Kuwait University		**Physics Department**
General Physics II		**PHY 102**

جامعة الكويت
KUWAIT UNIVERSITY

Final Examination
Summer Semester 2023 – 2024

July 29, 2024
Time: 5:00 – 7:00 PM

Name: ……………………………… Student No: …………… Sec. No: ……. Serial No: ….

Instructors: Drs. Alaa Alfailakawi, Peter Lajko, and 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)

$\mu_0 = 4\pi \times 10^{-7}$ T .m/A (Permeability of free space)

$|e| = 1.60 \times 10^{-19}$ 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)

$m_e = 9.11 \times 10^{-31}$ kg (Electron mass)

$m_p = 1.67 \times 10^{-27}$ kg (Proton mass)

Prefixes of units

m = 10^{-3}	μ = 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

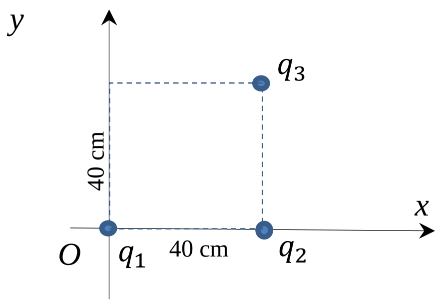
Problems	1	2	3	4	5	6	7	8	9	10	**Questions**	**Total**
Marks												

Instructions to the Students:

1. Mobile or other electronic devices are **strictly prohibited** during the exam.
2. Programmable calculators, which can mc
3. store equations, are not allowed.
4. **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, $q_1 = q_2 = q_3 = 2$ μC, are placed on the vertices of a square, as shown. Calculate the x and y components of the net electric force, $\vec{F}_1$, acting on q_1. **[5 points]**



$$r_{13} = \sqrt{(0.4\text{ m})^2 + (0.4\text{ m})^2} = 0.5657\text{ m}$$

$$F_{31,x} = -k\frac{|q_3q_1|}{r_{13}^2}\cos(45^o) = -0.08\text{ N};$$

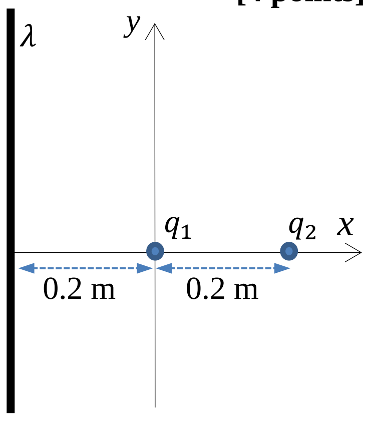
$$F_{31,y} = -k\frac{|q_3q_1|}{r_{13}^2}\sin(45^o) = -0.08\text{ N};$$

$$F_{21,x} = -\,k\frac{|q_1q_2|}{r_{21}^2} = -0.225\text{ N}; F_{21,y} = 0$$

$$F_{1,x} = F_{21,x} + F_{31,x} = -0.305\text{ N}$$

$$F_{1,y} = F_{21,y} + F_{31,y} = -0.08\text{ N}$$

2. Two equal point charges $q_1 = q_2 = 2$ μC are placed on the x-axis and a very long uniformly charged line, with uniform linear charge density, λ, is placed perpendicular to the x-axis, as shown. If the net force acting on the point charge q_2 is zero, find the value of λ. **[4 points]**



$$\vec{E}_\lambda = \frac{\lambda}{2\pi\varepsilon_0 0.4\text{ m}}\hat{\imath}$$

$$\vec{E}_{q_1} = \frac{kq_1}{(0.2\,m)^2}\hat{\imath}$$

$$\vec{F}_{net} = q_2(\vec{E}_1 + \vec{E}_2) = 0 \Rightarrow$$

$$\lambda = -\frac{q_2 0.4m}{2(0.2\,m)^2} = -10.0\text{ μC/m}$$

3. A spherical shell of inner radius $a = 10$ cm and outer radius $b = 20$ cm has uniform volume charge density $\rho = -300$ nC/m^3. Determine the magnitude and direction of the net electric field at distance of 15 cm from the center.

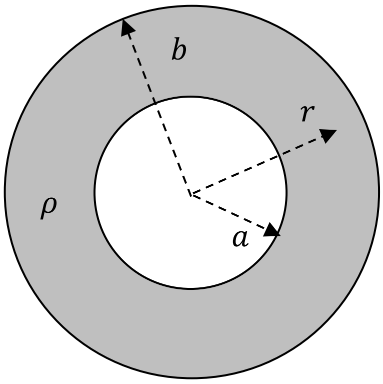
[3 points]

Gauss's Law:

$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{enc}}{\varepsilon_0} \Rightarrow E(4\pi r^2) = \frac{Q_{enc}}{\varepsilon_0}$

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

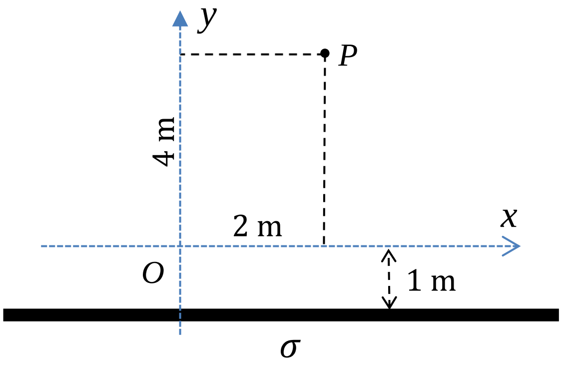
$E = \frac{Q_{enc}}{4\pi r^2 \varepsilon_0} = -1193$ N/C, inward



4. A very large sheet with uniform surface charge density, $\sigma = 70.8\ \mu\text{C/m}^2$, is placed perpendicular to the y-axis, as shown. If a point charge, $q = 4\ \mu$C, is moved from point P to O, calculate the work done by the electric field. [**3 points**]

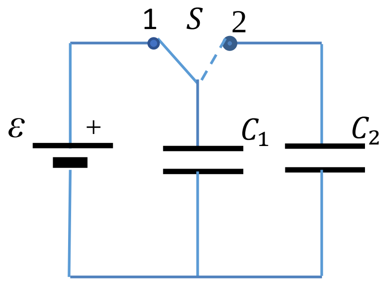
$W_E = \int_P^O \vec{F} \cdot d\vec{l} = \vec{F} \cdot \Delta\vec{L}$

$\vec{F} \cdot \Delta\vec{L} = -\frac{\sigma q}{2\varepsilon_0}\Delta y = -64$ J



5. A capacitor, C_1= 20 μF, is charged by the battery, $\mathcal{E}$ = 60 V, while the switch S is position 1, as shown. Then the switch is moved to position 2 so that capacitor C_1 is connected to the uncharged capacitor $C_2 = 40$ μF. Calculate the final energy stored in capacitor C_2.

[3 points]



$$V^{fin} = \frac{Q_0}{C_{eq}} = \frac{C_1}{C_1+C_2}\varepsilon \Rightarrow V^{fin} = \frac{\varepsilon}{3} = 20 \text{ V}$$

$$U_2^{fin} = \frac{C_2(V^{fin})^2}{2} = 8 \text{ mJ}$$

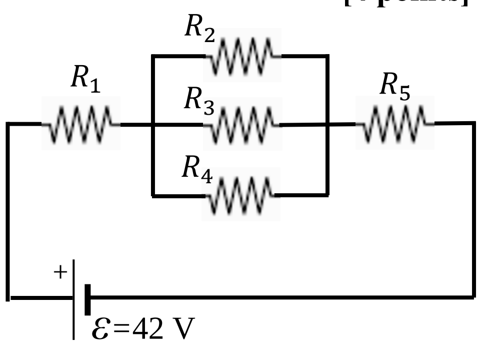
6. A cylindrical wire of resistivity $\rho = 1.72 \times 10^{-8}\Omega \cdot \text{m}$, length L, and diameter $d = 0.4$ mm is connected to a potential difference of V = 60 V. If the power dissipation on the wire is $P = 144$ W, calculate the electric field in the wire. **[3 points]**

$$P = \frac{V^2}{R} \Rightarrow R = \frac{V^2}{P} = 25\ \Omega$$

$$R = \rho\frac{L}{A} \Rightarrow L = \frac{R\pi r^2}{\rho} = 183 \text{ m}$$

$$E = \frac{V}{L} = 0.33 \text{ N/C}$$

7. Five identical resistors, $R_1 = R_2 = R_3 = R_4 = R_5 = 6\ \Omega$, are connected into circuit, as shown. Find the current on resistor R_4. **[4 points]**



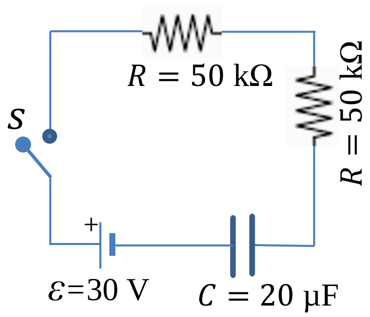
$$R_{234} = \frac{1}{\frac{1}{R_4}+\frac{1}{R_5}+\frac{1}{R_6}} = 2\ \Omega$$

$$R_{eq} = R_1 + R_{234} + R_5 = 14\ \Omega$$

$$I_{\mathcal{E}} = \frac{\mathcal{E}}{R_{eq}} = 3\text{ A}$$

$$R_4 I_{R_4} = R_{234} I_{R_{234}} \Rightarrow I_{R_4} = 1\text{ A}$$

8. In the circuit below, the capacitor is initially uncharged and the switch is closed at time $t = 0$ s. Calculate the time t_1 at which the charge of the capacitor is 1/4 of its final value. **[5 points]**



$$\tau = R_{eq}C = 2RC = 2\text{ s}$$

$$q(t) = \varepsilon C\left[1 - e^{-\frac{t}{R_{eq}C}}\right] \Rightarrow Q_{fin} = \varepsilon C$$

$$\frac{Q_{fin}}{4} = q(t_1) = \varepsilon C\left[1 - e^{-\frac{t_1}{R_{eq}C}}\right]$$

$$\frac{1}{4} = 1 - e^{-\frac{t_1}{R_{eq}C}} \Rightarrow \frac{3}{4} = e^{-\frac{t_1}{R_{eq}C}}$$

$$t_1 = -R_{eq}C\ln\left(\frac{3}{4}\right) = 0.575\text{ s}$$

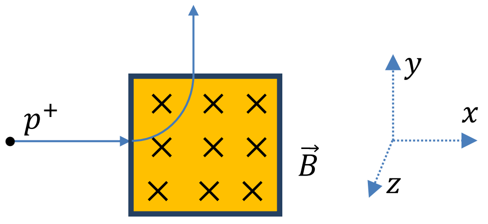
9. A point charge $q = 0.6$ mC moves momentarily with velocity $\vec{v} = (8000\ \frac{\text{m}}{\text{s}})\ \hat{\jmath}$ in a region of uniform magnetic field $\vec{B} = (3\text{ T})\ \hat{\imath} + (4\text{ T})\ \hat{k}$. Calculate the magnitude of magnetic force $\vec{F}$ acting on the point charge. **[4 points]**

$$\vec{F} = q\,\vec{v} \times \vec{B} = 0.6\text{ mC} \cdot (8000\frac{\text{m}}{\text{s}})\hat{\jmath} \times ((3\text{ T})\ \hat{\imath} + (4\text{ T})\ \hat{k})$$

$$\vec{F} = (19.2\text{ N})\hat{\imath} - (14.4\text{ N})\hat{k}$$

$$F = 24.0\text{ N}$$

10. A proton moves into a region of uniform magnetic field with a velocity $\vec{v} = \left(1500\frac{m}{s}\right)\hat{\imath}$ and leaves it with a velocity $\vec{v} = \left(1500\frac{m}{s}\right)\hat{\jmath}$. If the proton travels a distance $s = 0.25$ m in the magnetic field, find the magnitude of the magnetic field. **[3 points]**



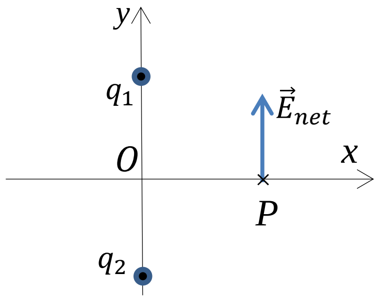
The path of the proton is a quarter circle.

$$s = \frac{2\pi R}{4} \Rightarrow\ R = \frac{4s}{2\pi} = 0.159\text{ m}$$

$$R = \frac{mv}{qB} \Longrightarrow B = \frac{mv}{qR} = 9.84 \times 10^{-5}\text{ T}$$

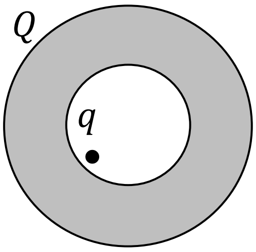
PART II: Conceptual Questions (each carries 1 point). Tick the best answer:

1. Two point charges q_1 and q_2 are fixed on the y-axis as shown. If the net electric field $\vec{E}_{net}$ at point P is along the y-axis, which statement can be correct for the charges?



a) $q_1 = q_2$.
b) $q_1 < 0$ and $q_2 < 0$.
c) $q_1 > 0$ and $q_2 > 0$.
d) $q_1 < 0$ and $q_2 > 0$. ⇐

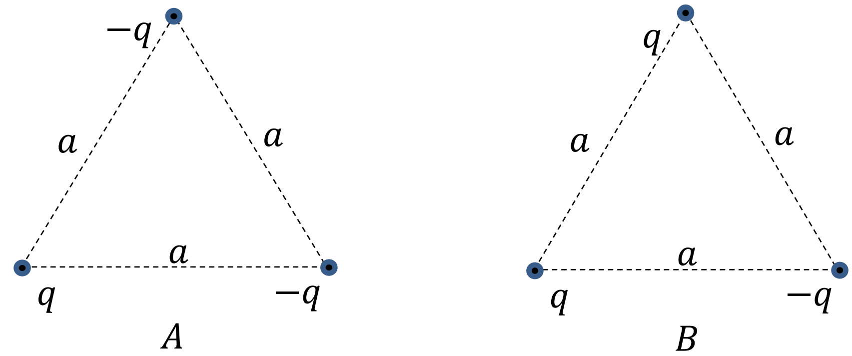
2. A conducting spherical shell has a net charge Q and a point charge q is fixed off-center of its cavity, as shown. Which statement is correct? The surface charge density is



a) uniform on the inner surface and non-uniform on the outer surface.
b) uniform on the inner surface and 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. Systems A and B are both made of 3 point charges, as shown. Which statement is true for the total potential energies of these systems, U_A, and U_B, respectively?

a) $U_A = -U_B$.
b) $U_A = U_B$. ⇐
c) $U_A = 2U_B$.
d) $U_A = 3U_B$.



4. If two identical capacitors are connected in series, their equivalent capacitance is C_{ser}. If the same capacitors are connected in parallel, their equivalent capacitance is C_{par}. The ratio of C_{ser}/C_{par} is

a) 1/2.
b) 1/4. ⇐

c) 1.

d) 2.

5. A cylindrical rod has resistance R. If the length and the diameter of the rod are both doubled, the rod has a resistance

a) $R/2$.

b) $R/4$.

c) $2R$.

d) $4R$.

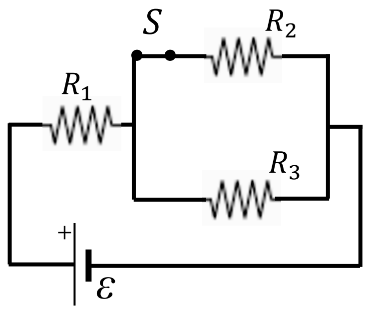
6. In the circuit shown, $R_1 = R_2 = R_3$. If the switch, S, is opened, the current supplied by the emf device

a) decreases.

b) increases.

c) remains the same.

d) drops to zero.



7. The magnetic force acting a charged particle can never do work because the force is

a) parallel with the velocity of the particle.

b) perpendicular to the velocity of the particle.

c) parallel with the magnetic field.

d) opposite to the magnetic field.

8. Three straight wires $A, B,$ and C, with identical lengths carrying identical currents I, are placed into a uniform magnetic field, as shown. The magnitude of magnetic force is

a) smallest for wire A.

b) largest for wire B.

c) largest for wire C.

d) smallest for wire C.