Problem 1:
Eight identical charges each of \( q = +10 \, \mu C \) are located on the rim of a circle (\( R = 0.3 \, m \)) while a charge \( Q = 5 \, \mu C \) 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

\[ \vec{F}_{net} = \sum_{k=1}^{8} \vec{F} = \text{Zero} \]

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

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

\[ F_7 = \frac{kQq_7}{R^2} = 5 \, N \]

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

\[ E_x = \text{Zero, By Symmetry} \]
\[ dE_y = dE \sin \theta \]
\[ E_y = \int \frac{a \, kdq}{r} \, \frac{1}{r^2} \]
\[ r = \sqrt{x^2 + a^2} \, \, dq = \lambda \, dx \]
\[ E_y = k\lambda a \int_0^L \frac{dx}{(x^2 + a^2)^{3/2}} = k\lambda a \frac{x}{a^2 \sqrt{x^2 + a^2}} \bigg|_0^L \]
\[ E_y = \frac{kQ}{a \sqrt{L^2 + a^2}}, \quad Q = 2\lambda L \]
\[ \vec{E}_p = \frac{kQ}{a \sqrt{L^2 + a^2}} \hat{j} \]

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 \( Q = -2 \text{nC} \) and mass \( m = 4 \times 10^{-8} \text{kg} \) in air near the earth’s surface.

\[ E \text{ must be downward so } \vec{F}_e \text{ is upward} \]
\[ F_e = W, \, QE = mg \]
\[ \therefore E = 200 \frac{N}{C} \]
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 \(\rho\)). The conducting shell has a net charge of \(+3Q\).

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

Point \(P_1\):
\[
\hat{E}_1 \cdot \hat{n} = \frac{q_{in}}{\varepsilon_0} = \text{zero}
\]
\[
\therefore E_1 = \text{Zero, No charges inside}
\]

Point \(P_2\):
\[
\hat{E}_2 \cdot \hat{n} = \frac{q_{in}}{\varepsilon_0}, \quad E_2 \times 4\pi r^2 = \frac{\rho \text{Vin}}{\varepsilon_0} = \frac{\rho}{3\varepsilon_0} \left(r^3 - a^3\right)
\]
\[
E_2 = \frac{\rho}{3\varepsilon_0} \left(\frac{r^3 - a^3}{r^2}\right)
\]

Point \(P_3\):
\[
\hat{E}_3 \cdot \hat{n} = \frac{q_{in}}{\varepsilon_0}, \quad E_3 \times 4\pi r^2 = \frac{Q}{\varepsilon_0}
\]
\[
E_3 = \frac{kQ}{r^2}
\]

Point \(P_4\):
\[
\hat{E}_4 \cdot \hat{n} = \frac{q_{in}}{\varepsilon_0}, \quad E_4 \times 4\pi r^2 = \frac{Q - Q}{\varepsilon_0} = \text{Zero}
\]
\[
E_4 = \text{Zero, inside a conductor}
\]

Point \(P_5\):
\[
\hat{E}_5 \cdot \hat{n} = \frac{q_{in}}{\varepsilon_0}, \quad E_5 \times 4\pi r^2 = \frac{+Q - Q + 3Q}{\varepsilon_0} = \frac{4Q}{\varepsilon_0}
\]
\[
E_5 = \frac{4kQ}{r^2}
\]

(b) Calculate the surface charge densities on the inner (\(\sigma_c\)) and outer (\(\sigma_d\)) surfaces of the thick conducting shell.

\[
\sigma_c = \frac{Q_c}{A} = \frac{-Q}{4\pi c^2}, \quad \sigma_d = \frac{Q_d}{A} = \frac{Q + 3Q}{4\pi d^2} = \frac{4Q}{4\pi d^2}
\]
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.

\[
V_A = \int \frac{k dq}{r} = \int \frac{k \lambda d \ell}{\sqrt{a^2 + y_A^2}} \\
V_A = \frac{k \lambda}{\sqrt{a^2 + y_A^2}} L = \frac{kQ}{\sqrt{a^2 + y_A^2}}
\]

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

\[
V_A = \frac{kQ}{\sqrt{a^2 + y_A^2}} = 212.13V \\
V_B = \frac{kQ}{\sqrt{a^2 + y_B^2}} = 94.86V \\
\Delta V = V_B - V_A = 94.86 - 212.13 = -117.3V
\]

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

\[
\Delta K = -\Delta U = -q\Delta V \\
\frac{1}{2}mv_B^2 - \frac{1}{2}mv_A^2 = -2 \times 10^{-6}(-117.3) \quad v_A = 0 \\
V_B = 15.3 m/s
\]