Kuwait University **Physics Department**

Physics 102

Second Midterm Examination
Spring Semester (2011-12)

May 5, 2012

Time: 12.00 to 1.30 p.m.

Name…… Student No…….

Instructors: Drs. Abdelkarim, Afrousheh, Davis, Farhan, Habib, Kokaj, Lajko, Marafi, Razee & Sharma

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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	(Premeability 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)
$g = 9.8\ \text{m/s}^2$	(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

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

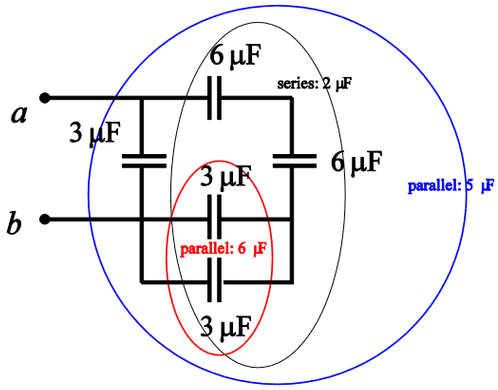
For use by Instructors only

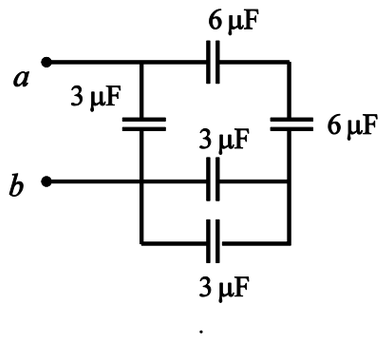
Prob.	1	2	3	4	5	6	7	8	Total
Marks									

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

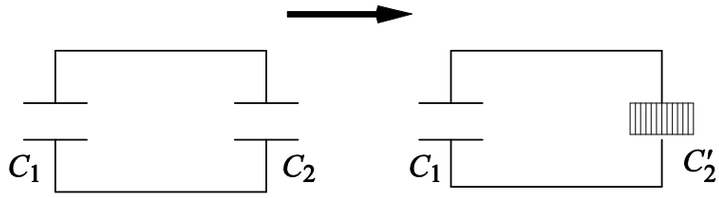
Problems **Please show ALL working.**

1. Calculate the equivalent capacitance between points *a* and *b*. [**3 points**]





2. Identical capacitors ($C_1 = C_2 = 4\ \mu F$) are connected together as shown. Each of the capacitors has an initial plate charge of 8 μC. Then, a slab of dielectric material ($K = 3$) is inserted between the plates of C_2 fully filling the space between the plates. What is the final plate charge of C_1? [**3 points**]



$$C_{eq}^{'} = C_1 + C_2^{'} = 4\mu F + 3 \cdot 4\ \mu F = 16\ \mu F$$

$$V' = \frac{8\mu C + 8\mu C}{C_{eq}^{'}} = \frac{16\mu C}{16\ \mu F} = 1.0\ V$$

$$Q_1 = C_1\, V' = 4\ \mu F \cdot 1.0\ V = 4\mu C$$

3. A parallel-plate capacitor has plate area $A = 0.5\,\mathrm{m}^2$, plate separation $d = 0.1\,\mathrm{mm}$ and energy density $u = 3.62\,\mathrm{J/m}^3$. Find the plate charge on the capacitor. [**4 points**]

$$u = \frac{\varepsilon_o}{2} E^2 = \frac{\varepsilon_o}{2}\left(\frac{\sigma}{\varepsilon_o}\right)^2 = \frac{1}{2\varepsilon_o}\left(\frac{Q}{A}\right)^2$$

$$Q^2 = 2\varepsilon_o A^2 u$$

$$Q = \sqrt{2\varepsilon_o u}\, A \quad = 4\,\mu C$$

4. The electric field is $E = 0.1\,\mathrm{V/m}$ in a cylindrical copper wire of resistivity $\rho = 1.72 \times 10^{-8}\,\Omega\mathrm{m}$. The density of free electrons is $n = 8.5 \times 10^{28}/\mathrm{m}^3$. Find the drift velocity of the electrons. [**3 points**]

$$\rho = \frac{E}{J} \Rightarrow \mathrm{nq}v_d = J = \frac{0.1\,\mathrm{N/C}}{1.72 \times 10^{-8}}$$

$$v_d = \frac{E}{\rho\, nq} = \frac{0.1\,\mathrm{N/C}}{1.72 \times 10^{-8} \cdot 8.5 \times 10^{28} \cdot 1.6 \times 10^{-19}}$$

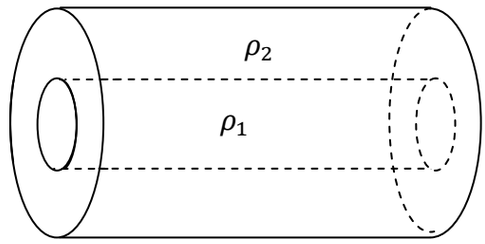
$$= 4.3 \times 10^{-4}\,\mathrm{m/s}$$

5. A cable consists of a solid cylinder (material 1, diameter = 10.0 mm) surrounded by a cylindrical shell (material 2, inner diameter = 10.0 mm, outer diameter = 20.0 mm). The cable carries a current of 100 A (parallel to its axis). If $\rho_1 = 2\,\rho_2$, find the current density in the shell. **[4 points]**

$$I = J_1 A_1 + J_2 A_2 = \frac{\pi}{4} J_1 d_1^2 + \frac{\pi}{4} J_2 \left(d_2^2 - d_1^2\right)$$

$$\frac{J_2}{J_1} = \frac{E/\rho_2}{E/\rho_1} = \frac{\rho_1}{\rho_2} = 2$$

$$J_2 = I/\frac{\pi}{4}\left(d_2^2 - \frac{1}{2} d_1^2\right) = 3.64 \times 10^5\ A/m^2$$



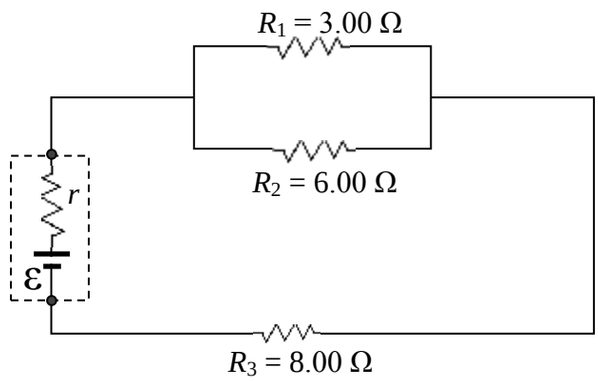
6. In the circuit below, the current through R_2 is 0.50 A. What is the terminal voltage of the source of emf with internal resistance r? **[4 points]**

$Upper\ loop:\ 0.5\ \text{A}\ R_2 - I_1\ R_1 = 0$

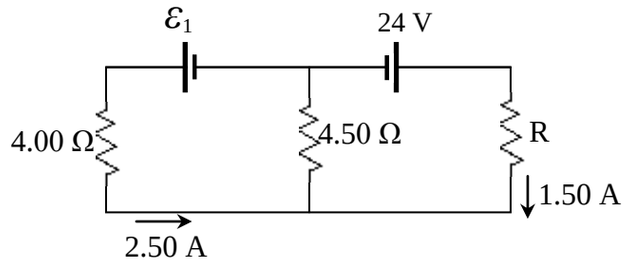
$I_1 = 1.0\ \text{A}$

$I_1 + I_2 = I_3 = 1.5\ \text{A}$

Terminal voltage $= I_2\ R_2 + I_3\ R_3 = 15\ \text{V}$



7. In the circuit shown, find the emf $\mathcal{E}_1$ and the resistance *R*. [**5 points**]



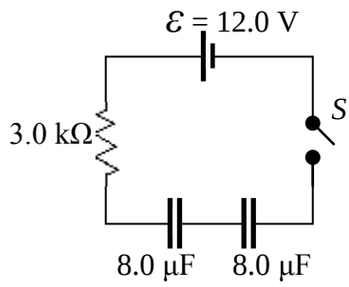
$I_{\mathrm{M}} = 2.5\ \mathrm{A} + 1.5\ \mathrm{A} = 4\ \mathrm{A}$

$\mathcal{E}_1 - 2.50\ \mathrm{A}\ (4.00\ \Omega) - 4\ \mathrm{A}\ (4.50\ \Omega) = 0$

$-1.50\ R - 4\ \mathrm{A}\ (4.50\ \Omega) + 24\ \mathrm{V} = 0$

$\varepsilon_1 = 28\ \mathrm{V}, \qquad R = 4.0\ \Omega$

8. In the circuit shown, the capacitors are initially uncharged. The switch *S* is closed at t=0. Find the time at which the current in the resistor is 5.4×10^{-4}A. [**6 points**]



$C_{eq} = 4\ \mu\mathrm{F}$

$\tau = RC_{eq} = 3\mathrm{k}\Omega \times 4\mu\mathrm{F} = 12\ \mathrm{ms}$

$$i = \frac{dq}{dt} = C\mathcal{E}\,\frac{d\left[1 - e^{-t/\tau}\right]}{dt} = \frac{\varepsilon}{R}\,e^{-t/\tau}$$

$$5.4 \times 10^{-4}\mathrm{A} = \frac{12\mathrm{V}}{3\mathrm{k}\Omega}\,e^{-t/\tau}$$

$$\Rightarrow \ln\left[\frac{5.4 \times 10^{-4}}{4 \times 10^{-3}}\right] = \frac{-t}{\tau} \Rightarrow t = -\tau \ln(0.135) = 24\ \mathrm{ms}$$

Conceptual Questions. Tick the best answer. (1 point for each question.)

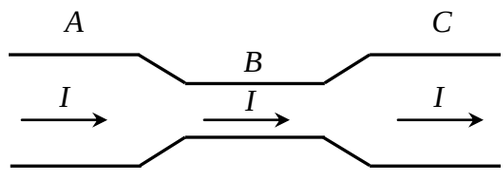
1. A parallel-plate capacitor is charged by a battery and kept connected to the battery. Then the separation between the plates is halved. How has the electric field in the capacitor changed?

   a. Decreased by a factor of 2.
   b. Increased by a factor of 2. **Ans**.
   c. Not changed.
   d. Increased by a factor of 4.

2. Two identical capacitors C_1 and C_2 have the same charge. Then we insert dielectric material (K=3) between the plates of C_2. The ratio U_1/U_2 of the energies stored in C_1 and C_2 is

   a. 3. **Ans**.
   b. 1/3.
   c. 1.
   d. 9.

3. The figure shows a steady electric current I passing through a wire of changing cross-section. How does the drift velocity change?



   a. Decreases from A to B, increases from B to C.
   b. Decreases from left to right.
   c. Remains constant.
   d. Increases from A to B, decreases from B to C. **Ans**.

4. A potential difference V is applied to the two ends of a cylindrical wire. If the diameter of the wire is doubled and the potential difference V is halved, then the *rate* of energy dissipation in the wire

   a. remains the same. **Ans.**
   b. decreases by a factor of 2.
   c. increases by a factor of 4.
   d. increases by a factor of 2.
   e. decreases by a factor of 4.

5. Which combination below is a unit of energy?

   a) $A^2 \cdot \Omega$.

   b) $\Omega \cdot m$.

   c) $\frac{A}{C}$.

   d) $V \cdot C$. **Ans**.

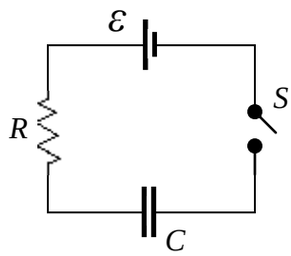
6. A capacitor and resistor are connected to an emf as shown. Just after the switch *S* is closed, which of the following statements is true?

   a) The current is zero.

   b) The voltage across the capacitor is ε.

   c) The voltage across the resistor is zero.

   d) The voltage across the resistor is ε. **Ans.**



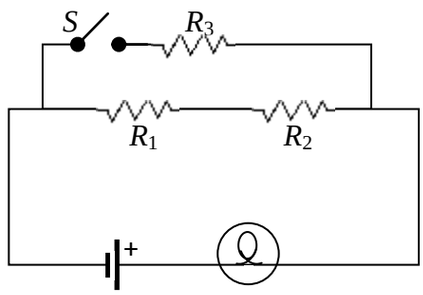
7. A light bulb is connected in a circuit as shown. If the switch *S* is closed, the bulb's brightness

   a) increases if $R_3 > R_1 + R_2$.

   b) decreases if $R_3 > R_1 + R_2$.

   c) always decreases.

   d) always increases. **Ans.**



8. The electrical properties of copper and rubber are different because:

   a) positive charges can move in copper but not in rubber.

   b) positive charges can move in rubber but not in copper.

   c) negative charges can move in copper but not in rubber. **Ans.**

   d) negative charges can move in rubber but not in copper.