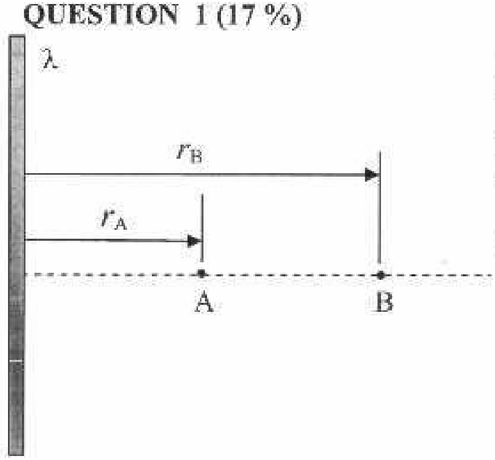
UNIVERSITY OF GAZIANTEP
DEPARTMENT OF ENGINEERING PHYSICS
EP 106 General Physics II
First Midterm Exam Questions
04/04/2006 - Duration 100 min.

Ques.	Mark
1	
2	
3	
4	
5	
6	
Total	
Out of	100 %

Name	Surname	Dep.	Signature
Solutions		EP	

- The steps of solution of each problem should be shown clearly in the space provided.
- Write your answers in boxes provided, otherwise your answer will not be considered.
- Useful constants: $k = 1/4\pi\epsilon_0 = 9\times10^9\ \mathrm{N\cdot m^2/C^2}$, $\sin30=1/2$, $\cos30=\sqrt{3}/2$, $e=1.6\times10^{-19}$ C

QUESTION 1 (17 %)

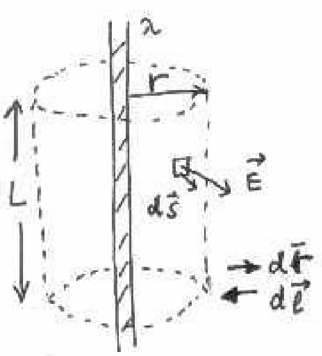


A very long insulating rod carries a constant linear charge density $\lambda = +0.5\times10^{-9}$ C/m.

Find the work done in moving a point charge $q = +15\times10^{-9}$ C from point B to point A?

Assume that $r_A = 60$ cm and $r_B = 120$ cm.

Electric field:



$\vec{E}\cdot d\vec{s} = E\,ds$

$$\epsilon_0 \oint \vec{E}\cdot d\vec{s} = q_{enc}$$

$$\epsilon_0 (E\,2\pi r L) = q L$$

$$E = \frac{\lambda}{2\pi\epsilon_0 r} = \frac{0.5\times10^{-9}}{(2\pi)(8.85\times10^{-12})r}$$

$$E = \frac{9}{r}\ \frac{\mathrm{V}}{\mathrm{m}}$$

here r is in meter.

Potential difference:

$$V_A - V_B = -\int_B^A \vec{E}\cdot d\vec{\ell} = -\int_B^A E\,d\ell\cos180^\circ$$

since $d\ell = -dr$

$$V_A - V_B = -\int_{r_B}^{r_A} E\,dr = -\int_{1.2}^{0.6} \frac{9}{r}\,dr = 9\ln 2 \approx 6.24\ \mathrm{V}$$

Work done:

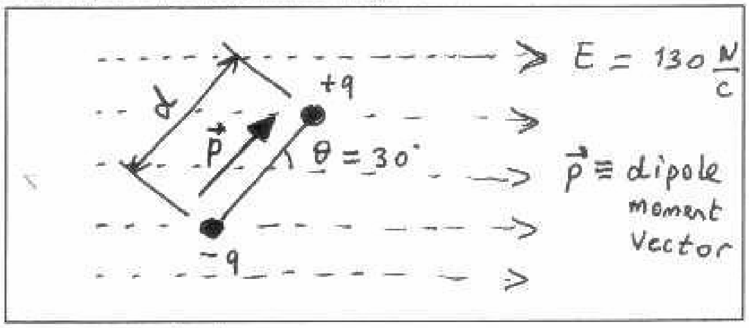
$$W_{BA} = (V_A - V_B)\,q = (6.24)(15\times10^{-9}\ \mathrm{C}) = +9.36\times10^{-9}\ \mathrm{J}$$

$W_{BA} = 9.36\times10^{-9}$ J

QUESTION 2 (17 %)

A molecule having two atoms has a dipole moment of 6×10^{-30} Cm. The distance between the atoms is known as 3.75×10^{-11} m. When the molecule is placed in an external uniform electric field of magnitude 130 N/C, its dipole moment makes angle of 30° with that field.

(a) Draw the system (inside the box given right) for these conditions and show the direction of the dipole moment vector explicitly.



(b) Calculate the amount of charge that generates the dipole moment

$$q = \frac{p}{d} = \frac{6\times10^{-30}\ C\cdot m}{3.75\times10^{-11}\ m} = 1.6\times10^{-19}\ C \equiv e$$

$q = 1.6\times10^{-19}$ C

(c) Calculate the magnitude of torque on the dipole.

$$|\vec{\tau}| = |\vec{p}\times\vec{E}|$$
$$= pE\sin\theta = (6\times10^{-30}\ C\cdot m)(130\ \tfrac{N}{C})\sin 30^\circ$$
$$= 3.9\times10^{-28}\ N\cdot m$$

$\tau = 3.9\times10^{-28}$ N·m

(d) Calculate the potential energy of the molecule in that electric field.

$$U = -\vec{p}\cdot\vec{E} = -pE\cos\theta$$
$$= -(6\times10^{-30}\ C\cdot m)(130\ \tfrac{N}{C})\cos 30^\circ$$
$$= -6.8\times10^{-28}\ J$$

$U = -6.8\times10^{-28}$ J

QUESTION 3 (17 %)

The electrostatic force between two like ions are separated by a distance of 5.0×10^{-10} m is 3.7×10^{-9} N.

(a) What is the charge on each ion?

$$F = k\frac{q^2}{r^2} \rightarrow q = \sqrt{\frac{F}{k}}\ r$$
$$= \sqrt{\frac{3.7\times10^{-19}}{9\times10^{9}}}\ (5\times10^{-10})$$
$$= 3.2\times10^{-19}\ C$$

$q = 3.2\times10^{-19}$ C

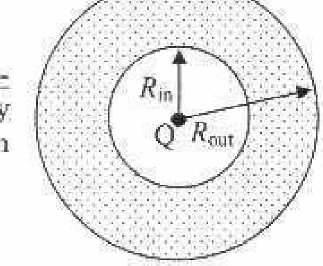
(b) How many electrons are missing from each ion?

$$n = \frac{q}{e} = \frac{3.2\times10^{-19}\ C}{1.6\times10^{-19}\ C} = 2$$

$n = 2$

QUESTION 4 (17 %)

Consider a point charge $Q = +4.0$ nC placed at the center of a non-conducting shell which has the same charge Q distributed uniformly in the sphere. The inner and outer radius of the shell are $R_{in} = 2$ cm and $R_{out} = 4$ cm, respectively.



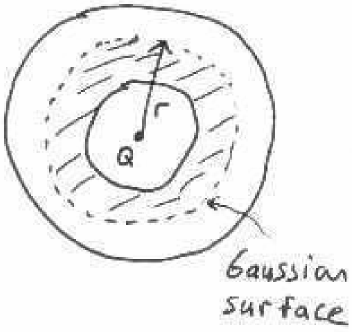
(a) What is the magnitude of electric field at a distance r from the center of the shell if $r = 3$ cm?

$$\varepsilon_0 \oint \vec{E}\cdot d\vec{s} = q_{enc}$$

$$\varepsilon_0 E(4\pi r^2) = Q + \frac{\frac{4\pi}{3}(r^3 - R_{in}^3)}{\frac{4\pi}{3}(R_{out}^3 - R_{in}^3)} Q$$

$$E = \frac{Q}{4\pi\varepsilon_0 r^2}\left[1 + \frac{r^3 - R_{in}^3}{R_{out}^3 - R_{in}^3}\right]$$

$$= \frac{4\times10^{-9}}{(4\pi)(8.85\times10^{-12})(3\times10^{-2})^2}\left[1 + \frac{3^3 - 2^3}{4^3 - 2^3}\right] = 1.2\times10^5 \text{ N/C}$$



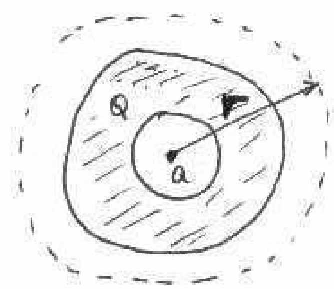
$E = 1.2\times10^5$ N/C

(b) What is the magnitude of electric field at a distance r from the center of the shell if $r = 8$ cm?

$$\varepsilon_0 \oint \vec{E}\cdot d\vec{s} = q_{enc}$$

$$\varepsilon_0 E(4\pi r^2) = Q + Q$$

$$E = \frac{2Q}{4\pi\varepsilon_0 r^2} = \frac{(2)(9\times10^9)(4\times10^{-9})}{(8\times10^{-2})^2} = 1.1\times10^4 \text{ N/C}$$



$E = 1.1\times10^4$ N/C

QUESTION 5 (15 %)

The electric potential in a region is given by $V(x, y, z) = x^2 - 4y + 3yz^2$ (volt) where x, y and z are in meters. Find the direction of electric field in unit vector notation at the point P(1.0 m, 2.0 m, 1.0 m).

$$E_x = -\frac{\partial V}{\partial x} = -(2x) = -2x$$

$$E_y = -\frac{\partial V}{\partial y} = -(-4 + 3z^2) = 4 - 3z^2$$

$$E_z = -\frac{\partial V}{\partial z} = -(6yz) = -6yz$$

$$\vec{E}(x,y,z) = -2x\,\hat{i} + (4 - 3z^2)\,\hat{j} - 6yz\,\hat{k}$$

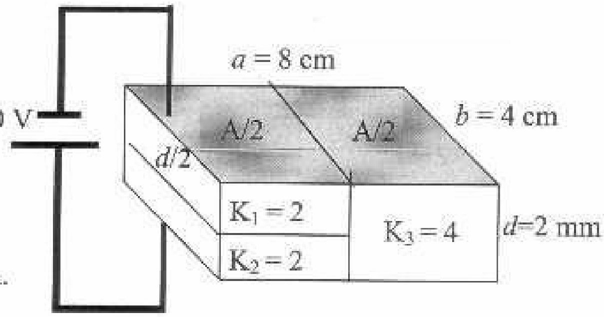
$$\vec{E}(1,2,1) = -(2)(1)\hat{i} + (4 - 3(1)^2)\hat{j} - (6)(2)(1)\hat{k} \text{ (N/C)}$$

$$\vec{E} = -2\hat{i} + \hat{j} - 12\hat{k} \text{ (N/C)}$$

$\mathbf{E} = -2\hat{i} + \hat{j} - 12\hat{k}$ $\frac{N}{C}$

QUESTION 6 (17 %)

A rectangular parallel plate capacitor having sides a and b and separation d is filled with three dielectric materials as seen in the Figure.



(a) Find the equivalent capacitance value of the system.

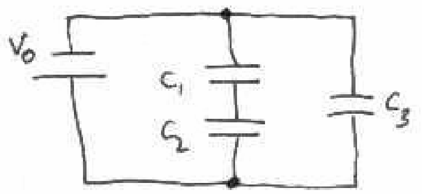


Plate area : $A = ab = (0.08)(0.04) = 3.2\times10^{-3}\ m^2$

$$C_1 = \frac{\varepsilon_0 K_1 (A/2)}{d/2} = \frac{\varepsilon_0 K_1 A}{d} = \frac{(8.85\times10^{-12})(2)(3.2\times10^{-3})}{2\times10^{-3}} = 2.8\times10^{-11}\ F$$

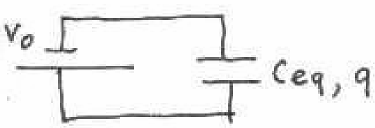
$$C_2 = \frac{\varepsilon_0 K_2 (A/2)}{d/2} = \frac{\varepsilon_0 K_2 A}{d} = \frac{(8.85\times10^{-12})(2)(3.2\times10^{-3})}{2\times10^{-3}} = 2.8\times10^{-11}\ F$$

$$C_3 = \frac{\varepsilon_0 K_3 (A/2)}{d} = \frac{\varepsilon_0 K_3 A}{2d} = \frac{(8.85\times10^{-12})(4)(3.2\times10^{-3})}{(2)(2\times10^{-3})} = 2.8\times10^{-11}\ F$$

$$C_{eq} = \frac{C_1 C_2}{C_1+C_2} + C_3 = \frac{C_1}{2} + C_3 = \frac{3C_1}{2} = \frac{3}{2}(2.8\times10^{-11}\ F) = 4.2\times10^{-11}\ F$$

C_{eq} = 4.2×10^{-11} F

(b) Find the charge on each capacitor (dielectric).



$q = C_{eq} V_0 = (4.2\times10^{-11})(60) = 2.5\times10^{-9}\ C$

$q_3 = C_3 V_0 = (2.8\times10^{-11})(60) = 1.7\times10^{-9}\ C$

$q_1 = q_2 = q_{12}$

$q_{12} = q - q_3 = (2.5 - 1.7)\times10^{-9} = 0.8\times10^{-9}\ C$

$q = q_{12} + q_3$

q_1 = 0.8×10^{-9} C
q_2 = 0.8×10^{-9} C
q_3 = 1.7×10^{-9} C