Kuwait University — Physics Department

General Physics II — PHY 102

جامعة الكويت
KUWAIT UNIVERSITY

Second Midterm Examination
Summer Semester 2024 - 2025

July 19, 2025
Time: 1:00 PM – 2:30 PM

Name: …… Student No: ……

Section No: …… Serial No: ……

Instructors: Drs. Yahya Al-Munin, Peter Lajko, & Elias Vagenas

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Fundamental constants

$k = \frac{1}{4\pi\varepsilon_0} = 9.0\times 10^{9}\ Nm^2/C^2$ (Coulomb constant)

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

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

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

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

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

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

$m_p = 1.67 \times 10^{-27}$ 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.

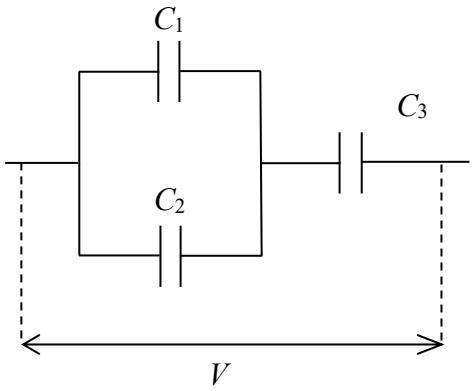
1. In the network of capacitors, with capacitances $C_1 = 2$ nF, $C_2 = 6$ nF, $C_3 = 5$ nF, the electric charge stored in the capacitor C_1 is $Q_1 = 40$ nC. Calculate the electric charge Q_3 stored in the capacitor C_3. **[4 points]**

$C_1 = \frac{Q_1}{V_1} \Longrightarrow V_1 = \frac{Q_1}{C_1} \Longrightarrow V_1 = 20$ V

$C_{12} = C_1 + C_2 \Longrightarrow C_{12} = 8$ nF

$Q_{12} = C_{12}V_1 \Longrightarrow Q_{12} = 160$ nC

$Q_{12} = Q_3 = 160$ nC



2. An air-filled parallel-plate capacitor is charged so that the positively charged plate has surface charge density $\sigma = 17.7$ μC/m^2. The volume between the two parallel plates of the conductor is 2×10^{-5} m^3. Calculate the electric potential energy stored in the capacitor. **[3 points]**

$E = \frac{\sigma}{\varepsilon_0} \Longrightarrow E = 2 \times 10^6$ N/C

$u = \frac{1}{2}\varepsilon_0 E^2 \Longrightarrow u = 17.7$ J/ m^3

$u = \frac{U}{(volume)} \Longrightarrow U = u \times (volume) \Longrightarrow U = 3.54 \times 10^{-4}$ J

3. An air-filled parallel-plate capacitor with plate area A and separation d, has capacitance $C_0 = 20$ μF. The capacitor is partially filled with two dielectric materials of dielectric constant $K_1 = 3$ and K_2, as shown. Each dielectric material fills half of the space between the capacitor plates. The capacitance now is $C = 100$ μF. Find the dielectric constant K_2. **[4 points]**

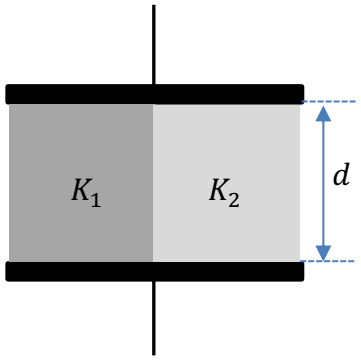
$$C_0 = \varepsilon_0 \frac{A}{d}$$

$$C_1 = K_1 \varepsilon_0 \frac{A/2}{d} = \frac{K_1}{2} C_0 = 1.5 C_0 = 30 \text{ nF}$$

$$C_2 = K_2 \varepsilon_0 \frac{A/2}{d} = \frac{K_2}{2} C_0 = 10\, K_2 \text{ nF}$$

C_1 and C_2 are in parallel

$$C = C_1 + C_2 \Longrightarrow 100 = 30 + 10\, K_2 \Longrightarrow K_2 = 7$$



4. A cylindrical gold wire with length L is connected to a battery which produces an electric field inside the wire of magnitude $E = 25$ N/C. The gold wire has resistivity 2.44×10^{-8} Ω·m and concentration of free electrons 5.90×10^{28} m^{-3}. If the electrons run the whole length of the wire in time $\Delta t = 100$ s, calculate the length L of the gold wire. **[4 points]**

$$E = \rho J \Longrightarrow J = \frac{E}{\rho} \Longrightarrow J = 1.025 \times 10^9 \text{ A/m}^2$$

$$J = n|q|v_d \Longrightarrow v_d = \frac{J}{n|e|} \Longrightarrow v_d = 0.109 \text{ m/s}$$

$$v_d = \frac{L}{\Delta t} \Longrightarrow L = v_d \Delta t$$

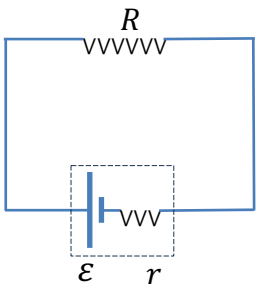
$$L = 10.9 \text{ m}$$

5. In the electric circuit below, the electric current is $I = 3$ A. The battery has emf of 10 V and internal resistance $r = 1\ \Omega$. Calculate the value of the resistance R. **[3 points]**

$V_{term} = \varepsilon - Ir \Longrightarrow V_{term} = 7$ V

$V_{term} = V_R \Longrightarrow V_R = 7$ V

$V_R = IR \Longrightarrow R = \frac{V_R}{I} \Longrightarrow R = 2.33\ \Omega$



6. In the electric circuit below, the electric current through the resistance R_4 is 2 A. Find the electric potential difference $V_{ab} = V_a - V_b$. **[5 Points]**

$V_4 = I_4 R_4 \Longrightarrow V_4 = 90$ V

$R_{23} = R_2 + R_3 \Longrightarrow R_{23} = 15\ \Omega$

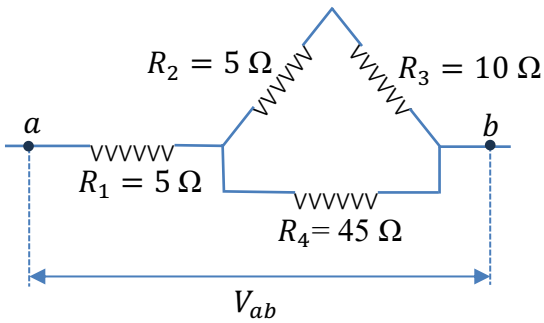
$V_{23} = V_4 = I_{23} R_{23} \Longrightarrow I_{23} = \frac{V_{23}}{R_{23}} \Longrightarrow I_{23} = 6$ A

$I = I_{23} + I_4 \Longrightarrow I = 8$ A

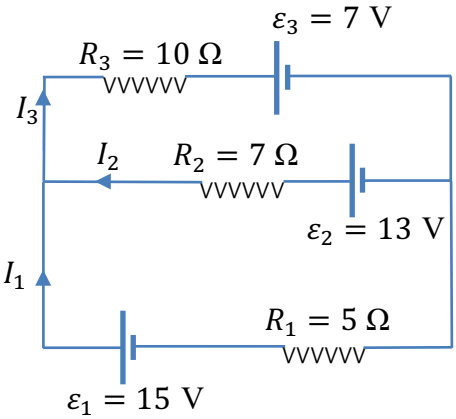
$R_{234} = \frac{R_4 R_{23}}{R_4 + R_{23}} \Longrightarrow R_{234} = 11.25\ \Omega$

$R_{eq} = R_1 + R_{123} \Longrightarrow R_{eq} = 16.25\ \Omega$

$V_{ab} = IR_{eq} \Longrightarrow V_{ab} = 130$ V



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



Junction rule:

$I_3 = I_1 + I_2$

Loop rules:

Lower loop

$15 + 7I_2 - 13 - 5I_1 = 0 \Longrightarrow 2 - 5I_1 + 7I_2 = 0$

Upper loop

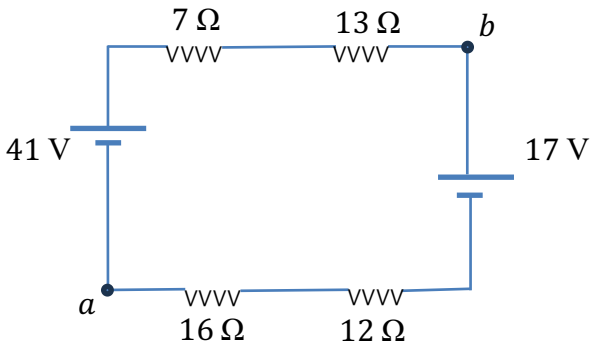
$13 - 7I_2 - 10I_3 - 7 = 0 \Longrightarrow 6 - 7I_2 - 10I_3 = 0 \Longrightarrow 6 - 10I_1 - 17I_2 = 0$

Multiply 2nd equation with (-2): $-4 + 10I_1 - 14I_2 = 0$

Add the last two questions: $2 - 31I_2 = 0 \Longrightarrow I_2 = 0.065$ A

Substitute in the 2nd equation to get: $2 - 5I_1 + 7 \times 0.0645 = 0 \Longrightarrow I_1 = 0.491$ A

8. In the circuit below, find the potential difference $V_a - V_b$. **[4 Points]**



Loop rule:

$41 - 7I - 13I - 17 - 12I - 16I = 0$

$24 - 48I = 0 \Longrightarrow I = 0.5$ A

$V_a + 41 - 7I - 13I = V_b$

$V_a - V_b = -41 + 20I \Longrightarrow V_a - V_b = -31$ V

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

1. In an air-filled parallel-plate capacitor, if the separation between the parallel plates of the capacitor is increased by a factor of 3, and the plate area decreases by a factor of 2, then the capacitance is

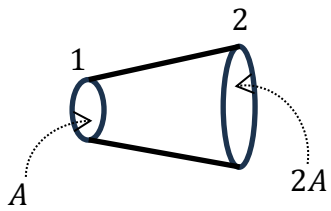
   a) increased by a factor of 3.
   b) increased by a factor of 6.
   c) decreased by a factor of 3.
   d) decreased by a factor of 6. (ANSWER)

2. An air-filled parallel-plate capacitor is charged by a battery and then the battery is disconnected. If the capacitor is fully filled with a dielectric constant K, then the electric energy stored in the capacitor

   a) increases.
   b) decreases. (ANSWER)
   c) remains the same.
   d) is undetermined.

3. A conductor has a variable cross section as shown in the figure. If the drift speed of the moving charges crossing the cross section 1 with cross-sectional area A is v_{d1}, then the drift speed of the moving charges crossing the cross section 2 with cross-sectional area $2A$ is

   a) $2v_{d1}$.
   b) $4v_{d1}$.
   c) $v_{d1}/2$. (ANSWER)
   d) $v_{d1}/4$.

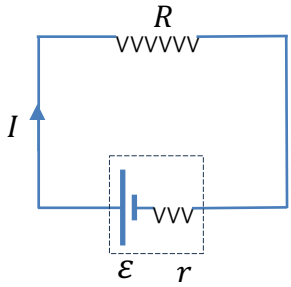


4. In conductors, the current density $\vec{J}$ is directly proportional to the applied electric field $\vec{E}$. This relationship is called

   a) Hooke's law.
   b) Faraday's law.
   c) Ohm's law. (ANSWER)
   d) Gauss's law.

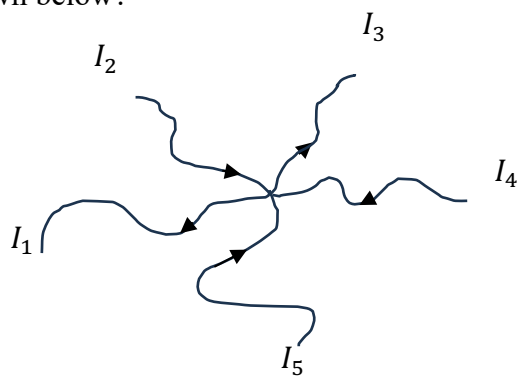
5. For the electric circuit below, the equation $I^2R = \varepsilon I - I^2 r$ expresses

a) the conservation of electric current.
b) the conservation of electric potential.
c) the conservation of electric charge.
d) the conservation of electric energy. (ANSWER)



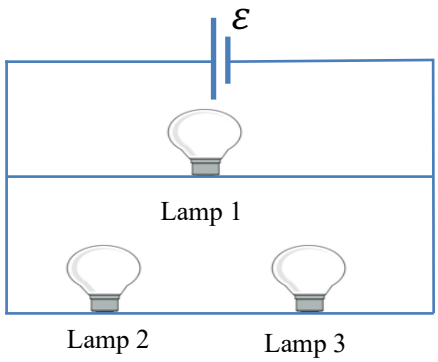
6. Which is the correct junction rule for the junction shown below?

a) $I_1 + I_2 - I_3 - I_4 + I_5 = 0.$
b) $I_1 - I_2 + I_3 - I_4 - I_5 = 0.$ (ANSWER)
c) $I_1 - I_2 + I_3 - I_4 + I_5 = 0.$
d) $I_1 - I_2 - I_3 + I_4 + I_5 = 0.$



7. In the electric circuit below, if lamp 3 is removed, then

a) lamp 1 and lamp 2 will light the same.
b) lamp 1 will light the same and lamb 2 will light less.
c) lamp 1 will light the same and lamp 2 will light more. (ANSWER)
d) lamp 1 and lamp 2 will light more.



8. In the electric circuit below, if $\varepsilon_2 > \varepsilon_1$, then the direction of the electric current is

a) clockwise
b) counterclockwise (ANSWER)
c) zero.
d) undetermined.