Kuwait University **Physics Department**

General Physics II **PHY 102**

جامعة الكويت
KUWAIT UNIVERSITY

Final Examination
Fall Semester 2024 – 2025

December 29, 2024
Time: 2:00 – 4:00 PM

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

Instructors: Drs. Abdulla, Almumin, Lajko, Sharma, and Vagenas

---

Fundamental constants

$k = \dfrac{1}{4\pi\varepsilon_o} = 9.0\times10^9\ N.m^2/C^2$	(Coulomb constant)
$\varepsilon_o = 8.85\times10^{-12}\ C^2/(N\cdot m^2)$	(Permittivity of free space)
$\mu_0 = 4\pi\times10^{-7}\ T.m/A$	(Permeability of free space)
$\lvert e\rvert = 1.60\times10^{-19}\ C$	(Elementary unit of charge)
$N_A = 6.02\times10^{23}$	(Avogadro's number)
$g = 9.8\ m/s^2$	(Acceleration due to gravity)
$m_e = 9.11\times10^{-31}\ kg$	(Electron mass)
$m_p = 1.67\times10^{-27}\ kg$	(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

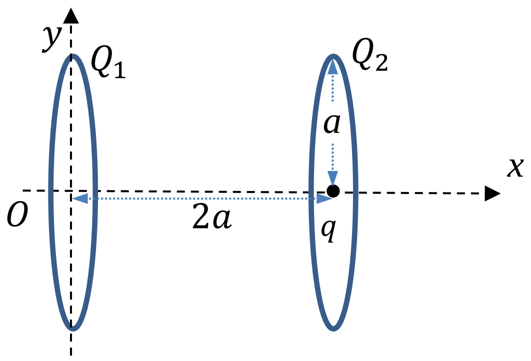
Problems	1	2	3	4	5	6	7	8	9	10	**Questions**	**Total**
Marks												

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. Two rings of identical radii, a, have charges $Q_1 = -4\ \mu\text{C}$ and $Q_2 = 4\ \mu C$, as shown, uniformly distributed along them. A point charge $q = 6\ \mu\text{C}$ is placed at the center point of the second ring. If $a = 0.4$ m, determine the net electric force vector $\vec{F}$ acting on q. **[3 points]**

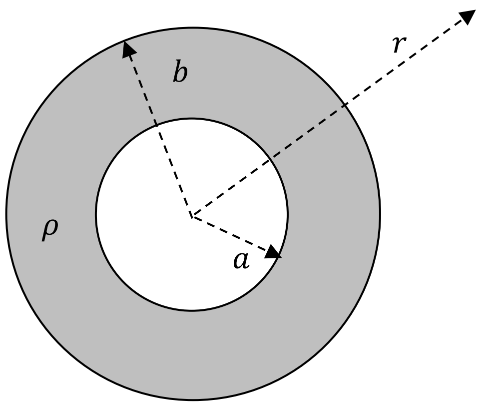


$\vec{E}_{\text{ring}_1} = k\frac{|Q_1|2a}{((2a)^2+a^2)^{3/2}}(-\hat{\imath})$
$= -\frac{9\times10^9\times4.0\times10^{-6}\times0.8}{(0.8^2+0.40^2)^{3/2}}\hat{\imath}$ N/C
$= -4.0\times10^4\hat{\imath}$ N/C

$\vec{F} = q\vec{E}_1 = 6.0\times10^{-6}\times(-4.0)\times10^4\,\hat{\imath}$ N
$= -0.24\,\hat{\imath}$ N

2. A spherical shell of inner radius $a = 8$ cm and outer radius $b = 16$ cm has uniform volume charge density $\rho = 300$ nC/m^3. Determine the magnitude and direction of the net electric field at a radial distance 24 cm from the center. **[3 points]**

Gauss's Law:
$\oint \vec{E}\cdot d\vec{A} = \frac{Q_{enc}}{\varepsilon_0}$
$E(4\pi r^2) = \frac{Q_{enc}}{\varepsilon_0}$
$Q_{encl} = \rho\left(\frac{4}{3}\pi(b^3 - a^3)\right) = 4.5\ nC$
$E = \frac{Q_{enc}}{4\pi r^2\varepsilon_0} = 703.7$ N/C, outward



3. A thin spherical shell of radius $R = 0.5$ m has uniform surface charge density $\sigma = 90$ nC/m^2. Calculate the electric potential difference, $V_A - V_B$, between points A and B. Given $r_A = 0.25$ m and $r_B = 1.5$ m.

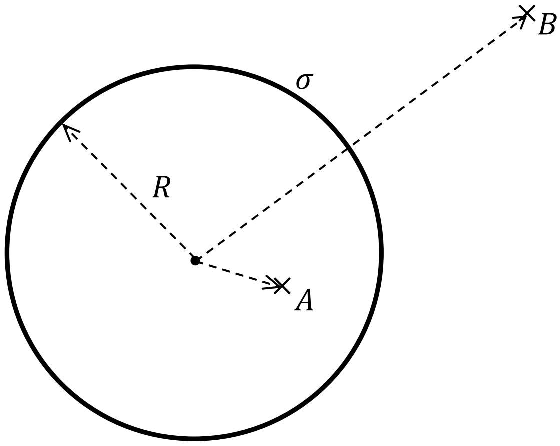
[4 points]

$Q = \sigma 4\pi R^2 = 283$ nC

$V_A = \frac{kQ}{R} = k\sigma 4\pi R = 5089.4$ V

$V_B = \frac{kQ}{r_B} = 1696.5$ V

$V_A - V_B = 3393\ V$



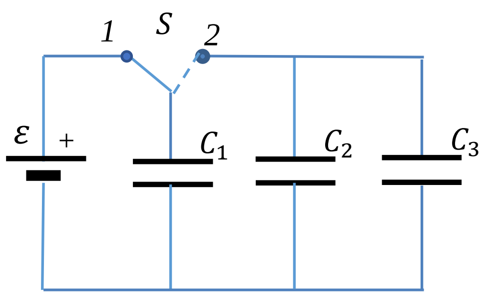
4. A capacitor, C_1= 20 µF, is charged by a battery, as shown. Then, the switch is moved to position 2 so that capacitor C_1 is connected to the uncharged capacitors $C_2 = C_3 = 10$ µF, as shown. If the final energy stored in C_3 is $U_3^{fin} = 45$ µJ, determine the value of ε .

[4 points]

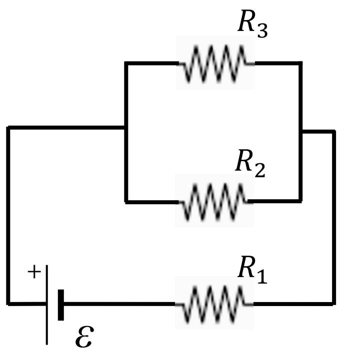
$U_2^{fin} = \frac{C_3 V^2}{2} = 45\ \mu J \Rightarrow V = 3\ V$

$Q_0 = Q_{fin} = (C_1 + C_2 + C_3)V = 120\ \mu C$

so $V = \frac{Q_0}{C_1+C_2+C_3} = \frac{C_1 \varepsilon}{C_1+C_2+C_3} \Rightarrow \varepsilon = 6\ V$



5. When an ideal emf is connected to a network of resistors, as shown, the power dissipated in R_2 is 32 W. If $R_1 = R_2 = R_3 = 8\ \Omega$, determine the value of $\mathcal{E}$. **[4 points]**

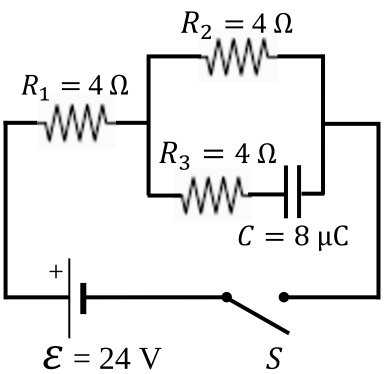


$P = I_2^2 R_2 = 32\ W \Rightarrow I_2 = 2$ A

From Junction rule: $I_1 = I_2 + I_3 = 4$ A

Loop rule: $\mathcal{E} = I_1 R_1 + I_2 R_2 = 48$ V

6. In the circuit shown below, the capacitor is initially uncharged and the switch, S, is closed at $t = 0$. What is the current in the emf device a long time after the switch, S, is closed? **[3 points]**

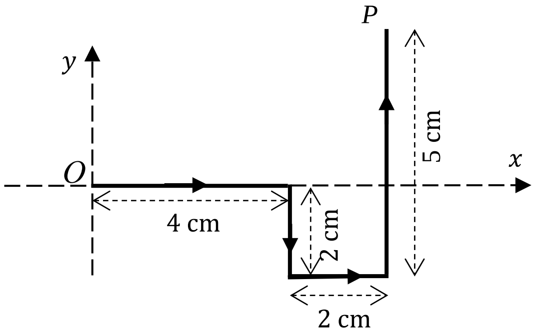


A long time after the switch is closed, the capacitor represents a cut, so no current through it.

$\Rightarrow R_{eq} = R_1 + R_2 = 8\ \Omega$

Loop rule: $I_1 = \frac{\varepsilon}{R_{eq}} = 3$ A

7. A wire carries a current of $I = 12.0$ A from point O (origin) to point P, as shown. Calculate the magnetic force vector, $\vec{F}$, acting on the wire due to a uniform magnetic field $\vec{B} = (-4.0\ T)\hat{k}$. [**3 points**]



$\vec{L}_{eff} = (\Delta x)\hat{\imath} + (\Delta y)\hat{\jmath} = (0.06\text{ m})\hat{\imath} + (-0.02\text{ m} + 0.05\text{m})\hat{\jmath}$

$\vec{F} = I\vec{L}_{eff} \times \vec{B} = 12.0\text{ A}[(0.06\text{ m})\hat{\imath} + (0.03\text{ m})\hat{\jmath}] \times [(-4.0\text{ T})\hat{k}]$

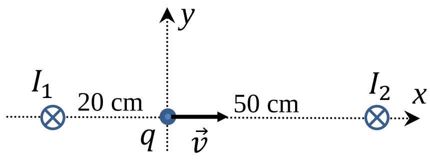
$\vec{F} = [-(1.44\text{ N})\hat{\imath} + (2.88\text{ N})\hat{\jmath}]$

8. A proton moves momentarily with a velocity of $\vec{v} = (3 \times 10^6\,\frac{\text{m}}{\text{s}})\hat{\imath} + (2 \times 10^6\,\frac{\text{m}}{\text{s}})\hat{\jmath}$ in a region of uniform magnetic field $\vec{B} = (2\ T)\hat{\jmath}$. Find the radius and pitch of the helical path of the proton. **[4 points]**

$$v_\perp = 3 \times 10^6\,\frac{\text{m}}{\text{s}}$$
$$v_\parallel = 2 \times 10^6\,\frac{\text{m}}{\text{s}}$$
$$R = \frac{mv_\perp}{|q|B} = 0.016\ \text{m}$$
$$P = v_\parallel T = v_\parallel \frac{2\pi m}{|q|B} = 0.066\ \text{m}$$

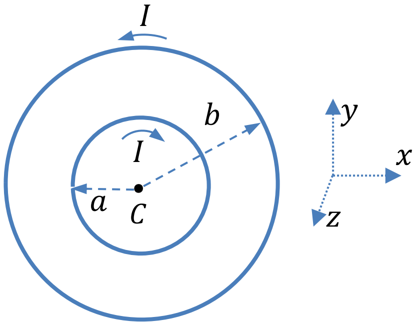
9. Two very long wires are perpendicular to the xy-plane. The wires carry a current of $I_1 = I_2 = 10$ A, as shown. Calculate the magnetic force vector, $\vec{F}$, acting on charge $q = 4$ μC of velocity $\vec{v} = \left(4\ \frac{\text{m}}{\text{s}}\right)\hat{\imath}$.

[4 points]



$$\vec{B}_1 = -\frac{\mu_0 I_1}{2\pi 0.2\text{m}}\hat{\jmath} = -(1.0 \times 10^{-5}\text{T})\hat{\jmath}$$
$$\vec{B}_2 = \frac{\mu_0 I_2}{2\pi 0.5\text{m}}\hat{\jmath} = (4.0 \times 10^{-6}\text{T})\hat{\jmath} \Rightarrow$$
$$\vec{B}_{net} = -(6 \times 10^{-6}\text{T})\hat{\jmath}$$
$$\vec{F} = q\vec{v} \times \vec{B}_{net} = -4\ \mu\text{C}\left(4\ \frac{\text{m}}{\text{s}}\right)\hat{\imath} \times (6 \times 10^{-6}\text{T})\hat{\jmath} = -(9.6 \times 10^{-11}\ \text{N})\hat{k}$$

10. Two concentric circular loops of radii, $a = 0.2$ m, $b = 0.5$ m, carry identical currents of $I = 5$ A, as shown. Calculate the magnitude and direction of magnetic field at the center point, C, of the loops. **[3 points]**

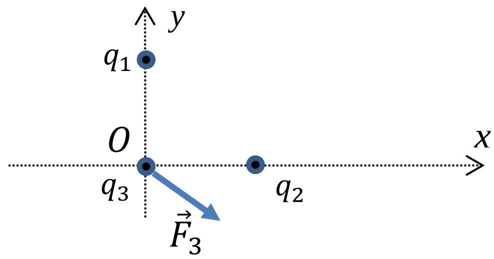


$$\vec{B}_a = -\left(\frac{\mu_0 I}{2a}\right)\hat{k} = -(1.57 \times 10^{-5}\text{T})\hat{k}$$
$$\vec{B}_b = \left(\frac{\mu_0 I}{2b}\right)\hat{k} = (6.3 \times 10^{-6}\text{T})\hat{k}$$
$$\vec{B}_{net} = \vec{B}_a + \vec{B}_b = -(9.4 \times 10^{-6}\text{T})\hat{k}$$

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

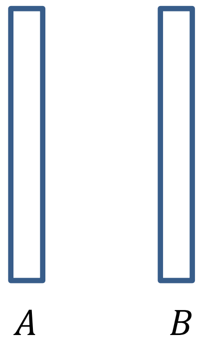
1. Three point charges $q_1, q_2,$ and q_3, are placed on the xy-plane. The net electric force $\vec{F}_3$, acting on charge q_3 is shown. If $q_3 < 0$, which statement can be correct for the charges?

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 $q_2 < 0$.



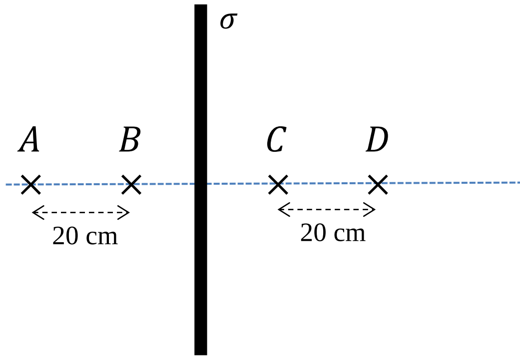
2. Two very large parallel conducting plates A, and B carry opposite charges $+Q$ and $-Q$. Which statement is correct for the location of the charges? The charges are

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.



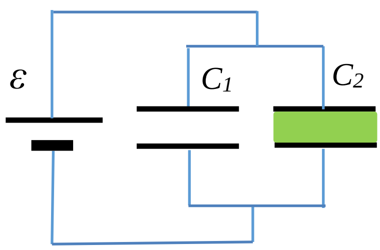
3. A large uniformly charged sheet has a uniform surface charge density $\sigma > 0$. Which relation is correct for the electric potential at point $A, B, C,$ and D?

a) $V_A - V_B = V_C - V_D$.
b) $V_A - V_B = V_B - V_C$.
c) $V_A - V_B = V_D - V_C$.
d) $V_A - V_C = V_C - V_D$.



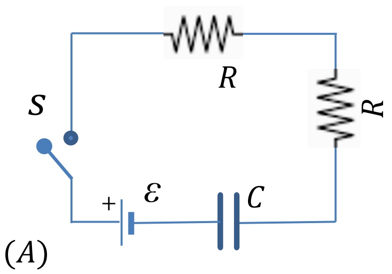
4. Two identical parallel-plate capacitors $C_1 = C_2$ are connected to a battery, and then capacitor C_2 is filled with a dielectric material of $K = 2$. If the energy density in the capacitors C_1, and C_2 are u_1, and u_2, respectively, which relation is correct?

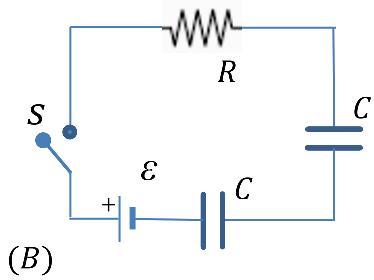
a) $u_1 = u_2$.
b) $u_1 = 2u_2$.
c) $4u_1 = u_2$.
d) $2u_1 = u_2$.



5. Two *R*-*C* circuits are shown. If the time constant in circuit A is τ_A, and the time constant in circuit B is τ_B,

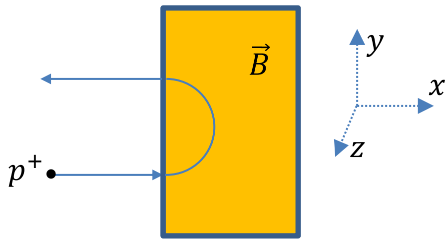
a) $\tau_A = \tau_B$.
b) $\tau_A = 2\tau_B$.
c) $\tau_A = 4\tau_B$.
d) $2\tau_A = \tau_B$.





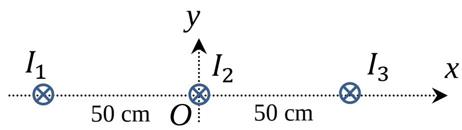
6. A proton enters and leaves a rectangular region of uniform magnetic field on a semicircular path, as shown. The direction of the magnetic field is

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



7. Three very long parallel wires are carrying identical currents $I_1 = I_2 = I_3$, as shown. If the magnitude of the net magnetic force acting on them are $F_1, F_2,$ and F_3, respectively, which statement is correct?

a) $F_1 = F_3$.
b) $F_2 = F_3$.
c) $F_1 = F_2$.
d) $F_1 = F_2 = F_3$.



8. The figure shows a closed curve, C, its orientation and currents I_1, I_2 which are perpendicular to the plane of the curve, as shown. If the value of the curve integral on C is $\oint \vec{B} \cdot d\vec{l} = \mu_0 I$, which relation is correct for the magnitudes of the currents, I_1, I_2?

a) $I_1 = I,\ I_2 = I$.
b) $I_1 = I,\ I_2 = 2I$.
c) $I_1 = 2I,\ I_2 = I$.
d) $I_1 = 2I,\ I_2 = 2I$.