1. PSE6 23.P.006. [316509] Two small silver spheres, each with a mass of 9.00 g, are separated by 1.00 m. Calculate the fraction of the electrons in one sphere that must be transferred to the other to produce an attractive force of $2.00 \times 10^4$ N (about 2 tons) between the spheres. (The number of electrons per atom of silver is 47, and the number of atoms per gram is Avogadro's number divided by the molar mass of silver, 107.87 g/mol.)

![Diagram of two charged spheres](image)

$$k = 9.0 \times 10^9 \text{ Nm}^2/\text{C}^2 \quad A = 6.02 \times 10^{23} \text{ mol}^{-1}$$

$$e = 1.60 \times 10^{-19} \text{ C}$$

Use Coulomb's Law to find charge transferred:

$$\vec{F} = \frac{k q^2}{r^2} \hat{r}$$ (Since $\vec{F}$ is in $\hat{r}$ direction - treat as scalar)

$$F = \frac{k q^2}{r^2} \Rightarrow q = \sqrt[2]{\frac{Fr^2}{k}} = \sqrt[2]{\frac{(2.00 \times 10^4 \text{ N} \times 1.00 \text{ m})^2}{9.0 \times 10^9 \text{ Nm}^2/\text{C}^2}} = 1.49 \times 10^{-3} \text{ C}$$

$N = \text{number of electrons transferred} = \frac{q}{e} = \frac{1.49 \times 10^{-3} \text{ C}}{1.60 \times 10^{-19} \text{ C}} = 9.32 \times 10^{15} \text{ electrons}$

$N = \text{total number of electrons per sphere}$

$N = (47 \text{ electrons/atom} \times \frac{6.02 \times 10^{23} \text{ atoms/mol}}{107.87 \text{ g/mol}}) (9.00 \text{ g}) = 2.36 \times 10^{24} \text{ electrons}$

$$\text{fraction transferred} = \frac{\frac{N}{N}}{2.36 \times 10^{24} \text{ electrons}} = \frac{9.32 \times 10^{15} \text{ electrons}}{2.36 \times 10^{24} \text{ electrons}} = 3.94 \times 10^{-9}$$
Three point charges are located at the corners of an equilateral triangle as shown in Figure P23.7 (q = 2.50 μC, L = 0.600 m). Calculate the resultant electric force on the 7.00 μC charge.

\[ \vec{F} = \vec{F}_1 + \vec{F}_2 \]

\[ \vec{F}_1 = \frac{kq_1q_3}{r_1^2} \hat{r}_1 = \frac{(9.0 \times 10^9 \text{ Nm}^2/\text{C}^2)(2.50 \times 10^{-6} \text{ C})(7.00 \times 10^{-6} \text{ C})}{(0.600 \text{ m})^2} \hat{r}_1 = 0.4375 \text{ N} \hat{r}_1 \]

\[ \hat{r}_1 = \cos 60^\circ \hat{i} + \sin 60^\circ \hat{j} = \frac{1}{2} \hat{i} + \frac{\sqrt{3}}{2} \hat{j} \]

\[ \Rightarrow \vec{F}_1 = (0.219 \hat{i} + 0.379 \hat{j}) \text{ N} \]

\[ \vec{F}_2 = \frac{kq_2q_3}{r_2^2} \hat{r}_2 = \frac{(9.0 \times 10^9 \text{ Nm}^2/\text{C}^2)(-4.00 \times 10^{-6} \text{ C})(7.00 \times 10^{-6} \text{ C})}{(0.600 \text{ m})^2} \hat{r}_2 \]

\[ \hat{r}_2 = -\cos 60^\circ \hat{i} + \sin 60^\circ \hat{j} = -\frac{1}{2} \hat{i} + \frac{\sqrt{3}}{2} \hat{j} \]

\[ \Rightarrow \vec{F}_2 = (0.350 \hat{i} - 0.606 \hat{j}) \text{ N} \]

\[ \vec{F} = \vec{F}_1 + \vec{F}_2 = [(0.219 + 0.350) \hat{i} + (0.379 - 0.606) \hat{j}] \text{ N} \]

\[ = (0.569 \hat{i} - 0.227 \hat{j}) \text{ N} \]

\[ F = \sqrt{F_x^2 + F_y^2} = \sqrt{(0.569 \text{ N})^2 + (0.227 \text{ N})^2} = 0.612 \text{ N} \]

\[ \Theta = \tan^{-1} \left( \frac{F_y}{F_x} \right) = \tan^{-1} \left( \frac{-0.227 \text{ N}}{0.569 \text{ N}} \right) = -21.7^\circ \approx 338^\circ \]
3. (a) Two protons in a molecule are separated by $4.10 \times 10^{-10}$ m. Find the electric force exerted by one proton on the other.

\[
\begin{align*}
\text{\textcolor{blue}{+}} & \leftrightarrow \text{\textcolor{blue}{+}} & \text{\textcolor{red}{q = e = 1.60 \times 10^{-19} C}} \\
F_e &= \frac{kq^2}{r^2} = \frac{(9.0 \times 10^9 \text{Nm/C}^2)(1.6 \times 10^{-19} \text{C})^2}{(4.10 \times 10^{-10} \text{m})^2} = 1.37 \times 10^{-9} \text{N} \\
\text{because the sign of } F \text{ is positive, the force is repulsive}
\end{align*}
\]

(b) How does the magnitude of this force compare to the magnitude of the gravitational force between the two protons?

\[
\begin{align*}
M &= 1.67 \times 10^{-27} \text{kg} & \text{G} &= 6.67 \times 10^{-11} \text{N \cdot m}^2/\text{kg}^2 \\
F_g &= -\frac{GM^2}{r^2} = -\frac{(6.67 \times 10^{-11} \text{N} \cdot \text{m}^2/\text{kg}^2)(1.67 \times 10^{-27} \text{kg})^2}{(4.10 \times 10^{-10} \text{m})^2} = -1.11 \times 10^{-45} \text{N} \\
\frac{|F_e|}{|F_g|} &= \frac{1.37 \times 10^{-9} \text{N}}{-1.11 \times 10^{-45} \text{N}} = 1.24 \times 10^{36}
\end{align*}
\]

(c) What must be the charge-to-mass ratio of a particle if the magnitude of the gravitational force between two of these particles equals the magnitude of electric force between them?

\[
\begin{align*}
\text{assume } F_e &= F_g & \frac{kq^2}{r^2} &= \frac{Gm^2}{r^2} & \Rightarrow \frac{q}{m} = \sqrt[3]{\frac{G}{k}} \\
\frac{q}{m} &= \left(\frac{(6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2)}{(9.0 \times 10^9 \text{Nm/C}^2)}\right)^{\frac{1}{3}} = 8.61 \times 10^{-11} \text{ C/kg}
\end{align*}
\]