Two identical conducting spheres are oppositely charged, with charges $Q_1$ and $-Q_2$ such that $|F_1| = 0.0360N$ when $d = 0.5m$.

Connecting them via a wire equivalent to touching them, redistributes the charge equally between them since the spheres are identical:

$Q'_1 = Q'_2 = \frac{Q_1 + (-Q_2)}{2} = \frac{Q_1 - Q_2}{2}$

We know $Q_1 > Q_2$; therefore $Q'_1 = Q'_2 > 0$.

We are given that $|F'_1| = 0.0360N$. Therefore, we have two equations with two unknowns for $Q_1$ and $Q_2$:

\[
\begin{align*}
    |F'_1| &= \frac{Q_1 Q_2}{k d^2} \\
    |F'_2| &= \frac{Q_1 Q_2}{k d^2}\
\end{align*}
\]

We want positive root, since we took charge of second sphere to be $-Q_2$. 

Note: Total charge between 3 spheres is conserved:

\[
\begin{align*}
    Q + Q + Q & = 2Q \\
    Q_1 + \frac{3Q}{4} + \frac{3Q}{4} & = 2Q
\end{align*}
\]
\[ Q_2 = \frac{d}{-\sqrt{E_1} + \sqrt{E_2}} \]

\[ Q_2 = \frac{10^4}{-\sqrt{1} + \sqrt{1}} \]

Putting in numbers:
\[ Q_2 = 1 \times 10^4 \text C \] (Note: charge on right sphere is \(-Q_2 = -1 \times 10^4 \text C\).)
\[ Q_4 = 3 \times 10^8 \text C \]

\[ |E_{AC}| = k \frac{|q_A|}{d^2} = \left( 9 \times 10^9 \text N \text m^2/\text C^2 \right) \frac{1.2 \times 10^{-8} \text C}{1 \text m^2} = 3.6 \times 10^{-6} \text N \text (attractive) \]

\[ 1) \text{ New connect A and B } \Rightarrow \begin{cases} q_A' = q_B = \frac{q_A + q_B}{2} = 8 \text nC \\ q_C' = q_C = 8 \text nC \end{cases} \]

\[ 2) \text{ Disconnect A and B, and ground B: } \begin{cases} q_B'' = 0 \\ q_A'' = q_A = -3 \text nC \\ q_C'' = q_C = 8 \text nC \end{cases} \]

\[ 3) \text{ Connect B and C } \Rightarrow \begin{cases} q_B''' = q_C'' = q_B'' + q_C'' = 4 \text nC \\ q_A''' = q_A'' = -3 \text nC \end{cases} \]

\[ |E_{AC}'''| = k \frac{|q_A'''|}{d^2} = \left( 9 \times 10^9 \text N \text m^2/\text C^2 \right) \frac{4 \times 10^{-9} \text C}{1 \text m^2} = 3.6 \times 10^{-6} \text N \text (attractive) \]

\[ |F_{BC}'''| = \frac{k |q_B'''| |q_C'''|}{d^2} = \frac{9 \times 10^9 |4 \times 10^{-9} \text C|}{1 \text m^2} = 3.6 \times 10^{-6} \text N \text (repulsive) \]

\[ \text{Note: } \text{ equilibrium are calculated shortcuts since distances between charges are the same.} \]
(a) Electric charge is quantized, with the smallest unit given by the fundamental charge $e = 2 \times 10^{-19}$ C. The charge on an electron is $e$.

(b) If you are approximated as a "charged conducting sphere," you will induce charge in a metal faucet:

$$Q = 2 \mu C$$

[caption: metal faucet charges separate, but still electrically neutral]

[Note: Our bodies are a bag of water ions; therefore, good conductors to first approximation.]

Since the faucet is fairly well grounded (via the internal plumbing), the excess negative charge (away from you, the inducing charged object) will flow out of the faucet (and spread on the Earth's surface far from the charged object), leaving the faucet of net positive charge:

[Diagram: You → + → Earth (ground) → - → -]
Then, some free electrons from nose (conductor) will cancel some of the positive charge on cat (in fur around nose).

Negatively charged finger

Having rubbed the cat, you are now positively charged. A spark is more likely ensues between you and the cat's nose, because that is where positive charge is most concentrated (has largest surface charge density) on the cat. [As we will see in the next chapter, the density of electric field lines, proportional to the magnitude of E-field, is greatest on cat's nose.]

(a) $F_x = 9q \text{ proton} \cdot E_x = (1.6 \times 10^{-19} \text{C})(40 \text{N/} \text{C})$

(b) $E_x$ is uniform in regions I and II; however, the density of field lines in region II is twice that in region I. Therefore,

$E_1 = \frac{1}{2} E_2 = \frac{1}{2} \cdot 40 \text{N/} \text{C} = 20 \text{N/} \text{C}$

(c) The force on a proton at A is,

$F_x = q \text{ proton} \cdot E_x = (1.6 \times 10^{-19} \text{C})(40 \text{N/} \text{C})$

$= -6.4 \times 10^{-18} \text{ N}$

(a) Look at net force on test charge $q$, at various points along $x$-axis:

\[ F_x = (F_1 - F_2) \]

\[ F_1 = q E_1 \]

\[ F_2 = q E_2 \]

Sine $|F_1| > |F_2|$ AND $x \leq L$

$E_{net} = (F_1 - F_2)$

always nonzero, pointing right

\[ F_{net} = - (F_1 + F_2) \]

always nonzero, pointing left
In Millikan's oil drop experiment, the charge on an oil drop is measured by adjusting the uniform electric field in the chamber such that the force due to the electric field on the drop exactly cancels the force due to gravity.

\[ \vec{F}_{\text{net}} = 0 \Rightarrow \left| \vec{F}_E \right| = \left| \vec{F}_g \right| \Rightarrow \left( k \frac{q^2}{(L-x)^2} \right) \frac{1}{\eta^2} = \frac{k e \eta}{\eta^2} \]

\[ r_1 = \frac{z}{\eta}, \quad r_2 = \frac{2-z}{\eta} \]

\[ \Rightarrow \frac{1}{x^2} = \frac{1}{(L-x)^2} \Rightarrow \frac{5}{x^2} = \frac{2}{(L-x)^2} \]

\[ 3x^2 - 10Lx + 5L^2 = 0 \]

\[ \Rightarrow x = \frac{5L \pm \frac{1}{2} \sqrt{25 - 15}}{3} = \frac{1}{3} \left( 5 \pm \sqrt{10} \right) \]

But, we know that \( x \) has to be less than \( \eta \), so pick the sign:

\[ x = \frac{1}{3} \left( 5 - \sqrt{10} \right) \]

(4) Must have \( 4/1/1/3 \), so many lines enter \( q_1 \), as leave \( q_0 \):

[Diagram of oil drop with electric field vectors and forces]

[Diagram of oil drop with electric field vectors and forces]
\[ \vec{F}_p = -2 \left( \frac{8.99 \times 10^9 \text{ Nm}^2}{e^2} \right) \left( 3.2 \times 10^{-19} \text{ C} \right) \left( \frac{\hat{z}}{25 \text{ m}^2} \right) \]

\[ \Rightarrow \vec{F}_p = \left( -1.4 \times 10^{10} \text{ N/C} \right) \hat{z} \]