Kuwait University | **Physics Department**

General Physics II | **PHY 102**

جامعة الكويت
KUWAIT UNIVERSITY

Final Examination
Summer Semester 2024 – 2025

August 04, 2025
Time: 6:00 – 8:00 PM

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

Section No: ………………… Serial No: …………………

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

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Fundamental constants

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

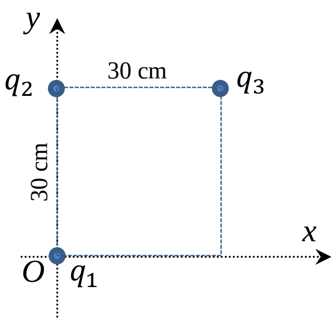
Problems	1	2	3	4	5	6	7	8	9	10	**Questions**	**Total**
Marks												

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 charges, $q_1 = q_2 = q_3 = 8$ μC, are placed at three vertices of a square, as shown. Calculate the *x* and *y* components of the net electric force, $\vec{F}_3$, acting on q_3. **[3 points]**

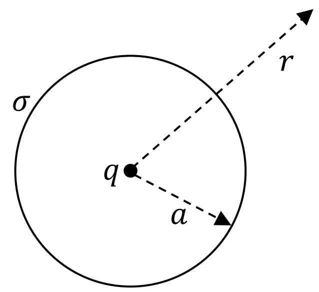


$$r_{13} = \sqrt{(0.3\text{ m})^2 + (0.3\text{ m})^2} = 0.42\text{ m}$$

$$F_{3,y} = F_{13,y} = k\frac{|q_1 q_3|}{r_{13}^2}\sin(45^o) = 2.26\text{ N}$$

$$F_{3,x} = F_{13,x} + F_{23,x} = k\frac{|q_1 q_3|}{r_{13}^2}\cos(45^o) + k\frac{|q_2 q_3|}{r_{23}^2} = 8.66$$
N

2. A point charge $q = 8$ nC is placed at the center of a spherical surface of radius $a = 5$ cm with uniform surface charge density $\sigma = -90$ nC/m^2. Calculate the magnitude and direction of the net electric field at distance $r = 12$ cm from the center. **[3 points]**

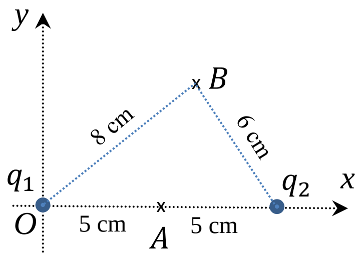


Gauss's Law: $\oint \vec{E}\cdot d\vec{A} = \frac{Q_{encl}}{\varepsilon_0} \Rightarrow E(4\pi r^2) = \frac{Q_{encl}}{\varepsilon_0}$

$$Q_{encl} = q + \sigma 4\pi a^2 = 5.2\text{ nC}$$

$$E = \frac{Q_{encl}}{\varepsilon_0 4\pi r^2} = 3233\text{ N/C, outward}$$

3. Two charges $q_1 = 12$ μC and $q_2 = -8$ μC, are fixed on the x-axis, as shown. Take $V = 0$ at infinity. If the unknown charge q_3 has 5.76 J electric potential energy at point A, calculate the potential energy of q_3 after it is moved to point B. **[4 points]**

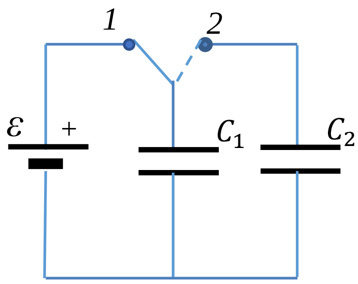


$$U_{q_3}^{A} = q_3(V_A^1 + V_A^2) = q_3\left(k\frac{q_1}{0.05\text{ m}} + k\frac{q_2}{0.05\text{ m}}\right) = 5.76\text{ J}$$

$$\Rightarrow\ q_3 = 8\ \mu\text{C}.$$

$$U_{q_3}^{A} = q_3(V_B^1 + V_B^2) = q_3\left(k\frac{q_1}{0.08\text{ m}} + k\frac{q_2}{0.06\text{ m}}\right) = 1.2\text{ J}$$

4. Initially, a capacitor, $C_1 = 10$ μF, is charged by a battery, as shown. Then the switch is moved to position 2 *so that the capacitor* C_1 is connected to an uncharged capacitor $C_2 = 20$ μF. If the final energy stored in C_2 is $U_{fin,2} = 90$ μJ, calculate the initial energy stored in C_1. **[3 points]**



$$U = \frac{CV^2}{2} \Rightarrow V_{fin} = \sqrt{2U_{fin,2}/C_2} = 3\text{ V}$$

$$Q_0 = (\text{C}_1 + \text{C}_2)V_{fin} = 90\ \mu\text{C}$$

$$U_{in,1} = \frac{Q_0^2}{2\text{C}_1} = 405\ \mu\text{J}$$

5. A potential difference $V = 60$ V is applied between the ends of a metal wire of length $L = 2$ m and radius $r = 0.3$ mm. If the resistivity of the wire is 18.7×10^{-8} Ω·m, how much charge passes through the wire in 5 minutes? **[3 points]**

$R = \rho \frac{L}{A} = \rho \frac{L}{\pi r^2} = 1.32\ \Omega$

$I = \frac{V}{R} = 45.4$ A

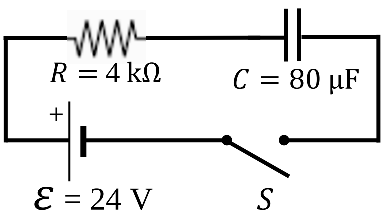
$Q = I \cdot t = 45.4\text{ A} \times (5 \times 60\text{ s}) = 1.4 \times$

6. In the circuit shown below, the capacitor is initially uncharged and the switch S, is closed at $t = 0$. Calculate the time t_1 at which the charge stored in the capacitor is 1/4 of its final value. **[3 points]**

$q(t) = \varepsilon C \left[1 - e^{-\frac{t}{RC}}\right] \Rightarrow \frac{\varepsilon C}{4} = \varepsilon C[1 - e^{-t_1/RC}$

$\Rightarrow \frac{3}{4} = e^{-t_1/RC}$

$\Rightarrow t_1 = -RCln\left(\frac{3}{4}\right) = 92$ ms



7. A proton moves momentarily with a velocity of $\vec{v} = (4 \times 10^6 \,\frac{\text{m}}{\text{s}})\hat{\imath} + (3 \times 10^6 \,\frac{\text{m}}{\text{s}})\hat{\jmath}$ in a uniform magnetic field $\vec{B} = B_x\hat{\imath}$. If the radius of the helical path is $R = 0.024$ m, what is the value of the pitch of the helical path? **[3 points]**

$v_\perp = 3 \times 10^6 \,\frac{\text{m}}{\text{s}}$

$v_\parallel = 4 \times 10^6 \,\frac{\text{m}}{\text{s}}$

$R = \frac{mv_\perp}{|q|B_x} = 0.024\, m \Rightarrow B_x = \frac{mv_\perp}{|q|R} = 1.3 \text{ T}$

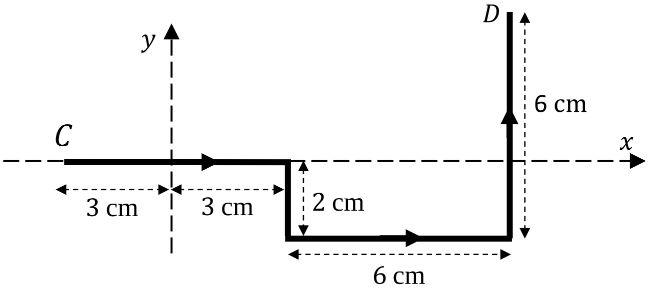
$P = v_\parallel T = v_\parallel \frac{2\pi m}{|q|B} = 0.20 \text{ m}$

8. A current $I = 6$ A flows in a wire from point C to point D, as shown in the figure. Calculate the magnetic force vector acting on the wire by a uniform magnetic field $\vec{B} = (8\text{ T})\hat{\imath} + (2\text{ T})\hat{\jmath}$. [**3 points**]

$\vec{L}_{eff} = (0.12 \text{ m})\hat{\imath} + (0.04 \text{ m})\,\hat{\jmath}$

$\vec{F}_B = I\vec{L}_{eff} \times \vec{B} =$

$= 6A[(0.12 \text{ m})\hat{\imath} + (0.04 \text{ m})\,\hat{\jmath}] \times [(8\,T)\hat{\imath} + (2\,T)\hat{\jmath}]$

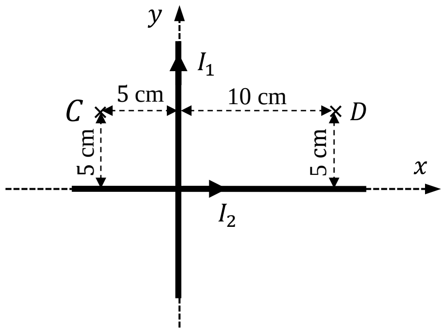


9. Two perpendicular insulated straight wires carry currents $I_1 = 10$ A and I_2, as shown. If the magnetic field at point C is $\vec{B}_C = (5\times10^{-5}\text{T})\hat{k}$, what is the magnetic field $\vec{B}_D$ at point D? **[4 points]**

$$\vec{B}_C = \vec{B}_C^1 + \vec{B}_C^2 = \frac{\mu_0 I_1}{2\pi 0.05\text{m}}\hat{k} + \frac{\mu_0 I_2}{2\pi 0.05\text{m}}\hat{k} = \left(5\times10^{-5}\text{T}\right)\hat{k}$$

$$\Rightarrow I_2 = 2.5 \text{ A}$$

$$\vec{B}_D = \vec{B}_D^1 + \vec{B}_D^2 = -\frac{\mu_0 I_1}{2\pi 0.10\text{m}}\hat{k} + \frac{\mu_0 I_2}{2\pi 0.05\text{m}}\hat{k} = -\left(1\times10^{-5}\text{T}\right)\hat{k}$$



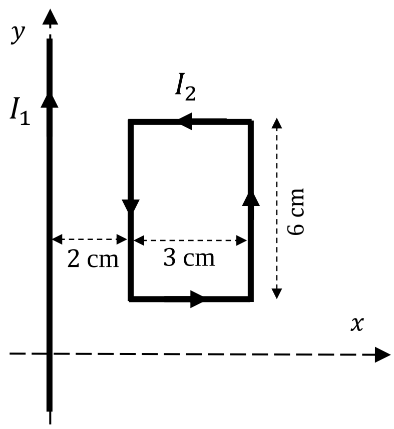
10. A very long straight wire carrying a current $I_1 = 4$ A and a rectangular loop carrying a current $I_2 = 6$ A are placed on the xy-plane as shown. Calculate the magnetic force acting on the loop. **[3 points]**

No net force acting on the horizontal segments of the loop, the net force is the sum of the force on the left and right vertical segments.

$$\vec{F}_{loop} = \vec{F}_{left} + \vec{F}_{right}$$
$$\vec{F}_{left} = \frac{\mu_0 I_1 I_2 L}{2\pi 0.02\text{m}}\ \hat{\imath} = \left(1.44\times10^{-5}\text{ N}\right)\hat{\imath}$$

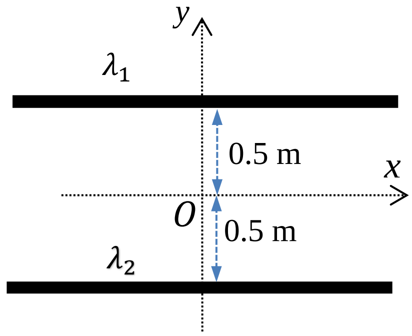
$$\vec{F}_{right} = -\frac{\mu_0 I_1 I_2 L}{2\pi 0.05\text{m}}\ \hat{\imath} = (-5.76\times10^{-6}\text{N})\hat{\imath}$$

$$\vec{F}_{loop} = (8.64\times10^{-6}\text{ N})\hat{\imath}$$



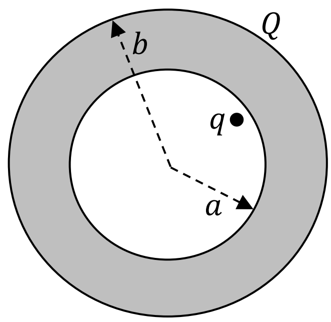
PART II: Conceptual Questions (each carries 1 point). Tick the best answer:

1. Two infinitely long charged lines with uniform linear charge densities $\lambda_1 > \lambda_2 > 0$ are placed parallel with the x-axis, as shown. On the y-axis, the net electric field vector, $\vec{E}_{net}$, is zero



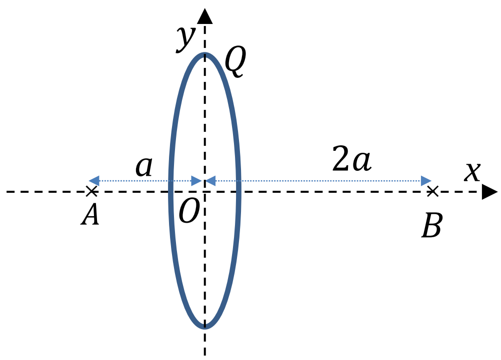
   a) somewhere above λ_1.
   b) somewhere below λ_2.
   c) somewhere between λ_1 and λ_2.
   d) everywhere.

2. A conducting spherical shell has charge Q and a point charge q is placed into its cavity as shown. Which statement is correct? The surface charge density is



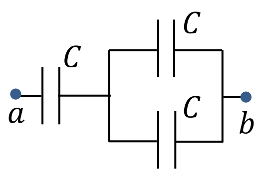
   a) uniform on the inner surface and uniform on the outer surface.
   b) uniform on the inner surface and non-uniform on the outer surface.
   c) non-uniform on the inner surface and uniform on the outer surface.
   d) non-uniform on the inner surface and non-uniform on the outer surface.

3. A circular ring has charge $Q > 0$ and it is centered at the origin. Take $V = 0$ at infinity. Consider the electric potential on the x-axis, which statement is correct?

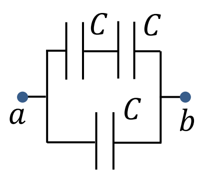


   a) The electric potential is the largest at point A.
   b) The electric potential is the largest at point O.
   c) The electric potential is the largest at point B.
   d) The electric potential is the same at points A and B.

4. Two networks of capacitors A and B are made of the identical capacitors of capacitance C, as shown. Which network has equivalent capacitance $2C/3$?



A



B

   a) A.
   b) B.
   c) Both of them.
   d) None of them.

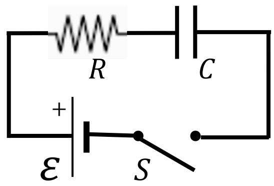
5. Two R-C circuits are made of the identical resistors, capacitors and emf devices as shown. If circuit A has time constant τ_A and circuit B has time constant τ_B, the relation of τ_A and τ_B is

a) $\tau_A = \tau_B$.

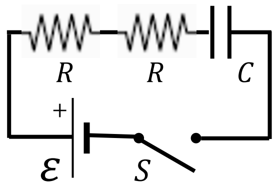
b) $\tau_A = 2\tau_B$.

c) $2\tau_A = \tau_B$.

d) $\tau_A = 4\tau_B$.



A



B

6. If a charged particle moves in a region of uniform magnetic field with a velocity perpendicular to the magnetic field, the path of the particle is a

a) straight line path.

b) helical path.

c) parabolic path.

d) circular path.

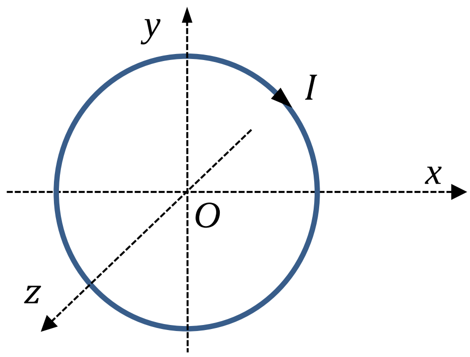
7. A circular loop with current I centered at the origin in the xy-plane as shown. The direction of magnetic field along the z-axis

a) is $+\hat{k}$ for any value of z.

b) is $-\hat{k}$ for any value of z.

c) is $+\hat{k}$ if $z < 0$, and $-\hat{k}$ if $z > 0$.

d) is $-\hat{k}$ if $z < 0$, and $+\hat{k}$ if $z > 0$.



8. If the Ampere's law, $\oint \vec{B} \cdot d\vec{l} = \mu_0 I_{enc}$, is considered on the closed curve C, shown in the figure, the I_{enc} is

a) $-I_1 - I_2$.

b) $+I_1 + I_2$.

c) $-I_1 + I_2$.

d) $+I_1 - I_2$.