Kuwait University **Physics Department**

Physics 102

Final Examination

Summer Semester 2016-2017

August 7, 2017

Time: 5:00 p.m. – 7:00 p.m.

Name…………………………………… Student No.……………….

Section No…………………………….

Instructors**:** Drs. R. Rodriguez-Guzman and E. Vagenas

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)
$\mu_0 = 4\pi \times 10^{-7}$ 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)
$g = 9.8\ \text{m/s}^2$	(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

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

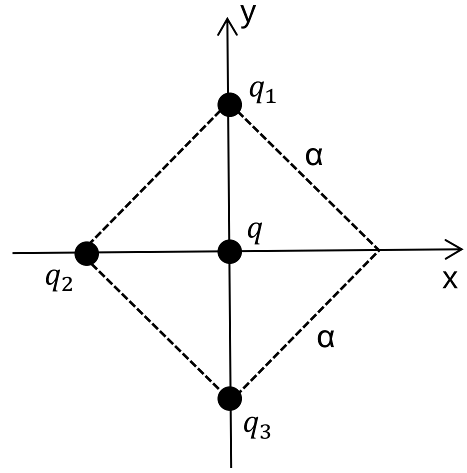
For use by Instructors only

Prob.	1	2	3	4	5	6	7	8	9	10	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. Three point charges are located at the vertices of a square of side $a = 5.0\ cm$, as shown in the figure. Compute the net force exerted on the point charge $q = 5.0\ nC$. Given $q_1 = 3.0\ nC$, $q_2 = 7.0\ nC$, and $q_3 = 6.0\ nC$. **[4 points]**



$$a^2 = r^2 + r^2 \;=>\; r^2 = a^2/2$$

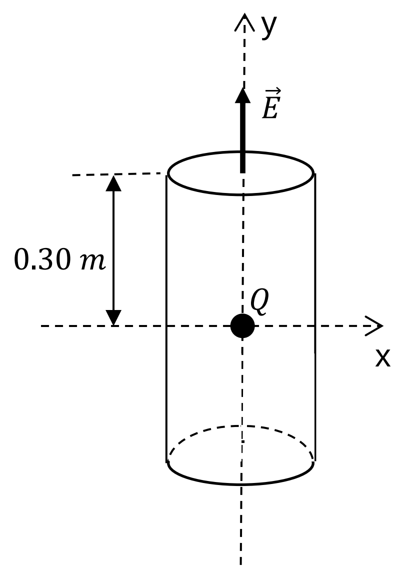
$$\vec{F}_1 = k\frac{q_1 q}{\left(\frac{a^2}{2}\right)}(-\hat{j}) \;=>\; \vec{F}_1 = 1.08\times10^{-4}\ N(-\hat{j})$$

$$\vec{F}_2 = k\frac{q_2 q}{\left(\frac{a^2}{2}\right)}(+\hat{\imath}) \;=>\; \vec{F}_2 = 2.52\times10^{-4}\ N\ \hat{\imath}$$

$$\vec{F}_3 = k\frac{q_3 q}{\left(\frac{a^2}{2}\right)}(+\hat{j}) \;=>\; \vec{F}_3 = 2.16\times10^{-4}\ N\ \hat{j}$$

$$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 \;=>\; \vec{F}_{net} = 2.52\times10^{-4}\ N\ \hat{\imath} + 1.08\times10^{-4}\ N\ \hat{j}$$

2. A point charge Q is placed in a cylinder as shown in the figure. The electric field at the center of the top of the cylinder is $4\times10^3\ N/C$, as shown in the figure. Find the flux through the cylinder. **[3 points]**



$$E = k\frac{Q}{(0.30)^2}$$

$$Q = \frac{(0.30)^2 E}{k} \;=>\; Q = 40\ nC$$

$$\Phi = \frac{Q}{\varepsilon_0} \;=>\; \Phi = 4520\ Nm^2/C$$

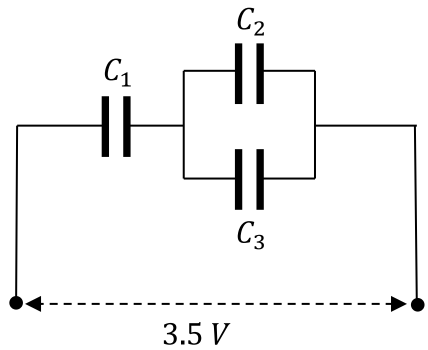
3. In the figure below, the charge on capacitor C_2 is $15\ \mu C$. Find the charge on capacitor C_3. Given $C_1 = C_2 = 10\ \mu F$. **[4 points]**

$$V_2 = \frac{Q_2}{C_2} => V_2 = V_3 = V_{23} = 1.5\ V$$

$$3.5\ V = V_1 + V_{23} => V_1 = 2.0\ V$$

$$Q_1 = C_1 V_1 => Q_1 = 20\ \mu C$$

$$Q_3 = Q_{23} - Q_2 => Q_3 = Q_1 - Q_2 = 5\ \mu C$$



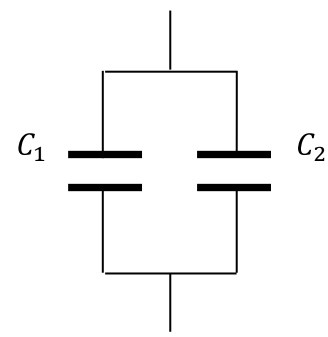
4. A fully charged capacitor $C_1 = 5\ \mu F$ is connected to an uncharged capacitor $C_2 = 10\ \mu F$, as shown in the figure. If the final energy stored in C_2 is $180\ \mu J$, find the initial energy stored in C_1 before it was connected to capacitor C_2 . **[4 points]**

$$U_2 = \frac{1}{2} C_2 V_2^2 => V_2 = \sqrt{\frac{2\ U_2}{C_2}} = 6.0\ V$$

$$C_{12} = C_1 + C_2 => C_{12} = 15\ \mu F$$

$$Q_{total} = C_{12} V_2 => Q_{total} = 90\ \mu C$$

$$U_1 = \frac{1}{2}\frac{1}{C_1} Q^2{}_{total} => U_1 = 810\ \mu J$$



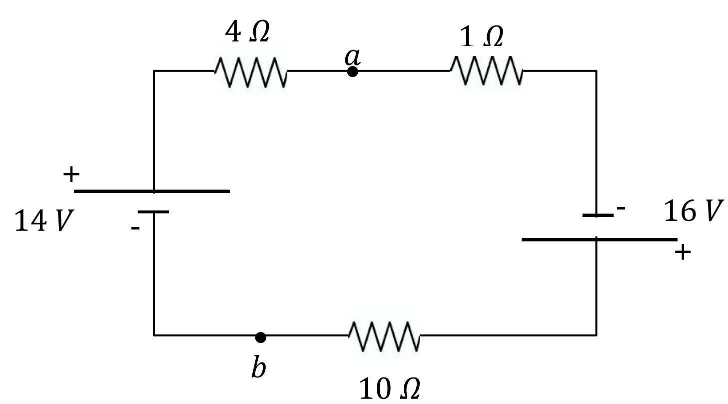
5. A uniform 1.0 m long steel wire is connected to a 12 V battery. The free electrons run the length of the steel wire in 250 s and the concentration of free electrons in steel is $9.0\times10^{28}\ electrons/m^3$. Find the resistivity of the steel. **[3 points]**

$$v_d = \frac{L}{t} => v_d = 4\times10^{-3} m/s$$

$$V = IR => V = n|e|v_d A\rho\frac{L}{A} = n|e|v_d\rho L$$

$$\rho = \frac{V}{n|e|v_d L} => \rho = 20.8\times10^{-8}\ \Omega m$$

6. In the circuit shown in the figure, find the potential difference V_{ab}. **[2 points]**



Loop rule:
$14 - 4I - 1I + 16 - 10I = 0 => I = 2\ A$

$$V_a - 1I + 16 - 10I = V_b => V_{ab} = -16 + 11I => V_{ab} = 6\ V$$

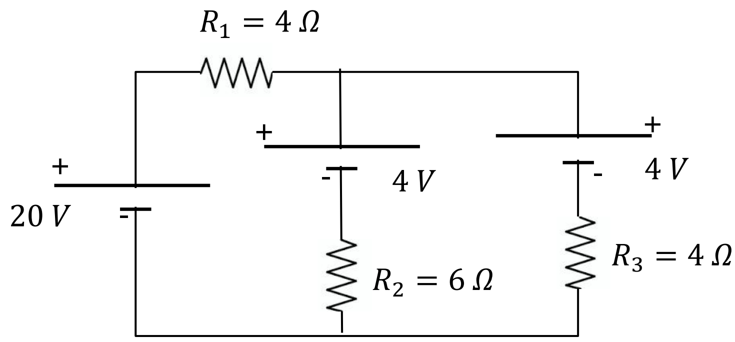
7. The power delivered in the circuit below by the $20\,V$ battery is $50.0\,W$. Find the current in the $R_3 = 4.0\,\Omega$ resistor. **[3 points]**

$P = VI => I = \frac{P}{V} => I = 2.5\,A$

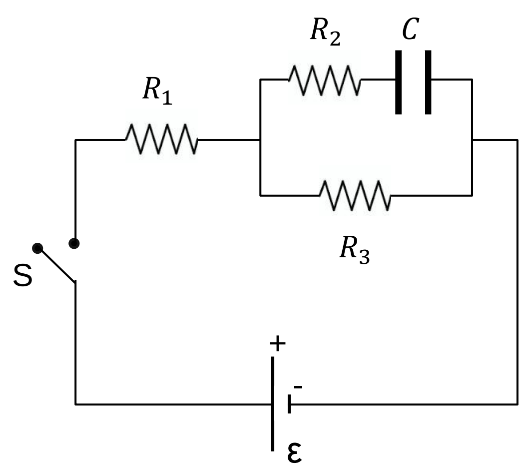
Big Loop:

$20 - 4I - 4 - 4I_2 = 0$

$I_2 = 1.5\,A$



8. In the circuit below, $R_1 = 10.0\,\Omega$, $R_2 = 15.0\,\Omega$, $R_3 = 20.0\,\Omega$, and $\varepsilon = 60.0\,V$. If the switch S is closed at $t = 0\,s$, find the charge on the capacitor of capacitance $C = 2\,nF$ after a very long time. **[3 points]**



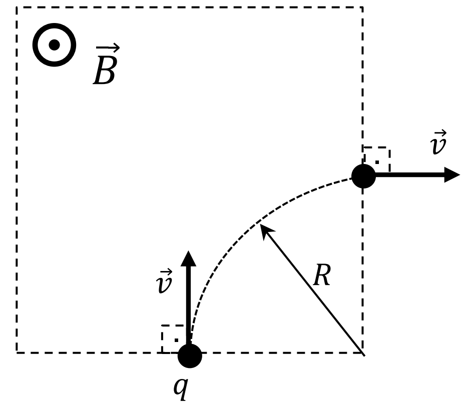
Loop rule:

$60V - IR_1 - IR_3 = 0 => I = 2\,A$

$V_c = V_3 = IR_3 => V_c = 40\,V$

$Q = CV_3 => Q = 80\,nC$

9. A positive point charge q enters perpendicularly a uniform magnetic field with velocity $\vec{v}$ as shown in the figure. The point charge exits perpendicularly the magnetic field after time $t = 4\pi \times 10^{-5}\ s$. Find the speed of the point charge. Given $R = 20.0\ cm$ **[3 points]**



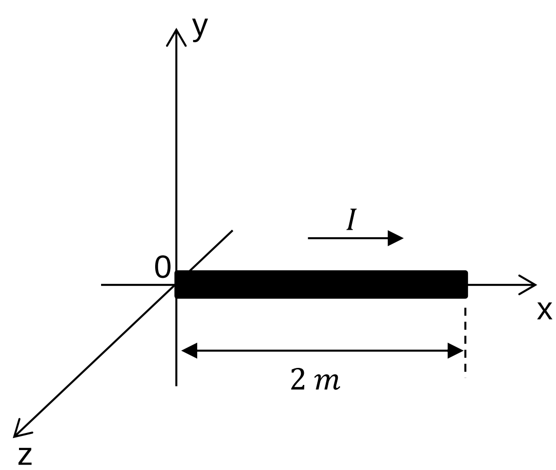
$$R = \frac{mv}{Bq}$$

$$t = \frac{T}{4} = \frac{1}{4}\frac{2\pi m}{Bq} => t = \frac{\pi m}{2Bq}$$

$$\frac{R}{t} = \frac{2v}{\pi} => v = \frac{\pi R}{2t}$$

$$v = 2500\ m/s$$

10. The $2m$ long wire shown in the figure carries a current $I = 5\ A$ and is placed in a magnetic field $\vec{B} = \left(4\hat{\imath} - 3\hat{\jmath} + 5\ \hat{k}\right)T$. Find the magnetic force acting on the wire. **[3 points]**



$$\vec{F} = I\vec{L} \times \vec{B}$$

$$\vec{F} = 5 \times \begin{vmatrix} \hat{\imath} & \hat{\jmath} & \hat{k} \\ 2 & 0 & 0 \\ 4 & -3 & 5 \end{vmatrix} \text{N}$$

$$\vec{F} = -50N\ \hat{\jmath} - 30N\ \hat{k}$$

Part II. Multiple Choice Questions (each carries 1 point). Tick the best answer.

1. Two point charges, q_1 and q_2, are a distance d apart. The force on q_1 increases by a factor of nine (9), if

   a. the distance between, q_1 and q_2 is increased by a factor of nine (9).
   b. the distance between, q_1 and q_2 is increased by a factor of three (3).
   c. the distance between, q_1 and q_2 is decreased by a factor of nine (9).
   d. the distance between, q_1 and q_2 is decreased by a factor of three (3).

2. A conductor with a cavity carries a net charge Q and then a point charge q is placed in the cavity. The magnitude of the electric field in the cavity (not at the location where the point charge is placed) and at a distance r from charge q is given by the expression

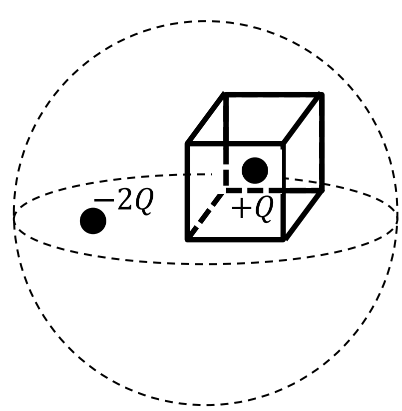
   a. $k\frac{Q}{r^2}$
   b. $k\frac{q}{r^2}$
   c. $k\frac{(Q+q)}{r^2}$
   d. $k\frac{(Q-q)}{r^2}$

3. Two infinitely large parallel sheets a distance d apart carry equal but opposite uniform surface charge densities. A point charge that is placed midway feels a force F due to the two sheets. If this point charge is now moved closer to one of the sheets, so that it is a distance $d/4$ from that sheet, what force will the point charge feel?

   a. F/4
   b. F/2
   c. F
   d. 2F

4. A point charge Q is placed inside a cube. A Gaussian sphere encloses the cube and a point charge $-2Q$ which is placed inside the sphere but outside the cube. If Φ_C is the flux through the cube while Φ_S is the flux through the sphere, then

   a. $\Phi_S = +\frac{Q}{\varepsilon_0}$ and $\Phi_C = +\frac{Q}{\varepsilon_0}$
   b. $\Phi_S = +\frac{Q}{\varepsilon_0}$ and $\Phi_C = -\frac{Q}{\varepsilon_0}$
   c. $\Phi_S = -\frac{Q}{\varepsilon_0}$ and $\Phi_C = -\frac{Q}{\varepsilon_0}$
   d. $\Phi_S = -\frac{Q}{\varepsilon_0}$ and $\Phi_C = +\frac{Q}{\varepsilon_0}$

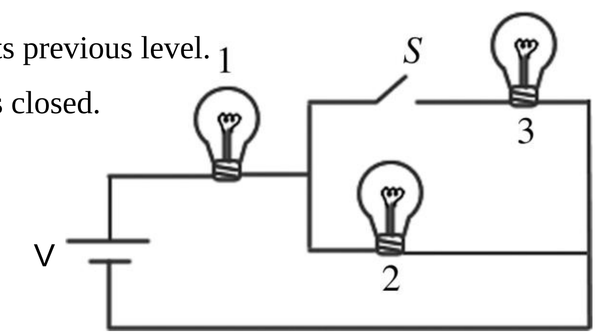


5. A capacitor is connected to a battery and has a charge Q when it is fully filled with a material of dielectric constant κ. If the battery remains connected but the dielectric material is taken out, what will be the potential energy of the capacitor?

a. $U = \frac{1}{2}QV$
b. $U = \frac{1}{2}\kappa QV$
c. $U = \frac{1}{2}\frac{1}{\kappa}QV$
d. $U = 0$

6. The figure shows three identical lightbulbs connected to a battery having constant voltage V across its terminals. What happens to the brightness of lightbulb 1 when the switch S is closed?

a. The brightness increases momentarily, then returns to its previous level.
b. The brightness remains the same as before the switch is closed.
c. The brightness decreases permanently.
d. The brightness increases permanently.



7. A charged particle is moving with a speed v perpendicular to a uniform magnetic field. A second identical charged particle is moving with speed $4v$ perpendicular to the same magnetic field. If the angular speed of the first particle is ω, the angular speed of the second particle is

a. 2ω
b. ω
c. $\omega/2$
d. $\omega/4$

8. A current-carrying wire with sides of length L and electric current I is placed in a uniform magnetic field $\vec{B}$ as shown in the figure. The magnitude of the magnetic force exerted on the wire is

a. F=3BIL
b. F=2BIL
c. F=BIL
d. F=0