An electron walks into a bar and asks for a drink. He gets it and is charged $5. A proton comes into the bar and he pays $5 for a drink. A neutron walks in, asks for a drink, but when the bartender gives it to him, never asks for any money. When the neutron walks out, the electron and the proton are upset. “How come he didn’t have to pay?” “Yeah!” “That guy? He’s a neutron – no charge.”

I love this joke!
(b) If instead of $+15.0 \text{nC}$, what charge would $q_4$ have to have if the total electric field, $\vec{E}$, acting on $q_1$ is zero?

\[
E_2 = \frac{kq_2}{r^2} = \frac{(8.988 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2)(15.0 \times 10^{-9} \text{ C})}{(0.0500 \text{ m})^2} = 53,930 \text{ N/C}
\]

\[
E_3 = \frac{kq_3}{r^2} = \frac{(8.988 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2)(15.0 \times 10^{-9} \text{ C})}{(0.100 \text{ m})^2} = 13,480 \text{ N/C}
\]

\[
E_4 = -(E_2 + E_3) = -(53,930 \text{ N/C} + 13,480 \text{ N/C}) = -67,410 \text{ N/C}
\]

\[
q_4 = \frac{E_4 r^2}{k} = \frac{(67,410 \text{ N/C})(0.150 \text{ m})^2}{(8.988 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2)} = -1.688 \times 10^{-7} \text{ C} = -168.8 \text{nC}
\]

You can put the negative sign in by hand – since $q_2$ and $q_3$ are both positive charges, $q_4$ has to be negative for $E_{\text{total}} = 0$. 

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A single charge $q_5 = -72.5 \times 10^{-9} \text{ C}$ and mass $m = 0.0135 \text{ kg}$, sits in a constant electric field $\vec{E} = +1190 \text{ N/C}$.

Find (c) the electric force vector, $\vec{F}_e$, and (d) the acceleration in the $x$-direction, $a_x$.

\[
\vec{F}_e = q\vec{E} = (-72.5 \times 10^{-9} \text{ C})(1190 \text{ N/C}) = -8.628 \times 10^{-4} \text{ N}
\]

\[
\begin{aligned}
F_x &= \frac{F_e}{m} = \frac{-8.628 \times 10^{-4} \text{ N}}{0.0135 \text{ kg}} \\
&= -0.00639 \text{ m/s}^2
\end{aligned}
\]

(e) Find the number of electrons added or subtracted which would be needed to neutralize $q_5$.

\[
q = \pm Ne
\]

\[
N = \frac{q}{e} = \frac{-72.5 \times 10^{-9} \text{ C}}{1.602 \times 10^{-19} \text{ C}} = -452,600,000,000
\]

Since the charge is negative, we have to SUBTRACT or REMOVE 452,600,000,000 electrons to neutralize $q_5$. 

A Capital Capacitance Experience  (50,000 points)  If you don't get an answer to (a), use \( C = 621 \text{ pF} \).

2.) A parallel plate capacitor consists of two metal plates, each 0.0700 m wide by 0.124 m long, with a gap \( d = 1.15 \text{ mm} \).  (a) Calculate the capacitance, \( C \), of this capacitor.

\[
A = (0.0700 \text{ m})(0.124 \text{ m}) = 0.008680 \text{ m}^2 \\
C = \frac{\varepsilon_0 A}{d} = \left(8.85 \times 10^{-12} \text{ F/m}\right) \left(\frac{0.008680 \text{ m}^2}{0.00115 \text{ m}}\right) \\
= 6.680 \times 10^{-11} \text{ F} = 66.80 \text{ pF}
\]

(b) Find the charge \( \pm Q \) on the plates with \( \Delta V = 555 \text{ volts} \).

\[
C = \frac{Q}{V} \\
Q = CV = \left(6.680 \times 10^{-11} \text{ F}\right)(555 \text{ volts}) \\
= 3.707 \times 10^{-8} \text{ C}
\]

(c) Find the strength of the E-field between the plates with \( \Delta V = 555 \text{ volts} \).

\[
E = \frac{V}{d} = \frac{555 \text{ volts}}{0.00115 \text{ m}} = 482,600 \text{ V/m} \\
\sigma = \frac{Q}{A} = \frac{3.707 \times 10^{-8} \text{ C}}{0.008680 \text{ m}^2} \\
= 0.00004271 \text{ C/m}^2 = 4.271 \times 10^{-6} \text{ C/m}^2 \\
E = \frac{\sigma}{\varepsilon_0} = \frac{4.271 \times 10^{-6} \text{ C/m}^2}{8.85 \times 10^{-12} \text{ F/m}} = 482,500 \text{ V/m}
\]

(d) Sketch the E-field for this capacitor, both in between the plates and include a couple of field lines “at the edges”.

(e) Four of our capacitors are connected together as shown in two configurations, A and B.  Find the equivalent capacitance, \( C_{eq} \), of each arrangement.  Are they the same?  If not, which is bigger, A or B?

\[ C_{eq} = C + C = 2C \\
\frac{1}{C_{eq}} = \frac{1}{2C} + \frac{1}{2C} = \frac{2}{2C} = \frac{1}{C} \\
C_{eq} = C = 66.80 \text{ pF} \\
\]

A and B are the SAME

(but only because all the capacitors are the same)