① a) $r = 4.0\,fm = 4.0\times10^{-15}\,m$

$$\vec{F} = K\frac{q_1 q_2}{r^2} = 8.99\times10^{9} \times \frac{(1.60\times10^{-19})^2}{(4.0\times10^{-15})^2} =$$

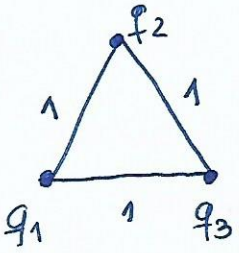
$$= 14.38\,N \approx 14\,N$$

b) $m = 1.67\times10^{-27}\,kg$

$$\vec{F}_g = G\frac{m_1 m_2}{d^2} = 6.67\times10^{-11}\,\frac{(1.67\times10^{-27})^2}{(4.0\times10^{-15})^2} =$$

$$= 1.2\times10^{-35}\,N$$

c) Força Forte

② 

$a = 1\,m$

$q_1 = -2\times10^{-6}\,C$

$q_2 = q_3 = 1\times10^{-6}\,C$

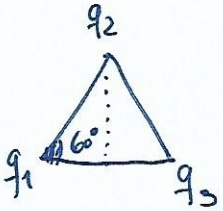
$$\vec{F}_R = \vec{F}_e q_1 q_2 + \vec{F}_e q_1 q_3$$

$$\vec{F}_{e\,q_1 q_2} = 8.99\times10^{9} \times \frac{(+2\times10^{-6}) \times (1\times10^{-6})}{1^2} =$$

$$= 17.98\times10^{-3}\,N$$

$$\vec{F}_{e\,q_1 q_3} = 8.99\times10^{9} \times \frac{(2\times10^{-6})\times(1\times10^{-6})}{1^2} =$$

$$= 17.98\times10^{-3}\ N$$



$$\vec{F}_3 = 17.98\times10^{-3}\,\vec{e}_x$$

$$\vec{F}_2 = F_2\cos 60^{\circ}\vec{e}_x + F_2 \operatorname{sen} 60^{\circ}\vec{e}_y =$$

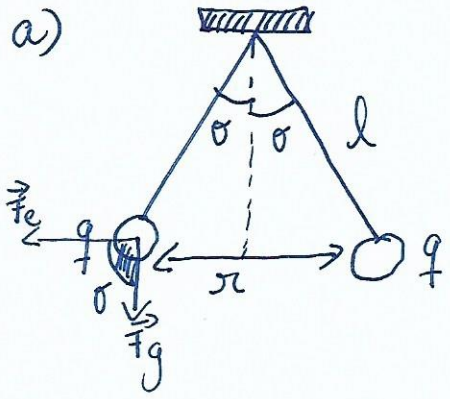
$$= 8.99\times10^{-3}\,\vec{e}_x + 16\times10^{-3}\,\vec{e}_y$$

$$\boxed{\vec{F}_R = 26.97\times10^{-3}\,\vec{e}x + 16\times10^{-3}\,\vec{e}y}$$

$$|\vec{F}_R| = \sqrt{(26.97\times10^{-3})^2 + (16\times10^{-3})^2} = 31.35\times10^{-3}\ N$$

③

a)



$\vec{F}_R = \vec{F}_g + \vec{F}_E = 0$ ↳ para estar em equilíbrio

$$\boxed{\vec{F}_g = m\,g}$$

$$\boxed{\vec{F}_e = \frac{K\,q_1\,q_2}{r^2}}$$

$$\boxed{\vec{F}_e = P\,tg\theta} \qquad tg\theta = \frac{\vec{F}_e}{P} \Leftrightarrow tg\theta = \frac{\frac{K\,q_1\,q_2}{r^2}}{P} \Leftrightarrow$$

$$\Leftrightarrow tg\theta = \frac{\frac{K\,q_1\,q_2}{r^2}}{m\,g} \Leftrightarrow$$

$$\Leftrightarrow m\,g\,tg\theta = \frac{K\,q^2}{r^2} \Leftrightarrow$$

$\Leftrightarrow \quad mg\,tg\theta = \dfrac{kq^2}{(2l\,sen\theta)^2} \Leftrightarrow$

$\Leftrightarrow mg\,tg\theta = \dfrac{kq^2}{4l^2\,sen^2\theta} \Leftrightarrow$

$\Leftrightarrow \boxed{sen^2\theta\,tg\theta = \dfrac{kq^2}{mg\,4l^2}}$

b)

$sen^2\theta\,tg\theta = \dfrac{kq^2}{mg\,4l^2} \Leftrightarrow$

$\Leftrightarrow \dfrac{kq^2}{4l^2 mg} = sen^3\theta \Leftrightarrow$

$\Leftrightarrow \dfrac{kq^2}{4l^2 mg} = \left(\dfrac{x/2}{l}\right)^3 \Leftrightarrow \dfrac{x^3}{8l^3} = \dfrac{kq^2}{4l^2 mg} \Leftrightarrow$

$\Leftrightarrow x^3 = \dfrac{kq^2\,8l^3}{4l^2 mg} \Leftrightarrow$

$\Leftrightarrow x^3 = k\,\dfrac{2lq^2}{mg} \Leftrightarrow$

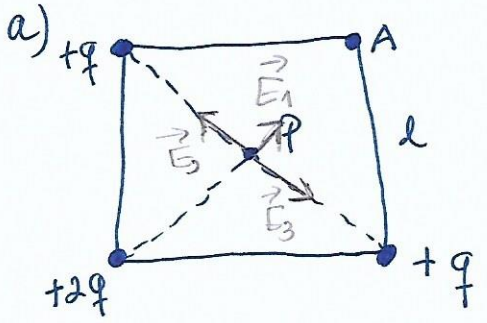
$\Leftrightarrow x^3 = \dfrac{1}{4\pi\varepsilon_0} \times \dfrac{2lq^2}{mg} \Leftrightarrow$

$\Leftrightarrow x^3 = \dfrac{2lq^2}{4\pi\varepsilon_0 mg} \Leftrightarrow x^3 = \dfrac{lq^2}{2\pi\varepsilon_0 mg} \Leftrightarrow$

$\Leftrightarrow x = \left(\dfrac{lq^2}{2\pi\varepsilon_0 mg}\right)^{1/3}$

⑤

a)



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

$l = 5,0 \times 10^{-3}\ m$

$\vec{E}_r = \vec{E}_1 + \underbrace{\vec{E}_2 + \vec{E}_3}_{=0} \Rightarrow \vec{E}_r = \vec{E}_1 = K\frac{q}{r^2} =$

(são opostas)

$$= \frac{(8.99\times10^9)\times 2 \times (1.6\times10^{-9})}{\left[\frac{\sqrt{2}}{2} \times (5\times10^{-3})\right]^2} =$$

$$= 2.3\times10^{-4}\ N\,C^{-1}$$

b)

$V_2 = V_3 = \frac{Kq}{r}$

$V_1 = \frac{2Kq}{r}$

$\Rightarrow +$

$$\frac{2Kq + 2Kq}{r} = \frac{4Kq}{r} =$$

$$= 4 \times \frac{8.99\times10^9 \times 1.6\times10^{-19}}{\frac{\sqrt{2}}{2} \times 5\times10^{-3}} =$$

$$= 1.62\times10^{-6}\ V$$

c) $\vec{F}_e = q \times \vec{E} = -100 \times 1.6\times10^{-19} \times 2.3\times10^{-4} =$

$= 3.68\times10^{-29}\ N$

$F_x = F\cos 45° = -2.6\times10^{-21}\ \vec{e}_x$

$F_y = F\sin 45° = -2.6\times10^{-21}\ \vec{e}_y$

$\vec{F} = (-2.6\times10^{-21}\ \vec{e}_x - 2.6\times10^{-21}\ \vec{e}_y)\ N$

d) $W_{P\to A} = q\,(V_A - V_B)$

$W_{P-A} = F\,d\cos\alpha =$

$= 3.7\times10^{-21} \times \left(\frac{\sqrt{2}}{2} \times 5\times10^{-3}\right) \times \cos$

$= -1.04\times10^{-23}\ J$

⑥ $m = 1.3\times10^{-10}\ Kg$

$q = 1.5\times10^{-13}\ C$

$V_x = 18\ m\,s^{-1}$

$L = 1.6\ cm = 1.6\times10^{-2}\ m$

$\vec{E} = 1.4\times10^{6}\ N\,C^{-1}$

$F_e = m \times a \iff$

$\iff a = \frac{F_e}{m} \iff$

$\iff a = \frac{q \times E}{m} \iff$ AN

$\iff a = 1.5\times10^{-13}\ m\,s^{-2}$

$\begin{cases} x = v_x t \\ y = \frac{1}{2} a t^2 \end{cases} \iff \begin{cases} t = \frac{x}{v_x} \\ — \end{cases} \iff \begin{cases} t = \frac{1.6\times10^{-2}}{18} \\ — \end{cases} \iff \begin{cases} t = 8.9\times10^{-4} \\ — \end{cases} \iff$

$\Leftrightarrow \begin{cases} \text{---} \\ y = \frac{1}{2} \times 1.6\times10^{3} \times 8.9\times10^{-4} \end{cases} \Leftrightarrow \begin{cases} t = 8.9\times10^{-4}\ s \\ \boxed{y = 6.3\times10^{-4}\ m} \end{cases}$

⑦ a) $|\vec{E}| = \frac{\Delta V}{d} \Leftrightarrow \Delta V = |\vec{E}| \times d \Leftrightarrow$

$\Leftrightarrow \Delta V = K\frac{q}{r^2} d \Rightarrow \Delta V = \frac{Kq}{d^2} d \Leftrightarrow$

Distância $r = d$

$\Leftrightarrow \boxed{\Delta V = \frac{Kq}{d}}$

$|\vec{F_E}| = q \times |\vec{E}| \Leftrightarrow$

$\Leftrightarrow |\vec{E}| = \frac{\vec{F_E}}{q} \Leftrightarrow |\vec{E}| = \frac{\frac{Kq}{d^2}}{q} \Leftrightarrow |\vec{E}| = \frac{Kq}{d^2} \Leftrightarrow |\vec{E}| = \frac{\Delta V}{d}$, c.q.m.

CA:

$\frac{Kq}{d} \times \frac{1}{d} = \frac{\Delta V}{d}$ ($\frac{Kq}{d} = \Delta V$)

b) $\Delta V = V_1 - V_2 = 300\ V$

$d = 5.0\times10^{-2}\ m$

$q = 2.0\times10^{-7}\ C$

$\vec{F} = q \times \vec{E} \Leftrightarrow \vec{F} = 2.0\times10^{-7} \times \frac{300}{5.0\times10^{-2}} \Leftrightarrow$ ($\vec{E} \rightarrow \frac{\Delta V}{d}$)

$\Leftrightarrow \vec{F} = 1.2\times10^{-3}\ N$

c) $W_{A\to B} = q(V_A - V_B) = 2.0\times10^{-7} \times 300 = 6.0\times10^{-5}\ J$

⑨

a) $|\vec{E}| = 3.0 \times 10^6 \ V m^{-1}$

$d = 5{,}0 \times 10^{-3} \ m$

$$|\vec{E}| = \frac{\Delta V}{d} \Leftrightarrow \Delta V = |\vec{E}| \times d \Leftrightarrow$$

$$\Leftrightarrow \Delta V = 3.0 \times 10^6 \times 5.0 \times 10^{-3} m \Leftrightarrow$$

$$\Leftrightarrow \Delta V = 15 \times 10^3 V \Leftrightarrow \Delta V = 15 kV$$

b) $|\vec{E}| = \frac{\sigma}{2\varepsilon_0} \Leftrightarrow \sigma = |\vec{E}| \, 2\varepsilon_0 \Leftrightarrow$

$\sigma = \frac{q}{A}$ →

$$\Leftrightarrow \frac{q}{A} = 3.0 \times 10^6 \times 2 \times 8.85 \times 10^{-12} \Leftrightarrow$$

$$\Leftrightarrow \frac{q}{A} = 2.66 \times 10^{-5} \ C m^{-2} \Leftrightarrow$$

$$\Leftrightarrow qA = 27 \ \mu C m^{-2}$$

NOTA:

Lei de Gauss:

$$E = \frac{\sigma}{2\varepsilon_0} = \frac{\frac{q}{A}}{2\varepsilon_0}$$

⑩

a) $|\vec{E}| = 8.0 \times 10^4 \ V m^{-1}$

$$\vec{F}_R = \vec{F}_g + \vec{F}_E = (m \times g) + (q \times |\vec{E}|) =$$

$$= (1.67 \times 10^{-27} \times 10) + (1.60 \times 10^{-19} \times 8.0 \times 10^4) =$$

$$= 1.3 \times 10^{-14} \ N$$

$d = 0.5 m$

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

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

$g = 10 \ m s^{-2}$

b)

$$|\vec{E}| = \frac{\Delta V}{d} \Leftrightarrow \Delta V = |\vec{E}| \times d \Leftrightarrow$$

$$\Leftrightarrow \Delta V = 8.0 \times 10^4 \times 0.5 \Leftrightarrow$$

$$\Leftrightarrow \Delta V = 4.0 \times 10^4 \ V$$

c) $Ec = W_{A \to B} = q(V_A - V_B) =$

$$= 1.6 \times 10^{-19} \left(4.0 \times 10^4\right) =$$

$$= 6.4 \times 10^{-5} \ J$$