Kuwait University **Physics Department**

General Physics II **PHY 102**

جامعة الكويت
KUWAIT UNIVERSITY

Second Midterm Examination
Fall Semester 2025 - 2026

November 29, 2025
Time: 11:00 AM – 12:30 PM

Name: …… Student No: ……

Section No: …… Serial No: ……

Instructors: Drs. Abdul Mohsen, Yahya, Lajko, Sharma, & Vagenas

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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

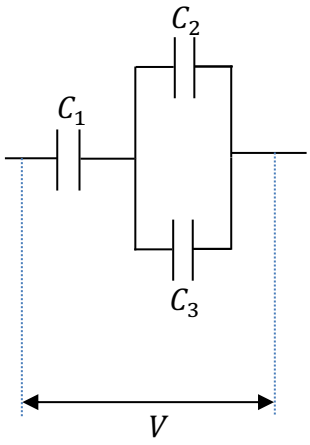
Problems	1	2	3	4	5	6	7	8	**Questions**	**Total**
Marks										

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. In the given network of capacitors with $C_1 = 30$ nF and $C_2 = C_3 = 10$ nF, the charge on capacitor C_1 is $Q_1 = 60$ nC. Find the electric energy stored in the network. **[4 points]**



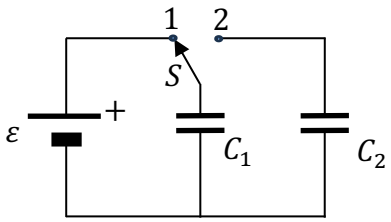
$C_{23} = C_2 + C_3 \Longrightarrow C_{23} = 20$ nF

$\frac{1}{C_{123}} = \frac{1}{C_1} + \frac{1}{C_{23}} \Longrightarrow C_{123} = 12$ nF

$Q_1 = Q_{23} = Q_{total} = 60$ nC

$U_{total} = \frac{1}{2}\frac{{Q_{total}}^2}{C_{123}} \Longrightarrow U_{total} = 150$ nJ

2. A capacitor $C_1 = 15$ μF is charged by a source of emf $\varepsilon = 6$ V. Then, the switch S is placed to position 2. The capacitor $C_2 = 30$ μF is uncharged initially. Find the final electric charge stored in C_2. **[4 points]**



Position 1: $Q = C_1\varepsilon \Longrightarrow Q = 90$ μC

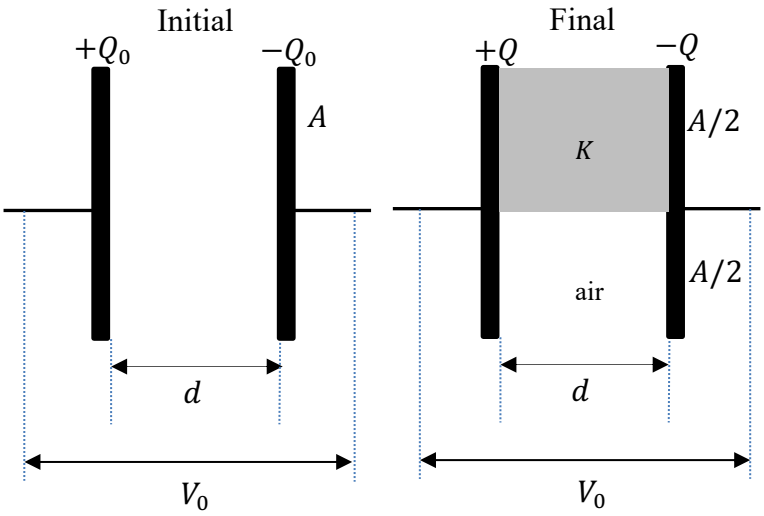
Position 2: $C_{12} = C_1 + C_2 \Longrightarrow C_{12} = 45$ μF

$V = \frac{Q}{C_{12}} \Longrightarrow V = 2$ V

$V = V_1 = V_2 = 2$ V

$C_2 = \frac{Q_2}{V_2} \Longrightarrow Q_2 = C_2V_2 \Longrightarrow Q_2 = 60$ μC

3. An air-filled parallel-plate capacitor with a surface area A, a plate separation d, and capacitance C_0 is charged by a battery V_0 and its initial charge is $Q_0 = 15$ nC. Then, while the battery remains connected, the capacitor is half filled with a dielectric material of dielectric constant $K = 4$, as shown. What is the new capacitance? **[4 points]**



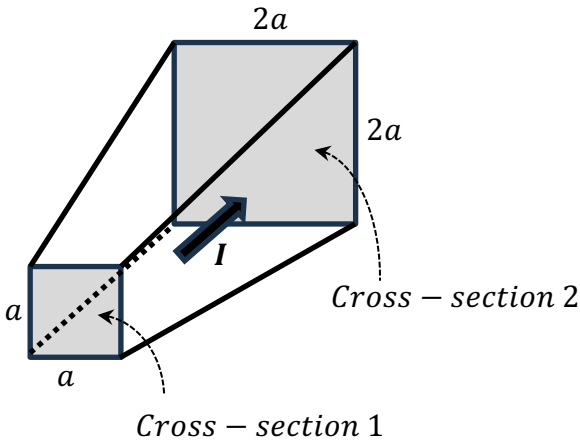
$C_0 = \frac{Q_0}{V_0}$ and. $C_0 = \varepsilon_0 \frac{A}{d}$

$C_{air} = \varepsilon_0 \frac{A/2}{d} \Longrightarrow C_{air} = 0.5C_0$

$C_{diel} = K\varepsilon_0 \frac{A/2}{d} \Longrightarrow C_{diel} = 2C_0$

$C_{eq} = C_{air} + C_{diel} \Longrightarrow C_{eq} = 2.5C_0$

4. A conductor has variable square cross-section as shown. The electric current in the conductor is steady, and the drift speed of the electrons at the cross-section 1 is 9.2×10^{-4} m/s. Find the drift speed at the cross-section 2. **[4 points]**



$I_1 = I_2 = I$

$J_1 A_1 = J_2 A_2$

$n|q|v_{d1}a^2 = n|q|v_{d2}(2a)^2$

$v_{d1} = 4v_{d2} \Longrightarrow v_{d2} = \frac{v_{d1}}{4}$

$v_{d2} = 2.3 \times 10^{-4}$ m/s

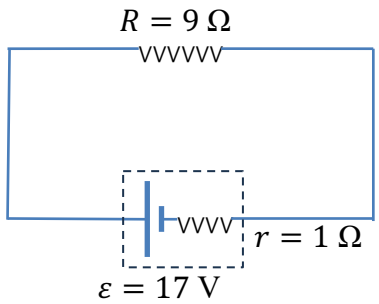
5. In the circuit below, calculate the total energy dissipated in the resistor with resistance R in a time period of 3 minutes. **[4 points]**

$$IR = \varepsilon - Ir \Longrightarrow I = \frac{\varepsilon}{R+r} \Longrightarrow I = 1.7 \text{ A}$$

$$P_R = I^2 R \Longrightarrow P_R = 26 \text{ W}$$

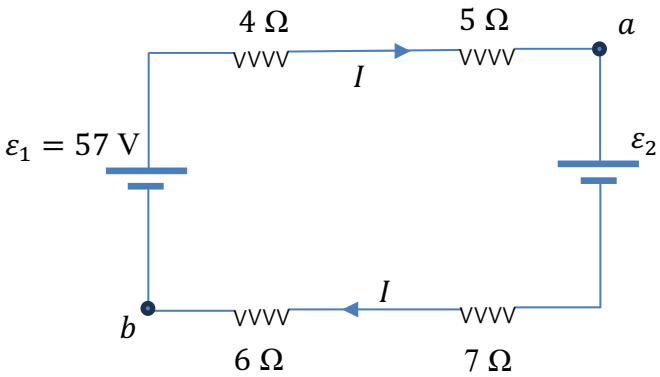
$$P_R = \frac{U}{\Delta t} \Longrightarrow U = P_R \Delta t$$

$$U = 26 \times 180 \text{ J} \Longrightarrow U = 4{,}681 \text{ J}$$



6. In the circuit below, the potential difference between a and b is 39 V, find the source of emf ε_2.

[4 Points]



$$V_a + 5I + 4I - 57 = V_b$$

$$V_a - V_b + 9I = 57 \Longrightarrow 39 + 9I = 57$$

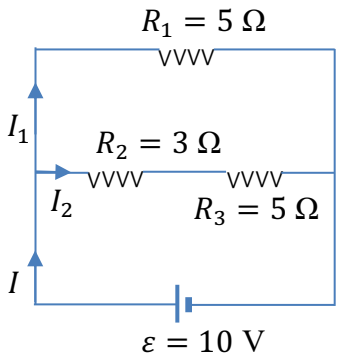
$$I = 2 \text{ A}$$

Loop rule:

$$\varepsilon_1 - 4I - 5I - \varepsilon_2 - 7I - 6I = 0$$

$$\varepsilon_2 = \varepsilon_1 - 22I \Longrightarrow \varepsilon_2 = 13 \text{ V}$$

7. Find the electric currents I_1, I_2, and I in the circuit below. **[4 Points]**



Junction rule: $I = I_1 + I_2$

Loop rules:

Lower loop

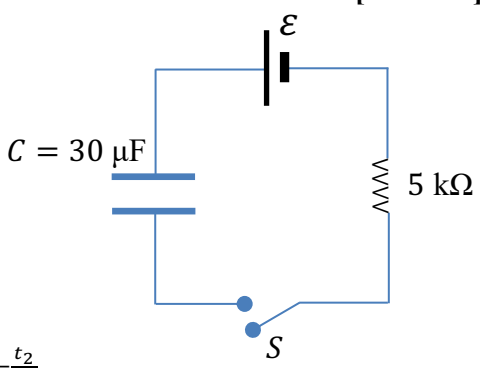
$10 - 3I_2 - 5I_2 = 0 \Longrightarrow I_2 = 1.25$ A

Big loop

$10 - 5I_1 = 0 \Longrightarrow I_1 = 2$ A

$I = I_1 + I_2 \Longrightarrow I = 3.25$ A

8. In the RC circuit below, the switch S is closed at time $t = 0$ s. At time t_1, the charge of the capacitor is 90 μC and the electric current in the circuit is 1 mA. Find the electric current in the circuit at the time $t_2 = 100$ μs. **[4 Points]**



At time t_1, apply loop rule:

$\varepsilon - i(t_1)R - \frac{q(t_1)}{C} = 0$

$\varepsilon - (5 \times 10^3) \times (1 \times 10^{-3}) - \frac{90 \times 10^{-6}}{30 \times 10^{-6}} = 0 \Longrightarrow \varepsilon = 8$ V

$i(t) = \frac{dq}{dt} \Longrightarrow i(t) = \frac{Q}{RC} e^{-\frac{t}{RC}} \Longrightarrow i(t_2) = \frac{Q}{RC} e^{-\frac{t_2}{RC}} \Longrightarrow i(t_2) = \frac{\varepsilon}{R} e^{-\frac{t_2}{RC}}$

$i(t_2) = 1.6$ mA

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

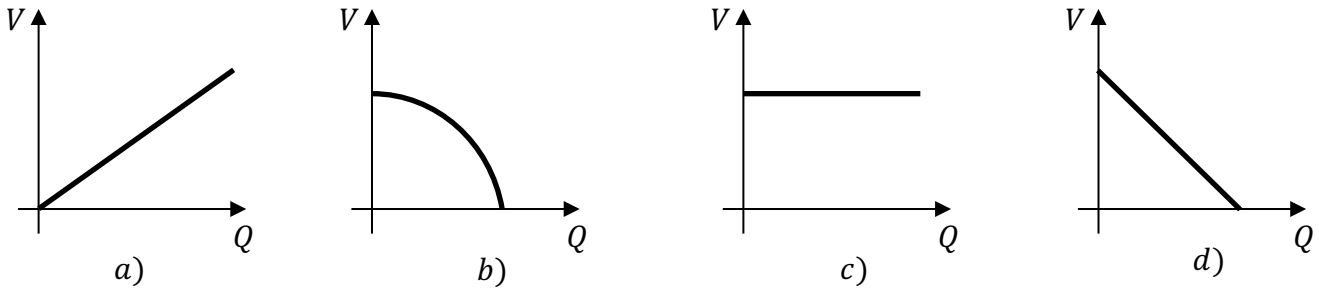
1. Which statement is correct? The capacitance of a capacitor depends on

   a) the charge of the capacitor.
   b) the potential difference between the plates of the capacitor.
   c) the geometry of the capacitor and the matter between its plates. **(ANSWER)**
   d) all the above.

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. Then a slab of dielectric material is inserted completely filling the space between the plates of the capacitor. The electric energy density will

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

3. Which diagram shows the potential difference versus electric charge (V vs Q) in a capacitor?



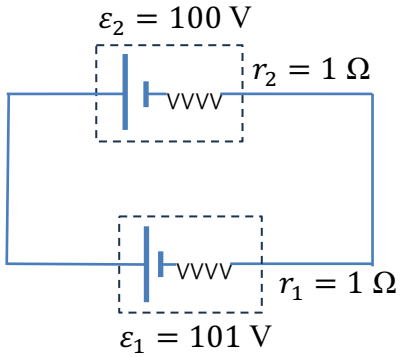
(ANSWER)

4. The value of the resistance R of a cylindrical conductor depends on

   a) the material of the conductor.
   b) the length of the conductor.
   c) the area of the cross-section of the conductor.
   d) all the above. **(ANSWER)**

5. In the circuit below, the terminal voltage across the upper battery is:

a) $V_{term,2} = \varepsilon_2 - Ir_1$.
b) $V_{term,2} = \varepsilon_2 - Ir_2$.
c) $V_{term,2} = \varepsilon_2 + Ir_1$.
d) $V_{term,2} = \varepsilon_2 + Ir_2$. **(ANSWER)**

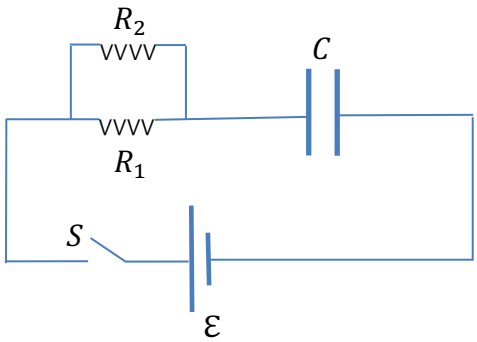


6. If two resistors R_1 and R_2 are connected in parallel and have currents I_1 and I_2, respectively, what is their relation?

a) $\frac{I_1}{I_2} = \frac{R_1}{R_2}$.
b) $\frac{I_1}{I_2} = \frac{R_2}{R_1}$. **(ANSWER)**
c) $\frac{I_1}{R_1} = \frac{R_2}{I_2}$.
d) $\frac{I_1}{I_2} = \frac{R_1 R_2}{R_1 + R_2}$.

7. In the RC circuit below, the time constant τ is equal to

a) $R_1 C$.
b) $(R_1 + R_2)C$.
c) $\frac{R_1 + R_2}{R_1 R_2} C$.
d) $\frac{R_1 R_2}{R_1 + R_2} C$. **(ANSWER)**



8. In an RC circuit, while the capacitor is discharging, the potential difference across the resistance R

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