Kuwait University — Physics Department

Physics 102
Second Midterm Examination

Fall Semester (2009 - 2010)
December 19, 2009

Time: 3:00 – 5:00 PM

Name……………………………………..Student No……………………….

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(Fundamental constants)

$k = \frac{1}{4\pi\varepsilon_o} = 9.0\times10^9\ N.m^2/C^2$	(Coulomb constant)
$\varepsilon_o = 8.85 \times 10^{-12}\ C^2/(N \cdot m^2)$	(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

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

For use by Instructors only

Prob.	1	2	3	4	5	6	7	8	Total
Marks									

Ques.	1	2	3	4	5	6	7	8	Total
Marks									

PART I: Solve the following problems. Show your solutions in detail.

1. In the figure shown, $C_1 = 1\ \mu F$, $C_2 = 6\ \mu F$, and $C_3 = 3\ \mu F$. If the electric-field energy stored on C_1 is 8 μJ, what is charge on C_2? **[4 points]**

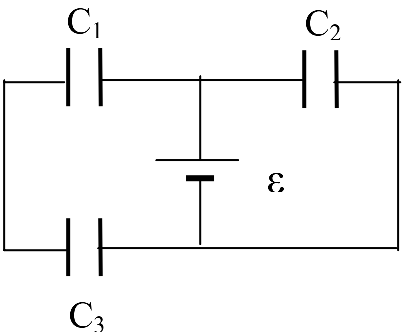
$$U_1 = \frac{q_1^2}{2C_1} \rightarrow q_1 = 4\,\mu C$$

$$q_1 = q_3 = q_{eq} = C_{13}\,\varepsilon$$

$$C_{13} = \frac{C_1 C_3}{C_1 + C_3} = \frac{1\times 3}{1+3} = \frac{3}{4}\,\mu F$$

$$\varepsilon = \frac{4\,\mu C}{\frac{3}{4}\,\mu F} = \frac{16}{3}\ V$$

$$q_2 = C_2\,\varepsilon = 6\,\mu F \times \frac{16}{3}\ V = 32\,\mu C$$



2. $N = 5\times 10^{13}$ electrons are removed from an isolated conducting ball of radius 2.5 cm. How much electrical energy is stored in the whole space around the ball? **[3 points]**

$$q = Ne = 8\ \mu C$$

$$C = 4\pi\varepsilon_o R = 2.78\,pF$$

$$U = \frac{q^2}{2C} = 11.5\ J$$

3. The figure shows a charged parallel-plate capacitor with the plate area A. A slab with dielectric constant K and thickness d_1 partially fills the space between the plates, leaving an air gap of thickness d_2. The strength of the electric field in the air gap is E_o.

a) Show that the potential difference between the plates is $V = (d_2 + d_1/K)E_o$. **[2 points]**

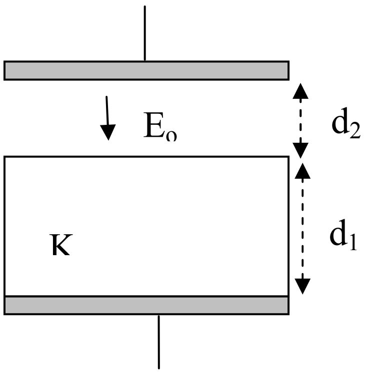
b) Obtain the capacitance of this capacitor <u>from the above equation</u>. **[2 points]**

$$a)\ V = E_0 d_2 + E_1 d_1, \quad \text{where } E_1 = \frac{E_0}{K}$$

$$\Rightarrow V = \left(d_2 + \frac{d_1}{k}\right) E_0$$

$$b)\ E_0 = \frac{\sigma}{\varepsilon_0} = \frac{q}{A\varepsilon_0} \rightarrow q = \frac{A\varepsilon_0}{\frac{d_1}{k} + d_2} V$$

$$\rightarrow C = \frac{q}{V} = \frac{A\varepsilon_0}{\frac{d_1}{K} + d_2}$$



4. A current of 16 mA passes through a light bulb as soon as it is turned on. The current drops to a steady value of 2 mA after a short while. What is the temperature of the filament when it is hot? (Take its initial temperature as 20 ºC and its temperature coefficient of resistivity 4.5×10^{-3} ºC^{-1}) **[3 points]**

$$R = R_0\left[1 + \alpha\ \Delta T\right]$$

$$\frac{\varepsilon}{I} = \frac{\varepsilon}{I_0}\left[1+\alpha\,\Delta T\right]$$

$$\frac{I_0}{I} = 1+\alpha\,\Delta T$$

$$\Delta T = 1556\ ^{\circ}C \ \rightarrow T = 15676\ ^{\circ}C$$

5. Copper has 8.5×10^{28} free electron per cubic meter. A copper wire of length 90 cm and radius 1.0 mm carries 5.0 A of current. How much time does it take for an electron to travel the length of the wire? **[3 points]**

$$I = JA = J\,\pi r^2$$

$$I = nev_d \cdot \pi r^2$$

$$v_d = 1.17\times10^{-4}\ \text{m/s}$$

$$t = \frac{L}{v_d} = 7691\ \text{s}$$

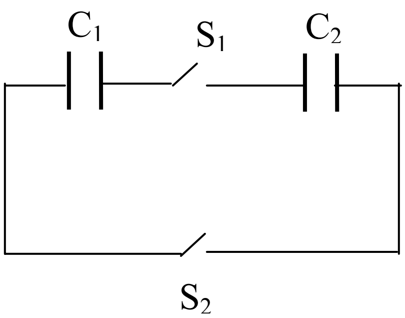
6. A capacitor C_1 = 2 μF with charge Q = 20 μC is connected to the initially uncharged capacitor C_2 = 3 μF by closing switches S_1 and S_2 shown below. How much charge is on C_2? **[2 points]**

C_1 and C_2 are in parallel (think about it).

$$C_{eq} = C_1 + C_2 = 5\,\mu\text{F}$$

$$V = \frac{Q}{C_{eq}} = 4\ \text{V}$$

$$q_2 = C_2 V = 12\ \mu\text{C}$$



7. In the circuit shown, ε = 12 V, r = 1 Ω (internal resistance of the battery), R = 5 Ω, C_1 = 3 μF and C_2 = 6 μF. What is the terminal voltage of the battery, 6 μs after the switch S is closed? **[4 points]**

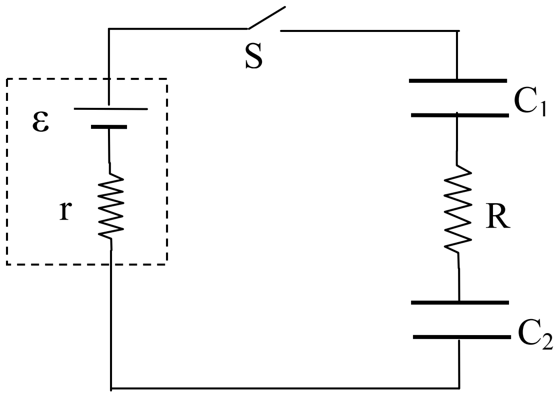
$$R_{eq} = R + r = 6\Omega$$

$$C_{eq} = \frac{C_1 + C_2}{C_1 + C_2} = 2\ \mu\text{F}$$

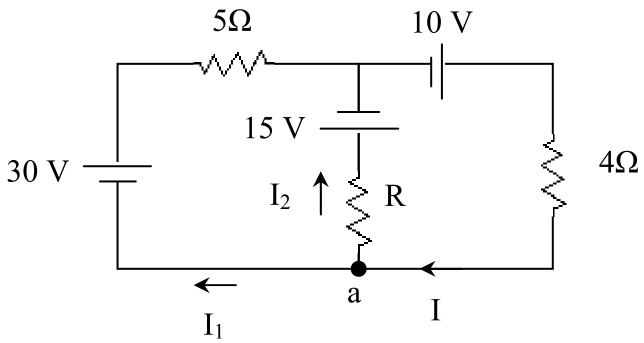
$$\tau = R_{eq}\, C_{eq} = 12\ \mu\text{s}$$

$$I = \frac{\varepsilon}{R_{eq}} e^{-\frac{t}{\tau}} = 1.2\ \text{A}$$

$$V_T = \varepsilon - Ir = 10.8\ \text{V}$$



8. In the circuit shown, the current I = 3 A. What is the value of the resistance R? **[4 points]**



- Arbitrary directions are taken for I_1 and I_2 as shown.

- Outer loop:

$$10 - 12 + 30 - 5I_I = 0$$

$$\rightarrow I_1 = 5.6\ \text{A}$$

- Junction a:

$$I = I_1 + I_2$$

$$\rightarrow I_2 = -2.6\,\text{A}$$

- Left loop:

$$-RI_2 - 15 + 5I_1 - 30 = 0$$

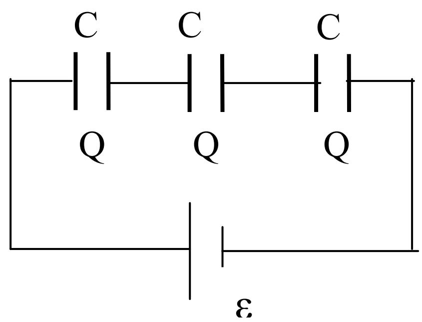
$$\rightarrow R = 6.5\ \Omega$$

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

1. A capacitor C_o connected to a battery has charge Q_o. The space between the plates of the capacitor is now filled with the dielectric K=3. Charge on the capacitor becomes

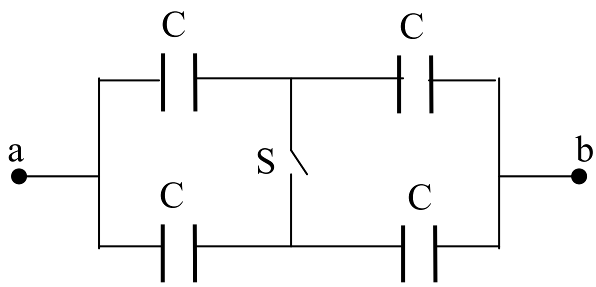
   a. Q_o
   b. $Q_o/3$
   c. $3Q_o$
   d. $4Q_o$

2. Three identical uncharged capacitors are connected in series to a battery. The charge passing through the battery during the charging is:



   a. Q
   b. 2Q
   c. 3Q
   d. Q/3

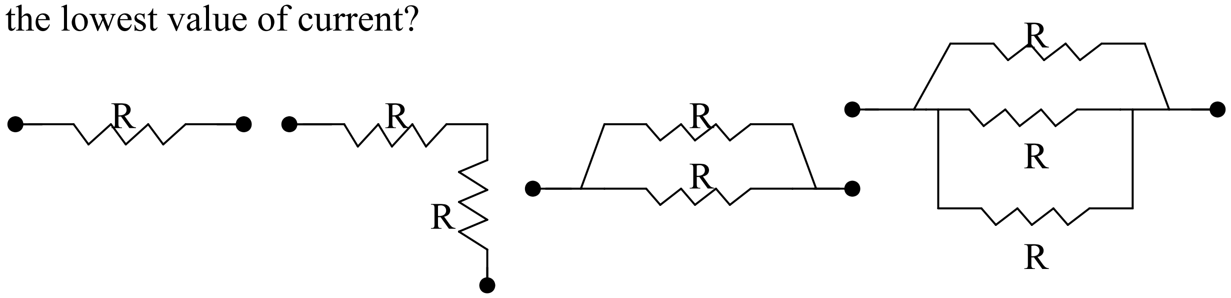
3. A potential difference is applied between the points a and b of the system of capacitors as shown. If the switch S is closed, the charge stored on each capacitor



   a. will become double.
   b. will become half.
   c. will not change.
   d. will become zero.

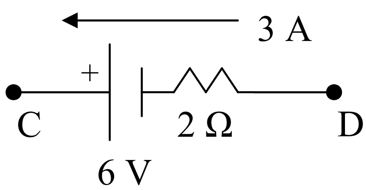
4. The resistors shown below are connected to a same potential difference. Which circuit has the lowest value of current?

   a. i
   b. ii
   c. iii
   d. iv



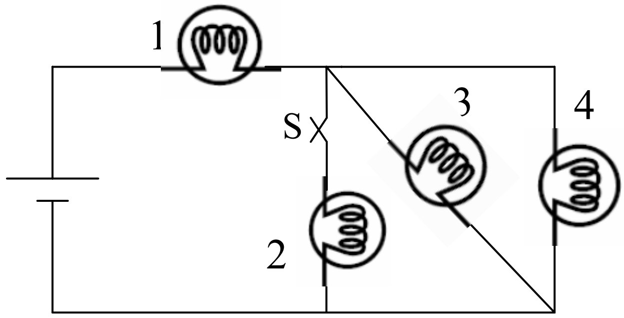
(i) (ii) (iii) (iv)

5. In a section of a circuit, the battery, the resistance and the current are shown in the figure. The potential of the point C



   a. is greater than that of the point D.
   b. is less than that of the point D.
   c. is the same as that of the point D.
   d. cannot be given without the full circuit.

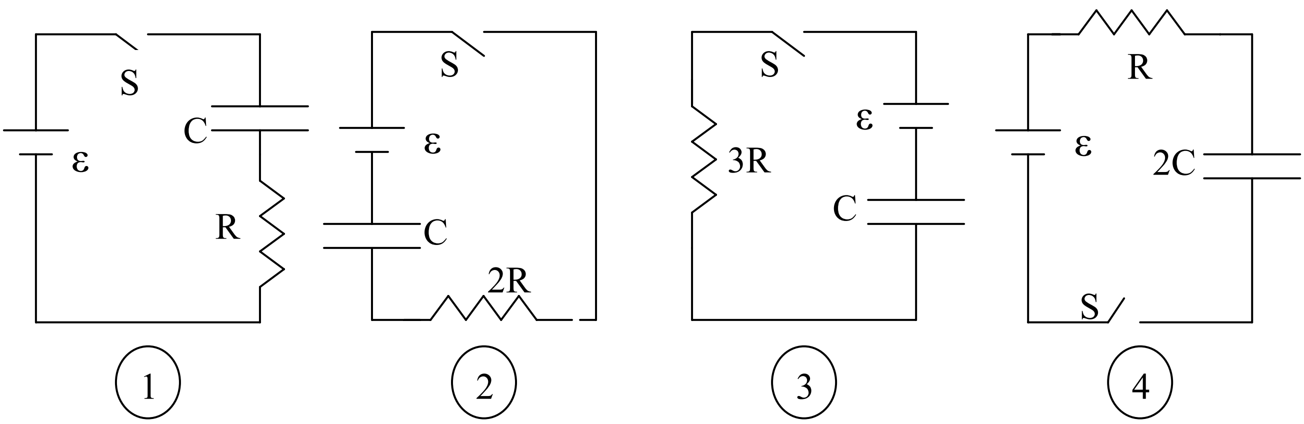
6. Four identical light bulbs are connected to a battery as shown. If the switch S is opened, which statement is correct?



a. All the bulbs become brighter.
b. All the bulbs become dimmer
c. Bulb 1 becomes brighter, but bulbs 3 and 4 become dimmer.
d. Bulbs 3 and 4 become brighter, but bulb 1 will be dimmer.

7. For the four RC circuits given, the time required to charge the capacitor to the 50% of the maximum charge is given by t_1, t_2, t_3 and t_4, respectively. These are related to each other as

a. $t_1 < t_2 < t_3 < t_4$
b. $t_2 < t_3 < t_1 < t_4$
c. $t_1 < t_2 = t_3 < t_4$
d. $t_1 < t_2 = t_4 < t_3$



8. A potential difference V is applied between the ends of cylindrical conductors shown in the figure. For which conductor is the current density highest? Shown are the radii and lengths of the conductors.