Kuwait University **Physics Department**

General Physics II **PHY 102**

جامعة الكويت
KUWAIT UNIVERSITY

Second Midterm Examination
Fall Semester 2023 – 2024

December 9, 2023
Time: 11:00 AM – 12:30 PM

Name: …… Student No: ……

Section No: …… Serial No: ……

Instructors: Drs. Alfailakawi, Hadipour, 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

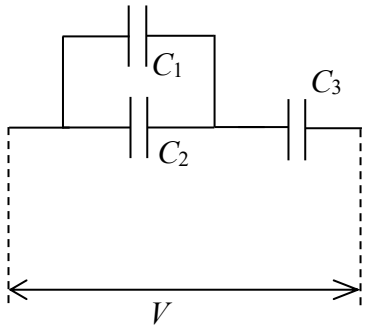
Problems	1	2	3	4	5	6	7	8	**Questions**	**Total**
Marks										

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 $C_1 = 5$ μF, and $C_2 = 10$ μF, the charge on capacitor C_2 is $Q_2 = 10$ μC. If the stored energy in capacitor C_3 is 11.25 μJ, find the capacitance C_3. **[4 points]**



$V_2 = \frac{Q_2}{C_2} = 1\text{ V} \Longrightarrow V_2 = V_1 = 1\text{ V}$ [1]

$Q_1 = C_1 V_1 = 5\ \mu\text{C}$ [1]

$Q_{12} = Q_1 + Q_2 = 15\ \mu\text{C} \Longrightarrow Q_3 = Q_{12} = 15\ \mu\text{C}$ [1]

$U_3 = \frac{1}{2}\frac{{Q_3}^2}{C_3} \Longrightarrow C_3 = \frac{{Q_3}^2}{2 \times U_3} \Longrightarrow C_3 = 10\ \mu\text{F}$ [1]

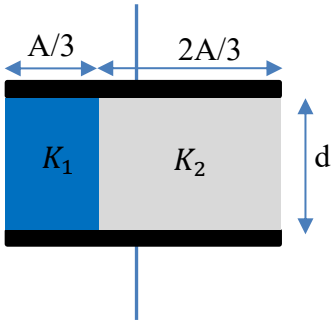
2. In an air-filled parallel-plate capacitor, the electric energy stored is 60 μJ. The space between the plates of the capacitor is of volume 4×10^{-3} m^3. Find the magnitude of the electric field $\vec{E}$ between the plates. **[3 points]**

$u = \frac{U_C}{(volume)}$ [1]

$u = \frac{60 \times 10^{-6}}{4 \times 10^{-3}}\ \text{J/m}^3 \Longrightarrow u = 1.5 \times 10^{-2}\ \text{J/m}^3$ [1]

$u = \frac{1}{2}\varepsilon_0 E^2 \Longrightarrow E = \sqrt{\frac{2u}{\varepsilon_0}} \Longrightarrow E = 58{,}222\ \text{N/C}$ [1]

3. An air-filled parallel-plate capacitor with a surface area A and a plate separation d, has capacitance C_0. When the capacitor is filled with two dielectric materials with dielectric constants $K_1 = 3$ and K_2, as shown, the capacitance is $C = 4C_0$. Calculate the dielectric constant K_2. **[5 points]**



C_1 and C_2 are in parallel

$C = C_1 + C_2$ [1]

$C_1 = K_1\varepsilon_0\frac{A/3}{d} = \frac{K_1}{3}\varepsilon_0\frac{A}{d} = \frac{K_1}{3}C_0 = C_0$ [1]

$C_2 = K_2\varepsilon_0\frac{2A/3}{d} = \frac{2K_2}{3}\varepsilon_0\frac{A}{d} = \frac{2K_2}{3}C_0$ [1]

$C = C_0 + \frac{2K_2}{3}C_0 \Longrightarrow 4C_0 = C_0 + \frac{2K_2}{3}C_0$ [1]

$4 = 1 + \frac{2}{3}K_2 \Longrightarrow K_2 = 4.5$ [1]

4. A cylindrical wire of material of resistivity $\rho = 1.72 \times 10^{-8}$ Ω·m has length 25 m and radius 0.1 mm. The power dissipated in the wire is 11.6 W. Find the number of electrons that pass through the cross section of the wire in 2 ms. **[5 points]**

$R = \rho\frac{L}{A} \Longrightarrow R = \rho\frac{L}{\pi r^2} \Longrightarrow R = 13.6\ \Omega$ [1]

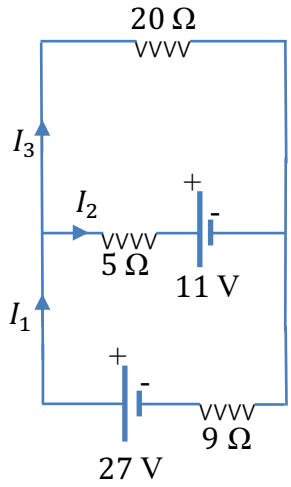
$P = I^2R \Longrightarrow I = \sqrt{\frac{P}{R}}$ [1]

$I = 0.92$ A [1]

$Q = I\,\Delta t \Longrightarrow Q = 1.84 \times 10^{-3}$ C [1]

$Q = N|e| \Longrightarrow N = 1.15 \times 10^{16}$ electrons [1]

5. The power dissipated in the 20 Ω resistance is 10.4 W. Find the electric currents I_1, I_2, and I_3. **[3 points]**



$P_{20\Omega} = {I_3}^2(20\,\Omega) \Rightarrow I_3 = 0.72$ A [1]

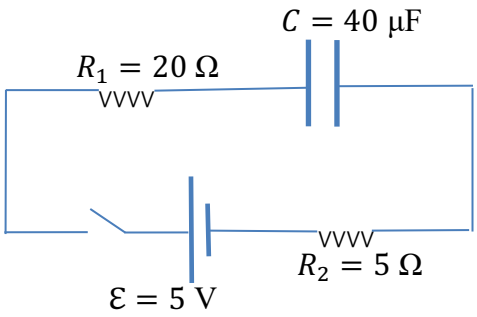
Big Loop (clockwise)

$27 - 20I_3 - 9I_1 = 0 \Longrightarrow I_1 = 1.4$ A [1]

Upper Loop (clockwise)

$11 + 5I_2 - 20I_3 = 0 \Longrightarrow I_2 = 0.68$ A [1]

6. The capacitor C is initially uncharged and at time $t = 0$ the switch is closed. Find the electric current at time $t_1 = 2$ ms after the switch is closed. **[4 Points]**



$\tau = R_{eq}C = (R_1 + R_2)C \Longrightarrow \tau = 1$ ms [1]

$q(t) = C\mathcal{E}(1 - e^{-\frac{t}{\tau}})$

$i(t) = \frac{dq(t)}{dt} = \frac{C\mathcal{E}}{\tau}e^{-\frac{t}{\tau}}$ [2]

$i(t_1) = \frac{C\mathcal{E}}{\tau}e^{-\frac{t_1}{\tau}} \Longrightarrow i(t_1) = \frac{200\times10^{-6}}{10^{-3}}e^{-\frac{0.002}{0.001}}$ A

$i(t_1) = 2.71 \times 10^{-2}$ A [1]

7. A particle with charge $q = -3.0$ nC is moving in a magnetic field $\vec{B} = 4.5$ T $\hat{k}$. If the magnetic force exerted on the particle is $\vec{F} = 2.70 \times 10^{-9}$ N $(-\hat{\imath}) + 4.05 \times 10^{-9}$ N $\hat{\jmath}$, then calculate the components of the velocity $\vec{v}$ of the particle. **[4 Points]**

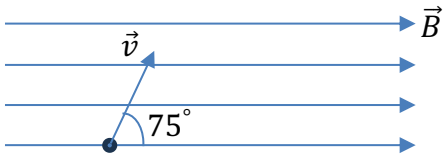
$$\vec{F} = q\,\vec{v} \times \vec{B} = (-3 \times 10^{-9}) \begin{vmatrix} \hat{\imath} & \hat{\jmath} & \hat{k} \\ v_x & v_y & v_z \\ 0 & 0 & 4.5 \end{vmatrix} \qquad [1]$$

$$\vec{F} = (-3 \times 10^{-9})\left[4.5v_y\hat{\imath} - 4.5v_x\hat{\jmath}\right] \qquad [1]$$

$$2.70 \times 10^{-9}\,(-\hat{\imath}) + 4.05 \times 10^{-9}\,\hat{\jmath} = 1.35 \times 10^{-8}v_y(-\hat{\imath}) + 1.35 \times 10^{-8}v_x(-\hat{\jmath}) \quad [1]$$

$v_x = 0.30$ m/s, $v_y = 0.20$ m/s, and v_z is indetermined [1]

8. A proton with speed $v = 2 \times 10^5$ m/s enters a uniform magnetic field $\vec{B} = 8.0 \times 10^{-3}$ T $\hat{\imath}$, as shown. Find the pitch of its helical motion. **[3 Points]**



$v_x = v\,cos(75^\circ) \Rightarrow v_x = 51{,}764$ m/s [1]

$T = \frac{2\pi m_p}{B|e|} \Longrightarrow T = 8.20 \times 10^{-6}$ s [1]

$P = v_x\,T \Longrightarrow P = 0.424$ m [1]

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

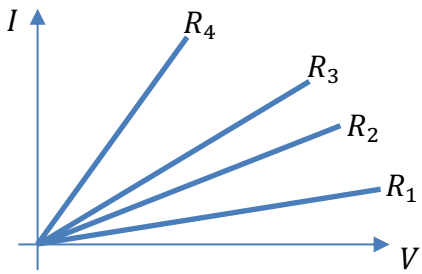
1. The capacitance of a capacitor depends only on

   a) its potential difference.
   b) the capacitor's stored energy.
   c) its geometry and the matter between its plates. (ANSWER)
   d) its electric charge.

2. An air-filled capacitor with plate separation d, area A and capacitance C_0 is charged by a battery V_0. The battery is disconnected. If a slab of dielectric constant K fully fills the space between the plates of the capacitor, then the potential difference between the plates is

   a) V_0.
   b) V_0/K. (ANSWER)
   c) KV_0.
   d) zero.

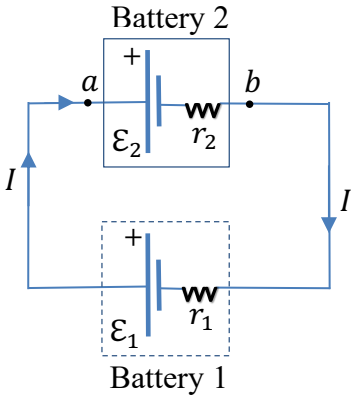
3. In the figure below the characteristic curves of four resistances are drawn. Which statement is correct?



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

4. In the circuit shown, two batteries are connected as shown. The terminal voltage of battery 2 is

   a) $V_{ab} = \mathcal{E}_1 + Ir_1$.
   b) $V_{ab} = \mathcal{E}_2 + Ir_2$. (ANSWER)
   c) $V_{ab} = \mathcal{E}_2 - Ir_2$.
   d) $V_{ab} = \mathcal{E}_1 + I(r_1 + r_2)$



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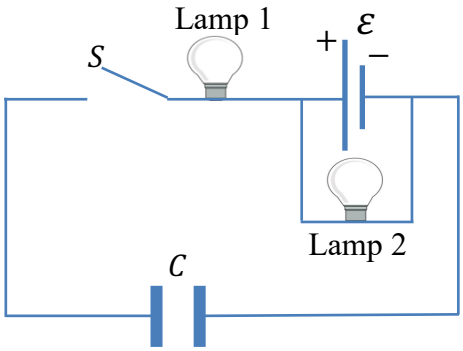
5. In the RC circuit, the switch S is closed at $t = 0$ s. After a very long time,



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

6. Which statement is correct?

a) The magnetic field lines can be open or closed.
b) The magnetic field lines are parallel with the magnetic field $\vec{B}$. (ANSWER)
c) The magnetic field lines are perpendicular to the magnetic field $\vec{B}$.
d) The magnetic field lines are always perpendicular to the electric field lines.

7. Which statement is **not** equivalent with the Gauss's law for magnetism?

a) We have never observed magnetic monopoles.
b) The magnetic field lines have no starting and end points.
c) The electric charge is conserved in any closed system. (ANSWER)
d) The magnetic charge does not exist.

8. Three particles enter a uniform magnetic field at point P. Which statement is correct?

a) Particle 1 is negatively charged and particle 2 is positively charged.
b) Particle 2 is neutral and particle 3 is positively charged.
c) Particle 2 is negatively charged and particle 3 is neutral.
d) Particle 1 is positively charged and particle 2 is neutral. (ANSWER)