NATIONAL UNIVERSITY OF SCIENES & TECHNOLOGY

APPLIED PHYSICS (PHY-102)

Assignment # 4

Submitted to: Dr. M. Imran Malik

Submitted by: Muhammad Umer

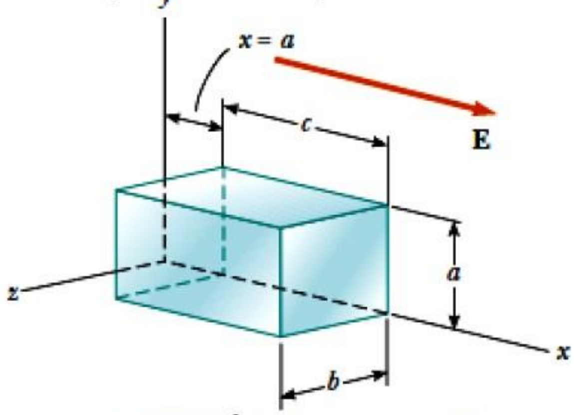
Class: BEE-12-C

Semester: 1st

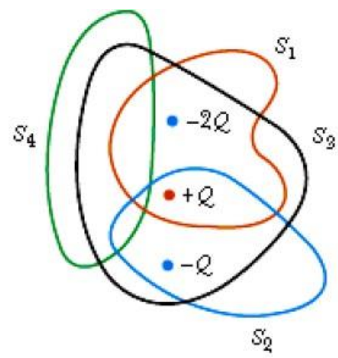
Dated: 17/01/2021

Deadline: 25/01/2021

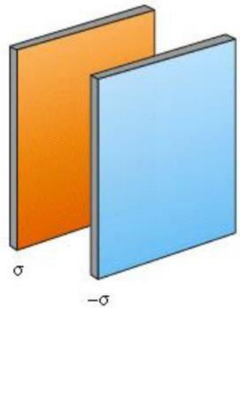
1. A closed surface with dimensions $a = b = 0.400$ m and $c = 0.600$ m is located as in Figure. 2. The left edge of the closed surface is located at position $x = a$. The electric field throughout the region is non-uniform and given by $\mathbf{E} = (3.0 + 2.0x^2)\hat{\mathbf{i}}$ N/C, where x is in meters. Calculate the net electric flux leaving the closed surface. What net charge is enclosed by the surface?



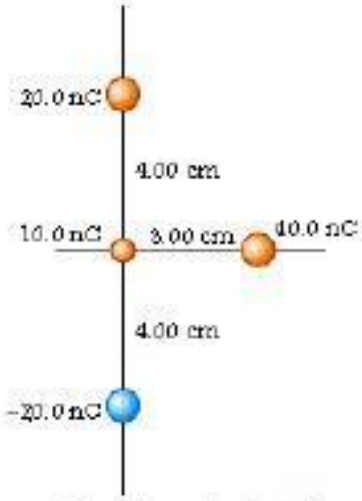
2. Two identical small charged spheres, each having a mass of 3.0×10^{-2} kg, hang in equilibrium. The length of each string is 0.15 m, and the angle is 5.0°. Find the magnitude of the charge on each sphere.
3. Four closed surfaces, S_1 through S_4, together with the charges -2Q, Q, and -Q are sketched in Figure 1. (The lines are the intersections of the surfaces with the page.) Find the electric flux through each surface.



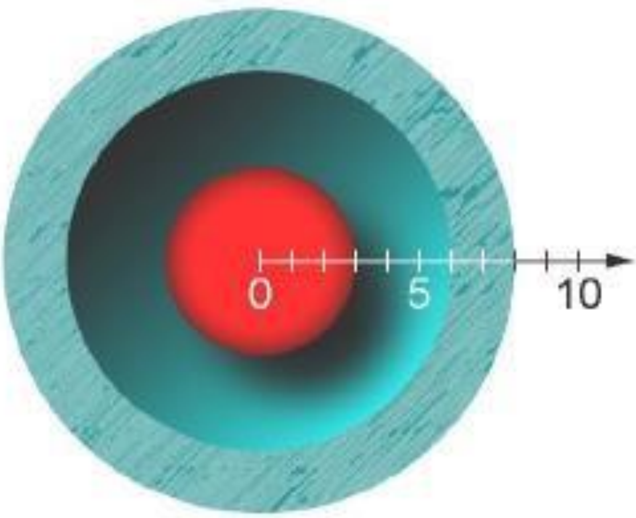
4. A solid sphere of radius 40.0 cm has a total positive charge of 26.0 μC uniformly distributed throughout its volume. Calculate the magnitude of the electric field (a) 0 cm, (b) 10.0 cm, (c) 40.0 cm, and (d) 60.0 cm from the center of the sphere. Answers: 0, 365kN/C, 1.46MN/C, 649kN/C
5. Two infinite, nonconducting sheets of charge are parallel to each other, as shown in Figure 2. The sheet on the left has a uniform surface charge density σ, and the one on the right has a uniform charge density - σ. Calculate the electric field at points (a) to the left of, (b) in between, and (c) to the right of the two sheets.



6. Two particles, with charges of 20.0 nC and -20.0 nC, are placed at the points with coordinates (0, 4.00 cm) and (0, -4.00 cm), as shown in Figure 3. A particle with charge 10.0 nC is located at the origin. (a) Find the electric potential energy of the configuration of the three fixed charges. (b) A fourth particle, with a mass of 2.00×10^{-13} kg and a charge of 40.0 nC, is released from rest at the point (3.00 cm, 0). Find its speed after it has moved freely to a very large distance away. Answers: -4.50×10^{5} J, & 3.46×10^{4} m/s



7. Two conducting spheres are concentrically nested as shown in the cross-sectional diagram below. The inner sphere has a radius of 3 cm and a net charge of +12 μC. The outer spherical shell has an inner radius of 6 cm, an outer radius of 8 cm, and a net charge of −6 μC.



a. Determine the net charge on the (i) inner surface of the outer spherical shell and (ii) outer surface of the outer spherical shell

b. Sketch the magnitude of the electric field as functions of distance from 0 to 10 cm.

c. Complete the following table.

distance from center (cm)	electric field (MV/m)	
	direction	magnitude
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

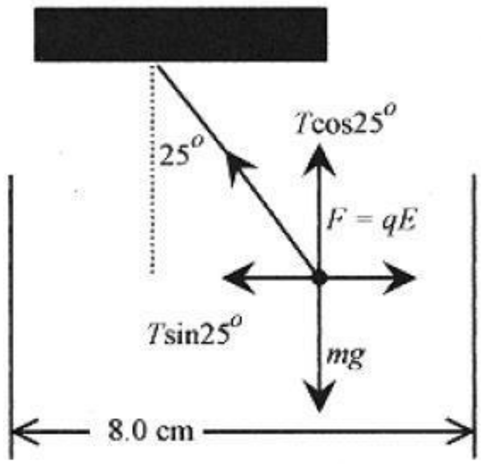
8. **(Select one option)** Two charges Q_1 and Q_2 are inside a closed cubical box of side a. What is the net outward flux through the box?

1. $\mathbf{\Phi = 0}$
2. $\Phi = (Q_1 + Q_2)/\varepsilon_0$
3. $\Phi = k(Q_1 + Q_2)/a^2$
4. $\Phi = \dfrac{Q_1 + Q_2}{4\pi\varepsilon_0 a^2}$
5. $\Phi = \dfrac{Q_1 - Q_2}{4\pi\varepsilon_0 a^2}$

9. A positive charge Q= 8 mC is placed inside the cavity of a neutral spherical conducting shell with an inner radius a and an outer radius b. Find the charges induced at the inner and outer surfaces of the shell.

10. A positive charge Q=8 mC is placed inside a spherical conducting shell with inner radius a and outer radius b which has an extra charge of 4 mC placed somewhere on it. When all motion of charges ends (after 10^{-15} sec), find the charges on the inner and outer surfaces of the shell.

11. A 5.0g conducting sphere with charge of 20 μC hangs by a non-conducting thread in an electric field produced by two plates separated by 8.0cm. What potential will cause the ball to hang at 25° to the vertical?

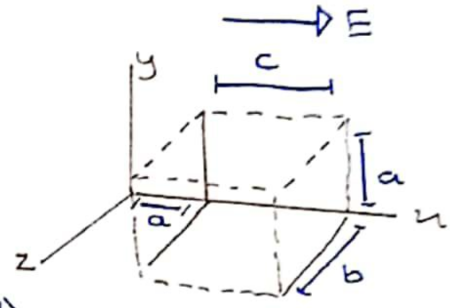


12. The water molecule H2O has an asymmetric charge distribution leading to a dipole moment p *of* 6.2 × 10^{-30}C.m. Calculate the electric potential 1.0nm a) at right angles to the direction of the dipole moment and b) at 45° to the direction of the dipole moment. (1.0 nm is approximately 10 hydrogen atom diameters).

Muhammad Umer
CMS : 345834
BEE -12C

- ① Problem

Only the sides parallel to ~~zy~~-plane contribute to the net flux.



$$\Phi_E = E_a A\cos(180) + E_{a+c} A\cos(0)$$
$$= -(3.0+2a^2)A + (3.0+2(a+c)^2)A$$
$$= -(3.0+2a^2)(ab) + (3.0+2(a+c)^2)(ab)$$
$$= ab\left[(3+2(a^2+c^2+2ac)) - (3+2a^2)\right]$$
$$= ab\left[(\cancel{3}+\cancel{2a^2}+2c^2+4ac) - \cancel{3} - \cancel{2a^2}\right]$$
$$= ab(2c^2+4ac)$$
$$\boxed{\Phi_E = 2abc(c+2a)}$$

Using $a=b=0.400m$, $c=0.600m$

$$\boxed{\Phi_E = 0.2688 \ \frac{N}{C}m^2}$$

Using Gauss's Law

$$\Phi_E = \frac{Q_{enclosed}}{\varepsilon_0}$$

$$Q = \Phi_E \varepsilon_0$$
$$= (0.2688)(8.85\times10^{-12})$$
$$\boxed{Q = 2.378\times10^{-12}\ C}$$

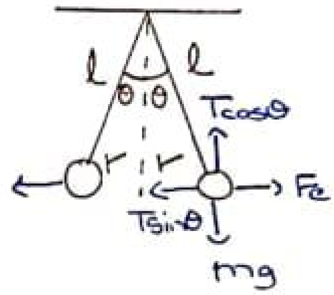
- ② Problem

Given

$m = 3\times10^{-2}\,kg$
$l = 0.15m$
$\theta = 5°$

In x-axis,

$$F_e - T\sin\theta = 0$$
$$T\cos\theta - mg = 0$$



- $T\sin\theta = F_e$
- $T\cos\theta = mg$

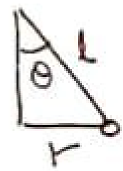
$$\tan\theta = \frac{F_e}{mg}$$

$$\tan(5) = \frac{F_e}{3\times10^{-2}\times 9.8}$$

$$0.0874 \times 3\times10^{-2}\times 9.8 = F_e$$

$$\boxed{F_e = 0.0257\,N}$$

Now, to find separation $(2r)$



$$\sin\theta = l^{-1}r = r/l$$
$$r = l\sin\theta$$
$$r = 0.15\sin(5)$$
$$\boxed{r = 0.013\,m}$$

Finding charge through coloumbs law,

$$F_e = \frac{k|q^2|}{(2r)^2}$$

$$|q^2| = \frac{F_e(2r)^2}{k}$$

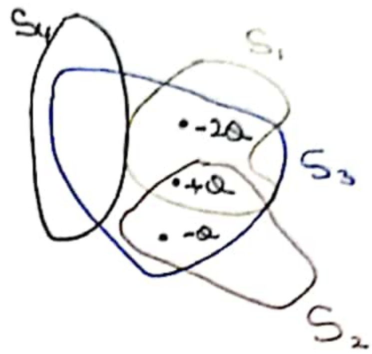
$$= \frac{0.0257\times(0.026)^2}{9\times10^9}$$

$$|q^2| = 1.877\times10^{-15}$$

$$\boxed{q = 4.33\times10^{-8}\,C}$$

③ Problem

Using Gauss Law



$$\Phi = \frac{q_{enclosed}}{\varepsilon_0}$$

$$S_1: \frac{-2Q+Q}{\varepsilon_0} = -\frac{Q}{\varepsilon_0}$$

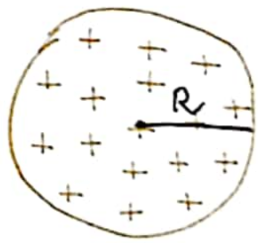
$$S_2: \frac{-Q+Q}{\varepsilon_0} = 0$$

$$S_3: \frac{-2Q+Q-Q}{\varepsilon_0} = -\frac{2Q}{\varepsilon_0}$$

$$S_4: \frac{0}{\varepsilon_0} = 0$$

④ Problem

E inside sphere:



$$6 = \frac{q}{\frac{4}{3}\pi R^3}$$

$$E\int dA = \frac{q_{enc}}{\varepsilon_0} \Rightarrow E4\pi \cancel{r^2} = \frac{6}{\varepsilon_0}\frac{4}{3}\pi r^{\cancel{3}}$$

$$E = \frac{6r}{3} = \frac{q}{\frac{4}{\cancel{3}}\pi R^3 \cancel{3}\varepsilon_0} r = \boxed{\frac{q}{4\pi R^3 \varepsilon_0} r}$$

E outside sphere:

$$E\int dA = \frac{q_{enc}}{\varepsilon_0} \Rightarrow E4\pi r^2 = \frac{6\,4\pi R^3}{3\varepsilon_0}$$

$$\boxed{E = \frac{Q}{4\pi r^2 \varepsilon_0}}$$

At $r = 0\,cm$

$$E = \frac{q}{4\pi R^3 \varepsilon_0} r = \frac{q}{4\pi R^3 \varepsilon_0}(0) = \boxed{0}$$

At $r = 10\,cm$

$$E = \frac{q}{4\pi R^3 \varepsilon_0}(10 \times 10^{-2}) = 365292 \frac{N}{C} = \boxed{365\, kN/C}$$

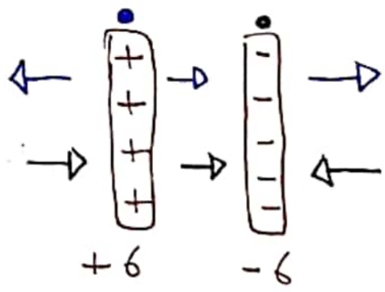
At $r = 40\,cm$

$$E = \frac{q}{4\pi R^{\cancel{3}2} \varepsilon_0} \cancel{r} = \frac{q}{4\pi R^2 \varepsilon_0} = 1461168 \frac{N}{C} = \boxed{1.46\, M\frac{N}{C}}$$

At $r = 60\,cm$

$$E = \frac{q}{4\pi r^2 \varepsilon_0} = 649408 \frac{N}{C} = \boxed{649\, k\frac{N}{C}}$$

(5) Problem



$$E_+ = \frac{\sigma}{2\varepsilon_0} \qquad E_- = \frac{\sigma}{2\varepsilon_0}$$

To the left

$$E = +\frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = \boxed{0}$$

To the right

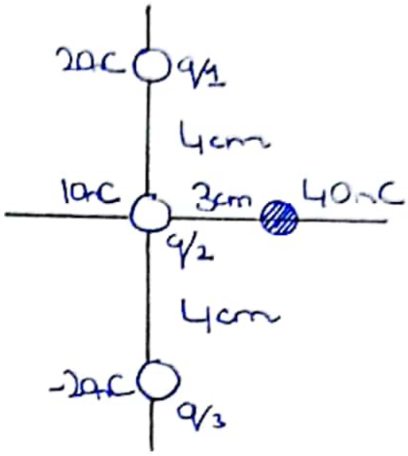
$$E = +\frac{\sigma}{2\varepsilon_0} - \frac{\sigma}{2\varepsilon_0} = \boxed{0}$$

In the middle

$$E = \frac{+\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0} = \boxed{\frac{\sigma}{\varepsilon_0}}$$

⑥ Problem

a) The electric potential energy of the system is:



$$U = U_{12} + U_{23} + U_{31}$$

$$= \frac{kq_1q_2}{r_{12}} + \frac{kq_2q_3}{r_{23}} + \frac{kq_3q_1}{r_{31}}$$

$$= k\left(\frac{q_1q_2}{r_{12}} + \frac{q_2q_3}{r_{23}} + \frac{q_3q_1}{r_{31}}\right)$$

$$= k\left(\cancel{\frac{20n \times 10n}{4\times10^{-2}}} + \cancel{\frac{10n \times -20n}{4\times10^{-2}}} + \frac{20n \times -20n}{8\times10^{-2}}\right)$$

$$= k\left(-\frac{20\times10^{-9} \times 20\times10^{-9}}{8\times10^{-2}}\right)$$

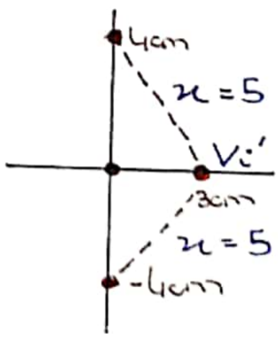
$$\boxed{U = -4.50 \times 10^{-5}\,J}$$

b) $(KE_i + U_i) = (KE_f + U_f)$

$$\boxed{\frac{1}{2}mv_i^2 + q\,V_i' = \frac{1}{2}mv_f^2 + qV_f'} \rightarrow 1$$

$\therefore v_i = 0$, $V_f' = 0$

V_i' is the potential created by the fixed charges on (3cm, 0).



- Finding hypotenuse:

$$x^2 = a^2 + b^2$$
$$x^2 = (4)^2 + (3)^2$$
$$x^2 = 25$$
$$\boxed{x = 5}$$

$$V_i' = V_1 + V_2 + V_3$$

$$V_i' = \frac{kq_1}{r_1} + \frac{kq_2}{r_2} + \frac{kq_3}{r_3}$$

$$V_i' = \frac{k\, \cancel{20\times10^{-9}}}{\cancel{5\times10^{-2}}} + \frac{k\, 10\times10^{-9}}{3\times10^{-2}} - \frac{k\, \cancel{20\times10^{-9}}}{\cancel{5\times10^{-2}}}$$

$$\boxed{V_i' = 3000\,V}$$

Using 1 :

$$qV_i' = \frac{1}{2}mV_f^2$$

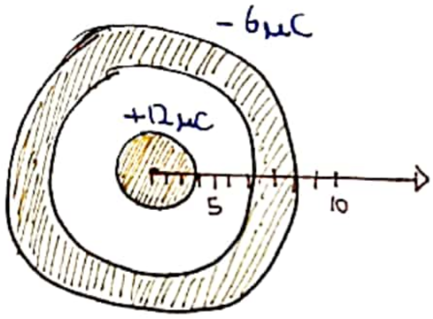
$$V_f^2 = \frac{2qV_i'}{m}$$

$$V_f = \sqrt{\frac{2qV_i'}{m}}$$

$$= \sqrt{\frac{2\times40\times10^{-9}\times3000}{2\times10^{-13}}}$$

$$\boxed{V_f = 34641\ m/s}$$

7. Problem.



a) Since the inner sphere has +12μC charge, the inner surface of outer sphere has -12μC charge.

Thus, to make the outer sphere with net charge -6μC, the outer sphere must have +6μC on its outer surface.

b) Electric Field as function of distance

$$\int E\,dA = \frac{Q}{\varepsilon_0}$$

$$E\,4\pi r^2 = \frac{Q}{\varepsilon_0}$$

$$E = \frac{Q}{4\pi\varepsilon_0 r^2} \Rightarrow \boxed{\frac{kQ}{r^2}}$$

- From 0cm to 3cm:

$$E = \frac{qk}{r^2} = \frac{(0)k}{r^2} = \boxed{0}$$

∴ Property of Conductors, No charge inside

- From 3cm to 6cm:

$$E = \frac{kq}{r^2} = \frac{9\times10^9 \times 12\times10^{-6}}{r^2} = \boxed{108000 \times \frac{1}{r^2}}$$

- From 6cm to 8cm:

$$E = \frac{kQ}{r^2} = \frac{k(0)}{r^2} = \boxed{0}$$

∴ No charge enclosed within a conductor

- From 8cm to 10cm:

$$E = \frac{kq}{r^2} = \frac{9\times10^9 \times 6\times10^{-6}}{r^2} = \boxed{54000 \times \frac{1}{r^2}}$$

c) Table

Distance cm	Electric Field MV/m Direction	Magnitude
0	n/a	0
1	n/a	0
2	n/a	0
3	out & ⊥	120.0
4	out & ⊥	67.5
5	out & ⊥	43.2
6	out & ⊥	30.0
7	n/a	0
8	out & ⊥	8.44
9	out & ⊥	6.67
10	out & ⊥	5.40

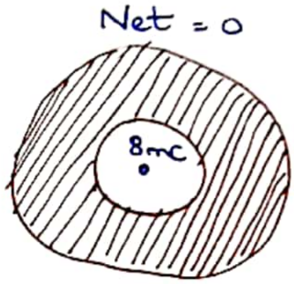
where ⊥ is perpendicular to the surface of conductive sphere

⑧ Problem

The correct option that is in accordance to Gauss' Law, $\phi = \frac{q_{enclosed}}{\varepsilon_0}$, is;

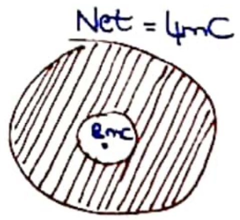
$$\boxed{\phi = \frac{(Q_1 + Q_2)}{\varepsilon_0}}$$

⑨ Problem



Since it retains neutrality, $\boxed{-8mC}$ is induced at inner and $\boxed{+8mC}$ on the outer surface. These values make the electric field inside conductor equal to zero.

⑩ Problem

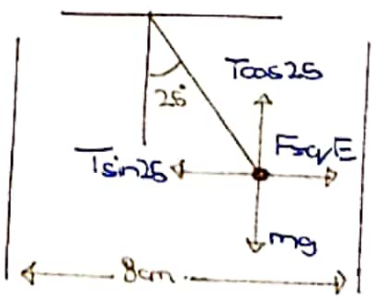


The 8mC charge will induce $\boxed{-8mC}$ charge on the inner surface of conductor. After motion ends, the shell has $\boxed{4mC}$ charge on it. In order to maintain electrical neutrality $+\boxed{12mC}$ is induced on the outer surface.

⑪ Problem

$\Sigma F_x = qE - T\sin(25) = 0$

$\Sigma F_y = T\cos(25) - mg = 0$



$$\boxed{\begin{aligned} T\cos(25) &= mg \\ T\sin(25) &= qE \end{aligned}}$$

$$\frac{\cancel{T}\sin(25)}{\cancel{T}\cos(25)} = \frac{qE}{mg}$$

$$mg\tan(25) = qE$$

$$E = \frac{mg\tan(25)}{q}$$

As,

$$\Delta V = Ed = \frac{mg\tan(25)}{q} d$$

$$\Delta V = \frac{(5\times10^{-3})(9.8)(0.4663)}{20\times10^{-6}} (8\times10^{-2})$$

$$\boxed{\Delta V = 91.394V}$$

⑫ Problem

We know that for electric dipole, electric potential is given by;

$$\boxed{V = \frac{kp\cos\theta}{r^2}}$$

As 1.0nm is 10 H diameters, $\boxed{r >> d}$

a) At right angle

$$V = \frac{kp\cos(90)}{r^2} = \boxed{0}$$

b) At 45°

$$V = \frac{kp\cos(45)}{r^2} = \frac{9\times10^{9}\times6.2\times10^{-30}\times0.707}{(1\times10^{-9})^2} = \boxed{0.0394V}$$