Kuwait University **Physics Department**

General Physics II **PHY 102**

جامعة الكويت
KUWAIT UNIVERSITY

Second Midterm Examination
Fall Semester 2024 - 2025

November 30, 2024
Time: 11:00 AM – 12:30 PM

Name: …… Student No: ……

Section No: …… Serial No: ……

Instructors: Drs. Abdullah, Al-Munin, Lajko, Sharma, & Vagenas

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Fundamental constants

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

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

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

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

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

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

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

$m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$ (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

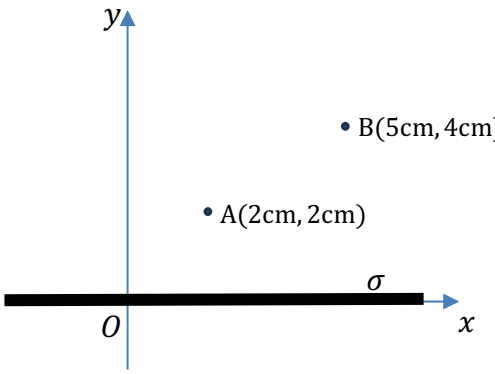
Problems	1	2	3	4	5	6	7	8	**Questions**	**Total**
Marks										

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. An infinite sheet of uniform surface charge density σ is placed perpendicular to the y-axis, as shown. If the potential difference $V_A - V_B$ between the two points A and B is 60 V, find the surface charge density σ. **[4 points]**



$d\vec{l} = dx\,\hat{\imath} + dy\,\hat{\jmath}$

$\vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{\jmath}$

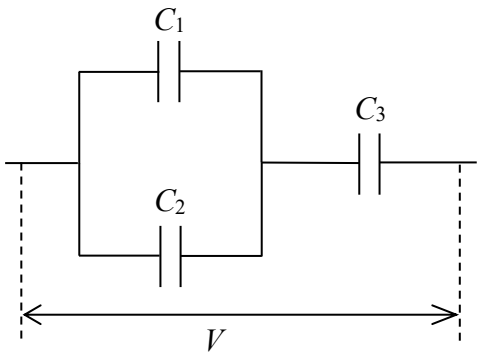
$V_A - V_B = \int \vec{E} \cdot d\vec{l}$

$V_A - V_B = \int \left(\frac{\sigma}{2\varepsilon_0}\hat{\jmath}\right) \cdot (dx\,\hat{\imath} + dy\,\hat{\jmath})$

$V_A - V_B = \frac{\sigma}{2\varepsilon_0} \int_{0.02\,m}^{0.04\,m} dy = \frac{\sigma}{2\times 8.85\times 10^{-12}}(0.04 - 0.02) = 60$ V

$\sigma = 53.1$ nC/m^2

2. In the given network of capacitors with $C_1 = C_2 = 10$ μF and $C_3 = 20$ μF, the charge on capacitor C_1 is $Q_1 = 20$ μC. Find the charge on capacitor C_3. **[4 points]**



$V_1 = \frac{Q_1}{C_1} = 2$ V $\Longrightarrow V_{12} = V_1 = V_2 = 2$ V

$Q_2 = C_2 V_2 = 20$ μC

$Q_{12} = Q_1 + Q_2 = 60$ μC

Since C_{12} and C_3 are in series, $Q_3 = Q_{12} = 40$ μC

3. An air-filled parallel-plate capacitor with a surface area A and a plate separation d, has capacitance $C_0 = 20$ μF. The capacitor is partially filled with a dielectric material of dielectric constant $K = 4$, as shown. Find the capacitance C of this arrangement. **[4 points]**

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

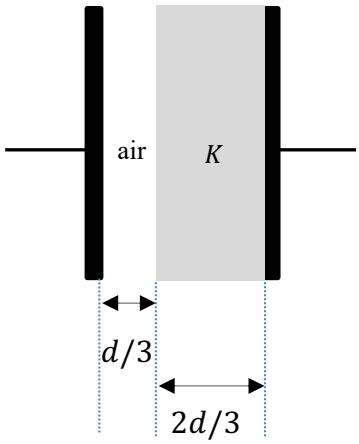
$C_1 = \varepsilon_0 \frac{A}{d/3} = 3\varepsilon_0 \frac{A}{d} = 3C_0 = 60$ μF

$C_2 = K\varepsilon_0 \frac{A}{2d/3} = \frac{3}{2} K\varepsilon_0 \frac{A}{d} = \frac{3}{2} 4C_0 = 120$ μF

C_1 and C_2 are in series

$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} \Longrightarrow \frac{1}{C} = \frac{1}{60\ \mu F} + \frac{1}{120\ \mu F}$

$C = 40$ μF



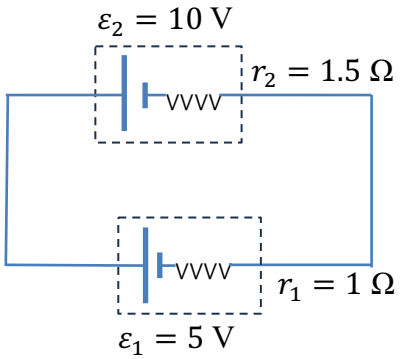
4. When a cylindrical wire of silver is connected to a battery of 3 V, the power dissipated on it is 15 W. The radius of the silver wire is 0.35 mm and the concentration of free electrons is 5.80×10^{28} m^{-3}. Calculate the drift speed v_d of the electrons. **[3 points]**

$P = I\,V \Longrightarrow I = \frac{P}{V} \Longrightarrow I = 5$ A

$I = JA \Longrightarrow I = n|e|v_d A \Longrightarrow I = n|e|v_d \pi r^2$

$v_d = \frac{I}{n|e|\pi r^2} \Longrightarrow v_d = 1.4 \times 10^{-3}$ m/s

5. In the circuit below, find the power dissipated in the internal resistance r_1. **[3 points]**



$V_{term,2} = \varepsilon_2 - Ir_2$

$V_{term,1} = \varepsilon_1 + Ir_1$

$V_{term,2} = V_{term,1} \Longrightarrow \varepsilon_2 - Ir_2 = \varepsilon_1 + Ir_1$

$I = \frac{\varepsilon_2 - \varepsilon_1}{r_1 + r_2} \Longrightarrow I = 2$ A

$P_1 = I^2 r_1 \Longrightarrow P_1 = 4$ W

2nd solution:

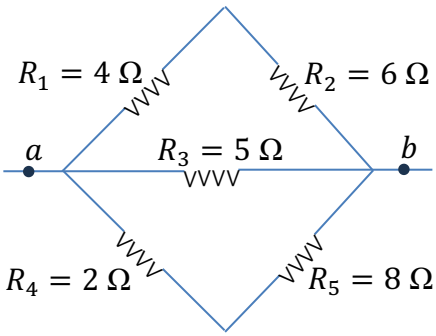
Loop rule (anti-clockwise)

$10 - 5 - Ir_1 - Ir_2 = 0$

$10 - 5 - I - 1.5I = 0 \Longrightarrow I = 2$ A

$P_1 = I^2 r_1 \Longrightarrow P_1 = 4$ W

6. In the circuit below, find the equivalent resistance R_{eq} between the terminal points a and b. **[4 Points]**



R_1 and R_2 are in series:

$R_{12} = R_1 + R_2 \Longrightarrow R_{12} = 10\ \Omega$

R_4 and R_5 are in series:

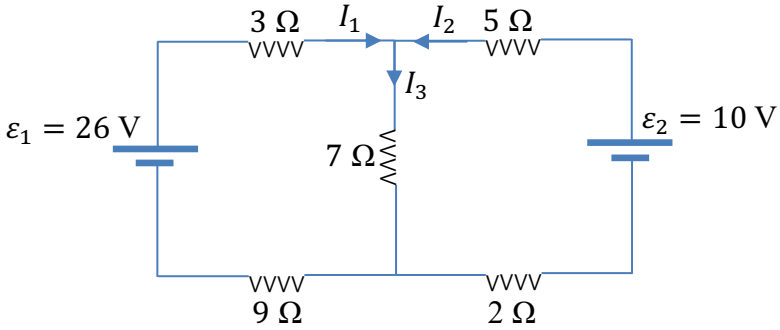
$R_{45} = R_4 + R_5 \Longrightarrow R_{45} = 10\ \Omega$

R_{12}, R_{45}, and R_3 are in parallel:

$$\frac{1}{R_{eq}} = \frac{1}{R_{12}} + \frac{1}{R_3} + \frac{1}{R_{45}}$$

$$\frac{1}{R_{eq}} = \frac{1}{10\ \Omega} + \frac{1}{5\ \Omega} + \frac{1}{10\ \Omega} \Longrightarrow R_{eq} = 2.5\ \Omega$$

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



Junction rule: $I_3 = I_1 + I_2$

Loop rules:

Left loop

$26 - 3I_1 - 7(I_1 + I_2) - 9I_1 = 0$

$26 - 19I_1 - 7I_2 = 0 \qquad (*)$

Right loop

$10 - 5I_2 - 7(I_1 + I_2) - 2I_2 = 0$

$10 - 7I_1 - 14I_2 = 0 \qquad (**)$

When we multiply equation $(*)$ with (-2) and add it to equation $(**)$, we get:

$-42 + 31I_1 = 0 \Longrightarrow I_1 = 1.355$ A

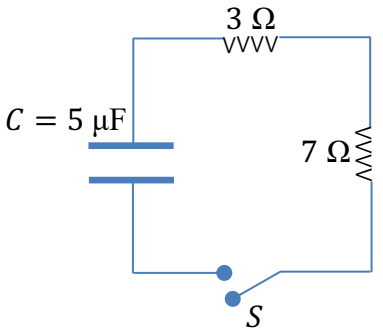
Then use equation (1) to calculate I_2:

$26 - 19 \times 1.355 - 7I_2 = 0 \Longrightarrow I_2 = 0.04$ A

8. The capacitor has an initial charge $Q_0 = 40$ μC and the switch S is closed at time $t = 0$ s. At time t_1 the charge of the capacitor is half of the initial charge. Find the electric current at the time t_1. **[3 Points]**

$R_{eq} = (3 + 7)\ \Omega = 10\ \Omega$

$q(t) = Q_0 e^{-\frac{t}{R_{eq}C}} \Longrightarrow q(t_1) = Q_0 e^{-\frac{t_1}{R_{eq}C}}$



$\frac{Q_0}{2} = Q_0 e^{-\frac{t_1}{R_{eq}C}} \Longrightarrow \frac{1}{2} = e^{-\frac{t_1}{R_{eq}C}}$

$i(t) = \frac{dq(t)}{dt} = \frac{Q_0}{R_{eq}C} e^{-\frac{t}{R_{eq}C}} \Longrightarrow i(t_1) = \frac{Q_0}{R_{eq}C} e^{-\frac{t_1}{R_{eq}C}}$

$i(t_1) = \frac{Q_0}{R_{eq}C}\frac{1}{2} \Longrightarrow i(t_1) = 0.4$ A

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

1. Which statement is correct? In electrostatic situation,

   a) on the outer surface of a charged conductor the electric field is zero.
   b) inside a charged conductor the electric field is nonzero.
   c) the full volume of a charged conductor is an equipotential volume. (ANSWER)
   d) on the outer surface of a charged conductor the electric field is parallel to the surface.

2. An air-filled parallel-plate capacitor with plate separation d, area A, and capacitance C is charged by a battery V and the battery remains connected. If the area A is increased, the electric energy density will

   a) be zero.
   b) increase.
   c) decrease.
   d) remain the same. (ANSWER)

3. When two identical capacitors are connected parallel with a battery (see Figure 1), their total electric energy is U_1. When these two identical capacitors are connected in series with the same battery (see Figure 2), their total electric energy, U_2, will be

   a) $U_1/2$.
   b) $U_1/4$. (ANSWER)
   c) $2U_1$.
   d) $4U_1$.

Figure 1

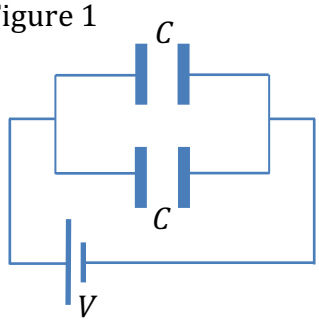
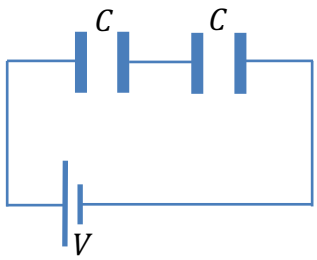


Figure 2

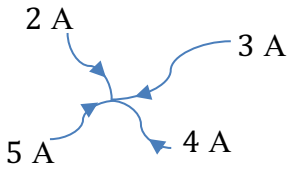


4. The value of the resistivity ρ of a conductor depends

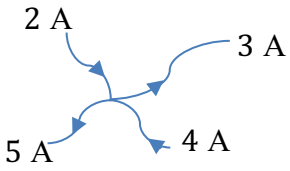
   a) on the nature of the moving charges in the conductor.
   b) on the geometrical characteristics of the conductor.
   c) on the drift speed of the electrons in the conductor.
   d) on the material and the temperature of the conductor. (ANSWER)

5. At a junction, four wires are met. Which diagram is correct?

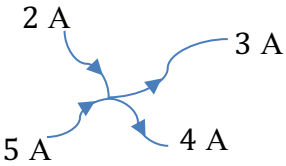
a)



c)

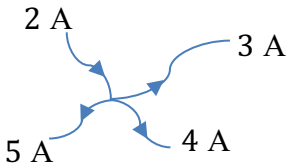


b)



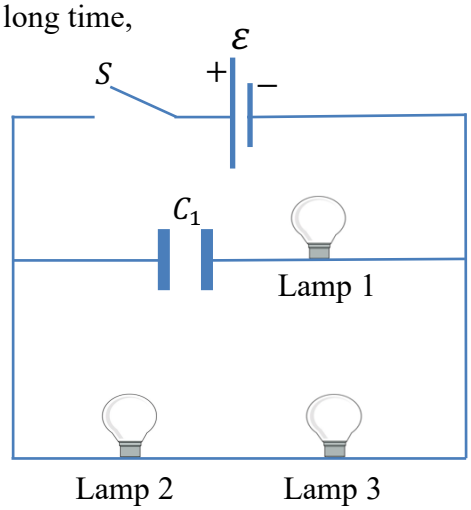
(ANSWER)

d)



6. In the RC circuit, the switch S is closed at $t = 0$ s. After a very long time,

a) lamps 1, 2, and 3 will light.
b) lamps 1 and 2 will light but not lamp 3.
c) lamps 2 and 3 will light but not lamp 1. (ANSWER)
d) lamps 1 and 3 will light but not lamp 2.



7. In an RC circuit, while a capacitor is charging, the electric current of the circuit

a) increases exponentially.
b) decreases exponentially. (ANSWER)
c) remains the same.
d) increases and then decreases.

8. In an RC circuit of time constant $\tau = RC$, the capacitor has initial electric charge Q_0 and it starts to discharge at $t = 0$. What fraction of the initial electric charge Q_0 will be on the capacitor at $t = \tau$?

a) 0
b) 0.37 (ANSWER)
c) 0.63
d) 1.0