Kuwait University | **Physics Department**

General Physics II | **PHY 102**

جامعة الكويت
KUWAIT UNIVERSITY

Final Examination
Summer Semester 2022 – 2023

July 24, 2023
Time: 5:00 – 7:00 PM

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

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

Instructors: Drs. Alaa Alfailakawi, Afshin Hadipour, & Peter Lajko

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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)
$\varepsilon_o = 8.85\times10^{-12}\ \text{C}^2/(\text{N}\cdot\text{m}^2)$	(Permittivity of free space)
$\mu_0 = 4\pi\times10^{-7}\ \text{T.m/A}$	(Permeability of free space)
$\lvert e\rvert = 1.60\times10^{-19}\ \text{C}$	(Elementary unit of charge)
$N_A = 6.02\times10^{23}$	(Avogadro's number)
$g = 9.8\ \text{m/s}^2$	(Acceleration due to gravity)
$m_e = 9.11\times10^{-31}\ \text{kg}$	(Electron mass)
$m_p = 1.67\times10^{-27}\ \text{kg}$	(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

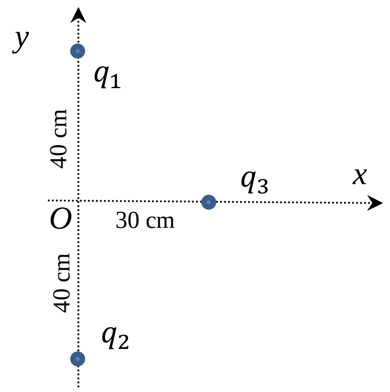
Problems	1	2	3	4	5	6	7	8	9	10	**Questions**	**Total**
Marks												

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 point charges, $q_1 = q_2 = -8$ μC, and $q_3 = 8$ 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]**

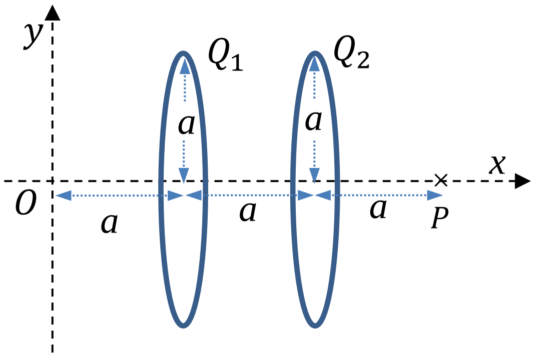


$$r_{13} = r_{23} = \sqrt{(0.3\text{m})^2 + (0.4\text{m})^2} = 0.5 \text{ m}$$

$$F_{3,y} = F_{13,y} + F_{23,y} = k\frac{|q_1q_3|}{r_{12}^2}\sin(\theta) - k\frac{|q_2q_3|}{r_{23}^2}\sin(\theta) = 0$$

$$F_{3,x} = F_{13,x} + F_{23,x} = -2k\frac{|q_1q_3|}{r_{13}^2}\cos(\theta) = -2k\frac{|q_1q_3|}{r_{13}^2}\frac{3}{5} = -2.8 \text{ N}$$

2. Two uniformly charged rings of identical radii a and of charges $Q_1 = -4$ nC and $Q_2 = 4$ nC are placed along the x-axis as shown. If $a = 0.4$ m, calculate the net electric field vector at point P. **[3 points]**

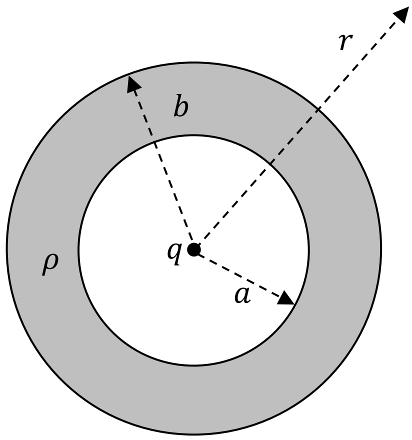


$$\vec{E}_1 = \frac{kQ_1 2a}{((2a)^2+a^2)^{3/2}}\hat{\imath} = \left(-40.25\ \frac{\text{N}}{\text{C}}\right)\hat{\imath}$$

$$\vec{E}_2 = \frac{kQ_2 a}{(a^2+a^2)^{3/2}}\hat{\imath} = (79.55\ \frac{\text{N}}{\text{C}})\hat{\imath}$$

$$\vec{E}_{net} = \vec{E}_1 + \vec{E}_1 = (39.3\ \frac{\text{N}}{\text{C}})\hat{\imath}$$

3. A spherical shell of inner radius $a = 5$ cm and outer radius $b = 10$ cm has uniform volume charge density $\rho = -90$ nC/m^3. A point charge q is placed to the center of the shell. At a radial distance $r = 20$ cm from the center, the net electric field points away from the center and has a magnitude of $E = 240$ N/C. Determine the value of q. **[3 points]**



Gauss's Law:

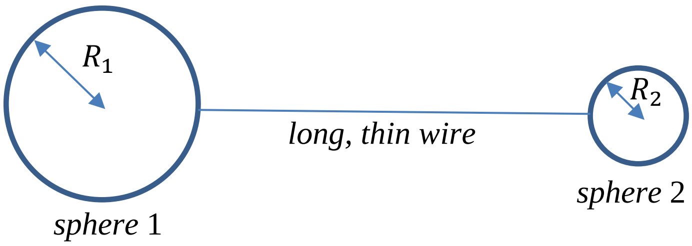
$$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{encl}}{\varepsilon_0}$$

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

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

$$q = E(4\pi r^2)\varepsilon_0 - \rho\left(\frac{4}{3}\pi(b^3 - a^3)\right) \Rightarrow q = 1.4 \text{ nC}$$

4. Two conducting spheres of radii $R_1 = 8$ cm and $R_2 = 4$ cm are placed far from each other. Initially, the *sphere* 1 has charge $Q_0 = 60$ μC and *sphere* 2 is uncharged. Then the spheres are connected to each other with a long, thin wire. Calculate the final charge of the sphere of radius R_2. **[4 points]**



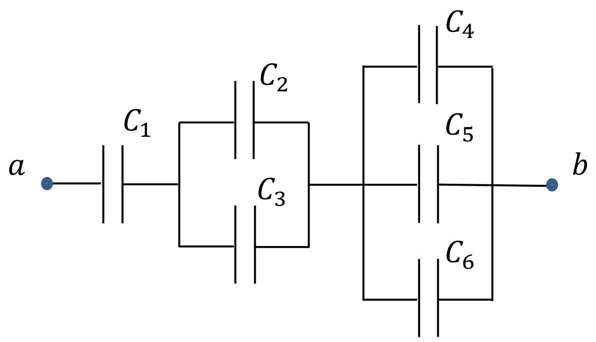
$$V_1 = V_2 \Rightarrow \frac{kQ_1}{R_1} = \frac{kQ_2}{R_2}$$

$Q_0 = Q_1 + Q_2$ so

$$\frac{Q_1}{Q_2} = \frac{R_1}{R_2} \Rightarrow \frac{Q_1}{Q_0 - Q_1} = \frac{R_1}{R_2} \Rightarrow$$

$Q_2 = 20$ μC

5. Calculate the equivalent capacitance between points a and b of the following network of six identical capacitors, $C_1 = C_2 = C_3 = C_4 = C_5 = C_6 = 4$ μF. **[3 points]**



$C_{23} = C_2 + C_3 = 8$ μF

$C_{456} = C_4 + C_5 + C_6 = 12$ μF

$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_{23}} + \frac{1}{C_{456}} \Longrightarrow C_{eq} = 2.2$ μF

6. A cylindrical conducting wire of length $L = 5.0$ m and radius $r = 0.1$ mm has resistance $R = 4\ \Omega$. The wire has a concentration of free electrons $n = 1.5 \times 10^{28}$ m^{-3}. If the magnitude of electric field in the wire is $E = 0.05$ N/C, calculate the drift speed v_d of the electrons. **[4 points]**

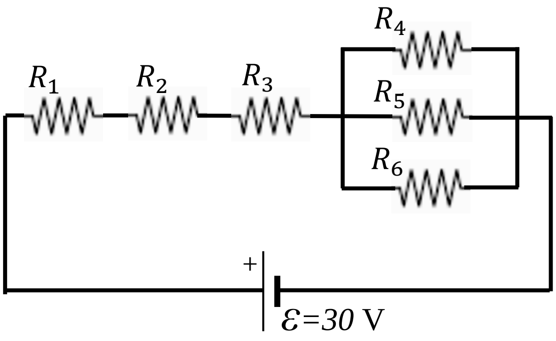
$R = \rho \frac{L}{A} = \rho \frac{L}{\pi r^2} \Rightarrow \rho = \frac{R\pi r^2}{L}$

$\rho = 2.5 \times 10^{-8}\ \Omega$ m

$E = \rho J \Rightarrow J = \frac{E}{\rho} = 2 \times 10^6$ A/m^2

$J = nev_d \Rightarrow v_d = \frac{J}{ne} = 8.3 \times 10^{-4}$ m/s

7. Six identical resistors, $R_1 = R_2 = R_3 = R_4 = R_5 = R_6 = 3\ \Omega$, are connected into circuit as shown. Find the power supplied by the ideal *emf* device. **[4 points]**



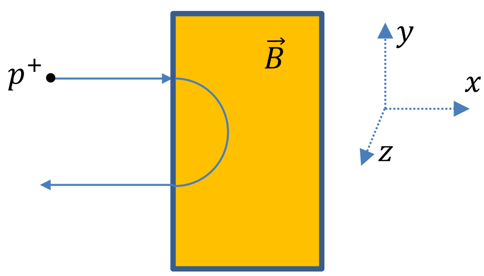
$R_{123} = R_1 + R_2 + R_3 = 9\ \Omega$

$R_{456} = \frac{1}{\frac{1}{R_4}+\frac{1}{R_5}+\frac{1}{R_6}} = 1\ \Omega$

$R_{eq} = R_{123} + R_{456} = 10\ \Omega$

$P_{sup} = \frac{\varepsilon^2}{R_{eq}} = 90\ \text{W}$

8. A proton moves into a region of uniform magnetic field with a velocity of $\vec{v} = \left(1500\,\frac{\text{m}}{\text{s}}\right)\hat{\imath}$ and leaves it by moving to opposite direction, as shown. The magnetic field is perpendicular to the *xy*-plane. If the proton travels a distance $s = 0.8$ m in the magnetic field, find the magnitude and direction of the uniform magnetic field. **[3 points]**



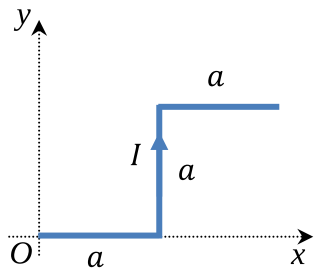
$s = \pi R,$ *since the proton completes a semicircle.*

$R = \frac{s}{\pi} = \frac{mv}{|q|B} \Rightarrow B = \frac{mv}{|q|R} = 61.5\ \mu\text{T}$

$\vec{B}$ is outward (or $\vec{B} = B_z\hat{k}$).

9. A three-segment wire of total length $3a$ carries a current $I = 3$ A, as shown in the figure. The wire is in uniform magnetic field, $\vec{B} = (2\text{ T})\hat{k}$. If $a = 0.4$ m, calculate the net magnetic force acting on the wire.

[3 points]

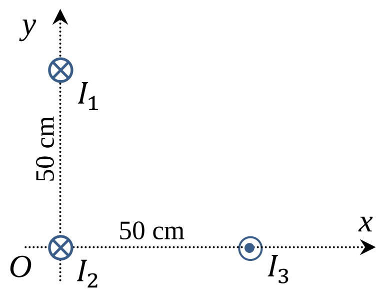


$$\vec{L}_{eff} = 2a\hat{\imath} + a\hat{\jmath}$$

$$\vec{F}_B = I\vec{L}_{eff} \times \vec{B} = (2.4\text{ N})\hat{\imath} + (-4.8\text{ N})\hat{\jmath}$$

10. Three very long, parallel wires are perpendicular to the xy-plane. Each wire carries a current of magnitude $I = 4$ A in the direction as shown. Calculate the force per unit length vector $\frac{\vec{F}_3}{L}$ acting on the wire of I_3.

[5 points]



$$\frac{F_{13,x}}{L} = \frac{\mu_0 I_1 I_3}{2\pi 0.5\text{m}\sqrt{2}}\cos(-45^o) = 3.2 \times 10^{-6}\text{ N/m}$$

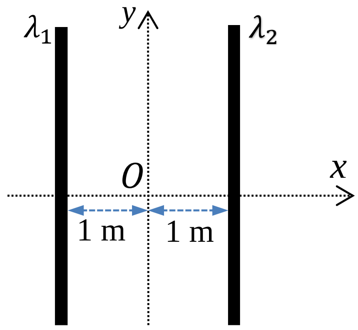
$$\frac{F_{13,y}}{L} = \frac{\mu_0 I_1 I_3}{2\pi 0.5\text{m}\sqrt{2}}\sin(-45^o) = -3.2 \times 10^{-6}\text{ N/m}$$

$$\frac{F_{23,x}}{L} = \frac{\mu_0 I_2 I_3}{2\pi 0.5\text{m}} = 6.4 \times 10^{-6}\text{ N/m}, \quad \frac{F_{23,y}}{L} = 0$$

$$\frac{\vec{F}_3}{L} = \left(9.6 \times 10^{-6}\,\frac{\text{N}}{\text{m}}\right)\hat{\imath} + \left(-3.2 \times 10^{-6}\,\frac{\text{N}}{\text{m}}\right)\hat{\jmath}$$

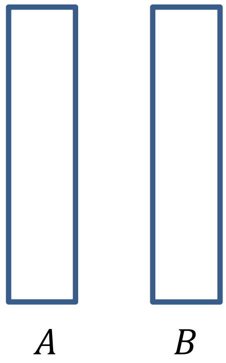
PART II: Conceptual Questions (each carries 1 point). Tick the best answer:

1. Two very long uniformly charged lines with linear charge densities $\lambda_1 = 9$ nC/m and $\lambda_2 = -6$ nC/m are placed perpendicular to the x-axis, as shown. Along the x-axis, the net electric field vector, $\vec{E}_{net}$, is zero



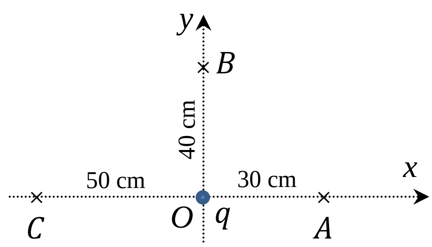
   a) somewhere to the left of λ_1.
   b) somewhere to the right of λ_2.
   c) somewhere between the two linear charge densities.
   d) everywhere.

2. Two very large parallel charged conducting plates A and B have identical charges Q and Q. Which statement is correct for the location of the charges? The charges are



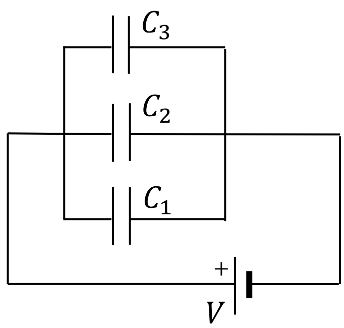
   a) on the right surface of plate A and on the right surface of plate B.
   b) on the right surface of plate A and on the left surface of plate B.
   c) on the left surface of plate A and on the right surface of plate B.
   d) on the left surface of plate A and on the left surface of plate B.

3. A point charge $q > 0$ is fixed at the origin as shown. Which relation is correct for the electric potential differences?



   a) $V_A - V_C < V_A - V_B$.
   b) $V_B - V_C < V_A - V_C$.
   c) $V_A - V_C < V_B - V_C$.
   d) $V_A - V_B < V_C - V_B$.

4. Three capacitors are connected into a circuit as shown. If $C_1 = C$, $C_2 = 2C$, $C_3 = 3C$, which relation is correct for the charges stored on the capacitors?



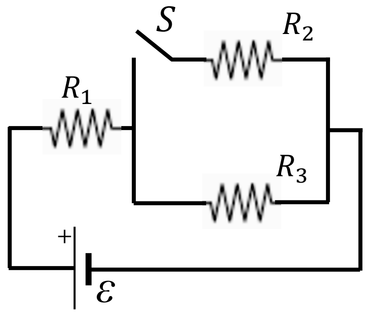
   a) $Q_1 = Q_2$.
   b) $Q_1 = Q_3$.
   c) $Q_1 = Q_2/2$.
   d) $Q_1 = Q_3/2$.

5. A cylindrical wire has length L, radius r and resistivity ρ. Another cylindrical wire made of the same material has length $2L$, radius $2r$, so, its resistivity is

a) ρ.
b) 2ρ.
c) 4ρ.
d) $\rho/2$.

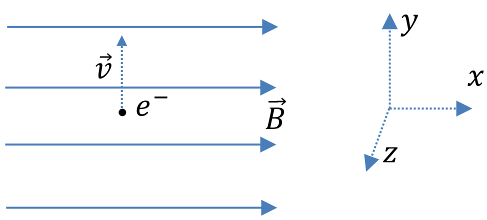
6. In the circuit shown, $R_1 = R_2 = R_3$. If the switch is closed, the potential change on R_1

a) will decrease.
b) will increase.
c) will remain the
d) will drop to zero.



7. An electron moves in a region of uniform magnetic field, $\vec{B} = B_x\hat{\imath}$. The velocity of the electron is momentarily parallel with the positive y-axis, as shown. At this moment, the magnetic force $\vec{F}_B$ acting on the electron is along the

a) negative x-axis.
b) negative y-axis.
c) negative z-axis.
d) positive z-axis.



8. A current I flows in a very long straight wire along the negative y-axis, as shown. Due to this current, the magnetic field $\vec{B}$ points parallel with the negative z-axis

a) at point A.
b) at point B.
c) at both points A and B.
d) at none of the points A and B.