Kuwait University | **Physics Department**

General Physics II | **PHY 102**

جامعة الكويت
KUWAIT UNIVERSITY

Final Examination
Spring Semester 2023 – 2024

May 22, 2024
Time: 5:00 – 7:00 PM

Name: ……………………………………… Student No: ……………………………

Sec. No: ……………………………………. Serial No: ……………………………….

Instructors: Drs. Alaa Alfailakawi, Peter Lajko, Madan Sharma, and Elias Vagenas

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Fundamental constants

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

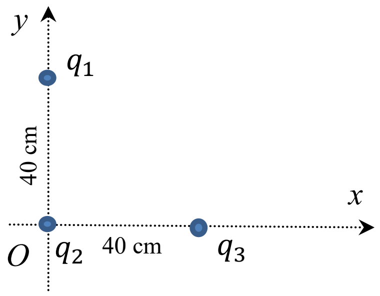
Problems	1	2	3	4	5	6	7	8	9	10	**Questions**	**Total**
Marks												

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, $q_1 = q_2 = q_3 = 4$ μC, are placed on the *xy*-plane, as shown. Calculate the *x* and *y* components of the net electric force, $\vec{F}_3$, acting on q_3. **[4 points]**



$$r_{13} = \sqrt{(0.4\text{ m})^2 + (0.4\text{ m})^2} = 0.57\text{ m}$$

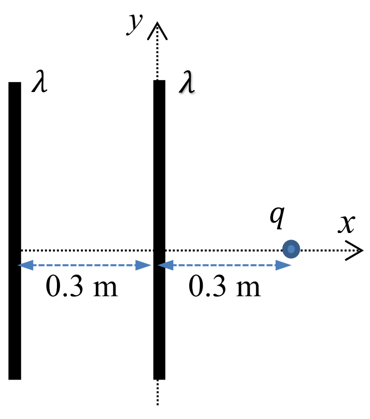
$$F_{13,x} = k\frac{|q_1q_3|}{r_{13}^2}\cos(\theta);\ F_{13,y} = -k\frac{|q_1q_3|}{r_{13}^2}\sin(\theta);$$

$$F_{23,x} = k\frac{|q_2q_3|}{r_{23}^2};\qquad F_{23,y} = 0;$$

$$F_{3,x} = F_{13,x} + F_{23,x} = k\frac{|q_1q_3|}{r_{13}^2}\cos(\theta) + k\frac{|q_2q_3|}{r_{23}^2} = 1.22\text{ N}$$

$$F_{3,y} = F_{13,y} + F_{23,y} = -k\frac{|q_1q_3|}{r_{13}^2}\sin(\theta) + 0 = -0.32\text{ N}$$

2. Two very long uniformly charged lines, with equal linear charge densities, λ, are placed perpendicular to the *x*-axis, as shown. If the net force acting on the point charge $q = 3$ μC is $\vec{F}_{net} = (6N)\hat{\imath}$, find the value of λ. **[4 point]**

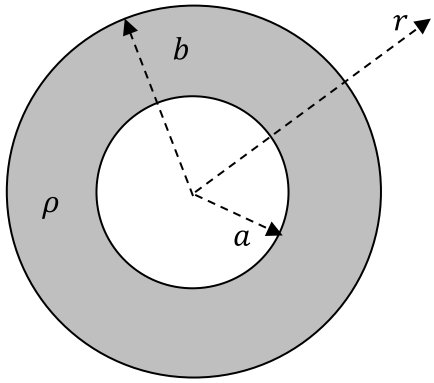


$$\vec{E}_1 = \frac{\lambda}{2\pi\varepsilon_0 0.6\text{m}}\hat{\imath}$$

$$\vec{E}_2 = \frac{\lambda}{2\pi\varepsilon_0 0.3\text{m}}\hat{\imath}$$

$$\vec{F}_{net} = q(\vec{E}_1 + \vec{E}_2) = (6\text{ N})\hat{\imath} \Rightarrow\ \lambda = 22.2\ \mu\text{C/m}$$

3. A spherical shell of inner radius $a = 5$ cm and outer radius $b = 10$ cm has uniform volume charge density $\rho = 480$ nC/m^3. Find the magnitude and direction of the electric field at 40 cm radial distance from the center. **[3 points]**



Gauss's Law:

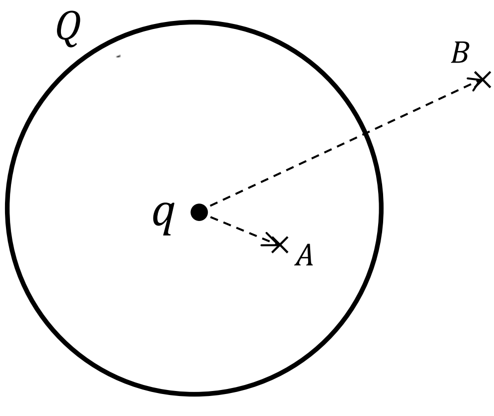
$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{enc}}{\varepsilon_0}$

$E(4\pi r^2) = \frac{Q_{enc}}{\varepsilon_0}$

$Q_{encl} = \rho\left(\frac{4}{3}\pi(b^3 - a^3)\right)$

$E = \frac{Q_{enc}}{4\pi r^2 \varepsilon_0} = 99$ N/C, outward

4. A spherical surface of radius $R = 0.5$ m has charge $Q = 2q$ uniformly distributed on its surface and a point charge q is fixed at its centre. If $V = 0$ at infinity, the electric potential at point A is 360 V. What is the electric potential at point B? Given $r_A = 0.25$ m and $r_B = 1.0$ m. [**4 points**]

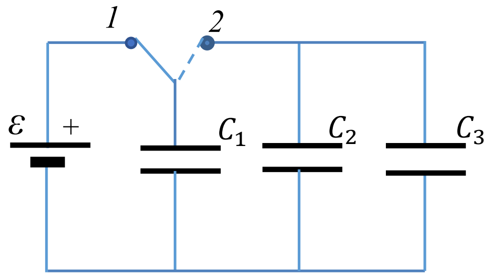


$V_A = V_{qA} + V_{QA} = k\frac{q}{r_A} + k\frac{2q}{R} = 360 \text{ V} \Rightarrow$

$q = 5$ nC

$V_B = V_{qB} + V_{QB} = k\frac{q}{r_B} + k\frac{2q}{r_B} = 135\ V$

5. A capacitor, C_1= 20 μF, is charged by a battery, $\varepsilon = 24$ V, as shown. Then the switch is moved to position 2 so that the capacitor C_1 is connected to uncharged capacitors C_2 and C_3. If $C_2 = C_3 = 20$ μF, what is the final energy stored in C_3? **[4 points]**



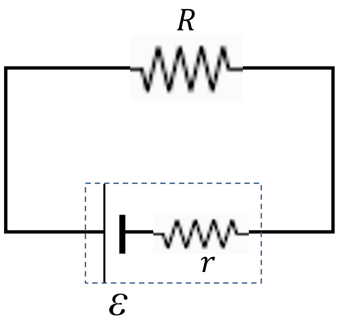
$$Q_0 = \varepsilon C_1 = 480\ \mu\text{C}$$

$$C_{eq} = C_1 + C_2 + C_3 = 60\ \mu\text{C}$$

$$V^{\text{fin}} = \frac{Q_0}{C_{eq}} = \frac{\varepsilon C_1}{C_1+C_2+C_3} = 8\ \text{V}$$

$$U_3^{\text{fin}} = \frac{C_3 (V^{\text{fin}})^2}{2} = 640\ \mu\text{J}$$

6. In the circuit shown below, $\varepsilon = 24$ V, $r = 1.3\ \Omega$, and the terminal voltage of the battery is 21. 4 V. Find the power dissipated on resistor R. **[4 points]**



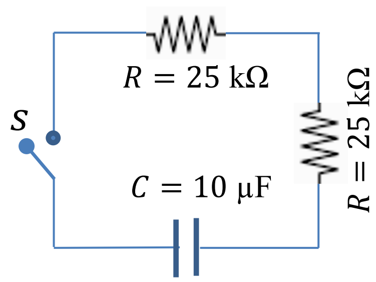
$$V_{ab} = \varepsilon - Ir = 24\ V - I1.3\Omega = 21.4\ V$$

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

$$I = \frac{\varepsilon}{r+R} \Rightarrow R = 10.7\ \Omega$$

$$P = I^2 R = 42.8\ \text{W}$$

7. In the circuit below, the initial charge on the capacitor is $Q_0 = 40$ nC and the switch is closed at time $t = 0$ s. Calculate the time t at which the current in the circuit, I, drops to 1/4 of its initial value. **[4 points]**



$$\tau = R_{eq}C = 50\text{ k}\Omega\ 10\ \mu\text{F} = 0.5\text{ s}$$

$$I(t) = I_0 e^{-t/\tau} \quad \Rightarrow \quad \frac{I_0}{4} = I_0 e^{-\frac{t}{\tau}}$$

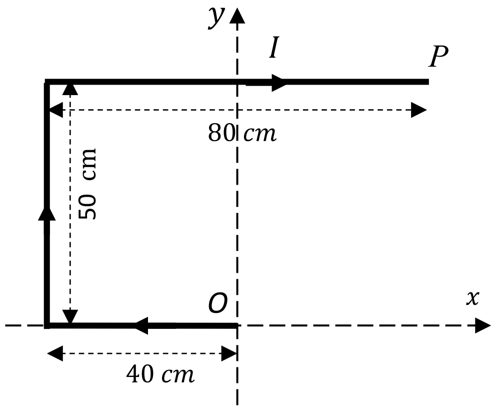
$$t = -R_{eq}C \ln\left(\frac{1}{4}\right) = 0.693\ s$$

8. A point charge $q = 0.4$ C moves momentarily with velocity $\vec{v} = (5\ \frac{\text{m}}{\text{s}})\ \hat{\imath} + (8\ \frac{\text{m}}{\text{s}})\ \hat{\jmath}$ in a region of uniform magnetic field $\vec{B} = (3\text{ T})\ \hat{k}$ and uniform electric field $\vec{E}$ so that the net force acting on the point charge is $\vec{F} = (20\text{ N})\ \hat{\imath} + (16\text{ N})\ \hat{\jmath}$. Calculate the electric field $\vec{E}$. **[4 points]**

$$\vec{F}_{net} = q\vec{E} + q\vec{v} \times \vec{B} \Rightarrow \vec{E} = \frac{\vec{F}_{net} - q\vec{v} \times \vec{B}}{q}$$

$$\vec{E} = 26\frac{\text{N}}{\text{C}}\hat{\imath} + 55\frac{\text{N}}{\text{C}}\hat{\jmath}$$

9. A current $I = 7.5\ A$ flows in a wire from the origin to point P, as shown. Calculate the magnetic force vector acting on the wire by a uniform magnetic field $\vec{B} = (6.0\ T)\hat{k}$. **[3 points]**

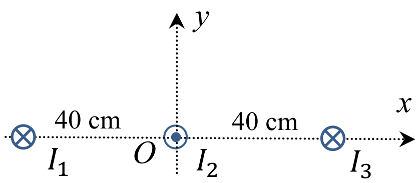


$$\vec{L}_{eff} = -0.4\ \text{m}\hat{\imath} + 0.5\ \text{m}\hat{\jmath} + 0.8\ \text{m}\hat{\imath} = 0.4\ \text{m}\hat{\imath} + 0.5\ \text{m}\hat{\jmath}$$

$$\vec{F} = I\ \ \vec{L}_{eff} \times \vec{B} = I[(0.4\ \text{m}\hat{\imath}) + (0.5\ \text{m}\hat{\jmath})] \times (6.0\ T)\hat{k}$$

$$\vec{F} = (22.5\ \text{N})\hat{\imath} - (18.0\ \text{N})\hat{\jmath}$$

10. Three very long, parallel wires are perpendicular to the xy-plane and carry currents of magnitude $I_1 = I_2 = I_3 = 8$ A in the directions, as shown. Calculate the net force acting on a 6-m length on the wire of I_3. **[3 points]**

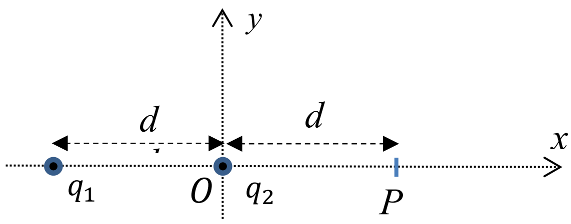


$$\vec{F}_{13} = \frac{\mu_0 I_1 I_2 L}{2\pi 0.8\text{m}} = -(9.6 \times 10^{-5}\ \text{N})\hat{\imath}$$
$$\vec{F}_{32} = \frac{\mu_0 I_1 I_3 L}{2\pi 0.4\text{m}} = +(19.2 \times 10^{-5}\ \text{N})\hat{\imath}$$

$$\vec{F_3} = -\left(9.6 \times 10^{-5} N\right)\hat{\imath} + \left(19.2 \times 10^{-5} N\right)\hat{\imath} = \left(9.6 \times 10^{-5} N\right)\hat{\imath}$$

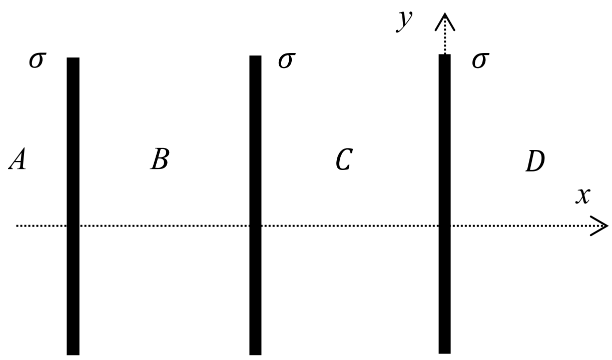
PART II: Conceptual Questions (each carries 1 point). Tick the best answer:

1. Point charge q_1 is fixed on the x-axis. Point charge q_2 is released from point O and moves to point P, as shown. If the electric force on q_2 is $\vec{F}$ at point P, at point O it was



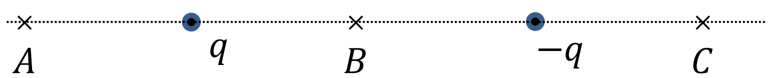
a) $-\vec{F}$.
b) $\vec{F}$.
c) $4\vec{F}$.
d) $-4\vec{F}$.

2. Three parallel infinite large planes have uniform surface charge densities σ. In which region is the magnitude of the electric field smallest?



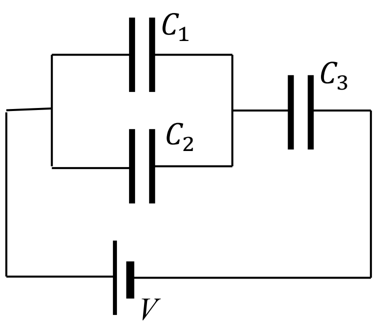
a) A & B.
b) B & C.
c) C & D.
d) A & D.

3. Three points $A, B,$ and C, are located around two point charges ($q > 0$), as shown. If $V = 0$ at infinity, at which of these points is the electric potential smallest?



a) A.
b) B.
c) C.
d) All the points are on the same potential.

4. Three different capacitors are connected into a network as shown. Which statement is correct?



a) The potential on C_1 is the same as on C_2.
b) The potential on C_1 is the same as on C_3.
c) The charge of C_1 is the same as of C_2.
d) The charge of C_1 is the same as of C_3

5. Cylindrical resistor *A* has length L, radius *r* and resistance R_A. Cylindrical resistor *B* is made of the same material, it has length *2L*, radius *2r,* and resistance R_B. Which relation is correct?

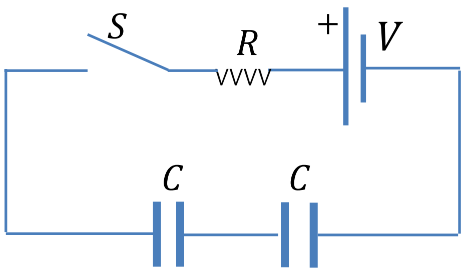
a) $R_A = R_B$.

b) $R_A = 2R_B$.

c) $R_A = R_B/2$.

d) $R_A = 4R_B$.

6. In the *R*-*C* circuit below, the switch is closed at time $t = 0$ s. After waiting a long time, the electric energy on the left capacitor is



a) $U_L = CV^2$.

b) $U_L = \frac{CV^2}{2}$.

c) $U_L = \frac{CV^2}{4}$.

d) $U_L = \frac{CV^2}{8}$.

7. A charged particle moves in a region of uniform magnetic field on a helical path. If the pitch of the helical path is larger than its radius, which relation is true for the parallel and perpendicular components of the velocity?

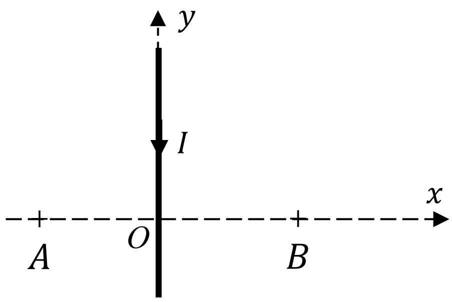
a) $v_\parallel < v_\perp$.

b) $v_\parallel > v_\perp$.

c) $2\pi v_\parallel < v_\perp$.

d) $2\pi v_\parallel > v_\perp$.

8. A wire carries a current, $I = 4$ A, along the y-axis as shown in the figure. At which point does the magnetic field show along the positive z-axis?



a) At point A.

b) At point B.

c) At point A and point B.

d) At none of these points.