P-19: Space vehicles traveling through Earth's radiation belts can intercept a significant number of electrons. The resulting charge buildup can damage electronic components and disrupt operations. Suppose a spherical metal satellite 1.3m in diameter accumulates 2.4μC of charge in one orbital revolution. (a) Find the resulting surface charge density. (b) Calculate the Magnitude of the electric field just outside the surface of the satellite, due to the surface charge.

(a) $\sigma = ?$

(b) $E = ?$ outside the surface of the satellite due to surface charge.

$$\sigma = \frac{q}{A} \Rightarrow \text{Formula to used}$$

diameter of metal satellite $= 1.3m$; $R = \frac{1.3}{2} = 0.65m$

$q = 2.4\mu C$ (in one orbital rev.)

so, $$\sigma = \frac{q}{A} = \frac{q}{4\pi R^2} = \frac{2.4 \times 10^{-6}}{4 \times 3.14 \times (0.65)^2}$$

$$\boxed{\sigma = \frac{2.4 \times 10^{-6}}{5.30} = 4.5 \times 10^{-7}\ C/m^2}$$

(b) $$E = \frac{\sigma}{\varepsilon_0} \quad \text{(Electric field for a charged conductor)}$$

$$= \frac{4.5 \times 10^{-7}}{8.85 \times 10^{-12}}$$

$$\boxed{E = 5.1 \times 10^{4}\ N/C}$$

P-31: Two long, charged, thin walled, concentric cylindrical shells have radii of 3.0 and 6.0cm. The charge per unit length is 5×10^{-6} C/m on the inner shell and -7.0×10^{-6} C/m on the outer shell. What are the (a) Magnitude E and (b) direction (radially inward or outward) of the Electric field at radial distance $r = 4.0$cm? What are (c) E and (d) direction at $r = 8.0$cm?

Two long charged, thin walled concentric cylindrical shells

$r_1 = 3$cm & (radii)

$r_2 = 6$cm

$\lambda_1 = 5\times10^{-6}$ C/m (inner shell) (+ve)

$\lambda_2 = -7\times10^{-6}$ C/m (outer shell)

what are (a) $|E| = ?$ (b) direction (inward or outward of Electric field)

at radial dist. $r = 4$cm? (c) $E = ?$

(d) at $r = 8$cm $\quad 3 < 4\text{cm} < 6 \quad$ & only λ_1, 4cm b/w 3cm & 6cm

$$E(r) = \frac{\lambda_1}{2\pi\varepsilon_0 r} = \frac{5\times10^{-6}}{2\pi\times8.85\times10^{-12}\times4\times10^{-2}}$$

$$\boxed{E = 2.3\times10^{6}\ N/C}$$

(b) $+E \Rightarrow$ points radially outward.

(c) $8\text{cm} > 6\text{cm}$

$$E(8\text{cm}) = \frac{\lambda_1+\lambda_2}{2\pi\varepsilon_0 r} = \frac{5\times10^{-6} - 7\times10^{-6}}{2\pi\times8.85\times10^{-12}\times8\times10^{-2}}$$

$$\boxed{E(8\text{cm}) = 4.5\times10^{5}\ N/C}$$

$|E| = 4.5\times10^{5}$ N/C $\quad$ (radially inward)

λ_1 — +ve $\qquad |\lambda_2| > |\lambda_1|$

λ_2 — −ve

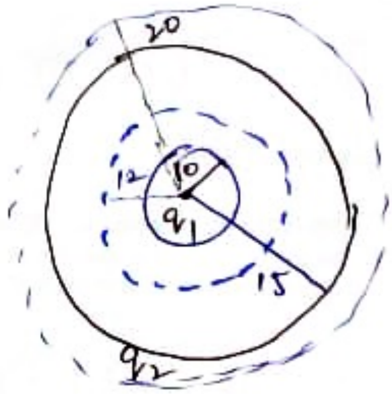
P-45: Two charged concentric spherical shells have radii 10cm and 15cm. The charge on the inner shell is 4.00×10^{-8}C, and that on the outershell is 2.00×10^{-8}C. Find the Electric field (a) at $r = 12$cm and (b) at $r = 20$cm

$r_1 = 10$cm (charged shell 1) (inner)
$r_2 = 15$cm (charged shell 2) (outer)

Charge on inner shell $= q_1 = 4 \times 10^{-8}$C
Charge on outer shell $= q_2 = 2 \times 10^{-8}$C

Find the Electric field at (a) $r = 12$cm
& (b) $r = 20$cm

$r_1 < r \quad , \quad r_2 > r$



(a) $E = \frac{q_1}{4\pi\varepsilon_0 r^2}$

$= \frac{9 \times 10^{9} \times 4 \times 10^{-8}}{(12 \times 10^{-2})}$

$\vec{E} = 2.5 \times 10^{4}$ N/C

(b) $r_1 < r$ & $r_2 > r$

$E = \frac{q_1 + q_2}{4\pi\varepsilon_0 r^2}$ or $q_{net} = q_1 + q_2$

$= \frac{4 \times 10^{-8} + 2 \times 10^{-8} \times 9 \times 10^{9}}{(20 \times 10^{-2})^2}$

$\vec{E} = 1.35 \times 10^{4}$ N/C

P-47: An unknown charge sits on a conducting solid Sphere of radius 10cm. If the electric field 15cm from the center of the sphere has the Magnitude 3.0×10^3 N/C and is directly radially inward, what is the net charge on the sphere?

(radius of conducting solid sphere) = 10cm

distance = 15cm (Electric field's from the center of the sphere)

$E = 3 \times 10^3$ N/C (radially inward)

q_{net}(on sphere) = ?

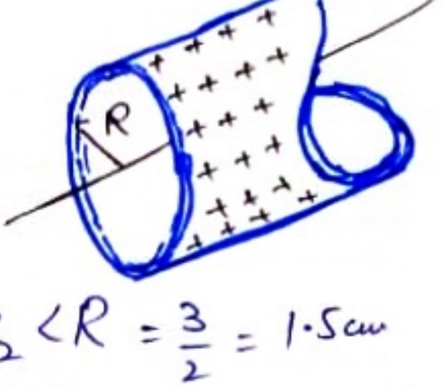
$E = \frac{q}{4\pi\varepsilon_0 r^2}$ $q \rightarrow$ charge on sphere

$3 \times 10^3 = \frac{q \times 9 \times 10^9}{(15 \times 10^{-2})^2}$

$q = 7.5 \times 10^{-9}\,C = 7.5\,nC$

It should be $q = -7.5\,nC$ (Because Electric field is radially inward)

P-24: Fig 23-40 shows a section of a long thin-walled metal tube of radius $R = 3.00\,cm$, with a charge per unit length of $\lambda = 2.00 \times 10^{-8}\,C/m$. What is the magnitude of E of the Electric field at radial distance (a) $r = R/2.00$ and (b) $r = 2.00R$? (c) Graph E versus r for the range r=0 to 2.00R.



long thin walled metal tube

$R = 3\,cm$

$\lambda = 2 \times 10^{-8}\,C\,m^{-1}$

E=? at radial distance $\begin{cases} r = R/2 < R = \frac{3}{2} = 1.5\,cm \\ (b)\ r = 2R \Rightarrow r = 2 \times 3 = 6\,cm \\ \quad r > R \end{cases}$

$$\phi = \int E \cdot dA$$

$$= \int E(2\pi r) = \frac{q_{enc}}{\varepsilon_0} \quad (1)$$

circumference of circle $= 2\pi r$

(a) for $r < R$
(inside the tube)

$$\boxed{E = 0}$$

(b) for $r > R$ using eq (1), $E = \frac{\lambda}{2\pi r \varepsilon_0}$ (Electric field by charged rod)

$$E = \frac{2 \times 10^{-8}}{2 \times 3.14 \times 8.85 \times 10^{-12} \times 6 \times 10^{-12}}$$

$$\boxed{E = 6 \times 10^3\,N/C}$$

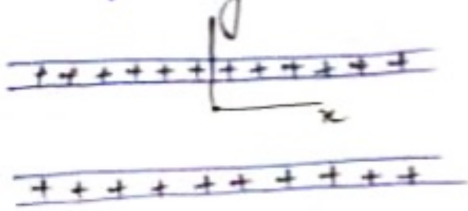
(c) Write a Matlab code

```
lamb = 2*10^-8;
r1 = 0.03;
r2 = 0:0.001:2*r1;
E= lamb./(2*Pi*8.85*10^-12).*r2);
Plot(r2,E);
```

P-36 : Fig 23-47 shows cross sections through two large, parallel, non-conducting sheets with identical distributions of positive charge with surface charge density $\sigma = 1.77 \times 10^{-22}$ C/m². In unit vector notation, what is $\vec{E}$ at points (a) above the sheets, (b) b/w them, and (c) below them?

Two large parallel non-conducting sheets

$\sigma = 1.77 \times 10^{-22}$ C/m²



(a) unit vector Notation

$\vec{E} = ?$ (above the sheets)

(b) b/w them

(c) below them

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

$$= \frac{\cancel{2}\sigma}{\cancel{2}\varepsilon_0} = \frac{\sigma}{\varepsilon_0}$$

$$\boxed{\vec{E} = \frac{1.77 \times 10^{-2}}{8.85 \times 10^{-12}} = 2 \times 10^{-11} \text{ N/C } (\hat{j})}$$

(upward direction)

$$\boxed{\text{(b) } E = 0 \text{ (b/w them)}}$$

$$\boxed{\text{(c) } \vec{E} = (2 \times 10^{-11})(-\hat{j}) \text{ N/C}}$$

P-25: An infinite line of charge produces a field of Magnitude 4.5×10^4 N/C at distance 2.0m. Find the linear charge density.

$$E = 4.5\times10^4 \, N/C$$

distance = 2 m

linear charge density = λ = ?

using $E = \lambda / 2\pi\varepsilon_0 r$

So,

$$4.5\times10^4 = \frac{\lambda}{2\times3.14\times8.85\times10^{-12}\times2}$$

$$\boxed{\lambda = 5\times10^{-6} \, C/m}$$

P-22: An electron is released 9.0cm from a very long non-conducting rod with a uniform 6µC/m. What is the magnitude of the electron's initial acceleration?

Released from rest at $\perp$ distance of 9cm from a line of charge

$$\lambda = 6\mu C/m$$

a = initial acceleration = ?

$F = ma$ & $F = qE = eE$

$$ma = eE$$

$$ma = e\frac{\lambda}{2\pi\varepsilon_0 r} \Rightarrow a = \frac{e\lambda}{2\pi\varepsilon_0 r m}$$

$$a = \frac{1.6\times10^{-19}\times6\times10^{-6}}{2\times3.14\times8.85\times10^{-12}\times9\times10^{-2}\times9.11\times10^{-31}} = 9.6\times10^{-25}$$

$$\boxed{a = 2.1\times10^{17} \, m/s^2}$$