**Kuwait University** **Physics Department**

# Physics 102

## Final Examination
## Fall Semester (2022 - 2023)
## December 27, 2022

Time: 5:00 – 7:00 PM

Name…………………………………… Student ID…………………

Section No………………… Serial No…………………..

Instructors: Drs. Afrousheh, Alfailakawi, Farhan, Lajko, and Vagenas.

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**Fundamental constants**

$k = \frac{1}{4\pi\varepsilon_o} = 9.0 \times 10^9 \text{ N.m}^2/\text{C}^2$ (Coulomb constant)

$\varepsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/(\text{N}\cdot\text{m}^2)$ (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*

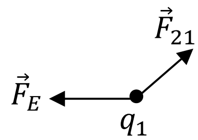
| | | | |
|---|---|---|---|
| $\text{m} = 10^{-3}$ | $\mu = 10^{-6}$ | $\text{n} = 10^{-9}$ | $\text{p} = 10^{-12}$ |
| $\text{k} = 10^{3}$ | $\text{M} = 10^{6}$ | $\text{G} = 10^{9}$ | $\text{T} = 10^{12}$ |

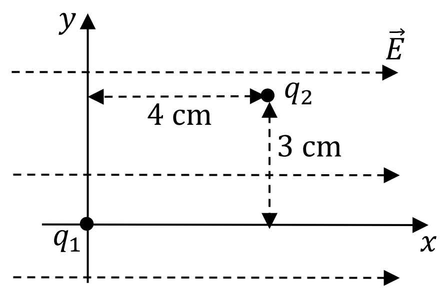
For use by Instructors only

| Prob. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Questions | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Marks | | | | | | | | | | | | |

## Part I. Solve the following problems. Show your solutions in detail.

1. Two point charges $q_1 = -5.0\ \mu\text{C}$ and $q_2 = 6.0\ \mu\text{C}$ are placed in a uniform electric field of $\vec{E} = (2.0 \times 10^7\ \text{N/C})\hat{\imath}$ as shown. Find the net electric force $\vec{F}$ on charge $q_1$. **[4 points]**



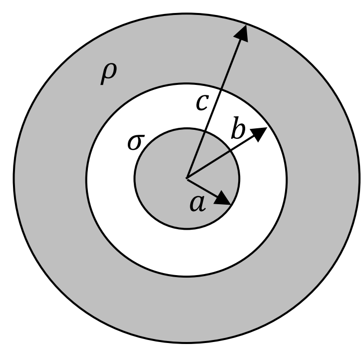

$$\vec{F}_{21} = k\frac{|q_1 q_2|}{r^2}(cos\theta\hat{\imath} + sin\theta\hat{\jmath})$$

$$= (86.4\ \text{N})\hat{\imath} + (64.8\ \text{N})\hat{\jmath}$$

$$\vec{F}_E = q_1\vec{E} = -(100\ \text{N})\hat{\imath}$$

$$\vec{F}_1 = \vec{F}_{21} + \vec{F}_E = -(13.6\ \text{N})\hat{\imath} + (64.8\ \text{N})\hat{\jmath}$$

2. A charged conducting sphere of radius $a = 4.0$ cm and surface charge density of $\sigma = -2.0\ \mu\text{C/m}^2$ is concentric with a uniformly charged spherical shell of inner radius $b = 6.0$ cm and outer radius $c = 9.0$ cm. The volume charge density of the shell is $\rho = 8.0\ \mu\text{C/m}^3$. Find the magnitude and direction of the net electric field at a radial distance of 12.0 cm from the center. **[4 points]**



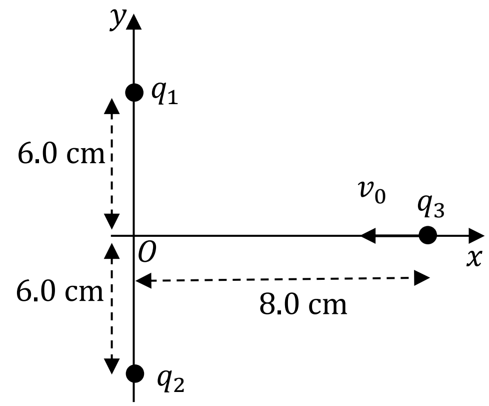

$$q_1 = \sigma \cdot 4\pi a^2 = -40.2\ \text{nC}$$

$$q_2 = \rho \cdot \frac{4\pi}{3}(c^3 - b^3) = 17.2\ \text{nC}$$

$$E = k\frac{|q_1 + q_2|}{r^2} = 14.4 \times 10^3\ \text{N/C}$$

Inward

3. Two point charges $q_1 = q_2 = q$ are fixed on the $y$-axis and a point charge $q_3 = 4.0\ \mu\text{C}$ with a mass of $m_3 = 3 \times 10^{-6}$ kg is on the $x$-axis moving towards the origin as shown. The speed of $q_3$ is $v_0 = 2 \times 10^3$ m/s at a distance of 8.0 cm from the origin. If $q_3$ stops momentarily at a distance of 3.0 cm from the origin, find the value of $q$. **[4 Points]**



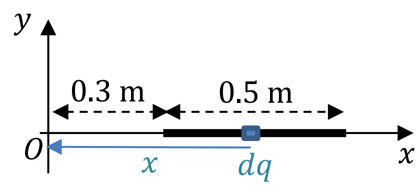

$$2k\frac{qq_3}{r_1} + \frac{1}{2}m_3 v_0^2 = 2k\frac{qq_3}{r_2} + 0$$

$r_1 = 10$ cm and $r_2 = 6.7$ cm

$7.2 \times 10^5 q + 6 = 1.08 \times 10^6 q$

$q = 16.9\ \mu\text{C}$

4. A uniformly charged line of length 0.5 m and net charge $Q = 6.0$ nC is along the $x$-axis as shown. Find the electric potential of the line at the origin. **[4 points]**



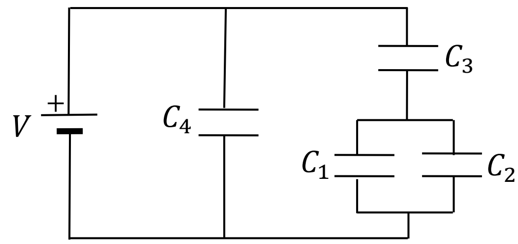

$$dV = k\frac{dq}{x} = k\frac{\lambda dx}{x}$$

$$V = k\frac{Q}{L}\int_{0.3}^{0.8}\frac{dx}{x}$$

$$V = k\frac{Q}{L}(\ln x)\Big|_{0.3}^{0.8}$$

$V = 106$ V

5. In the capacitor network below $C_1 = C_2 = 6.0\ \mu\text{F}$, $C_3 = C_4 = 12.0\ \mu\text{F}$ and the charge on capacitor $C_4$ is $Q_4 = 24\ \mu\text{C}$. Find the charge on capacitor $C_3$. **[4 points]**




$C_{12} = 12\ \mu\text{F}, \quad C_{123} = 6\ \mu\text{F}$

$V_4 = V_{123} = \frac{Q_4}{C_4} = 2\ \text{V}$

$Q_{123} = Q_3 = C_{123}V_{123} = 12\ \mu\text{C}$

6. An electric field of magnitude $0.86\ \text{V/m}$ is applied in a conducting wire of resistivity $1.72 \times 10^{-8}\ \Omega \cdot \text{m}$ and diameter $0.2\ \text{mm}$. How much charge goes through a cross-section of the wire in $0.5\ \text{min}$?

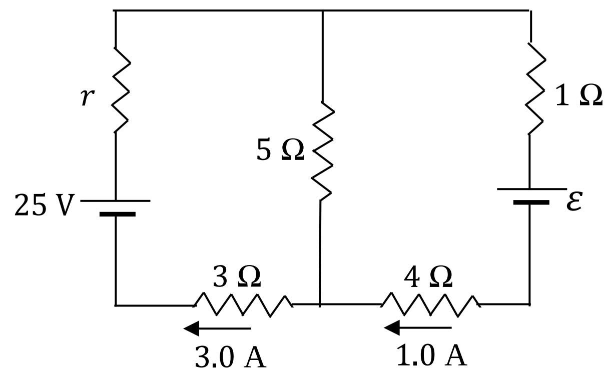
**[3 points]**

$J = \frac{E}{\rho} = 5 \times 10^7\ \text{A/m}^2$

$I = JA = J\pi(\frac{D}{2})^2 = 1.57\ \text{A}$

$Q = It = 47.1\ \text{C}$

7. In the circuit shown find the emf $\mathcal{E}$ and resistance $r$. **[5 points]**

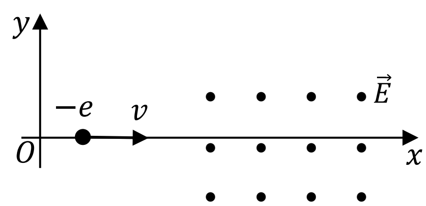



Junction: $I = 3 - 1 = 2$ A

Left loop: $-3 \times 3 + 25 - 3r - 5 \times 2 = 0 \quad \rightarrow \quad r = 2\,\Omega$

Right loop: $-4 \times 1 + 5 \times 2 - 1 \times 1 - \mathcal{E} = 0 \quad \rightarrow \quad \mathcal{E} = 5$ V

8. An electron is accelerated by a potential difference of 80 V, then it goes through a region of crossed electric and magnetic fields with $\vec{E} = (1000\ \mathrm{N/C})\hat{k}$ as shown. Find a magnetic field $\vec{B}$ that keeps the electron on a straight path. **[3 points]**



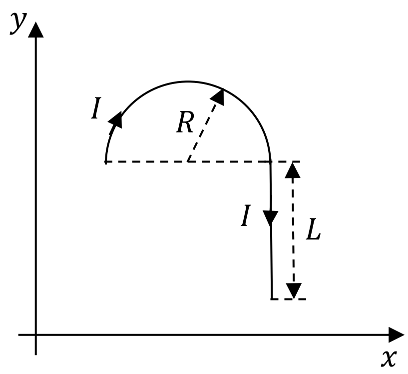

$eV = 1/2mv^2 \quad \rightarrow \quad v = 5.3 \times 10^6$ m/s

$\vec{E} = -\vec{v} \times \vec{B} \quad \rightarrow \quad E\hat{k} = -v\hat{\imath} \times \vec{B} \quad \rightarrow \quad \vec{B} = B_x\hat{\imath} + B_y(-\hat{\jmath})$

$B_y = \frac{E}{v} = 1.9 \times 10^{-4}$ T

$B_x$ is arbitrary and can't be determined.

9. A wire carrying a current of $I = 0.5$ A is made of a semicircle of radius $R = 0.5$ m and a straight section of length $L = 0.8$ m as shown. The wire is in a magnetic field of $\vec{B} = (0.4 \text{ T})\hat{\imath} - (0.6 \text{ T})\hat{\jmath}$. Calculate the magnetic force $\vec{F}$ on the wire. [**4 points**]

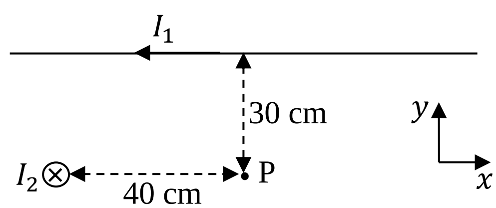



$\vec{l} = 2R\hat{\imath} - L\hat{\jmath} = 1.0\hat{\imath} - 0.8\hat{\jmath}$ m

$\vec{F} = I\vec{l} \times \vec{B} = 0.5(1.0\hat{\imath} - 0.8\hat{\jmath}) \times (0.6\hat{\imath} - 0.4\hat{\jmath})$

$= -0.3\hat{k} + 0.16\hat{k} = (-0.14 \text{ N})\hat{k}$

10. Two infinitely long wires carry currents $I_1 = 15$ A and $I_2 = 8$ A as shown. Find the net magnetic field $\vec{B}$ at point $P$. **[3 Points]**

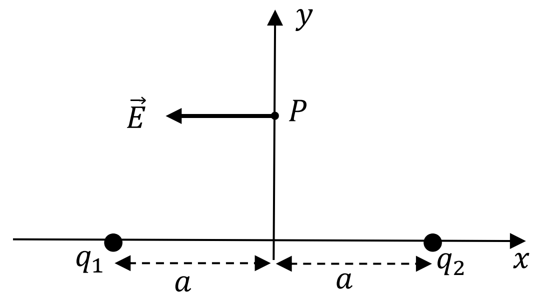



$\vec{B} = \vec{B}_1 + \vec{B}_2 = \frac{\mu_0 I_1}{2\pi r_1}\hat{k} - \frac{\mu_0 I_2}{2\pi r_2}\hat{\jmath}$

$= -(4 \times 10^{-6} \text{ T})\hat{\jmath} + (1 \times 10^{-5} \text{ T})\hat{k}$

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

1. Two point charges $q_1$ and $q_2$ of the same magnitude are located on the $x$-axis. The net electric field $\vec{E}$ at point $P$ is shown on the figure. Which statement is correct?

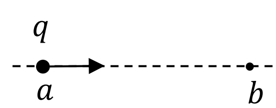



a) $q_1 > 0$ and $q_2 < 0$.
b) $q_1 > 0$ and $q_2 > 0$.
c) $q_1 < 0$ and $q_2 < 0$.
**d) $q_1 < 0$ and $q_2 > 0$.**

2. A point charge $q$ is placed inside the cavity of a charged conductor. The charge on the inner and outer surfaces of the conductor is $Q_{in}$ and $Q_{out}$, respectively. The electric field at a point outside the conductor is given by

a) $\vec{E} = k\frac{q+Q_{in}}{r^2}\hat{r}$.
b) $\vec{E} = k\frac{q+Q_{out}}{r^2}\hat{r}$.
c) $\vec{E} = k\frac{q}{r^2}\hat{r}$
**d) $\vec{E} = k\frac{Q_{out}}{r^2}\hat{r}$.**

3. A point charge $q$ that is released from rest at point $a$ moves to point $b$. The change in the electric potential energy of the point charge

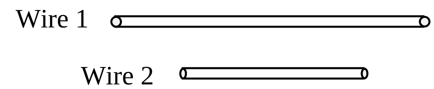



**a) is negative.**
b) is positive.
c) is zero.
d) can be any of the above.

4. An air-filled parallel-plate capacitor is charged and then disconnected from the battery. If the plate separation of this capacitor is increased now,

a) the capacitor voltage decreases.
b) the capacitor voltage remains constant.
c) the energy stored in the capacitor remains constant.
**d) the energy stored in the capacitor increases.**

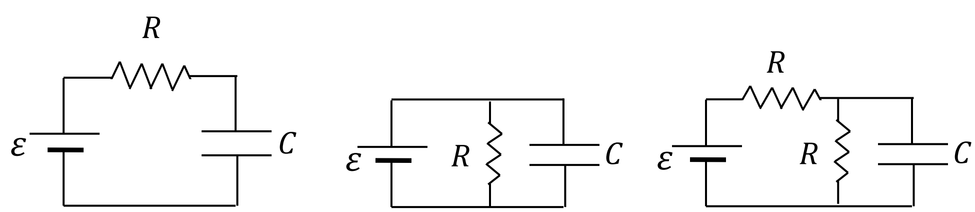
5. Two wires are made of the same material and have equal diameters, but different lengths as shown. If the same potential difference is applied across each wire, the power dissipation




a) is greater in wire 1.
**b) is greater in wire 2.**
c) is the same in the two wires.
d) does not depend on the potential difference.

6. If $Q_A$, $Q_B$ and $Q_C$ are the final charges on capacitors in circuits A, B and C respectively, which statement is correct

a) $Q_A < Q_B < Q_C$.
**b) $\boldsymbol{Q_C < Q_A = Q_B}$.**
c) $Q_C > Q_A = Q_B$.
d) $Q_A = Q_B = Q_C$.

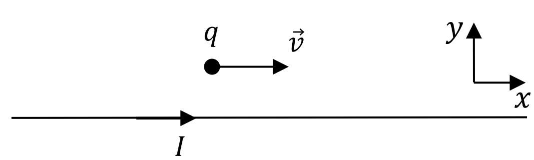



(A) (B) (C)

7. Two charged particles enter a uniform magnetic field. One particle goes on a circular motion and the other on a helical motion. The work done by the magnetic field on these particles

a) is zero only in circular motion.
b) is zero only in helical motion.
**c) is zero in both motions.**
d) is not zero in circular or helical motion.

8. A long straight wire carries a current $I$ and a positively charged particle $q$ is launched parallel to the wire as shown. The direction of the magnetic force acting on the particle at this moment is




a) $\hat{k}$.
**b) $-\hat{\boldsymbol{j}}$.**
c) $-\hat{\imath}$.
d) $\hat{\jmath}$.