Kuwait University **Physics Department**

Physics 122
First Midterm Examination
October 18, 2005

Time: 12:30 – 1.55

Name………………………. **Student No…………….**

Instructors: Drs. Kokay, Rakshani, Sharma

(Fundamental Constants)

$k = \frac{1}{4\pi\varepsilon_o} = 9.0 \times 10^9 \text{N}\cdot\text{m}^2/\text{C}^2$	(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)

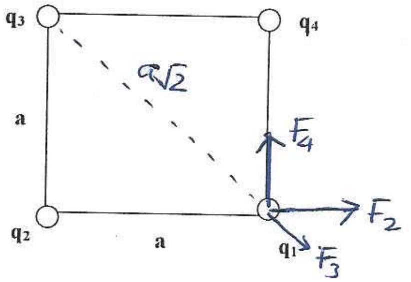
Prefixes of units

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

For use by Instructors only

Prob.	1	2	3	4	5	6	7	8	9	10
Marks										

1. Charges $q_1 = q_2 = q_3 = 5\ \mu C$ and $q_4 = -5\ \mu C$ are placed at the corners of a square ($a = 20$ cm) as shown in the figure. What is the magnitude of the resultant force acting on q_1?



a) 2.4 N
[✓ b) 8.4 N]
c) 5.3 N
d) 16 N
e) other

$$F_2 = F_4 = k\frac{(5\mu C)^2}{(0.20)^2} = 5.625\ N$$

$$F_3 = \frac{k(5\mu C)^2}{(0.20\sqrt{2})^2} = 2.81\ N$$

$$F_x = F_2 + F_3\cos 45^\circ = 7.61\ N$$

$$F_y = F_4 - F_3\sin 45^\circ = 3.64\ N$$

$$F = \sqrt{F_x^2 + F_y^2}$$

$$= 8.4\ N$$

2. A non-conducting rod of length 1 m and cross sectional area 4 cm^2 has a uniform charge density of $-4\ \mu C/m^3$. The number of excess electrons in the rod is:

a) 2×10^8 electrons
[✓ b) 1×10^{10} electrons]
c) 4×10^5 electrons
d) 8×10^{10} electrons
e) other

$$\rho = -4\mu C/m^3 = -4\times10^{-6}\ C/m^3$$

Volume of the rod : $V = LA = 1\times 4\times10^{-4}\ m^3$

$$q = \rho V = -4\times10^{-6}\times4\times10^{-4}\ C$$

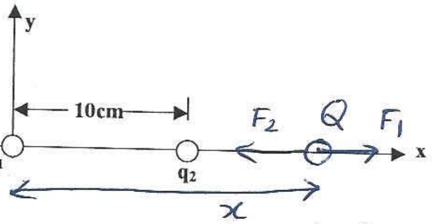
$$= -16\times10^{-10}\ C$$

$$N = \frac{q}{e} = \frac{-16\times10^{-10}\ C}{-1.6\times10^{-19}\ C}$$

$$= 1\times10^{10}\ \text{electrons}$$

3. Two charges $q_1 = 9q$ and $q_2 = -q$ are located as shown in the figure. Where should a third charge be located so that the net force on it becomes zero?

a) x = 10.3 cm
b) x = 13.3 cm
[✓ c)] x = 15.0 cm
d) x = 20.0 cm
e) other



Assume a charge Q is located at the coordinate x.
In equilibrium, $\Sigma F = 0$, i.e.

$$|\vec{F_1}| = |\vec{F_2}|$$

$$k\frac{|q_1||Q|}{x^2} = \frac{k|q_2||Q|}{(x-0.10)^2} \Rightarrow \frac{9}{x^2} = \frac{1}{(x-0.10)^2}$$

$$9 = \left(\frac{x}{x-0.10}\right)^2$$

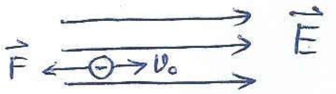
Taking square root $\pm 3 = \dfrac{x}{x-0.10}$

with +ve root, $+3(x-0.10) = x$
$x = 0.15$ m
$= 15$ cm ✓

with -ve root, $-3(x-0.10) = x$
$x = 0.075\text{m} = 7.5$ cm. ✗
Here, two forces will be in same direction.

4. An electron enters a region of uniform electric field $\acute{E} = 50$ N/C with an initial speed of 40 km/s in the same direction as the electric field. What is the speed of the electron 1.5 ns after it enters the region?

a) 43.2 km/s
b) 13.4 km/s
[✓ c)] 26.8 km/s
d) 6.4 km/s
e) other



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

$$a = -\frac{eE}{m} = -\frac{1.6\times10^{-19}\times 50}{9.1\times10^{-31}}$$

$$= -8.8\times10^{12}\ \text{m/s}^2$$

$$v = v_0 + at$$

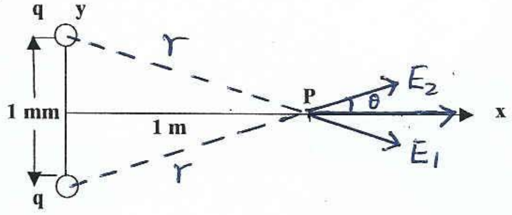
$$= 4\times10^{4} - 8.8\times10^{12}\times1.5\times10^{-9}$$

$$= -2.68\times10^{4}\ \text{m/s}$$

$$= -26.8\ \text{km/s}$$

5. What is the magnitude and direction of the electric field at point P due to the two charges as shown in the figure, if q = 2 μC and their separation is 1 mm? The point P lies along the perpendicular bisector at a distance of 1 m as shown schematically in the figure.

a) 4.3×10^4 N/C ĵ
b) 6.8×10^4 N/C î
c) 1.8×10^4 N/C î
[✓ d) 3.6×10^4 N/C î]
e) other



$$E_1 = E_2 = k\frac{q}{r^2}$$

1 mm = 10^{-3} m. This is very small compared to 1 m.

$\Rightarrow$ r = 1 m. Therefore you can treat the two charges as together. (Also $\theta \simeq 0^\circ$)

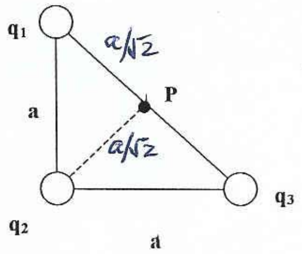
$$\Rightarrow \quad E = 2E_1 = 2E_2 = 2k\frac{q}{r^2}$$

$$= \frac{2 \times 9 \times 10^9 \times 2 \times 10^{-6}}{(1.0)^2} = 3.6 \times 10^4 \text{ N/C}$$

$$\vec{E} = +3.6 \times 10^4 \,\hat{j} \text{ N/C}$$

6. Three point charges q_1 = 10 μC, q_2 = 15 μC and q_3 = 20 μC are located at the corners of a right-angled triangle as shown in the figure. How much work must be done to move the charge q_2 to the point P midway between q_1 and q_3? (Given, a = 40 cm).

a) 2.8 J
[✓ b) 4.2 J]
c) −4.2 J
d) −2.8 J
e) other



$$W = \Delta U = U_f - U_i$$

$$= q_2(V_f - V_i)$$

$$V_f = k\frac{q_1}{a/\sqrt{2}} + k\frac{q_3}{a/\sqrt{2}} = \sqrt{2}\,\frac{k}{a}(10+20)\times 10^{-6} = 9.86 \times 10^5 \text{ V}$$

$$V_i = k\frac{q_1}{a} + k\frac{q_3}{a} = \frac{k}{a}(10+20)\times 10^{-6} = 6.98 \times 10^5 \text{ V}$$

$$\Delta U = q_2 \Delta V = 15 \times 10^{-6}(9.86 - 6.98)\times 10^5 \text{ J}$$

$$= +4.2 \text{ J}$$

The P.E. increases. $\Rightarrow$ Work done = +4.2 J (external)

7. An isolated parallel plate capacitor with a dielectric (κ = 3) and a plate area of $0.15\ \text{m}^2$ has a charge Q = 240 pC. The dielectric slab is taken out. What is the electric field between the plates now?

a) 5.4×10^2 N/C
b) 8.2×10^2 N/C
[✓ c) 1.8×10^2 N/C]
d) 3.6×10^2 N/C
e) other

$$E = \frac{V}{d} \qquad C = k\epsilon_0 \frac{A}{d}$$

In presence of dielectric :

$$E = \frac{V}{d} = \frac{Q}{Cd} = \frac{Q}{k\epsilon_0 \frac{A}{d} \cdot d} = \frac{Q}{k\epsilon_0 A}$$

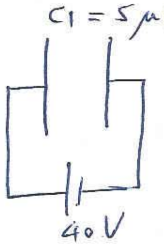
On taking out the dielectric k = 1

$$\therefore\ E = \frac{Q}{\epsilon_0 A} = \frac{240 \times 10^{-12}}{8.85 \times 10^{-12} \times 0.15}$$

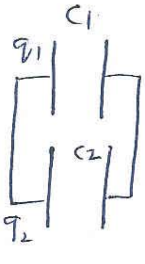
$$= 1.8 \times 10^{2}\ \text{N/C}$$

8. A 5 μF capacitor is charged to 40 V and then connected across an initially uncharged 25 μF capacitor. What is the final potential difference across the 25 μF capacitor?

[✓ a) 6.7 V]
b) 18 V
c) 15 V
d) 21 V
e) other



$$Q_1 = C_1 V_1 = 5\mu F \times 40V = 200\,\mu C$$



$$V = \frac{q_1}{C_1} = \frac{q_2}{C_2} \quad \text{and} \quad q_1 + q_2 = 200\,\mu C$$

$$\frac{q_1}{5} = \frac{q_2}{25} \Rightarrow q_2 = 5q_1$$

$$q_1 + 5q_1 = 200\,\mu C$$

$$q_1 = 33.3\,\mu C$$

$$\therefore\ V = \frac{q_1}{C_1} = \frac{33.3\,\mu C}{5\,\mu F} = 6.7\ V$$

9. A light bulb connected to a 220 V source has a power rating of 100 W when the bulb is on. What is the temperature of the filament when the bulb is ON? Given, $\alpha = 0.005\ ^{\circ}\mathrm{C}^{-1}$, and the resistance of the filament is 41 Ω at the room temperature (25 °C).

a) 2386 °C
[✓ b) 2186 °C]
c) 2020 °C
d) 1946 °C
e) other

$$P = \frac{V^2}{R} \Rightarrow R = \frac{V^2}{P} = \frac{220^2}{100} = 484\,\Omega$$

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

$$484 = 41\left[1 + 0.005 \times \Delta T\right]$$

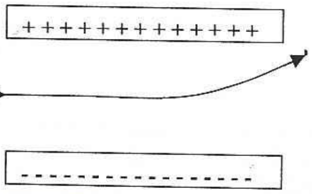
$$\Delta T = 2161\ ^{\circ}C$$

$$T - T_o = 2161\ ^{\circ}C$$

$$T = 2161 + 25 = 2186\ ^{\circ}C$$

10. An electron is accelerated horizontally from the rest in a television picture tube by a potential difference of 15 kV. It then enters midway between two horizontal plates 6.5 cm long and 1.3 cm apart (as shown in the figure), which have a potential difference of 250 V. At what angle (with respect to the horizontal direction) will the electron be traveling after it passes out of the plates?

a) 1.4°
[✓ b) 2.4°]
c) 4.0°
d) 8.0°
e) other



$$\Delta V = 15\ kV = 15\times10^{3}\ V$$

$$K = q\Delta V$$

$$\frac{1}{2} m v_x^2 = q\Delta V \qquad v_x = \sqrt{\frac{2q\Delta V}{m}} = 7.26\times10^{7}\ m/s = \text{constant}$$

Time t to travel the length L of the plates:

$$t = \frac{L}{v_x} = 8.95\times10^{-10}\ s$$

Velocity v_y after time t:

$$v_y = v_{y0} + at = 0 + \frac{qE}{m}t = \frac{qV}{md}\cdot t$$

$$= 3.02\times10^{6}\ m/s$$

$$\theta = \tan^{-1}\left(\frac{v_y}{v_x}\right) = 2.4^{\circ}$$