Kuwait University   Physics Department

Physics 122

First Midterm Examination
Summer Semester 2009

20 July 2009 (6.00 – 7.30 p.m)

Name:……………………………………   **Student No. ……………………..**

Instructor: Prof. M.M. Sharma

<u>Instructions to the students</u>:

1. Solve all the problems. Points for each problem are indicated.
2. The solution should be given explicitly for each problem.

(Fundamental Constants)

$k = \frac{1}{4\pi\varepsilon_0} = 9.0\times10^9 \text{N.m}^2/\text{C}^2$	(Coulomb's constant)
$\varepsilon_o = 8.85 \times 10^{-12}\ \text{C}^2 / (\text{N}\cdot\text{m}^2)$	(Permittivity of free space)
$e = 1.60 \times 10^{-19}$ C	(Elementary unit of charge)
$N_A = 6.022 \times 10^{23}$	(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)

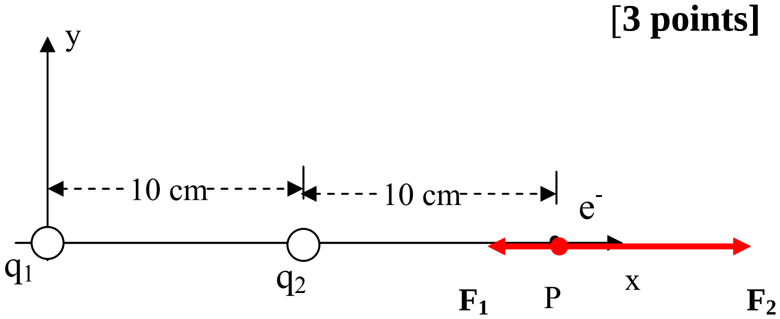
<u>Prefixes of units</u>

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

Problem	1	2	3	4	5	6	7	8	Total
Marks									

1. Two charges $q_1 = +4\ \mu C$ and $q_2 = -4\ \mu C$ are located as shown in the figure. What is the magnitude and direction of the resultant force on an electron placed at the point P? **[3 points]**



$$F_1 = \frac{k|q_1||-e|}{(0.20)^2} = \frac{9\times10^9 \times 4\times10^{-6} \times 1.6\times10^{-19}}{(0.20)^2} = 1.4\times10^{-13}\,\text{N}$$

$$F_2 = \frac{k|q_2||-e|}{(0.10)^2} = \frac{9\times10^9 \times 4\times10^{-6} \times 1.6\times10^{-19}}{(0.10)^2} = 5.7\times10^{-13}\,\text{N}$$

$$F_x = F_2 - F_1 = 5.7\times10^{-13} - 1.4\times10^{-13} = 4.3\times10^{-13}\,\text{N along} + \text{x axis}$$

OR :

$$E_1 = \frac{k|q_1|}{r_1^2} = \frac{9\times10^9 \times 4\times10^{-6}}{0.20} = 9\times10^5\ \text{N/C along} + \text{x - axis}$$

$$E_2 = \frac{k|q_2|}{r_2^2} = \frac{9\times10^9 \times 4\times10^{-6}}{0.10} = 36\times10^5\ \text{N/C along} - \text{x - axis}$$

$$E = E_2 - E_1 = 36\times10^5 - 9\times10^5\ \text{N} = 27\times10^5\ \text{N/C along} - \text{x - axis}$$

$$\vec{F} = q\vec{E} = -e\vec{E}$$

$$F = 1.6\times10^{-19} \times 27\times10^5\ \text{N} = 4.3\times10^{-13}\ \text{along} + \text{x - axis}$$

2. What is the magnitude and direction of the resultant electric field at the point P due to the two charges as shown in the figure? Given, $q = 2\ \mu C$. **[4 points]**

Distance $r = \sqrt{(0.52)^2 + (0.30)^2} = 0.60\ \text{m}$

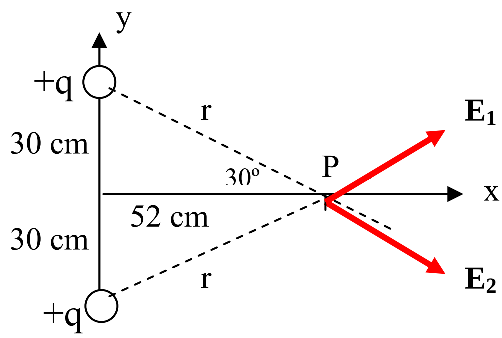
$$E_1 = E_2 = \frac{kq}{r^2} = \frac{9\times10^9 \times 2\times10^{-6}}{(0.60)^2} = 5.0\times10^4\,\text{N/C}$$

$$E_x = E_1 \cos 30^\circ + E_2 \cos 30^\circ = 2E_1 \cos 30^\circ$$

$$= 8.6\times10^4\,\text{N/C}$$

$$E_y = +E_1 \sin 30^\circ - E_2 \sin 30^\circ = 0$$

$$E = \sqrt{E_x^2 + E_y^2} = E_x = 8.6\times10^4\,\text{N/C along} + \text{x axis}$$



3. A Na^+ ion is accelerated from *rest* through a potential difference of 5 kV. What is the final speed of the ion? Assume the mass of the Na^+ ion is 23 times that of the proton. **[3 points]**

Given, $q = +e = +1.6\times10^{-19}$ C,

$$m = 23\times m_p = 23\times1.67\times10^{-27}\text{ kg} = 3.8\times10^{-26}\text{ kg}$$

$\Delta V = 5\text{ kV} = 5000\text{ V}$

$\Delta K = -\Delta U = -q\Delta V$

$K_f - K_i = -q\Delta V$

$K_f - 0 = -q\Delta V$ or simply $K = |q\Delta V|$

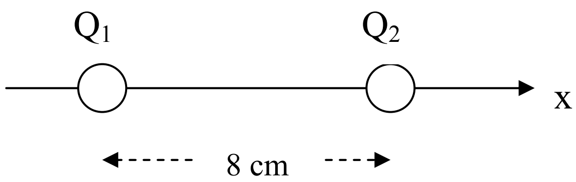
$K = |q\Delta V| = 1.6\times10^{-19}\times5000\text{ J} = 8.0\times10^{-16}\text{ J}$

(kinetic energy can never be negative)

$\frac{1}{2}mv^2 = 8.0\times10^{-16}\text{ J}$

$$v = \sqrt{\frac{2\times8.0\times10^{-16}}{3.8\times10^{-26}}} = 2.0\times10^5\text{ m/s}$$

4. Two charges Q_1= +8 μC and Q_2 = +4 μC are located along the x-axis as shown. The charge Q_1 is held fixed and Q_2 is allowed to move freely. What is the kinetic energy of Q_2 when it has moved very far away from Q_1? **[2 points]**



$\Delta K = -\Delta U$

$K_f - K_i = -(U_f - U_i)$

$K_f - 0 = -(0 - U_i)$

$K_f = U_i$

$$K_f = \frac{kQ_1Q_2}{r_i} = \frac{9\times10^9\times8\times10^{-6}\times4\times10^{-6}}{0.8}\text{ J}$$

$= 3.6$ J

5. The electric field between the plates of a parallel plate capacitor is E = 4.5 × 10^5 N/C. If the plate area is 40 cm^2 and the plate separation is 1.2 mm, what is the charge on the capacitor plates? **[3 points]**

$$\Delta V = -Ed$$
$$V = |\Delta V| = |-Ed| = 4.5\times10^5 \times 1.2\times10^{-3}\,\text{V} = 540\ \text{V}$$
$$C = \varepsilon_0 \frac{A}{d} = \frac{8.85\times10^{-12}\times40\times(10^{-2})^2}{1.2\times10^{-3}} = 2.95\times10^{-11}\ \text{F}$$
$$Q = CV = 2.95\times10^{-11}\,\text{F}\times540\ \text{V} = 1.6\times10^{-8}\ \text{C}$$
OR
$$Q = CV = \varepsilon_0 \frac{A}{d}.V = \varepsilon_0 A\left(\frac{V}{d}\right) = \varepsilon_0 AE = 1.6\times10^{-8}\ \text{C}$$

6. If 1.5×10^{21} electrons pass through a 15 Ω resistor in 10 minutes, what is the potential difference across the resistor? **[3 points]**

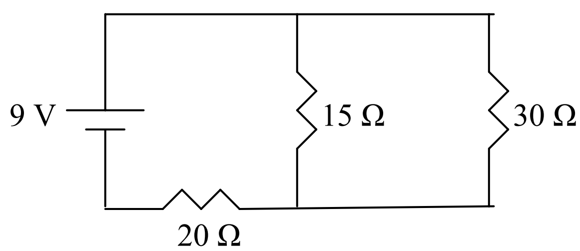
$$q = Ne = 1.5\times10^{21}\times1.6\times10^{-19}\,\text{C} = 240\ \text{C}$$
$$I = \frac{q}{t} = \frac{240\ \text{C}}{10\times60\ \text{s}} = 0.4\ \text{A}$$
$$V = IR = 0.4\ \text{A}\times15\ \Omega = 6.0\ \text{V}$$

7. An *ac*-source with the peak voltage of 340 V is applied to a heater with a resistance of 75 Ω. If it is used half hour every day for a month (30 days), how many kWh of energy is used? **[3 points]**

$$V_{rms} = \frac{1}{\sqrt{2}}V_0 = 0.707\times340\ \text{V} = 240.4\ \text{V}$$
$$\overline{P} = \frac{V_{rms}^2}{R} = \frac{(240.4)^2}{75} = 770\ \text{W} = \frac{770}{1000}\ \text{kW} = 0.770\ \text{kW}$$
Time $t = 0.5\ \text{h}\times30 = 15\ \text{h}$

Energy consumed:
$$E = \overline{P}t = 0.77\ \text{kW}\times15\ \text{h} = 11.6\ \text{kWh}$$

8. In the figure shown, what is the current in the 20 Ω resistor? **[3 points]**



$$R_p = \frac{15\times30}{15+30} = 10\ \Omega$$
$$R_{eq} = R_s = 20+10 = 30\ \Omega$$
Current I from the battery:
$$I = \frac{\varepsilon}{R} = \frac{9\ \text{V}}{30\ \Omega} = 0.30\ \text{A}$$
Thus, current in 20 Ω resistor is 0.30 A.