac{\mathcal{E}}{r}$.
c) $I = \frac{\mathcal{E}}{R+r}$.
d) $I = \frac{\mathcal{E}}{(R+r)^2}$.



7. In the electric circuit below, there are 4 resistors of same resistance R. The equivalent resistance of this network is:

a) R.
b) $2R$.
c) $3R$.
d) $4R$.



8. Which statement is wrong?

a) Kirchhoff's junction rule is based on the conservation of electric charge.
b) Kirchhoff's loop rule is based on the statement that the electrostatic force is conservative.
c) Kirchhoff's junction rule is about the sum of currents around any loop.
d) Kirchhoff's loop rule is about the sum of potential differences around any loop.