Chapter 21 Examples

21.1) An α particle (nucleus of a helium atom has a mass $m = 6.64 \times 10^{-27}$ kg & charge $q = +2e = 3.2 \times 10^{-19}$ C. Compare the electrical repulsion between two α particles w/ that of the gravitational charge between them.

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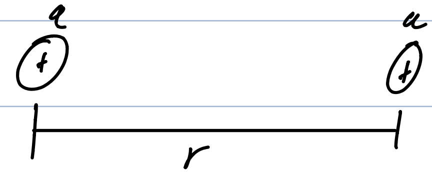


$K = 9 \times 10^{9} \, N \frac{m^2}{C^2}$

$G = 6.67 \times 10^{-11} \, N \frac{m^2}{kg^2}$

$$F_e = K \frac{|q_1 q_2|}{r^2} = K \frac{q^2}{r^2}$$

$$F_e = \frac{9 \times 10^{9} \, N \frac{m^2}{C^2} \left(3.2 \times 10^{-19} \, C\right)^2}{r^2}$$

$$= \frac{9 \times 10^{9} \, N \frac{m^2}{\cancel{C^2}} \left(10.24 \times 10^{-38} \, \cancel{C^2}\right)}{r^2}$$

$$= \frac{92.16 \times 10^{-29} \, N \, m^2}{r^2}$$

$$F_e = \frac{9.22 \times 10^{-28} \, N \cdot m^2}{r^2}$$

$$F_g = \frac{G m_1 m_2}{r^2} = G \frac{m^2}{r^2}$$

$$F_g = \frac{6.67 \times 10^{-11} \, N \frac{m^2}{kg^2} \left(6.67 \times 10^{-27} \, kg\right)^2}{r^2}$$

$$= \frac{6.67 \times 10^{-11} \, N \frac{m^2}{\cancel{kg^2}} \left(4.45 \times 10^{-53} \, \cancel{kg^2}\right)}{r^2}$$

$$= \frac{31.88 \times 10^{-64} \, N \cdot m^2}{r^2}$$

$$F_g = \frac{3.18 \times 10^{-63} \, N \cdot m^2}{r^2}$$

$$\frac{F_e}{F_g} = \frac{9.22 \times 10^{-28} \, \cancel{N m^2}}{\cancel{r^2}} \cdot \frac{\cancel{r^2}}{3.18 \times 10^{-63} \, \cancel{N m^2}} = \boxed{2.90 \times 10^{35}}$$

21.2) Two point charges, $q_1 = +25\,nC$ & $q_2 = -75\,nC$, are separated by distance $r = 3.0$ cm. Find the magnitude and direction of the electric force (a) that q_1 exerts on q_2 & (b) that q_2 exerts on q_1.

$$F_{1\to 2} = k\frac{|q_1\, q_2|}{r^2}$$

$$k = 9.0\times10^{9}\ N\cdot \frac{m^2}{C^2}$$

$$F_{1\to2} = \frac{\left(9.0\times10^{9}\,N\frac{m^2}{C^2}\right)\left|25nC \cdot -75nC\right|}{(0.03\,m)^2}$$

$$= \frac{9.0\times10^{9}\,N\frac{\cancel{m^2}}{\cancel{C^2}}\left(1.88\times10^{-18}\,\cancel{C^2}\right)}{9\times10^{-4}\,\cancel{m^2}}$$

$$= \frac{1.69\times10^{-6}}{9\times10^{-4}}\,N$$

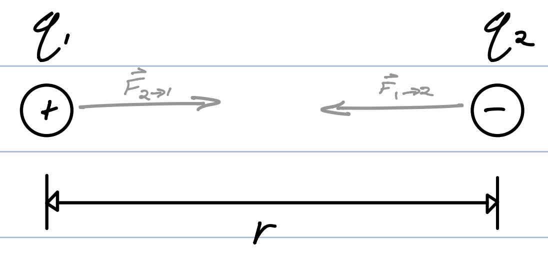
$$= 0.001877\,N$$

(a) $\boxed{F_{1\to2} = 0.0019\,N}$

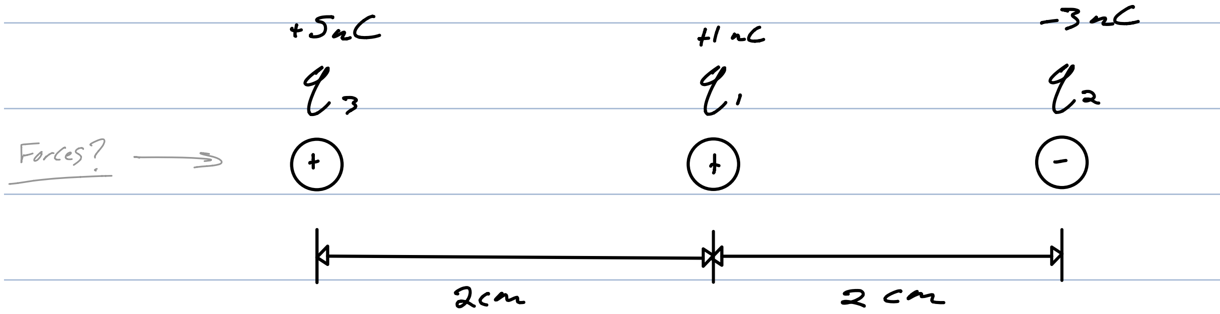
$$F_{2\to1} = k\frac{|-75nC \cdot 25nC|}{r^2}$$

[Same as $F_{1\to2}$, but with charges reversed]

(b) $\boxed{F_{2\to1} = 0.0019\,N}$



21.3) Two point charges are located on the x-axis of a coordinate system: $q_1 = 1.0$ nC is at $x = +2.0$ cm, and $q_2 = -3.0$ nC is at $x = +4.0$ cm. What is the total electric force exerted by q_1 and q_2 on a charge $q_3 = 5.0$ nC at $x = 0$?



$$F = \frac{k\,|q_1 q_2|}{r^2}$$

$$k = 9 \times 10^9 \, N \frac{m^2}{C^2}$$

$$F_{q_1 \to q_3} = \frac{(9.0 \times 10^9 \, N \frac{m^2}{C^2})(5nC \cdot 1nC)}{(0.02\,m)^2}$$

$$F = \frac{(9.0 \times 10^9 \, N \frac{\cancel{m^2}}{\cancel{C^2}})(5 \times 10^{-18} \cancel{C^2})}{4 \times 10^{-4} \, \cancel{m^2}}$$

$$F = \frac{4.5 \times 10^{-9}}{4.0 \times 10^{-4}} N$$

$$F_{q_1 \to q_3} = 1.12 \times 10^{-5} \, N$$

$$F_{q_2 \to q_3} = \frac{(9.0 \times 10^9 \, N \frac{m^2}{C^2})(5nC \cdot -3nC)}{(0.04\,m)^2}$$

$$= \frac{9 \times 10^9 \, N \frac{\cancel{m^2}}{\cancel{C^2}} \, (15 \times 10^{-18} \cancel{C^2})}{1.6 \times 10^{-3} \, \cancel{m^2}}$$

$$= \frac{135 \times 10^{-7}}{1.6 \times 10^{-3}} N$$

$$= 0.84 \times 10^{-4} \, N$$

$$F_{q_2 \to q_3} = 8.4 \times 10^{-5} \, N$$

Odd Questions (Start at pg 742)

21.1) Excess electrons are placed on a small lead sphere w/ mass of 8.00g so that its net charge is -3.20×10^{-9} C.

(a) Find the number of electrons on the sphere

(b) How many excess electrons are there per lead atom?

(lead atomic #: 82 ; atomic mass: 207 g/mol)

6.022×10^{23}

(a)

$$\frac{-3.2 \times 10^{-9}\ C}{1.6 \times 10^{-19}\ C/e^-} = \boxed{2.00 \times 10^{10}\ e^-}$$ on the sphere

Charge of on e^-: $1.6 \times 10^{-19}\ C/1e^-$

$$\frac{8.00g}{1} \cdot \frac{1\ mol}{207\ g} = 0.038647\ \text{mol lead}$$

x Avg. Const.

2.32734×10^{22} lead atoms

(b)

$$\frac{2.00 \times 10^{10}\ e^-}{2.33 \times 10^{22}\ \text{lead atoms}} = \boxed{8.593 \times 10^{-13}\ e^-/\text{atom}}$$

21.7 Estimate how many e^- are in your body. Make assumptions if necessary but clearly state what they are. What is the combined charge of all these e^-?

150 lbs of mostly carbon. Carbon molar mass: 12.011 g/mol

Assuming I'm neutrally charged

$$\frac{68{,}038.8555\ g}{1} \cdot \frac{1\ mol}{12.011\ g} = 5{,}664.71\ mol\ \text{of Carbon}$$

$\times$ Avg. Const.

3.411×10^{27} Carbon Atoms

$\times\ 6\ e^-/C\ atom$

$\boxed{2.047 \times 10^{27}\ e^-}$ in my body

$\times -1.6 \times 10^{-19}\ C/e^-$

Charge of an e^-: $-1.6 \times 10^{-19}\ C/1e^-$

$\boxed{-3.275 \times 10^{9}\ C}$ total charge of all e^-

21.57) Measurements have shown that 5.6×10^{11} Na^+ per meter, each w/ charge +e, enter the axon. How many Colombs of charge enter a 1.5-cm length of the axon during this process?

1.5 cm = 0.015 m

Charge of on e^-: -1.6×10^{-19} C/1e^-

Na: 11 e^-

Na^+: 10 e^-

$$\begin{array}{r} 5.6 \times 10^{11}\ Na^+/m \\ \times\ 0.015\ m \\ \hline \end{array}$$

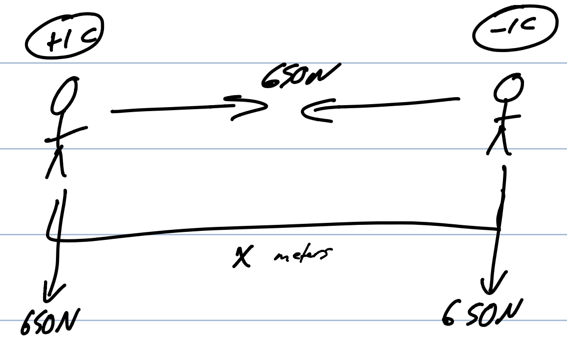
$8.4 \times 10^9\ Na^+ = 8.4 \times 10^9\ e^-$ of charge

$$\begin{array}{r} \times\ 1.6 \times 10^{-19}\ C/e^- \\ \hline \end{array}$$

$\boxed{1.344 \times 10^{-9}\ C}$ of charge entering the axon

$= \boxed{1.344\ nC}$

21.7) An average human weighs about 650N. If two average humans each had a 1.0 Coulomb charge (1 positive; 1 negative), how far apart would they have to be for the attraction between them to equal their weight?



$$F = k\frac{|q_1 q_2|}{r^2}$$

$$r^2 = k\frac{|q_1 q_2|}{F}$$

$$r = \sqrt{k\frac{|q_1 q_2|}{F}}$$

$$x^2 = 8.988\times10^9\ N\frac{m^2}{C^2}\left[\frac{-1C \times 1C}{650N}\right]$$

$$k = 8.988\times10^9\ N\frac{m^2}{C^2}$$

$$x^2 = 8.988\times10^9\ \cancel{N}\frac{m^2}{\cancel{C^2}}\left[\frac{1\cancel{C^2}}{650\cancel{N}}\right]$$

$$x^2 = \frac{-8.988\times10^9\ m^2}{650}$$

$$\sqrt{x^2} = \sqrt{-1.3827\times10^7\ m^2}$$

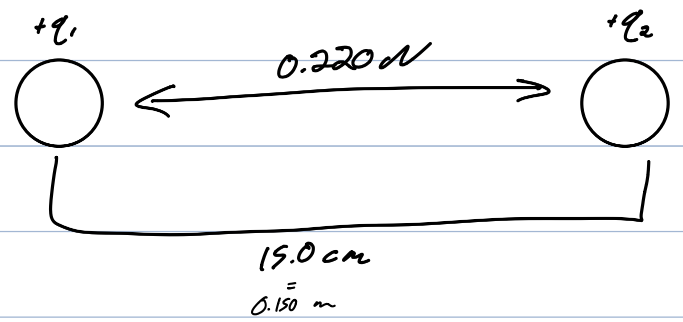
$$\boxed{x = 3718.56\ m}$$

$$\boxed{3.72\ km}$$

21.9) Two plastic spheres w/ positive charge. 15.0 cm apart, the repulsive force between them is 0.220 N.
What is the charge on each sphere:

(a) if the two charges are equal

(b) if one sphere has 4 times the charge of the other



$$F = k\frac{|q_1 q_2|}{r^2}$$

$$\frac{F \cdot r^2}{k} = |q_1 q_2|$$

$$k = 8.988 \times 10^9 \, N\frac{m^2}{C^2}$$

$$|q_1 q_2| = \frac{(0.220\,N)(0.150^2\,m^2)}{8.988\,\frac{N\,m^2}{C^2}}$$

$$|q_1 q_2| = \frac{(0.220)(0.225)}{8.988}\,C^2$$

0.15 m is diameter, not radius

$$|q_1 q_2| = 0.000551\,C^2$$

This wrong too?

$$|q_1 q_2| = 0.0235\,C \quad \text{total charge}$$

(a)

$0.0235\,C \cdot \frac{1}{2} = \boxed{0.0117\,C}$ on each sphere

(b)

$0.0235\,C \cdot \frac{4}{5} = \boxed{0.0188\,C}$ on one sphere &

$\quad \cdot \frac{1}{5} = \boxed{0.00469\,C}$ on the other

Wrong answer.

Book: a: 0.742 μC on each

b: 0.371 μC, 1.48 μC

21.11) ... Add e^- to get two spheres to 25.0g accelleration...

[python program got right answer]

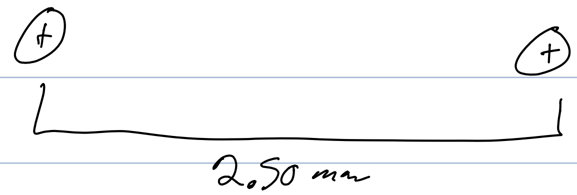
$g = 9.8$ m/s²

$25g = 245$ m/s²

21.(3) In an experiment in space, one proton is held fixed & another proton is released from rest at a distance of 2.50 mm away.

(a) What is the initial acceleration of the proton after it's released?

(b) Sketch qualitative (no numbers) acceleration-time & velocity-time graphs of the released protons motion.



$F = k\dfrac{|q_1 q_2|}{r^2}$

$k = 8.988 \times 10^9 \ N\dfrac{m^2}{C^2}$

$r = 0.0025 \ m$

$q_1 = q_2 = 1.6 \times 10^{-19} \ C$

proton mass $= 1.67 \times 10^{-27}$ kg

$$F = \frac{8.988 \times 10^9 N \frac{m^2}{C^2}\left[1.6 \times 10^{-19} C \times 1.6 \times 10^{-19} C\right]}{0.000006 \ m^2}$$

$$F = \frac{8.988 \times 10^9 N/\cancel{C^2}\left[2.56 \times 10^{-38} \cancel{C^2}\right]}{0.00006}$$

$$F = \frac{2.3 \times 10^{-28} N}{0.000006}$$

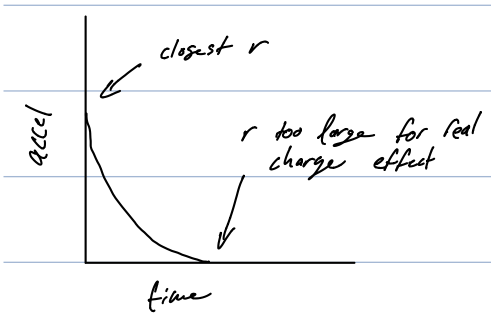
$F = 3.68 \times 10^{-23} \ N$

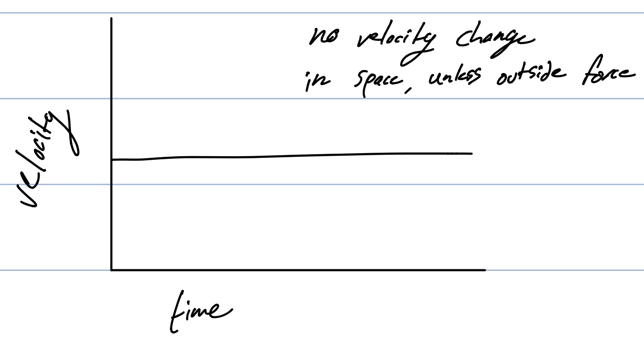
$1 N = 1 kg \cdot m/s^2$

$$\frac{3.68 \times 10^{-23} \ kg\frac{m}{s^2}}{1.67 \times 10^{-27} \ kg} = \boxed{22044.8 \ m/s^2}$$

(a) $\boxed{2.21 \times 10^4 \ m/s^2}$

(b)





21.15) Three point charges are arranged on a line. Charge $q_3 = +5.00\,nC$ & is at the origin. Charge $q_2 = -3.00\,nC$ & is at $x = +4.00$ cm. Charge q_1 is at $x = +2.00$ cm. What is q_1 (magnitude & sign) if the net force on q_3 is zero?