Kuwait University — Physics Department

General Physics II — PHY 102

جامعة الكويت
KUWAIT UNIVERSITY

Second Midterm Examination
Fall Semester 2022 – 2023

December 10, 2022
Time: 11:00 AM – 12:30 PM

Name: …… Student No: ……

Section No: …… Serial No: ……

Instructors: Drs. Alfrousheh, Al-Failakawi, Farhan, Lajko, 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

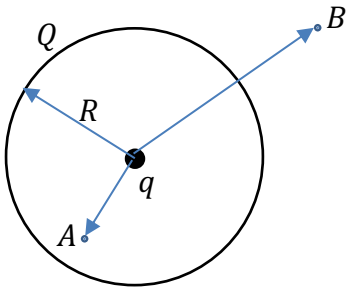
Problems	1	2	3	4	5	6	7	8	**Questions**	**Total**
Marks										

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. A thin conducting spherical shell with radius R = 9 cm is uniformly charged with charge Q. A point charge $q = -3$ nC is placed at the center of the spherical shell as shown. If the potential is zero at infinity, the potential at point A, $r_A = 7$ cm, is $V_A = 400$ V. Find the potential at point B, $r_B = 13$ cm. **[4 points]**



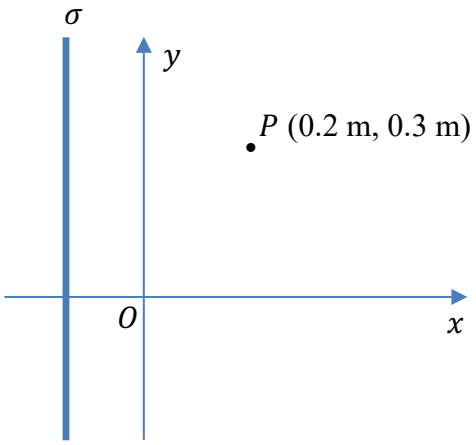
$V_A = V_q + V_Q = k\frac{q}{0.07} + k\frac{Q}{0.09}$

$Q = 7.86$ nC

$V_B = V_q + V_Q = k\frac{q}{0.13} + k\frac{Q}{0.13}$

$V_B = 336.5$ V

2. An infinite sheet of uniform surface charge density σ is placed perpendicular to the x-axis, as shown below. If the potential difference between the origin O of the axes and point P is 18 V, find the surface charge density σ of the infinite sheet. **[5 points]**



$V_0 - V_P = \int \vec{E} \cdot d\vec{l}$

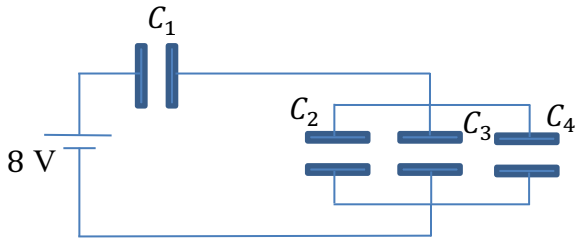
$\vec{E} = \frac{\sigma}{2\varepsilon_0}\hat{\imath}$

$V_0 - V_P = \int [\frac{\sigma}{2\varepsilon_0}\hat{\imath}\,] \cdot d\vec{l}$

$18 = \frac{\sigma}{2\varepsilon_0}(0.2 - 0)$

$\sigma = 1.60$ nC/m^2

3. A network of four capacitors with identical capacitance, $C_1 = C_2 = C_3 = C_4 = 9$ nF, are connected in a circuit as shown. Calculate the electric charge on capacitor C_3. **[4 points]**



C_2, C_3, C_4 are in parallel

$C_{234} = C_2 + C_3 + C_4 = 27$ nF

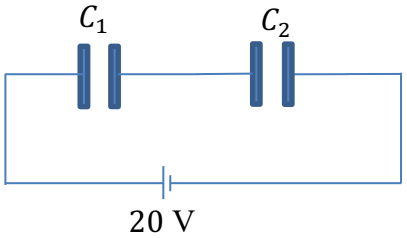
C_{234}, C_1 are in series

$C_{eq} = \frac{C_1 \times C_{234}}{C_1 + C_{234}} \Longrightarrow C_{eq} = 6.75$ nF

$Q = C_{eq}\, V \Longrightarrow Q = 54$ nC

$Q_3 = \frac{Q}{3} \Longrightarrow Q_3 = 18$ nC

4. Two identical capacitors with capacitances $C_1 = C_2$, are connected to a 20 V battery, as shown in the figure, with charge $Q_0 = 30$ nC. Then, while the capacitors remain connected to the battery, a dielectric slab with constant $K = 2$ fully fills the space between the plates of one of the capacitors. Calculate the charge on C_1 after inserting the dielectric material. **[4 points]**



C_1 and C_2 are in series:

$C_{12} = \frac{C_1 C_2}{C_1 + C_2} = \frac{C_1}{2}$

$Q_0 = C_{12}\, V = \frac{C_1}{2} V \Rightarrow C_1 = 3$ nF

After the dielectric is inserted in C_2:

$C'_{12} = \frac{C_1 C'_2}{C_1 + C'_2} = \frac{C_1(2C_2)}{C_1 + 2C_2} = \frac{2}{3} C_1 = 2$ nF

$Q'_0 = C'_{12}\, V = 40$ nC

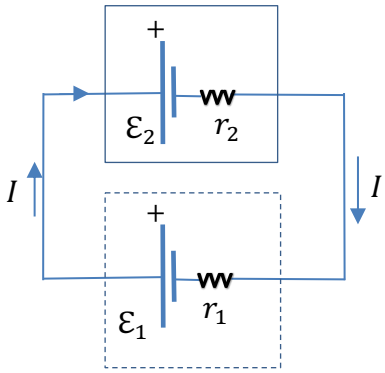
5. An electric current in a wire varies with time as $I(t) = 28.8 \times 10^{-3} \sin(12t)$ with current $I(t)$ in ampere and time t in seconds. Calculate the electric charge that passes through a given crossection of the wire between time $t = 0$ and $t = \frac{\pi}{4}$ s. **[3 Points]**

$I(t) = \frac{dQ}{dt} \Longrightarrow dQ = I(t)dt \Longrightarrow Q = \int_0^{\frac{\pi}{4}} I(t)dt$

$Q = 28.8 \times 10^{-3} \int_0^{\frac{\pi}{4}} sin(12t)dt = \frac{28.8\times10^{-3}}{12}\left[-\cos\left(12\frac{\pi}{4}\right) + \cos(0)\right]$

$Q = 4.8 \times 10^{-3}$ C

6. In the circuit shown, two batteries are connected as shown. Battery 1 has emf $\mathcal{E}_1 = 15$ V and internal resistance $r_1 = 1.0\ \Omega$, and battery 2 has emf $\mathcal{E}_2$ and internal resistance $r_2 = 1.5\ \Omega$. The power dissipated on the internal resistance r_1 is 4 W. Find the emf $\mathcal{E}_2$. **[4 Points]**



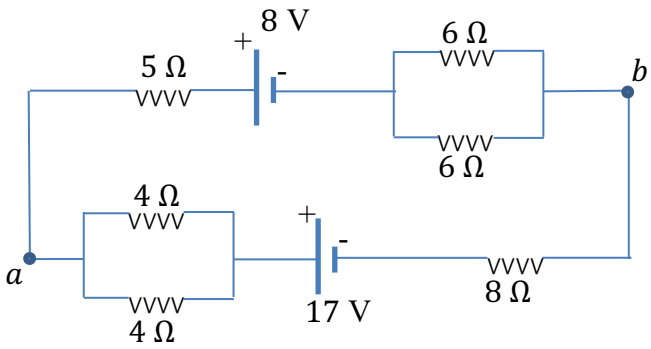
$P_{r_1} = I^2 r_1 \Rightarrow I = \sqrt{\frac{P_{r_1}}{r_1}}$

$I = 2$ A

$\mathcal{E}_1 - \mathcal{E}_2 - Ir_1 - Ir_2 = 0$

$\mathcal{E}_2 = 10$ V

7. In the circuit shown, calculate the potential difference V_{ab} **[5 Points]**



$$R_{up} = \frac{6\times6}{6+6}\Omega = 3\ \Omega$$

$$R_{down} = \frac{4\times4}{4+4}\Omega = 2\ \Omega$$

Loop rule

$$17 - 2I - 5I - 8 - 3I - 8I = 0$$

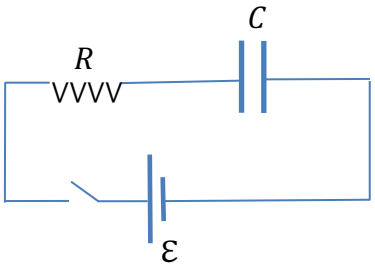
$$I = 0.5\ \text{A}$$

$$V_a - 5\times0.5 - 8 - 3\times0.5 = V_b$$

$$V_a - V_b = 5\times0.5 + 8 + 3\times0.5$$

$$V_{ab} = 12\ \text{V}$$

8. In the RC circuit shown below, the time constant is $\tau = 1$ ms. At time $t = 0$ s, when the switch is closed, the electric current is 3 mA. Find the electric charge at time $t = 2$ ms. **[3 Points]**



$$I_0 = \frac{\mathcal{E}}{R} \Longrightarrow \mathcal{E} = I_0 R$$

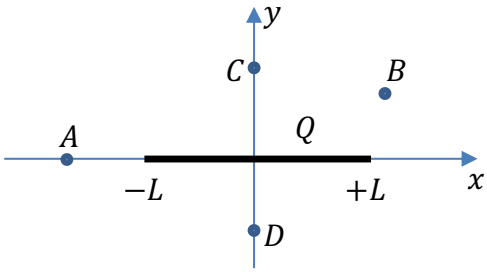
$$q(t) = \mathcal{E}C\left[1 - e^{-\frac{t}{RC}}\right]$$

$$q(t) = I_0 RC\left[1 - e^{-\frac{t}{RC}}\right] = I_0\tau\left[1 - e^{-\frac{t}{\tau}}\right]$$

$$q(t) = 2.59\ \mu\text{C}$$

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

1. A uniformly charged rod of length $2L$ and charge $Q > 0$ lies on the x-axis as shown. If the potential is zero at infinity, which statement is correct?



a) The electric potential at point A is negative.
b) The electric potential at point B is positive.
c) The electric potential at point C is negative.
d) The electric potential at point C and D is zero.

2. For the equipotential surfaces (EPSs), which statement is correct?

a) The EPSs of a point charge are infinite planes
b) The EPSs of a point charge are infinite lines.
c) The EPSs of a point charge are concentric spheres with the point charge at the center.
d) The EPSs of a point charge are of cubic shape.

3. A capacitor is charged by a battery. After disconnecting the battery, the space between the two conductors of the capacitor is fully filled with a dielectric material. The energy stored in the capacitor will

a) increase.
b) decrease.
c) remain the same.
d) increase and later decrease.

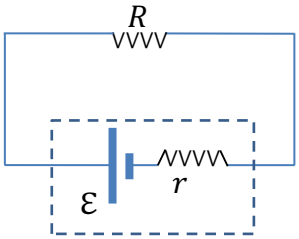
4. For a network of three identical capacitors $C_1 = C_2 = C_3$, which statement is correct?

a) **If all three are connected in series, the equivalent capacitance has its minimum value.**
b) If all three are connected in series, the equivalent capacitance has its maximum value.
c) If all three are connected in parallel, the equivalent capacitance has its minimum value.
d) If two are in parallel and then in series with the third one, the equivalent capacitance is zero.

5. If the potential difference across a conducting wire is increased, then

a) the current density will increase, and the drift speed will decrease.
b) the current density will remain the same and the drift speed will increase.
c) **the current density will increase, and the drift speed will increase.**
d) the current density will increase, and the drift speed will remain the same.

6. In the electric circuit below, if the resistance R is increased, then

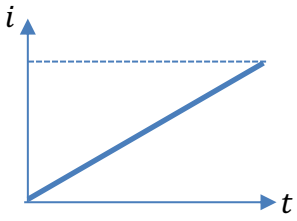


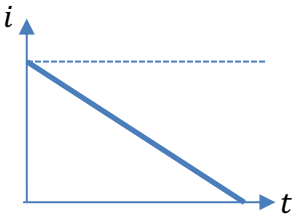
a) the terminal voltage of the battery will increase.
b) the terminal voltage of the battery will remain the same.
c) the power dissipated in the internal resistance will increase.
d) the power output of the battery will remain the same.

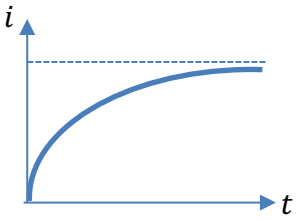
7. The Kirchhoff junction rule is a consequence of

a) the conservation of linear momentum.
b) the conservation of electric charge.
c) the conservation of angular momentum.
d) the conservation of electric energy.

8. In a charging RC circuit, which diagram gives the electric current as a function of time

a) 

c) 

b) 

d)