Assignment # 1

Q1 In figure, particle 1 of charge $+1.0\ \mu C$ and particle 2 of charge $-3.0\ \mu C$ are held at separation $L = 10.0$ cm on an x axis. If particle 3 of unknown charge q_3 is to be located such that the net electrostatic force on it from particles 1 and 2 is zero, what must be the (a) x and (b) y coordinates of particle 3?

1 charge $= q_1 = +1.0\ \mu C$

2 charge $= q_2 = -3\ \mu C$

Distance $= L = 10.0$ cm

Net electrostatic force $= \vec{F}_{net} = 0$

The forces $\vec{F}_{13}$ and $\vec{F}_{23}$ are equal but in opposite direction

$$\vec{F}_{13} = -\vec{F}_{23}$$

$$\frac{\cancel{k} q_1 q_3}{(10+x)^2} = -\left[\frac{\cancel{k} q_2 q_3}{x^2}\right]$$

$$\frac{q_1}{(10+x)^2} = -\frac{q_2}{x^2}$$

$$\frac{x^2}{(10+x)^2} = -\frac{(-3\times 10^{-6})}{1\times 10^{-6}}$$

$$\left[\frac{x}{(10+x)}\right]^2 = 3$$

$$x = \sqrt{3}\,(10+x)$$

$$x = (10)(1.7320) + 1.7320\,x$$

$$-17.320 = 1.7320\,x - x$$

$$0.7320\,x = -17.3205$$

$$x = \frac{-17.320}{0.7320}$$

$$\boxed{x = -23.6602\ \text{cm}}$$

Total distance from origin

$$d = 10 - 23.6602 = \boxed{-13.6602\ \text{cm}}$$

x-coordinate $= -13.660$ y-coordinate of $q_3 = 0$

Q2 How many electrons would have to be removed from a coin to leave it with a charge of $+1.0 \times 10^{-7}$ C?

$q = 1 \times 10^{-7}$ C

$e = 1.6 \times 10^{-19}$ C

$n = ?$

$q = ne$

$n = \frac{q}{e}$

$n = \frac{1 \times 10^{-7}}{1.6 \times 10^{-19}}$

$\boxed{n = 6.25 \times 10^{11}}$

Q3 At each point on the surface of the cube shown in fig, the electric field is parallel to the z axis. The length of each edge of the cube is 3.0 m. On the top face of the cube the field is $E = -34k$ N/C and on the bottom face it is $E = +20k$ N/C. Determine the net charge contained within the cube.

Length of each edge of cube $= L = 3.0$ m

$\vec{E}$ on Top face $= \vec{E}_T = -34k$ N/C

$\vec{E}$ on bottom face $= \vec{E}_b = +20k$ N/C

Net charge within cube $= q = ?$

Flux at Top face:-

$\Phi = \vec{E} \cdot \vec{A} = EA \cos\theta$

$\Phi_T = (-34)(3)^2 \cos 0°$

$\Phi_T = -306$ Nm²/C

Flux at bottom face:-

$\Phi_b = \vec{E} \cdot \vec{A} = EA \cos\theta$

$\Phi_b = (20)(3)^2 \cos 180°$

$\Phi_b = -180$ Nm²/C

Total flux:

$$\Phi = \Phi_T + \Phi_b$$

$$\Phi = -306 - 180$$

$$\Phi = -486 \ Nm^2/C$$

By Gauss's law

$$\Phi = \frac{q_{enc}}{\varepsilon_o}$$

$$q_{enc} = \varepsilon_o \Phi$$

$$= (8.85 \times 10^{-12})(-486)$$

$$= -4301.1 \times 10^{-12} \ C$$

$$\boxed{q = -4.3 \times 10^{-9} \ C}$$

Q4 A long, straight wire - - - - - - - - - - - - - electric field zero. Calculate :-

Linear charge density $= \lambda = 3.6 \ n \ C/m$

Radius $= r = 1.5 cm$

Surface charge density $= ?$

Net electric field is sum of all electric fields.

$$\vec{E}_{net} = \vec{E}_{wire} + \vec{E}_{cylin}$$

$$0 = \frac{\lambda}{4\pi r \varepsilon_o} + \frac{\lambda'}{4\pi r \varepsilon_o}$$

$$0 = \lambda + \lambda'$$

$$\lambda' = -\lambda \quad \text{--- i)}$$

For wire:-

$$\lambda = q/l$$

$$q = \lambda l \quad \text{--- ii)}$$

For cylinder:-

$$\lambda' = q/V$$

$$q = \lambda' V$$

Volume of cylinder $= \pi r^2 l$

$$q = \lambda' \pi r^2 l \quad \text{--- iii)}$$

comparing eq ii and iii

$$\lambda L = \lambda' \pi r^2 L$$
$$\lambda = \lambda' \pi r^2$$
$$\lambda' = \lambda/\pi r^2$$
$$\lambda' = \frac{(3.6 \times 10^{-9}\ C/m)}{\pi (1.5 \times 10^{-2}\ cm)^2}$$
$$\lambda' = \frac{3.6 \times 10^{-9}}{7.068 \times 10^{-4}}$$
$$\lambda' = 0.5093 \times 10^{-5}$$
$$\boxed{\lambda' = 5.093 \times 10^{-6}\ C/m^2}$$

Q5 Two charged concentric spherical shells have radii 10.0 cm ------ (b) at $r = 20.0$ cm.

Outer Radius $= R = 15$ cm
Inner Radius $= r = 10$ cm
Charge on inner shell $= q_1 = 4 \times 10^{-8}$ C
Charge on outer shell $= q_2 = 2 \times 10^{8}$ C
$\vec{E}$ at $r = 12$ cm $= ?$
$\vec{E}$ at $r = 20$ cm $= ?$

Electric field through inner shell.

$$\Phi = \oint E.A$$
$$= \oint E ds = E \oint ds$$
$$\Phi = 4 E \pi r^2 \quad \text{--- i}$$
$$\Phi = q/\varepsilon_0$$
$$\vec{E}\, 4\pi r^2 = q/\varepsilon_0$$
$$\vec{E} = \frac{q}{4\pi\varepsilon_0 r^2}$$
$$\vec{E} = \frac{kq}{r^2}$$
$$\vec{E} = \frac{(9 \times 10^9)(4 \times 10^{-8})}{(12 \times 10^{-2})^2} = \frac{36 \times 10}{14.4 \times 10^{-4}}$$
$$\vec{E} = 0.25 \times 10 \times 10^4$$
$$\boxed{E = 2.5 \times 10^4\ N/C}$$

• Electric feild through outer shell.

$\Phi = \vec{E} \cdot \vec{A} = \oint E\, ds$

$\Phi = E \int ds = 4E\pi r^2 = \Phi$

$\Phi = Q/\epsilon_0$

$\vec{E} = \frac{kq}{r^2}$

$= \frac{(9 \times 10^9)(2 \times 10^{-8})}{(20 \times 10^{-2})^2}$

$\boxed{\vec{E} = 4.5 \times 10^{3}\ N/C}$