Kuwait University — **Physics Department**

General Physics II — **PHY 102**

جامعة الكويت
KUWAIT UNIVERSITY

Second Midterm Examination
Summer Semester 2022 – 2023

July 15, 2023
Time: 12:00 – 1:30 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)
$\varepsilon_o = 8.85 \times 10^{-12}\ \text{C}^2/(\text{N}\cdot\text{m}^2)$	(Permittivity of free space)
$\mu_0 = 4\pi \times 10^{-7}$ T .m/A	(Permeability of free space)
$\lvert e \rvert = 1.60 \times 10^{-19}$ C	(Elementary unit of charge)
$N_A = 6.02 \times 10^{23}$	(Avogadro's number)
$g = 9.8$ 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

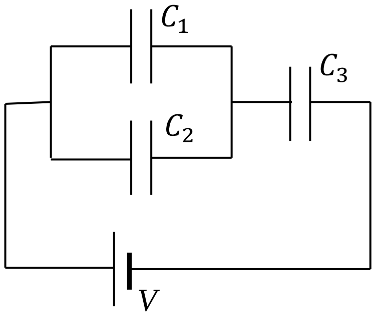
Problems	1	2	3	4	5	6	7	8	**Questions**	**Total**
Marks										

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 capacitors are connected to a potential difference as shown. If $C_1 = 3$ μF, $C_2 = 3$ μF, $C_3 = 4$ μF, and the energy stored in C_3 is $U_3 = 8$ μJ, what is the potential difference V? **[5 points]**



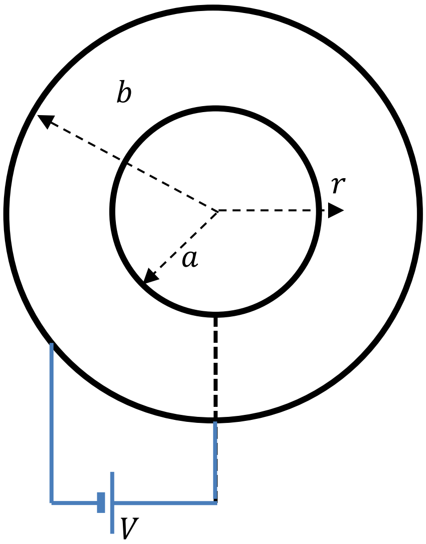
$$C_{12} = C_1 + C_2 = 3\text{ μF} + 3\text{ μF}$$

$$C_{eq} = \frac{C_3 . C_{12}}{C_3 + C_{12}} = \frac{4\text{ μF} \times 6\text{ μF}}{(4+6)\text{ μF}} = 2.4\text{ μF}$$

$$Q = Q_3 = \sqrt{2U_3C_3} = 8\text{ μC}$$

$$V = \frac{Q}{C_{eq}} = 3.33\text{ V}$$

2. An air-filled spherical capacitor has inner radius $a = 4$ cm, outer radius $b = 8$ cm, and a potential difference of $V = 1200$ V is connected between its plates. Determine the energy density u_E at a distance $r = 5$ cm from its center. **[4 points]**

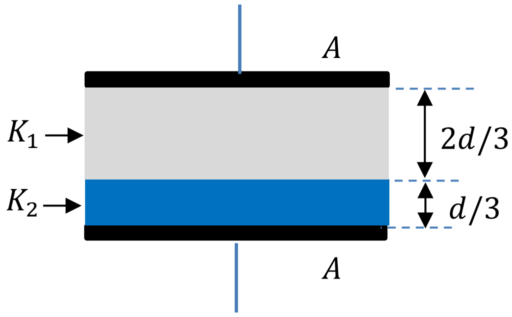


$$Q = CV = \frac{4\pi\varepsilon_0 ab}{b-a}V = 10.7\text{ nC}$$

$$E = \frac{kQ}{r^2} = 3.8 \times 10^4\text{ N/C}$$

$$u_E = \frac{\varepsilon_0}{2}E^2 = 6.4 \times 10^{-3}\text{ J/m}^3$$

3. An air-filled parallel-plate capacitor with surface area A and plate separation d has capacitance $C_0 = 60$ μF. If the capacitor is filled with two dielectric materials with dielectric constants $K_1 = 6$ and $K_2 = 4$, as shown, calculate its capacitance. **[4 points]**



$$C_0 = \varepsilon_0 \frac{A}{d}$$

$$C_1 = K_1\varepsilon_0 \frac{A}{2d/3} = 3K_1\varepsilon_0 \frac{A}{2d} = 9C_0$$

$$C_2 = K_2\varepsilon_0 \frac{A}{d/3} = 3K_2\varepsilon_0 \frac{A}{d} = 12C_0$$

$$C = \frac{C_1C_2}{C_1+C_2} = 308.6\ \mu\text{F}$$

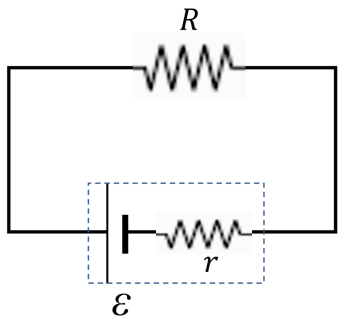
4. Cylindrical wires A and B are made of copper. Wire A has length L and radius r and wire B has length $2L$ and radius $2r$. When wire A is connected between a potential difference V, the power dissipation on it is $P_A = 24$ W. If wire B is connected between the same potential difference V, calculate the power dissipation, P_B, on wire B. **[4 points]**

$$R_A = \frac{\rho L}{\pi r^2};\ \ R_B = \frac{\rho 2L}{\pi(2r)^2} = R_A/2$$

$$P_A = \frac{V^2}{R_A}$$

$$P_B = \frac{V^2}{R_B} = \frac{V^2}{R_A/2} = 48\ \text{W}$$

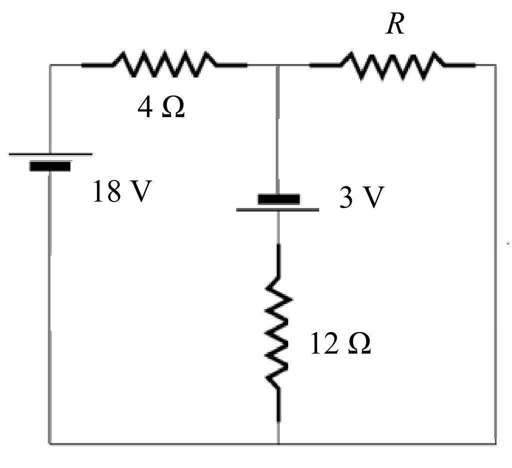
5. In the circuit shown below, $\varepsilon = 16.0$ V, $R = 7.6\ \Omega$ and the power dissipated on the external resistor R is $P_R = 30.4$ W. Find the power dissipated on the internal resistance r of the battery. **[3 points]**



$$P_R = I^2 R \Longrightarrow \quad I = 2A = \frac{\varepsilon}{r+R} \Longrightarrow \quad r = 0.4\ \Omega$$

$$P_r = I^2 r = 1.6\ \text{W}$$

6. In the circuit shown, the current through resistor R is 0.4 A. Calculate the power dissipation on the resistor R. **[5 points]**



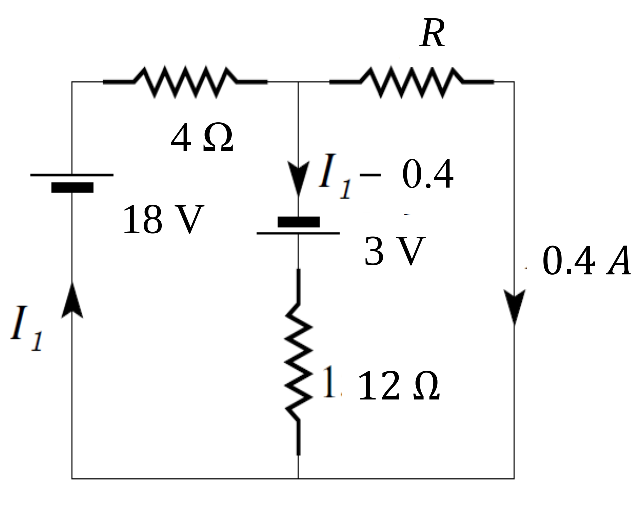
Junction rule: $I_1 = I_2 + 0.4\ \text{A} \Rightarrow I_2 = I_1 - 0.4\ \text{A}$

Loop rule (clockwise) for the left loop:
$18\text{V} - 4\Omega I_1 + 3\text{V} - 12\Omega(I_1 - 0.4\ \text{A}\,) = 0 \Rightarrow I_1 = 1.6\ \text{A}$

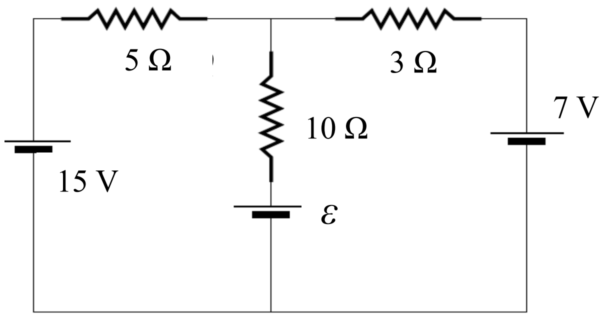
Loop rule (clockwise) for the big loop gives
$18\text{V} - 4\ \Omega I_1 - 0.4\text{A}R = 0 \rightarrow R = 29\ \Omega$

$P = RI^2 = (29\ \Omega) \times (0.4\ \text{A})^2 = 4.64\ \text{W}$

Figure for the solution:



7. The current is zero through the unknown *emf* source ε in the circuit shown. Calculate the value ε of the *emf* source. **[4 points]**



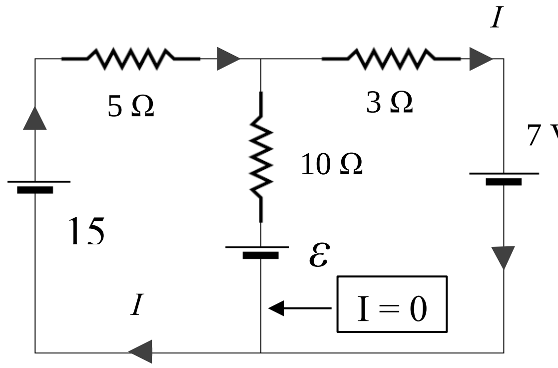
Loop rule for the outer loops (clockwise) gives:

$$15 - 5\,I - 3\,I - 7 = 0 \Rightarrow$$
$$-8\,I = -15 + 7 \rightarrow I = 1\text{ A}$$

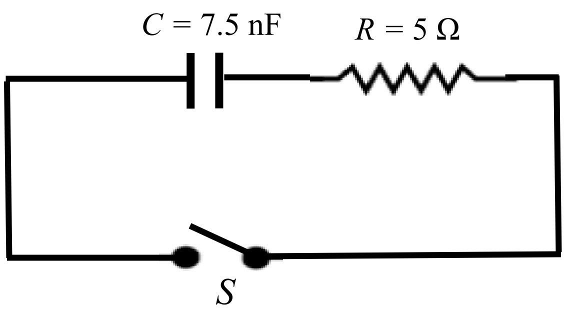
Loop rule for the left loop (clockwise) gives:

$$15 - 5\,I - \varepsilon = 0$$
$$\varepsilon = 15 - 5\,I = 10\text{ V}$$

Figure for the solution:



8. In the circuit below, the initial charge of the capacitor is $Q_0 = 65$ nC. If the switch is closed at time $t = 0$ s, calculate the power dissipated in the resistor at time $t = 1.8\,\tau$. **[3 points]**



$$V = \frac{Q}{C} \text{ and } q(t) = Q_0 e^{-\frac{t}{RC}} \rightarrow V = \frac{Q_0}{C} e^{-\frac{t}{RC}}$$

$$P = \frac{V^2}{R} = \frac{Q_0^2}{RC^2}\, e^{-\frac{2t}{RC}}$$

$$t = 1.8\,RC \rightarrow P = \frac{Q_0^2}{RC^2}\, e^{-3.6}$$

$$P = 0.41\text{ W}$$

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

1. An air-filled parallel-plate capacitor with plate separation d is charged by a potential difference V. While the potential difference remains connected, the plate separation is decreased to $d/2$. So, the energy stored on the capacitor

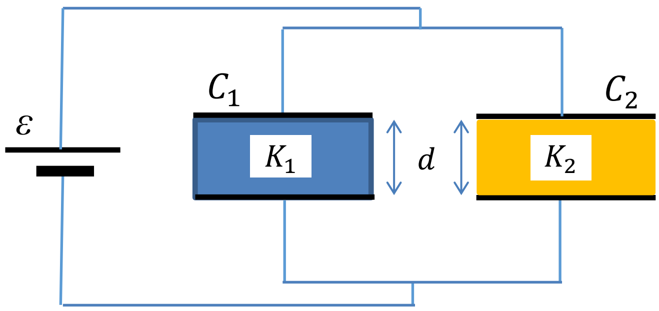
   a) does not change.
   b) becomes double.
   c) becomes half.
   d) becomes zero.

2. An air-filled spherical capacitor of capacitance C has inner radius a and outer radius b. A second spherical capacitor has inner radius $2a$ and outer radius $2b$ and fully filled with a dielectric material of $K = 2$. The second spherical capacitor has capacitance

   a) C.
   b) $2C$.
   c) $3C$.
   d) $4C$.

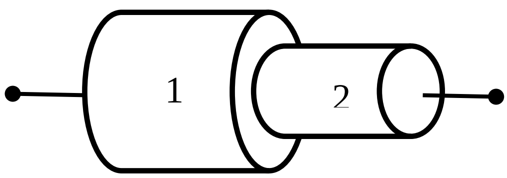
3. Two parallel-plate capacitors C_1 and C_2, of identical separation d, are filled with materials of dielectric constant K_1 and K_2, respectively, and are connected to potential source as shown. The magnitude of electric field is E_1 in C_1, and it is E_2 in C_2. Which relation is true for the electric fields?

   a) $\frac{E_1}{E_2} = \frac{K_1}{K_2}$.
   b) $\frac{E_1}{E_2} = \frac{K_2}{K_1}$.
   c) $\frac{E_1}{E_2} = 1$.
   d) $\frac{E_1}{E_2} = \left(\frac{K_1}{K_2}\right)^2$.

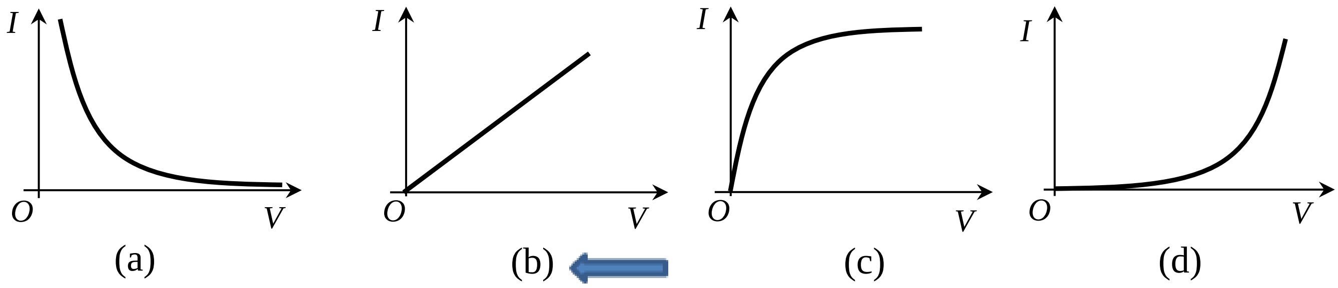


4. A potential difference is applied across the two ends of a conductor made of two cylinders of the same material with radii $r_1 = 2r_2$. If the magnitude of electric field is E_1 in wire 1, and it is E_2 in wire 2, which relation is correct?

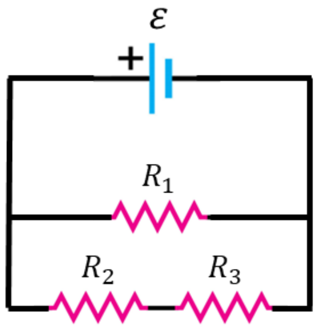
   a) $E_1 = E_2/2$.
   b) $E_1 = E_2/4$.
   c) $E_1 = 2E_2$.
   d) $E_1 = 4E_2$.



5. Which of the following figures does illustrate the electric current *I* in a resistor as a function of the potential difference *V*?



6. In the circuit shown, $R_1 = R_2 = R_3$. Which of the statements below is correct for the currents in the resistors?



a) $I_1 = I_2 = I_3$.

b) $I_1 > I_2 > I_3$.

c) $I_1 < I_2 < I_3$.

d) $I_1 > I_2 = I_3$.

7. To simultaneously measure the current in and the voltage across the resistor in a circuit, we must connect

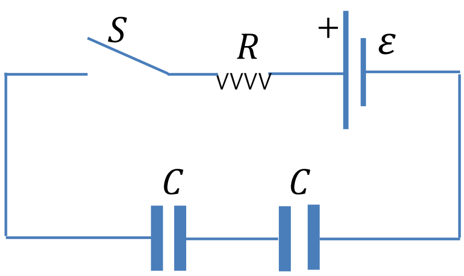
a) ammeter and voltmeter in series connection with the resistor.

b) ammeter in series and voltmeter in parallel connection with the resistor.

c) ammeter and voltmeter in parallel connection with the resistor.

d) ammeter in parallel and voltmeter in series connection with the resistor.

8. In the *R*-*C* circuit below, the switch is closed at time $t = 0$ s. After waiting a long time, the electric charge on each capacitor is



a) $Q = \varepsilon C$.

b) $Q = 2\varepsilon C$.

c) $Q = \varepsilon C/2$.

d) $Q = \varepsilon C[1 - e^{-t/RC}]$.