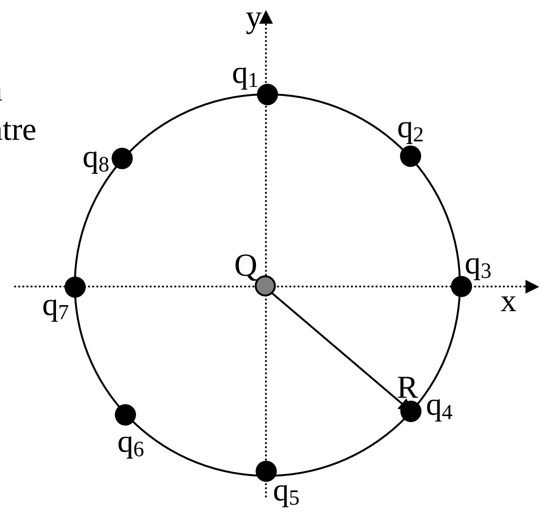
University of Bahrain	Physics 102 First Exam	Fall 2004
Department of Physics	Tuesday 26/10.2004	10:45 –11:45

Name:____ ID no.:____________________

Instructor Name:________________________________ Section:____________________

$k = 9\times10^9$ Nm^2/C^2, $e = 1.6\times10^{-19}$C, $m_p = 1.67\times10^{-27}$ Kg,
$\varepsilon_0 = 8.85\times10^{-12}$ C^2/Nm^2 $m_e = 9.11\times10^{-31}$ Kg, $g = 10$ m/s^2



Problem 1:

Eight identical charges each of q= +10 μC are located on the rim of a circle (R=0.3m) while a charge Q = 5μC is located at the centre as shown in the figure.

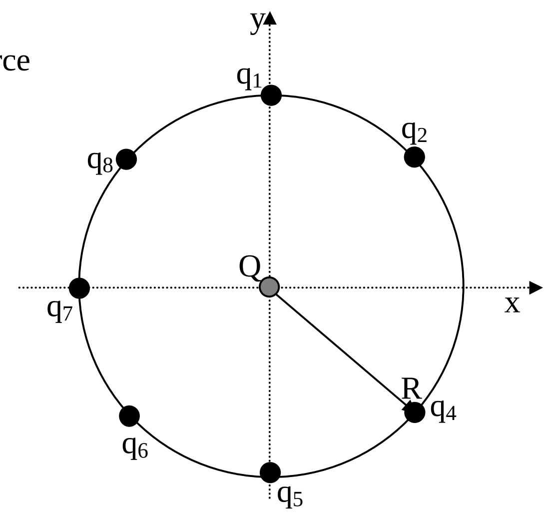
(a)- Show on the diagram all the electric forces that are acting on the charge Q.

(b)- Find the net electric force exerted on the charge Q.

All eight forces are equal in magnitude, and

$$\vec{F}_{net} = \sum_{k=1}^{8} \vec{F}_k = Zero$$

(c)- If the charge q_3 is removed, then calculate the net electric force exerted on the charge Q (**give its magnitude and direction**).



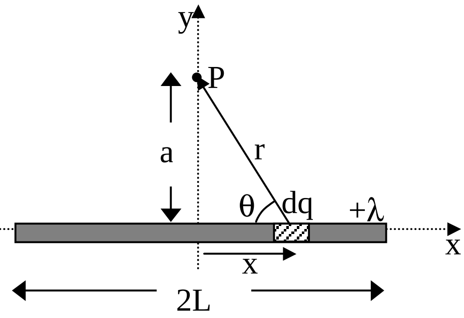
$$\vec{F}_{net} = \sum_{k=1}^{8} \vec{F}_k = \vec{F}_7$$

$$F_7 = \frac{kQq_7}{R^2} = 5N$$

$$\vec{F}_{net} = F_7\hat{i} = 5\hat{i}\,(N)$$

Problem 2:

(I)- A positive charge Q is uniformly distributed on a thin rod of length 2L. If the rod is placed as shown in the figure then find the **magnitude and direction** of the electric field at point P that is located on the bisector line.



$E_X = Zero\,, By\, Symmetry$

$d\,E_y = dE\sin\theta$

$E_y = \int \frac{a}{r}\frac{kdq}{r^2}$

$r = \sqrt{x^2 + a^2} \qquad dq = \lambda dx$

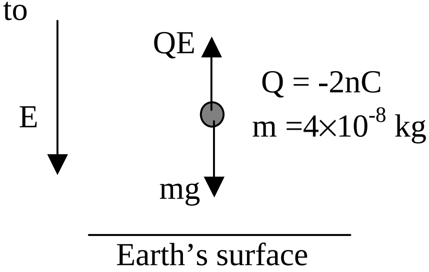
$$E_y = k\lambda a\int_{-L}^{L}\frac{dx}{\left(x^2+a^2\right)^{3/4}} = k\lambda a\frac{x}{a^2\sqrt{x^2+a^2}}\Bigg]_{-L}^{L}$$

$$E_y = \frac{kQ}{a\sqrt{L^2+a^2}}, \qquad Q = 2\lambda L$$

$$\vec{E}_p = \frac{kQ}{a\sqrt{L^2+a^2}}\,\hat{j}$$

You may use the following: $\int \frac{du}{(u^2+c^2)^{3/2}} = \frac{u}{c^2\sqrt{u^2+c^2}}$

(II)- Find the **magnitude and direction** of the electric field required to suspend (remain stationary) a charge Q = – 2 nC and mass m= 4×10^{-8} kg in air near the earth's surface.

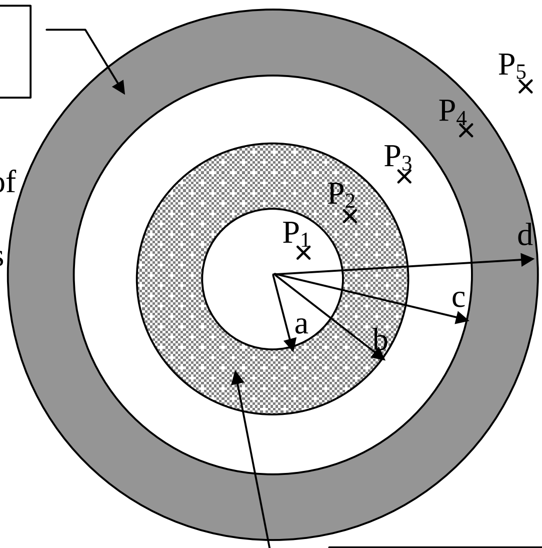


E must be downward so $\vec{F}_e$ is upward

$F_e = W, QE = mg$

$\therefore E = 200\frac{N}{C}$

Problem 3:
A thick insulating spherical shell of radii *a* and *b* is concentric with another thick conducting spherical shell of radii *c* and *d* as shown in the figure. The insulating shell has a total charge +Q distributed uniformly throughout its volume (i.e. has a uniform volume charge density ρ). The conducting shell has a net charge of +3Q.



(a)-Calculate the electric field at the following points:

Point P1:

$$\oint \vec{E}_1 . \vec{dA} = \frac{q_{in}}{\in_o} = zero$$

$$\therefore E_1 = Zero, \text{No charges inside}$$

Point P2:

$$\oint \vec{E}_2 . \vec{dA} = \frac{q_{in}}{\in_o}, \qquad E_2 \times 4\pi r^2 = \frac{\rho Vin}{\in_o} = \rho \frac{4\pi}{3}\left(r^3 - a^3\right)$$

$$E_2 = \frac{\rho}{3\in_o}\frac{\left(r^3 - a^3\right)}{r^2}$$

Point P3:

$$\oint \vec{E}_3 . \vec{dA} = \frac{q_{in}}{\in_o}, \quad E_3 \times 4\pi r^2 = \frac{Q}{\in_o}$$

$$E_3 = \frac{kQ}{r^2}$$

Point P4:

$$\oint \vec{E}_4 . \vec{dA} = \frac{q_{in}}{\in_o}, \qquad E_4 \times 4\pi r^2 = \frac{Q - Q}{\in_o} = Zero$$

$$E_4 = Zero, \text{inside a conductor}$$

Point P5:

$$\oint \vec{E}_5 . \vec{dA} = \frac{q_{in}}{\in_o}, \qquad E_5 \times 4\pi r^2 = \frac{+Q - Q + Q + 3Q}{\in_o} = \frac{4Q}{\in_o}$$

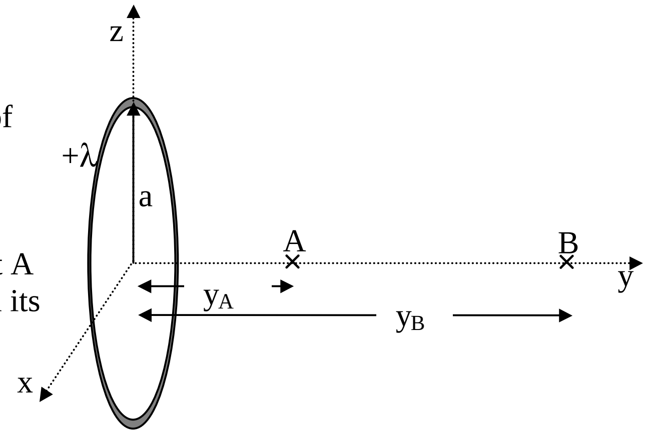
$$E_5 = \frac{4kQ}{r^2}$$

(b) Calculate the surface charge densities on the inner (σ_c) and outer (σ_d) surfaces of the thick conducting shell.

$$\sigma_c = \frac{Q_c}{A} = \frac{-Q}{4\pi c^2}, \qquad \sigma_d = \frac{Q_d}{A} = \frac{Q + 3Q}{4\pi d^2} = \frac{4Q}{4\pi d^2}$$

Problem 4:

A 10 nC charge is uniformly distributed on a thin ring of radius a = 0.3 m. The ring is placed in the x-z plane as shown in the figure.



(a)- Find an expression for the electric potential at point A that is located on the ring axis at a distance y_A from its centre.

$$V_A = \int \frac{kdq}{r} = \int \frac{k\lambda d\ell}{\sqrt{a^2 + y_A^2}}$$

$$V_A = \frac{k\lambda}{\sqrt{a^2 + y_A^2}} \int d\ell = \frac{k\lambda L}{\sqrt{a^2 + y_A^2}} = \frac{kQ}{\sqrt{a^2 + y_A^2}}$$

(b)- Calculate the electric potential difference V_B-V_A between points A and B if y_A=0.3m and y_B=0.9m.

$$V_A = \frac{kQ}{\sqrt{a^2 + y_A^2}} = 212.13V$$

$$V_B = \frac{kQ}{\sqrt{a^2 + y_B^2}} = 94.86V$$

$$\Delta V = V_B - V_A = 94.86 - 212.13 = -117.3V$$

(c)- If a charge of q = 2 μC and mass m = 2×10^{-6} kg starts from rest at point A, then find its final speed

at point B.

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

$$\frac{1}{2}mv_B^2 - \frac{1}{2}mv_A^2 = -2\times10^{-6}\left(-117.3\right),\quad v_A = 0$$

$$V_B = 15.3m/s$$