Folha 1

1)

a. $F = ?$ $\quad d = 1,0\ fm = 1,0 \times 10^{-15}\ m$

$$F_e = K \frac{q_1 q_2}{R^2} = 8,99 \times 10^9 \times \frac{(1,60 \times 10^{-19})^2}{(1,0 \times 10^{-15})^2} = 1,4384 \times 10^{1} \approx 14,4\ N$$

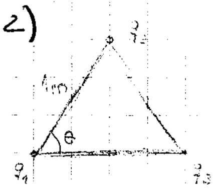
b. $m = 1,67 \times 10^{-27}\ Kg$

$$F_g = G \frac{m_1 m_2}{R^2} = 6,67 \times 10^{-11} \times \frac{(1,67 \times 10^{-27})^2}{(1,0 \times 10^{-15})^2} = 1,2 \times 10^{-35}\ N$$

Não, pois $F_g \ll F_e$

c. Podemos concluir que existe outra força que mantém os protões juntos no volume limitado do núcleo atómico. Tal força é designada por força forte.

2)

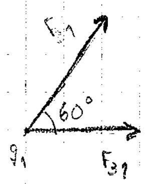


$q_1 = -2 \times 10^{-6}\ C$

$q_2 = q_3 = 1 \times 10^{-6}\ C$

$\theta = 60°$

Como $q_1 < 0$ e q_2 e $q_3 > 0$, as forças individuais de q_2 e q_3 sobre q_1 são atrativas (de q_1 para q_2 e de q_1 para q_3)



$$\vec{F}_{21} = 8,99 \times 10^9 \frac{|(-2 \times 10^{-6})(1 \times 10^{-6})|}{1^2} \times (\cos 60\ \hat{e}_x + \operatorname{sen} 60\ \hat{e}_y)$$

$$\approx 8,99 \times 10^{-3}\ \hat{e}_x + 1,56 \times 10^{-2}\ \hat{e}_y$$

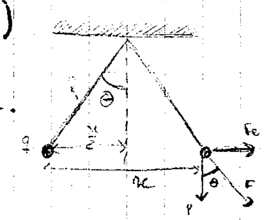
$$\vec{F}_{31} = 8,99 \times 10^9 \frac{|(-2 \times 10^{-6})(1 \times 10^{-6})|}{1^2} \times (\cos 0\ \hat{e}_x + \operatorname{sen} 0\ \hat{e}_y)$$

$$\approx 1,8 \times 10^{-2}\ \hat{e}_x$$

$$\vec{F}_R = 8,99 \times 10^{-3}\ \hat{e}_x + 1,56 \times 10^{-2}\ \hat{e}_y + 1,8 \times 10^{-2}\ \hat{e}_x = (2,7 \times 10^{-2}\ \hat{e}_x + 1,6 \times 10^{-2}\ \hat{e}_y)\ N$$

3)

a.



$$\frac{x}{2} = l \operatorname{sen} \theta \Leftrightarrow x = 2 l \operatorname{sen} \theta$$

$$\operatorname{tg} \theta = \frac{F_e}{mg} = \frac{\frac{Kq^2}{x^2}}{mg} = \frac{Kq^2}{x^2 mg} = \frac{Kq^2}{4 l^2 \operatorname{sen}^2 \theta\, mg}$$

$$\downarrow$$

$$\boxed{\operatorname{sen}^2 \theta \operatorname{tg} \theta = \frac{Kq^2}{4 l^2 mg}}$$

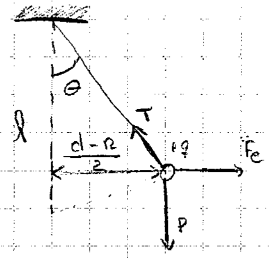
b. θ pequeno $\rightarrow \operatorname{sen} \theta \approx \operatorname{tg} \theta$

$$\operatorname{sen}^2 \theta \operatorname{tg} \theta = \operatorname{sen}^3 \theta \qquad K = \frac{1}{4\pi\varepsilon_0} \quad e \quad x = 2 l \operatorname{sen} \theta$$

logo, $\operatorname{sen}^3 \theta = \frac{Kq^2}{4 l^2 mg} \Rightarrow \operatorname{sen} \theta = \left(\frac{Kq^2}{4 l^2 mg}\right)^{1/3}$

$$x = 2 l \left(\frac{q^2}{4\pi\varepsilon_0 \times 4 l^2 mg}\right)^{1/3} = \left(\frac{8 l^3 q^2}{16\pi\varepsilon_0 l^2 mg}\right)^{1/3} = \boxed{\left(\frac{l q^2}{2\pi\varepsilon_0 mg}\right)^{1/3}}$$

4)



$$F_e = K\frac{|q_1 q_2|}{R^2} = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{R^2} = \frac{q^2}{4\pi\varepsilon_0 R^2}$$

$$q^2 = 4\pi\varepsilon_0 R^2 F_e \;\leadsto\; q = \sqrt{4\pi\varepsilon_0 R^2 F_e}$$

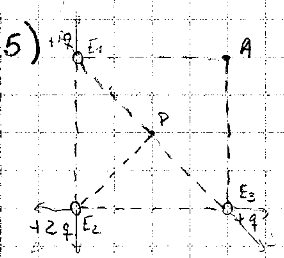
carga esquerda: $T\cos\theta = p$ e $T\,\text{sen}\,\theta = F_e \rightarrow F_e = \frac{P}{\cos\theta}\,\text{sen}\,\theta = p\,tg\,\theta$

$$tg\,\theta = \frac{\frac{d-R}{2}}{\left(l^2-\left(\frac{d-R}{2}\right)^2\right)^{1/2}} =$$

$$F_e = mg\,\frac{\frac{d-R}{2}}{\left(l^2-\left(\frac{d-R}{2}\right)^2\right)^{1/2}}$$

$$q = \sqrt{\frac{4\pi\varepsilon_0 R^2\, mg\left(\frac{d-R}{2}\right)}{\left(l^2-\left(\frac{d-R}{2}\right)^2\right)^{1/2}}}$$

5)



$q = 1,6\times10^{-19}\,C$

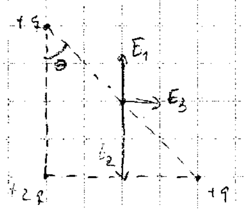
$l = 5,0\,mm = 5,0\times10^{-3}\,m$

a. $|\vec{E}| = |\vec{E_1}| + |\vec{E_2}| + |\vec{E_3}| = 5,75\times10^{-5} + 1,15\times10^{-4} + 5,75\times10^{-5} = 2,3\times10^{-4}$

$$|\vec{E_1}| = K\frac{q}{R^2} = 8,99\times10^{9}\times\frac{1,6\times10^{-19}}{(5,0\times10^{-3})^2} \approx 5,75\times10^{-5}\,NC^{-1}$$

$$|\vec{E_2}| = K\frac{2q}{R^2} = 8,99\times10^{9}\times\frac{2\times1,6\times10^{-19}}{(5,0\times10^{-3})^2} \approx 1,15\times10^{-4}\,NC^{-1}$$

$$|\vec{E_3}| = K\frac{q}{R^2} = 8,99\times10^{9}\times\frac{1,6\times10^{-19}}{(5,0\times10^{-3})^2} \approx 5,75\times10^{-5}\,NC^{-1}$$



$\theta = 45°$

$$\vec{E} = \vec{E_1} + \vec{E_2} + \vec{E_3} = 2(4,07\times10^{-5}\,\hat{e}_x + 4,07\times10^{-5}\,\hat{e}_y) + (8,13\times10^{-5}\,\hat{e}_x + 8,13\times10^{-5}\,\hat{e}_y)$$
$$\approx (1,62\times10^{-4}\,\hat{e}_x + 1,62\times10^{-4}\,\hat{e}_y)\,NC^{-1}$$

$$\vec{E_1} = K\frac{q}{R^2}(\cos\theta\,\hat{e}_x + \text{sen}\,\theta\,\hat{e}_y) = 8,99\times10^{9}\times\frac{1,6\times10^{-19}}{(5,0\times10^{-3})^2}(\cos45\,\hat{e}_x + \text{sen}\,45\,\hat{e}_y)$$
$$= 4,07\times10^{-5}\,\hat{e}_x + 4,07\times10^{-5}\,\hat{e}_y$$

$$\vec{E_2} = K\frac{2q}{R^2}(\cos\theta\,\hat{e}_x + \text{sen}\,\theta\,\hat{e}_y) = 1,15\times10^{-4}\times(\cos45\,\hat{e}_x + \text{sen}\,45\,\hat{e}_y) = 8,13\times10^{-5}\,\hat{e}_x + 8,13\times10^{-5}\,\hat{e}_y$$

$$\vec{E_3} = \vec{E_1}$$

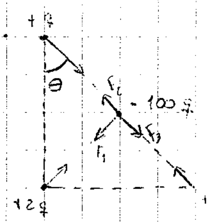
b. $V = V_1 + V_2 + V_3 = k\frac{q}{R} + k\frac{2q}{R} + k\frac{q}{R} = 4k\frac{q}{R}$

$$V_P = 4 \times 8,99\times10^{9}\ \frac{1,6\times10^{-19}}{5\times10^{-3}\times\frac{\sqrt{2}}{2}} \approx 1,63\times10^{-6}\ V$$

$\cos(45) = \frac{\sqrt{2}}{2}$

$\mathrm{sen}(45) = \frac{\sqrt{2}}{2}$

c.



$\theta = 45°$

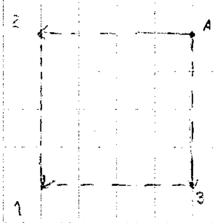
$$|\vec{F_1}| = k\frac{|2(1,6\times10^{-19})(-100\times1,6\times10^{-19})|}{(5,0\times10^{-3})^2} \approx 1,84\times10^{-21}\ N$$

$$|\vec{F_2}| = k\frac{|1,6\times10^{-19}(-100\times1,6\times10^{-19})|}{(5,0\times10^{-3})^2} \approx 9,21\times10^{-22}\ N$$

$$|\vec{F}| = \vec{F_1} + 2\vec{F_2} \approx 3,68\times10^{-21}\ N$$

d. $W_{P\to A} = -100q\,(V_P - V_A) = -1,6\times10^{-17}\,(1,63\times10^{-6} - 9,82\times10^{-7})$

$\approx -1,04\times10^{-23}\ J$



$$V_A = V_{1A} + V_{2A} + V_{3A} = k\frac{2q}{5\times10^{-3}\times\sqrt{2}} + k\frac{q}{5\times10^{-3}} + k\frac{q}{5\times10^{-3}} = k\frac{q}{5\times10^{-3}}\left(\frac{2}{\sqrt{2}} + 2\right)$$

$$= k\frac{q}{5\times10^{-3}}\left(\frac{2\sqrt{2}}{2} + 2\right) = 8,99\times10^{9}\ \frac{1,6\times10^{-19}}{5\times10^{-3}}\left(\sqrt{2} + 2\right) \approx 9,82\times10^{-7}\ V$$

6) $m = 1,3\times10^{-10}\ kg$ $\quad q = 1,5\times10^{-13}\ C$ $\quad v_x = 18\ m\,s^{-1}$ $\quad L = 1,6\ cm = 1,6\times10^{-2}\ m$

$\downarrow |\vec{E}| = 1,4\times10^{6}\ N C^{-1}$ $\quad$ constante $\Rightarrow a = 0$

① $x = \cancel{x_0} + v_{0x}t + \frac{1}{2}a_x t^2$ $\quad$ ② $y = \cancel{y_0} + \cancel{v_{0y}t} + \frac{1}{2}a_y t^2$

① $1,6\times10^{-2} = 0 + 18t + \frac{1}{2}\times 0\,t^2 \Rightarrow t = \frac{1,6\times10^{-2}}{18} \Rightarrow t \approx 8,89\times10^{-4}\ s$

② $a_y = \frac{qE}{m} = \frac{1,5\times10^{-13}\times1,4\times10^{6}}{1,3\times10^{-10}} \approx 1615,39\ m\,s^{-2}$

$y = \frac{1}{2}\times1615,39\times(8,89\times10^{-4})^2 \approx 6,38\times10^{-4}\ m$

7)

a. $E = ?$ $V = K\frac{q}{d}$ $E = \frac{V}{d}$ $E = E_1 + E_2 \Rightarrow E = \frac{V_1}{d} + \frac{V_2}{d}$

Como uma carga é o negativo da outra, com igual quantidade de carga logo

V_2 é negativo $\rightarrow E = \frac{V_1}{d} - \frac{V_2}{d} = \frac{V_1 - V_2}{d}$

b. $V_1 - V_2 = 300\ V$ $d = 0{,}05\ m$ $q = 2{,}0 \times 10^{-7} C$

$F = E \times q$ $E = \frac{V_1 - V_2}{d} = \frac{300}{0{,}05} = 6000\ NC^{-}$

$F = 6000 \times 0{,}05 = 1{,}2 \times 10^{-3}\ N$

c. $W_{A \to B} = q(V_A - V_B) = 2{,}0 \times 10^{-7} \times 300 = 6{,}0 \times 10^{-5}\ J$

8) $r = 1{,}7 \times 10^{-6} m$ $\rho = 858\ kg\,m^{-3}$ $T = 4986\ V$ $d = 1{,}99 \times 10^{-2} m$ $\eta = 1{,}83 \times 10^{-5}\ kg\,m^{-1}s^{-1}$

$t_d = 21{,}0\ s$ $t_a = 46{,}0\ s$ $n^\circ q = ?$ $V_{terminal} \Rightarrow V_{constante}$ $F_v = 6\pi\eta r V$

Determinar carga da gota:

$qE - w = 6\pi\eta(rV_a) = \left|\frac{V_d}{V_a}\right| w$

$w \rightarrow$ peso da gota

Considerando $qE - w = 6\pi\eta(rV_a)$

nº e⁻ - carga elementar

$q = n q_e$

$n q_e \overset{V/d}{E} = 6\pi\eta(rV_a) + w \Leftrightarrow n = \frac{6\pi\eta(rV_a) + w}{q_e E}$

$\Leftrightarrow n = \frac{6\pi\eta\, d\,(r \times V_a)}{q_e V} + \frac{w\,d}{q_e V}$

$n = \frac{6\pi(1{,}83 \times 10^{-5})}{1{,}60 \times 10^{-19} \times 4986} \times (1{,}99 \times 10^{-2})(1{,}7 \times 10^{-6} \times 1{,}30$

$\rho = \frac{m}{V} \Leftrightarrow m = \rho V$ $E = \frac{V}{d}$

$w = mg = \rho V = (\rho_{óleo} - \rho_{ar}) \times \overbrace{\frac{4\pi}{3} r^3}^{\text{volume esfera}} g = \frac{4\pi(1{,}7 \times 10^{-6})^3}{3}(858 - 1{,}2922) \times 9{,}98$

$\approx 1{,}76 \times 10^{-13}\ N$

$v_a = \frac{0{,}600 \times 10^{-2}}{46{,}0} = 1{,}30 \times 10^{-4}\ ms^{-1}$

$n = \frac{6\pi(1{,}83 \times 10^{-5})}{1{,}60 \times 10^{-19} \times 4986}(1{,}99 \times 10^{-2})(1{,}7 \times 10^{-6} \times 1{,}30 \times 10^{-4}) + \frac{(1{,}76 \times 10^{-13})(1{,}99 \times 10^{-2})}{1{,}60 \times 10^{-19} \times 4986}$

$\approx 1{,}90 + 4{,}39 = 6{,}29 \approx 6$ cargas elementares

9)

a. $\Delta V = ?$ $\quad |\vec{E}| = 3,0 \times 10^6 \ Vm^{-1}$ $\quad d = 0,50 \times 10^{-2} \ m$

$\Delta V = |\vec{E}| \times d = 3,0 \times 10^6 \times 0,50 \times 10^{-2} = 1,5 \times 10^4 \ V$

b. $\sigma = \frac{q}{A}$ $\quad |\vec{E}| = \frac{\sigma}{\varepsilon_0} \Rightarrow \sigma = 2\varepsilon_0 |\vec{E}| \Rightarrow \sigma = 8,85 \times 10^{-12} \times 3,0 \times 10^6 \Rightarrow \sigma \approx 2,7 \times 10^{-5} \ C \, m^{-2}$

$\sigma \doteq 27 \, \mu C m^{-2}$

10) $v_0 = 0 \ ms^{-1}$ $\quad |\vec{E}| = 8,0 \times 10^4 \ Vm^{-1}$

a. $|\vec{F_e}| = q \, |\vec{E}| = 1,6 \times 10^{-19} \times 8,0 \times 10^4 = 1,28 \times 10^{-14} \ N$

$|\vec{P}| = m g = 1,67 \times 10^{-27} \times 10 = 1,67 \times 10^{-26} \ N$

$|\vec{F_R}| = \sqrt{|\vec{F_e}|^2 + |\vec{P}|^2} = \sqrt{(1,28 \times 10^{-14})^2 + (1,67 \times 10^{-26})^2} \approx 1,28 \times 10^{-14} \ N$

b. $\Delta V = |\vec{E}| \times d = 8,0 \times 10^4 \times 0,50 = 4,0 \times 10^4 \ V$

c. $x_A = x_B + \overset{v_0 = 0 ms^{-1}}{\cancel{v_0} t} + \frac{1}{2} a t^2$

$\Rightarrow x_A = x_B + \frac{1}{2} \times \frac{qE}{m} t^2 \Rightarrow t^2 = \frac{(x_A - x_B) m}{qE} \Rightarrow t = \sqrt{\frac{2(x_A - x_B) m}{qE}}$

$\Rightarrow t = 3,61 \times 10^{-7} \ s$

$v = \overset{v_0 = 0 ms^{-1}}{\cancel{v_0}} + a t \Rightarrow v = \frac{qE}{m} t \Rightarrow v = \frac{1,6 \times 10^{-19} \times 8,0 \times 10^4}{1,67 \times 10^{-27}} \times 3,61 \times 10^{-7} \Rightarrow v \approx 2,8 \times 10^6 \ ms^{-1}$

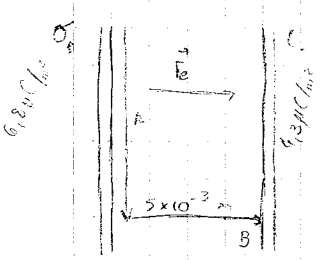
$E_c = \frac{1}{2} m v^2 = \frac{1}{2} \times (1,67 \times 10^{-27}) \times (2,8 \times 10^6)^2 = 6,54 \times 10^{-15} \ J$

11) $\sigma_{(+)} = 6,8 \ \mu C/m^2$ $\quad \sigma_{(-)} = 4,3 \ \mu C/m^2$

a. $|\vec{E}| = \frac{(\sigma_{(+)} + \sigma_{(-)})}{2 \varepsilon_0} = \frac{6,8 \times 10^{-6} + 4,3 \times 10^{-6}}{2 \times 8,85 \times 10^{-12}} \approx 6,27 \times 10^5 \ NC^{-1}$

b. $\Delta V = |\vec{E}| \times d = (6,2$ $\quad (5 \times 10^{-3}) = 3,14 \times 10^3 \ V$

c.



$W = \vec{F_e} \times d = -2,1945 \times 5 \times 10^{-3} \approx -11 \times 10^{-3} \ J$

$\vec{F_e} = q |\vec{E}| = -3,5 \times 10^{-6} \times 6,27 \times 10^5 \approx -2,1945 \ N$

12) $q = 5{,}0 \times 10^{-9}\ C$ $\qquad d = 8{,}0 \times 10^{-2}\ m$

a. $x_p = 4{,}0 \times 10^{-2}\ m$

$$V = 2k\frac{q}{r} = 2 \times 8{,}99 \times 10^{9} \times \frac{5{,}0 \times 10^{-9}}{4{,}0 \times 10^{-2}} \approx 22{,}5 \times 10^{2}\ V$$

b. $x_q = -6{,}0 \times 10^{-2}\ m$ $\qquad q = 3{,}0 \times 10^{-9}\ C$

$$|\vec{F_e}| = 8{,}99 \times 10^{9}\ \frac{(3{,}0 \times 10^{-9})(5{,}0 \times 10^{-9})}{(6{,}0 \times 10^{-2})^2} + 8{,}99 \times 10^{9}\ \frac{(3{,}0 \times 10^{-9})(5{,}0 \times 10^{-9})}{(8{,}0 \times 10^{-2} + 6 \times 10^{-2})^2}$$

$\approx 4{,}43 \times 10^{-5}\ N$ $\quad xx$ negativo

c. $x_q = -6{,}0 \times 10^{-2}\ m$ $\quad x_p = 4{,}0 \times 10^{-2}\ m$ $\quad q = 3{,}0 \times 10^{-9}\ C$

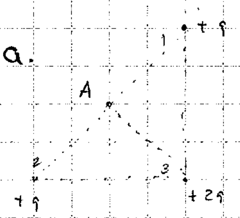
$$w = q\,(V_f - V_i)$$

$$V_{i\,(-6cm)} = 8{,}99 \times 10^{9}\ \frac{5{,}0 \times 10^{-9}}{6{,}0 \times 10^{-2}} + 8{,}99 \times 10^{9}\ \frac{5{,}0 \times 10^{-9}}{14{,}0 \times 10^{-2}} \approx 1070{,}24\ V$$

$$w = 3{,}0 \times 10^{-9}\,(22{,}5 \times 10^{2} - 1070{,}24) \approx 3{,}54 \times 10^{-6}\ J$$

13) $q = 3{,}2 \times 10^{-19}\ C$ $\qquad r = 7{,}5 \times 10^{-3}\ m$

a.



$$V_A = V_1 + V_2 + V_3 = K\frac{q}{d} + K\frac{q}{d} + K\frac{2q}{d} = K\frac{4q}{d}$$

$$V_A = 4 \times 8{,}99 \times 10^{9}\ \frac{3{,}2 \times 10^{-19}}{7{,}5 \times 10^{-3} \times \frac{\sqrt{2}}{2}} \approx 2{,}17 \times 10^{-6}\ V$$

b. $|\vec{E_A}| = |\vec{E_1}| + |\vec{E_2}| + |\vec{E_3}| = 5{,}11 \times 10^{-5} + 5{,}11 \times 10^{-5} + 1{,}02 \times 10^{-4} \approx 2{,}04 \times 10^{-4}\ NC^{-1}$

$$|\vec{E_1}| = K\frac{q}{r^2} = 8{,}99 \times 10^{9}\ \frac{3{,}2 \times 10^{-19}}{(7{,}5 \times 10^{-3})^2} \approx 5{,}11 \times 10^{-5}\ NC^{-1}$$

$$|\vec{E_2}| = |\vec{E_1}|$$

$$|\vec{E_3}| = K\frac{2q}{r^2} = 8{,}99 \times 10^{9}\ \frac{2 \times 3{,}2 \times 10^{-19}}{(7{,}5 \times 10^{-3})^2} \approx 1{,}02 \times 10^{-4}\ NC^{-1}$$

c. $q_A = -150 \times 3{,}2 \times 10^{-19} = -4{,}8 \times 10^{-17}\ C$ $\qquad |\vec{F_e}| = |\vec{F_1}| + |\vec{F_2}| + |\vec{F_3}| = 2|\vec{F_1}| + |\vec{F_3}|$ $\qquad |\vec{F_1}| = |\vec{F_2}|$

$$|\vec{F_1}| = 8{,}99 \times 10^{9}\ \frac{|3{,}2 \times 10^{-19} \times (-4{,}8 \times 10^{-17})|}{(7{,}5 \times 10^{-3})^2} \approx 2{,}45 \times 10^{-21}\ N$$

$$|\vec{F_3}| = 8{,}99 \times 10^{9}\ \frac{|2 \times 3{,}2 \times 10^{-19}\,(-4{,}8 \times 10^{-17})|}{(7{,}5 \times 10^{-3})^2} \approx 4{,}91 \times 10^{-21}\ N$$

$$|\vec{F_e}| = 2 \times 2{,}45 \times 10^{-21} + 4{,}91 \times 10^{-21} \approx 9{,}81 \times 10^{-21}\ N$$

14) $q_1 = 20 \times 10^{-9}\, C \qquad q_2 = -80 \times 10^{-9}\, C \qquad d = 100 \times 10^{-2}\, m$

a. $x_A = 40 \times 10^{-2}\, m$

$$|\vec{E}_A| = |\vec{E}_1| + |\vec{E}_2| = k\frac{|q_1|}{R^2} + k\frac{|q_2|}{R^2} = 8{,}99 \times 10^9 \frac{20 \times 10^{-9}}{(40 \times 10^{-2})^2} + 8{,}99 \times 10^9 \frac{80 \times 10^{-9}}{(60 \times 10^{-2})^2} \approx 3\,122\, \hat{e}_x\ (V/m)$$

b. $x_B = 40 \times 10^{-2}\, m \qquad y_B = 50 \times 10^{-2}\, m$

$$d_{1\to B} = \sqrt{(40 \times 10^{-2})^2 + (50 \times 10^{-2})^2} \approx 6\ 4 \times 10^{-2}\, m \qquad \cos\theta = \frac{40 \times 10^{-2}}{64 \times 10^{-2}} \qquad \operatorname{sen}\theta = \frac{50 \times 10^{-2}}{6\ 4 \times 10^{-2}}$$

$$d_{2\to B} = \sqrt{(60 \times 10^{-2})^2 + (50 \times 10^{-2})^2} \approx 7\ 8 \times 10^{-2}\, m \qquad \cos\alpha = \frac{60 \times 10^{-2}}{7\ 8 \times 10^{-2}} \qquad \operatorname{sen}\alpha = \frac{50 \times 10^{-2}}{7\ 8 \times 10^{-2}}$$

$$|\vec{E}_B| = |\vec{E}_{1B}|(\cos\theta\, \hat{e}_x + \operatorname{sen}\theta\, \hat{e}_y) + |\vec{E}_{2B}|(\cos\alpha\, \hat{e}_x - \operatorname{sen}\alpha\, \hat{e}_y)$$

$$|\vec{E}_{1B}| = k\frac{|q_1|}{d_{1\to B}^2} = 8{,}99 \times 10^9 \frac{20 \times 10^{-9}}{(6\ 4 \times 10^{-2})^2} \approx 438{,}96\ (V/m)$$

$$|\vec{E}_{2B}| = k\frac{|q_2|}{d_{2\to B}^2} = 8{,}99 \times 10^9 \frac{80 \times 10^{-9}}{(78 \times 10^{-2})^2} = 1182{,}12\ (V/m)$$

$$|\vec{E}_B| = 438{,}96(0{,}623\, \hat{e}_x + 0{,}781\, \hat{e}_y) + 1182{,}12(0{,}769\, \hat{e}_x - 0{,}641\, \hat{e}_y)$$

$$\approx 273{,}47\, \hat{e}_x + 342{,}83\, \hat{e}_y + 909{,}05\, \hat{e}_x - 757{,}74\, \hat{e}_y$$

$$\approx 1183\, \hat{e}_x - 415\, \hat{e}_y\ (V/m)$$

c. $q_3 = -15 \times 10^{-9}\, C$

$$\vec{F} = q\,E = -15 \times 10^{-9}(1183\, \hat{e}_x - 415\, \hat{e}_y) \approx -1{,}77 \times 10^{-5}\, \hat{e}_x + 6{,}23 \times 10^{-6}\, \hat{e}_y$$

$$F = \sqrt{(-1{,}77 \times 10^{-5})^2 + (6{,}23 \times 10^{-6})^2} \approx 1{,}88 \times 10^{-5}\, N$$

$$\theta_{(x_n\ \text{negativo})} = \operatorname{arctg}\left(\frac{6{,}23 \times 10^{-6}}{1{,}77 \times 10^{-5}}\right) \approx 19{,}4^\circ$$

15) $C = 0{,}5 \times 10^{-6}\, F \qquad \varepsilon_r = 2{,}3 \qquad d = 0{,}2 \times 10^{-3}\, m \qquad \Delta V = 80\, V$

a. $$C = \varepsilon_0 \varepsilon_r \frac{A}{d} \Rightarrow A = \frac{d\,C}{\varepsilon_0 \varepsilon_r} \Rightarrow A = \frac{(0{,}2 \times 10^{-3})(0{,}5 \times 10^{-6})}{2{,}3\,(8{,}85 \times 10^{-12})} \Rightarrow A \approx 4{,}91\, m^2$$

b. $$C = \frac{Q}{\Delta V} \Rightarrow Q = C\,\Delta V$$

$$E = \frac{1}{2} Q\,\Delta V = \frac{1}{2} C\,\Delta V^2 = \frac{1}{2}(0{,}5 \times 10^{-6}) \times 80^2 = 1{,}6 \times 10^{-3}\, J$$

c. $$E = \frac{\Delta V}{d} = \frac{80}{0{,}2 \times 10^{-3}} = 400\,000\ NC^{-1} \qquad F = q\,E = 1{,}6 \times 10^{-19} \times 400\,000 = 6{,}4 \times 10^{-14}\, N$$

$\overset{x_0=0}{\cancel{x_0}}$ $\overset{v_0=0}{\cancel{v_0}}$ $\overset{v_0=0}{}$

$x = \cancel{x_0} + \cancel{v_0}t + \frac{1}{2}at^2$ $\quad v = \cancel{v_0} + at$

$F_e = ma \rightarrow a = \frac{F_e}{m} \quad \frac{6,4\times10^{-14}}{9,1\times10^{-31}} \approx 7,03\times10^{16}\ ms^{-2}$

$x = \frac{1}{2}at^2 \rightarrow t = \sqrt{\frac{2x}{a}} = \sqrt{\frac{2\times0,2\times10^{-3}}{7,03\times10^{16}}} \approx 7,54\times10^{-11}\ s$

$v = at = 7,03\times10^{16}\times7,54\times10^{-11} \approx 5,30\times10^{6}\ ms^{-1}$

16) $q = 3,0\times10^{-15}C \qquad E = 2,0\times10^{3}\ V/m$

a. $F_e = qE = 3,0\times10^{-15}\times2,0\times10^{3} = 6,0\times10^{-12}\ N$

b. $W = \vec{F}\cdot\vec{d} = \vec{F}d\cos\theta = 6,0\times10^{-12}\times(4,0\times10^{-2})(-1) = -2,4\times10^{-13}\ J$

c. $m = 200\times10^{-12}g \rightarrow m = 2,0\times10^{-13}\ Kg \qquad \Delta U = ?$

$\Delta U = -W \Leftrightarrow \Delta U = 2,4\times10^{-13}\ J$ ← variação de energia potencial elétrica

variação de energia potencial gravítica

$\Delta E_p = mg(h_f - h_i) = 2,0\times10^{-13}\times10\times(-3,0\times10^{-2}) = -6,0\times10^{-14}\ J$

$\Delta U_{total} = \Delta U + \Delta E_p = 2,4\times10^{-13} + (-6,0\times10^{-14}) = 1,8\times10^{-13}\ J$

17) $\varepsilon_{ar} \approx \varepsilon_{vácuo} = 8,85\times10^{-12}\ C^2N^{-1}m^{-2} \qquad q_1 = 2\times10^{-9}C \qquad q_2 = -2\times10^{-9}C$

$q_3 = 4\times10^{-9}\ C \qquad d = 4\times10^{-2}\ m$