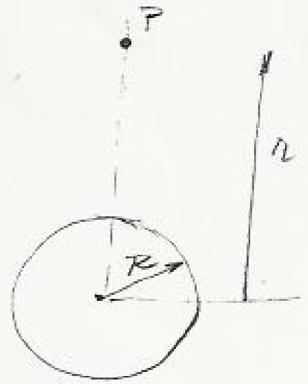
Cap. 11

11.26 -



DET A VELOCIDADE DE ESCAPE

$$v = 0 \longrightarrow r \to \infty$$

$$a = -g\,R^2/r^2$$

$$a\,ds = v\,dv$$

$$\int -g\frac{R^2}{r^2}\,dr = \int v\,dv$$

$$-gR^2\int_R^\infty r^{-2}\,dr = \int_v^0 v\,dv$$

$$-gR^2\left(-\frac{1}{r}\right)\Big|_R^\infty = \frac{v^2}{2}\Big|_v^0$$

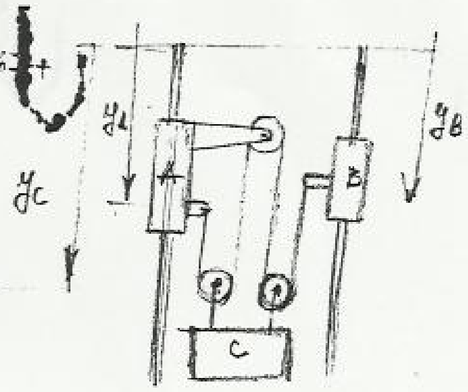
$$gR^2\left(\underbrace{\frac{1}{\infty}}_{0} - \frac{1}{R}\right) = 0 - \frac{v^2}{2}$$

$$\cancel{-}\,\frac{gR^{\cancel{2}}}{\cancel{R}} = \cancel{-}\,\frac{v^2}{2}$$

$$v^2 = 2gR$$

$$v = \sqrt{2gR}$$

11.47 +



$$3(y_C - y_A) + y_C - y_B = L$$

$$3y_C - 3y_A + y_C - y_B = L$$

$$4y_C - 3y_A - y_B = L$$

$$\frac{d}{dt} \quad 4v_C - 3v_A - v_B = 0$$

$$\frac{d}{dt} \quad 4a_C - 3a_A - a_B = 0$$

$\uparrow +$

$v_{0A} = 0$

$a_A = 6{,}25\ cm/s^2 \uparrow$

$v_{0B} = 37{,}5\ cm/s \downarrow$

$a_B = 0$

$$4v_C - 3v_A - v_B = 0$$

$$4v_C - 0 - (-37{,}5) = 0$$

$$v_{0C} = -9{,}37\ m/s \downarrow$$

$$4a_C - 3 \times 6{,}25 - 0 = 0$$

$$a_C = 4{,}69\ m/s^2 \uparrow$$

$$v_C = v_{0C} + at$$

$$0 = -9{,}37 + 4{,}69t$$

$$\boxed{t = 2\,s}$$

$$\Delta y = v_{0C}t + \frac{1}{2}at^2$$

$$\Delta y = -9{,}37 \times 2 + \frac{1}{2} \times 4{,}69 \times 2^2$$

$$\boxed{\Delta y = 9{,}36\ cm \downarrow}$$

//

11.48 -

$v_{0A} = 0$

$v_{0B} = 0$

$a_A = 7{,}5t\ cm/s^2 \uparrow$

$a_B = 22{,}5\ cm/s^2 \downarrow$

$$4a_C - 3a_A - a_B = 0$$

$$4a_C - 3 \times 7{,}5t - (-22{,}5) = 0$$

$$4a_C - 22{,}5t + 22{,}5 = 0$$

$$a_C = 5{,}62t - 5{,}62$$

$$a_C = \frac{dv}{dt} \qquad \int_0^v dv = \int_0^t (5{,}62t - 5{,}62)\,dt$$

$$v = \frac{5{,}62t^2}{2} - 5{,}62t \qquad v = 0 \Rightarrow t\left(\frac{5{,}62t}{2} - 5{,}62\right) = 0$$

$$t = 0$$

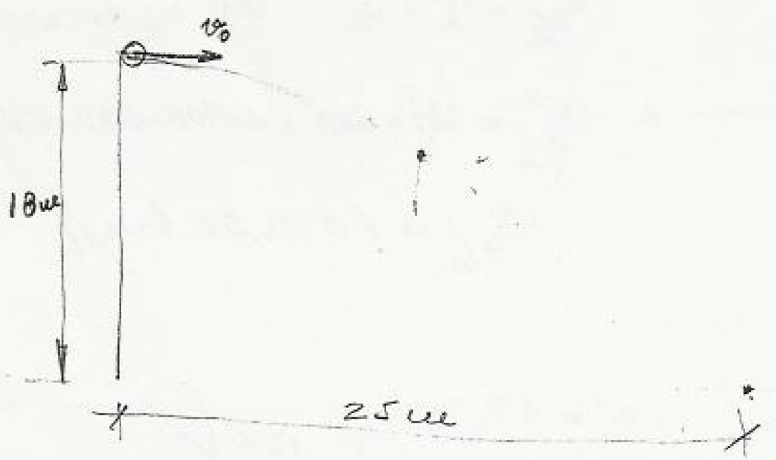
$$\boxed{t = 2s}$$

$$\int_0^y dy = \int_0^2 \left(\frac{5{,}62t^2}{2} - 5{,}62t\right) dt$$

$$\Delta y = \left[\frac{5{,}62}{6}t^3 - \frac{5{,}62}{2}t^2\right]_0^2$$

$$\boxed{\Delta y = 3{,}75\ cm \downarrow}$$

11.87 -



$v_{0x} = v_0$

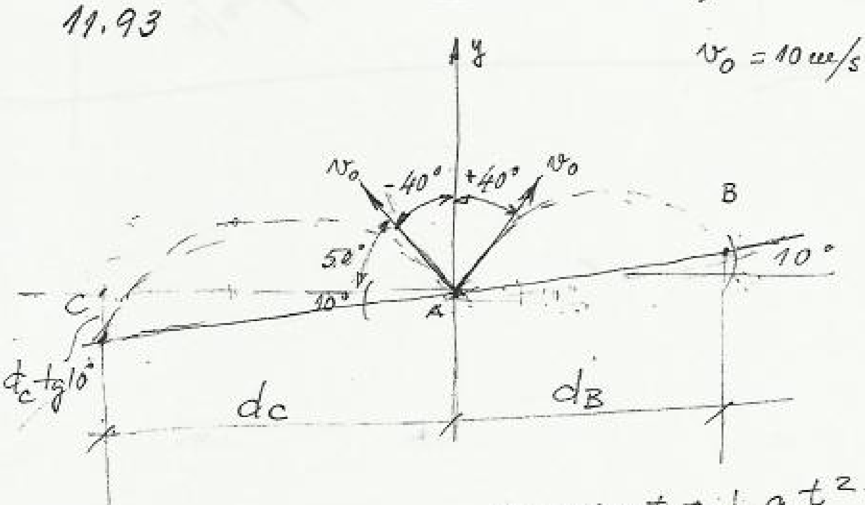
$v_{0y} = 0$

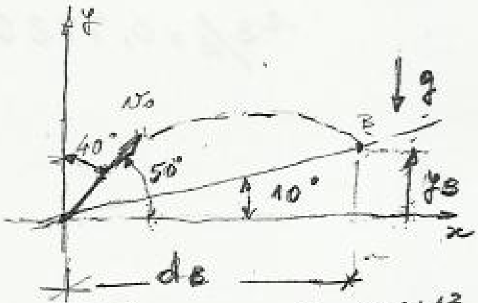
$y = \frac{1}{2} g t^2$

$18 = \frac{1}{2} \times 9{,}81 \times t^2$ $\qquad t = 1{,}92$ s.

$x = v_0 t$ $\qquad 25 = v_0 \times 1{,}92$ $\qquad \boxed{v_0 = 13{,}05 \text{ m/s}}$

11.93





$10\cos 50° tg 10° t = 10\cos 40° t - \frac{1}{2} 9{,}81 t^2$

$-6{,}527 t = -\frac{1}{2} 9{,}81 t^2$

$t(\frac{1}{2} 9{,}81 t - 6{,}527) = 0$

$t = 0$

$t = 1{,}33$ s

$d_B = 10\cos 50° \times t$

$\boxed{d_B = 8{,}55 \text{ m}}$

$y_C = d_C\, tg 10°$

$d_C = v_{0x}\, t$

$d_C = 10\cos 50° \times t$

$y_C = v_{0y} t + \frac{1}{2} g t^2$

$-d_C tg 10° = 10\cos(40°) t + \frac{1}{2} 9{,}81 t^2$

$-10\cos 50° tg 10° t = 10\cos 40° t + \frac{1}{2} 9{,}81 t^2$

$-8{,}79 t = -\frac{1}{2} 9{,}81 t^2$

$t(\frac{1}{2} \times 9{,}81 t - 8{,}79) = 0$

$y_B = v_{0y} t - \frac{1}{2} g t^2$

$y_B = d_B\, tg 10°$

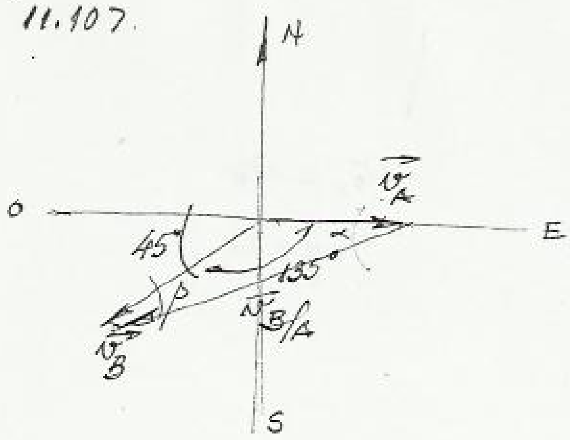
$d_B = v_{0x}\, t$

$t = 0$

$\boxed{t = 1{,}79 \text{ s}}$

$d_C = 10\cos 50° \times t$ $\qquad \boxed{d_C = 11{,}50 \text{ m}}$

11.107.

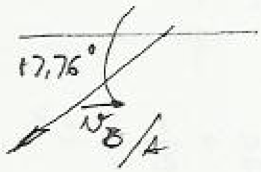


$$v_{B/A}^2 = v_A^2 + v_B^2 - 2 v_A v_B \cos 135^\circ$$

$$v_{B/A}^2 = 900^2 + 600^2 - 2 \times 900 \times 600 \times \cos 135^\circ$$

$$v_{B/A} = 1.390,56 \text{ km/h}$$

$$\frac{v_B}{\operatorname{sen} \alpha} = \frac{v_{B/A}}{\operatorname{sen} 135^\circ} \qquad \alpha = 17,76^\circ$$



$t = 2s$

$r_{B/A} = v_{B/A}\, t \qquad t = \frac{2}{3600}\, h$

$r_{B/A} = 1.390,56 \times \frac{2}{3600}$

$r_{B/A} = 0,7725 \text{ km}$

$$\boxed{r_{B/A} = 772,54 \text{ m}}$$

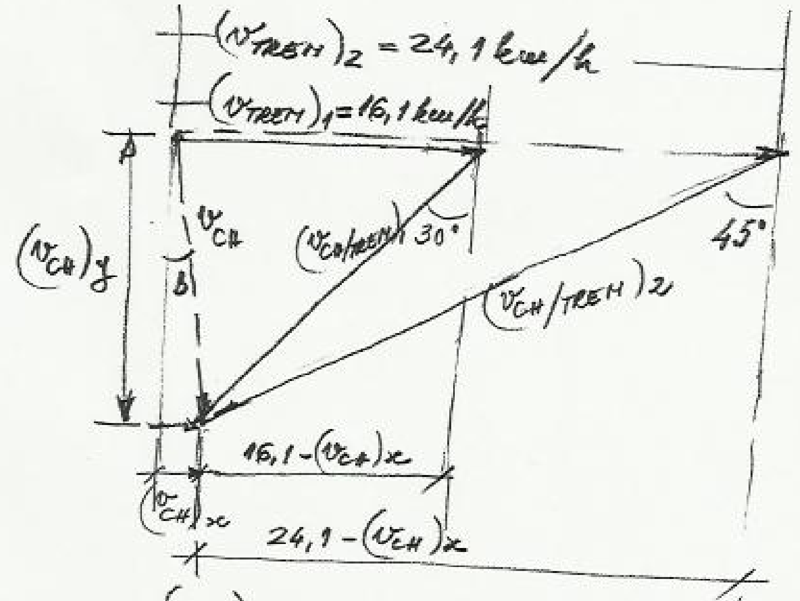
17,76
$\vec{r}_{B/A}$

11.117

$$v_{CH} = v_{TREM} + v_{CH/TREM}$$

CASO ①: $v_{TREM} = 16,1\ km/h$; $v_{CH/TREM}$ $\swarrow 30°$

CASO ②: $v_{TREM} = 24,1\ km/h$; $v_{CH/TREM}$ $\swarrow 45°$



$$tg\,30° = \frac{(v_{CH})_y}{16,1-(v_{CH})_x} \qquad tg\,45° = \frac{(v_{CH})_y}{24,1-(v_{CH})_x}$$

$$(v_{CH})_y = tg\,30°\left[16,1-(v_{CH})_x\right] \qquad (v_{CH})_y = tg\,45°\left[24,1-(v_{CH})_x\right]$$

$$tg\,30°\left[16,1-(v_{CH})_x\right] = tg\,45°\left[24,1-(v_{CH})_x\right]$$

$$0,5774\left(16,1-(v_{CH})_x\right) = 24,1-(v_{CH})_x$$

$$0,42\,(v_{CH})_x = 14,80 \qquad (v_{CH})_x = 35,03\ km/h$$

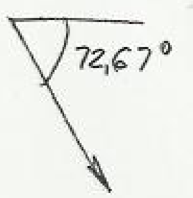
$$(v_{CH})_y = -10,93\ km/h$$

$$v_{CH} = \sqrt{(35,03)^2 + (-10,93)^2}$$

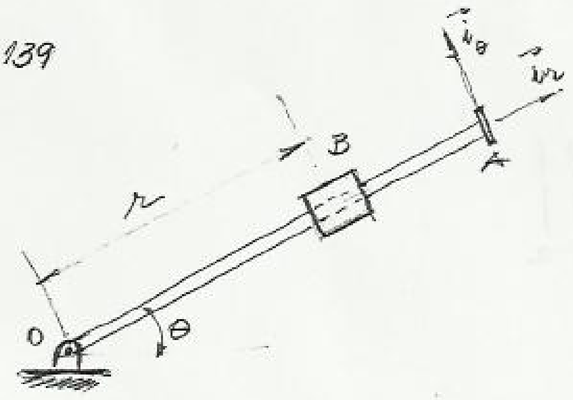
$$v_{CH} = 36,70\ km/h$$

$$tg\,\beta = \frac{35,03}{10,93} \qquad \beta = 72,67°$$

$v_{CH} = 36,70\ km/h$



11.139



$$\theta = t^3 - 4t$$
$$r = 25t^3 - 50t^2$$

$$\dot\theta = \frac{d\theta}{dt} = 3t^2 - 4 \qquad \dot r = 75t^2 - 100t$$
$$\ddot\theta = \frac{d^2\theta}{dt^2} = 6t \qquad \ddot r = 150t - 100$$

$t = 1s$

a) $\vec{v} = \dot r \, \vec{i_r} + r\dot\theta \, \vec{i_\theta}$

$$\vec{v} = (75t^2 - 100t)\vec{i_r} + (25t^3 - 50t^2)(3t^2 - 4)\vec{i_\theta}$$

$$\boxed{\vec{v} = (75t^2 - 100t)\vec{i_r} + (75t^5 - 150t^4 - 100t^3 + 200t^2)\vec{i_\theta}}$$

$\vec{v} = -25 mm/s \, \vec{i_r} + 25 mm/s$

b) $\vec{a} = (\ddot r - r\dot\theta^2)\vec{i_r} + (r\ddot\theta + 2\dot r\dot\theta)\vec{i_\theta}$

$$\vec{a} = [(150t - 100) - (25t^3 - 50t^2)(3t^2 - 4)^2]\vec{i_r} + [(25t^3 - 50t^2)6t + 2(75t^2 - 100t)3t$$

$t = 1s$

$$\vec{a} = [50 - (-25)(-1)]\vec{i_r} + [-150 + (-25)(-1)]$$

$$\boxed{\vec{a} = 25 \, mm/s^2 \, \vec{i_r} - 125 \, mm/s^2 \, \vec{i_\theta}}$$

c) A aceleração do cursor em relação a haste é $\ddot r$:

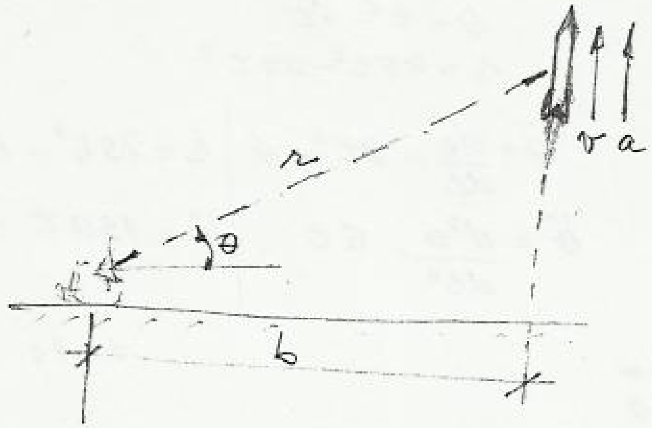
$$\vec{a}_{B/OA} = \ddot r \, \vec{i_r}$$

$$a_{B/OA} = 150t - 100$$

P/ $t = 1s$

$$\boxed{a_{B/OA} = 50 \, mm/s^2}$$

11.145



$$r = \frac{b}{\cos\theta} = b\cos^{-1}\theta = b\sec\theta \qquad \vec{v} = v_r\,\vec{i_r} + v_\theta\,\vec{i_\theta}$$

$$\vec{v} = \dot{r}\,\vec{i_r} + r\dot{\theta}\,\vec{i_\theta}$$

$$\dot{r} = -b\cos^{-2}\theta\,(-\sin\theta)\,\dot{\theta}$$

$$v_r = \dot{r} = b\sec\theta\,tg\theta\,\dot{\theta}$$

$$v_\theta = b\sec\theta\,\dot{\theta}$$

$$v = \sqrt{v_r^2 + v_\theta^2}$$

$$v = \sqrt{b^2\sec^2 tg^2\theta\,\dot{\theta}^2 + b^2\sec^2\theta\,\dot{\theta}^2}$$

$$v = b\sec\theta\,\dot{\theta}\underbrace{\sqrt{1 + tg^2\theta}}_{\sec\theta}$$

$$\boxed{v = b\sec^2\theta\,\dot{\theta}}$$

$$\boxed{v = \frac{b}{\cos^2\theta}\,\dot{\theta}}$$

11.149 - $\theta = 42{,}0° \longrightarrow \theta = 43{,}2°$ $\qquad \Delta\theta = 1{,}2°$

$\Delta t = 0{,}5\,s$

$$\dot{\theta} \simeq \frac{\Delta\theta}{\Delta t} = \frac{1{,}2°}{0{,}5\,s} \qquad \dot{\theta} = 2{,}4°/s = 0{,}0419\,rad/s$$

$b = 3\,km = 3.000\,m$

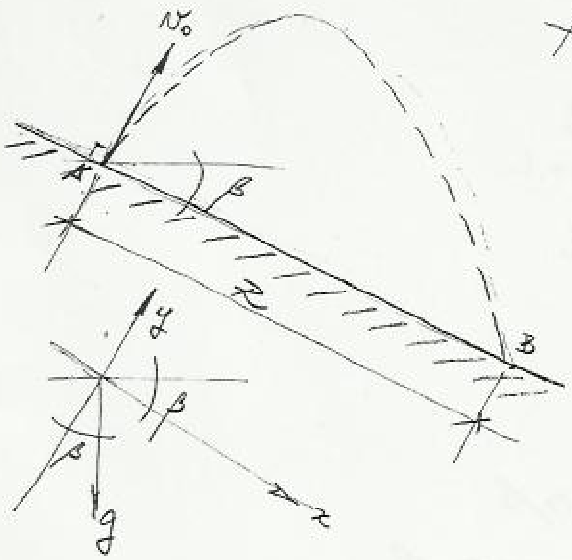
$\theta = 43{,}2°$

$$v = \frac{3000 \times 0{,}0419}{(\cos 43{,}2°)^2} \qquad \boxed{\begin{array}{l} v = 236{,}54\ m/s \\ v = 851{,}54\ km/h \end{array}}$$

EXERCÍCIOS: 10; 25; 26; 30; 31; 35; 40; 41; 42; 47; 48; 53; 56; 88; 90; 92; 93; 94; 97; 99; 100; 108; 113; 114; 120; 127; 132; 135; 139; 140; 145; 146; 147; 148; 155; 156

11.1 -

11.169



$$x = 0 + \frac{1}{2} a_x t^2$$

$$x = \frac{1}{2} g \operatorname{sen}\beta \, t^2$$

$$y = v_0 t - \frac{1}{2} g \cos\beta \, t^2$$

$a_x = g \operatorname{sen}\beta \qquad v_{0x} = 0$

$a_y = -g\cos\beta \qquad v_{0y} = v_0$

p/ $x = R$

$y = 0$

$$0 = v_0 t - \frac{1}{2} g \cos\beta \, t^2$$

$$t\left(\frac{1}{2} g \cos\beta \, t - v_0\right) = 0$$

$$t = 0 \quad e \quad t = \frac{2 v_0}{g \cos\beta}$$

$$x = \frac{1}{2} g \operatorname{sen}\beta \, t^2$$

$$R = \frac{1}{2} g \operatorname{sen}\beta \left(\frac{2 v_0}{g\cos\beta.}\right)^2 \qquad R = \frac{1}{2} \cancel{g} \operatorname{sen}\beta \, \frac{4 v_0^2}{g^{\cancel{2}} \cos^2\beta}$$

$$\boxed{R = \frac{2 v_0^2}{g} \operatorname{tg}\beta \sec\beta}$$

11.170 - $v_0 = 10 \, m/s$

$\beta = 30°$

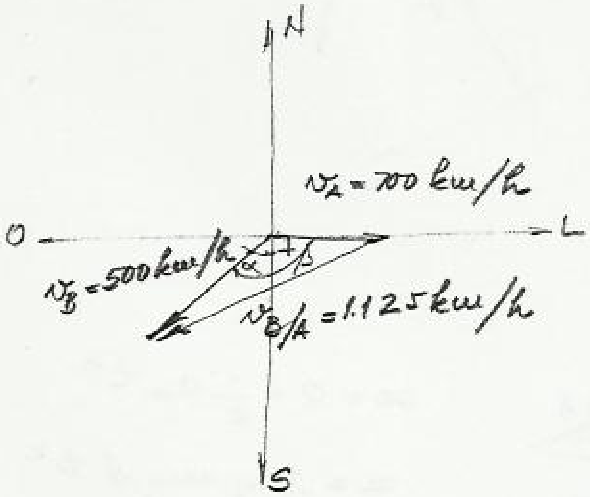
$g = 9{,}81 \, m/s^2$

$$R = \frac{2 . v_0^2}{g} \operatorname{tg}\beta . \sec\beta$$

$$R = \frac{2 \times 10^2}{9{,}81} \times \operatorname{tg} 30° \frac{1}{\cos 30°}$$

$$\boxed{R = 13{,}59 \, m}$$

11.171 –



$$v_{B/A}^2 = v_A^2 + v_B^2 - 2\, v_A\, v_B \cos\beta$$

$$1125^2 = 700^2 + 500^2 - 2 \times 700 \times 500 \cos\beta$$

$$\cos\beta = -0,7509$$

$$\beta = 138,67^\circ$$

$$\beta = \alpha + 90^\circ \longrightarrow \boxed{\alpha = 48,67^\circ}$$

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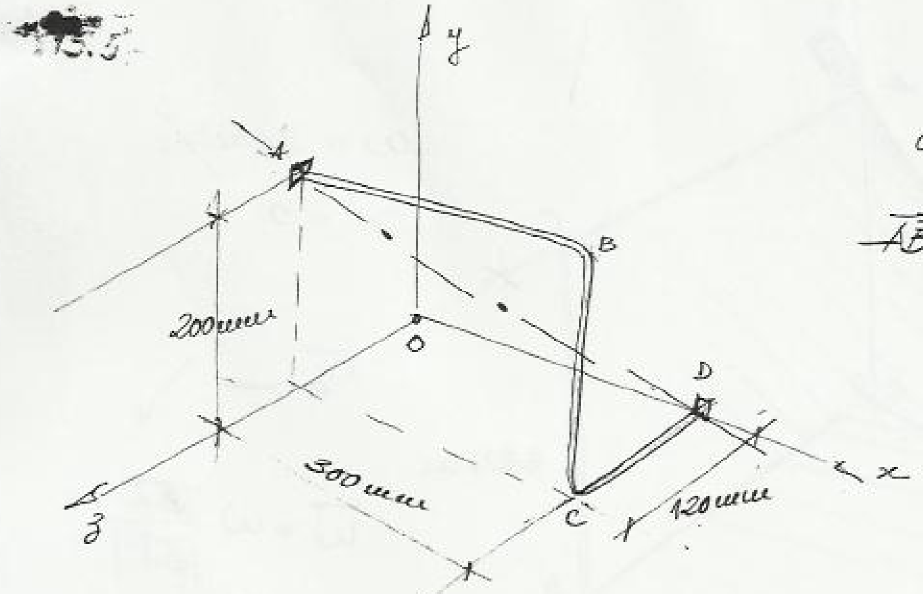
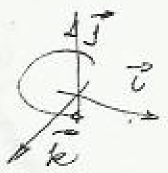
Cap. 15

15.5



$\omega = 95\ rad/s$

$\vec{AB} = 0{,}3m\ \vec{i}$



$$\vec{\omega} = \omega \frac{\vec{AD}}{|\vec{AD}|} = 95 \frac{0{,}3\vec{i} - (0{,}2\vec{j} + 0{,}12\vec{k})}{\sqrt{0{,}3^2 + 0{,}2^2 + 0{,}12^2}}$$

$$\vec{\omega} = 75\ rad/s\ \vec{i} - 50\ rad/s\ \vec{j} - 30\ rad/s\ \vec{k}$$

$$\vec{v}_B = \vec{\omega} \wedge \vec{AB}$$

$$\vec{v}_B = (75\vec{i} - 50\vec{j} - 30\vec{k}) \wedge 0{,}3\vec{i} = +50 \times 0{,}3\vec{k} - 30 \times 0{,}3\vec{j}$$

$$\boxed{\vec{v}_B = (-9{,}0\ m/s)\vec{j} + (15\ m/s)\vec{k}}$$

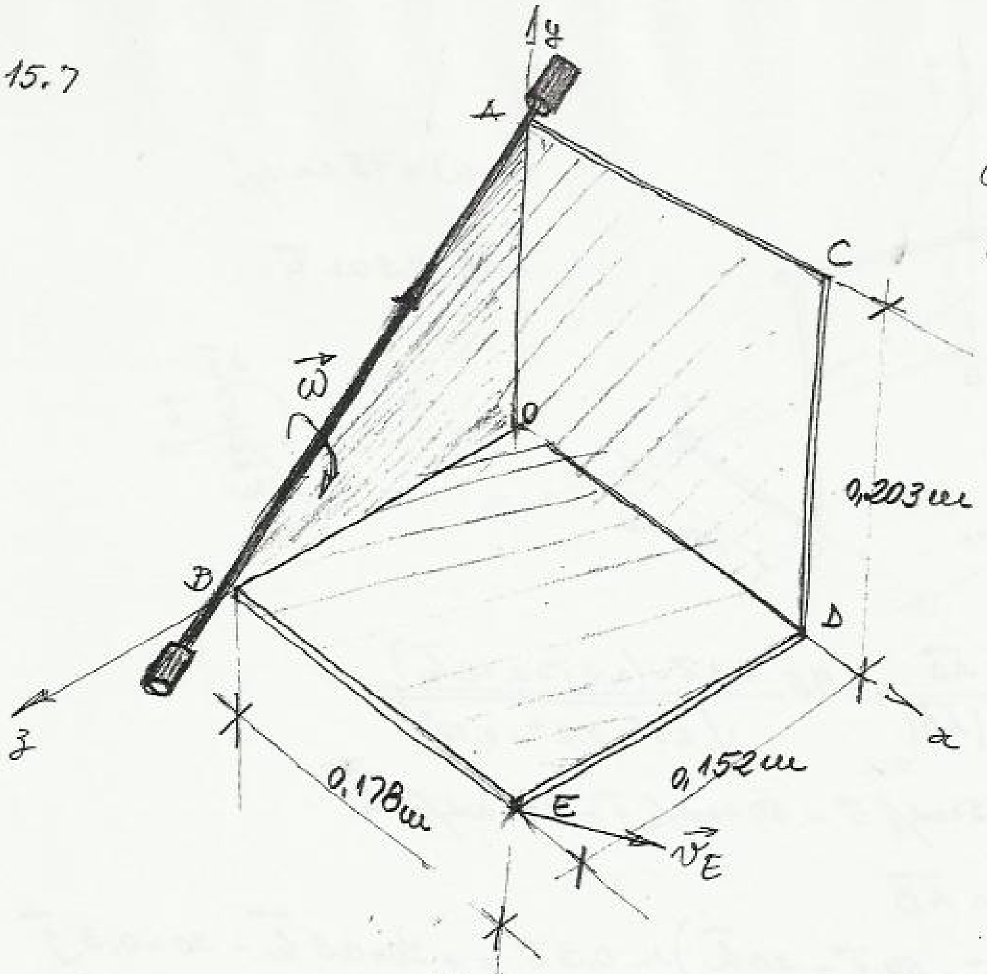
$$\vec{a}_B = \vec{\alpha} \wedge \vec{AB} + \vec{\omega} \wedge (\vec{\omega} \wedge \vec{AB}) \qquad \vec{\alpha} = 0$$

$$\vec{a}_B = (75\vec{i} - 50\vec{j} - 30\vec{k}) \wedge (-9\vec{j} + 15\vec{k})$$

$$\vec{a}_B = -675\vec{k} - 1.125\vec{j} - 750\vec{i} - 270\vec{i}$$

$$\boxed{\vec{a}_B = (-1020\ m/s^2)\vec{i} + (-1.125\ m/s^2)\vec{j} + (-675\ m/s^2)\vec{k}}$$

15.7

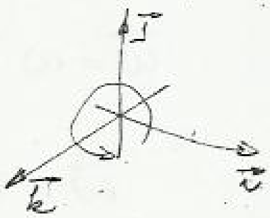


$\omega = 5\ rad/s$

$\alpha = 0$

$\vec{v}_E$ —

$\vec{\omega} = \omega \dfrac{\vec{BA}}{|\vec{BA}|}$



$$\vec{\omega} = 5\,\frac{+0{,}203\vec{j} - 0{,}152\vec{k}}{\sqrt{0{,}203^2 + 0{,}152^2}} \qquad \vec{\omega} = (4\,rad/s)\,\vec{j} + (-3\,rad/s)\,\vec{k}$$

$$\vec{v}_D = \vec{\omega} \wedge \vec{BD} = (4\vec{j} - 3\vec{k}) \wedge (0{,}178\,\vec{i} - 0{,}152\,\vec{k})$$

$$\vec{v}_D = -0{,}71\,\vec{k} - 0{,}61\,\vec{i} + 0{,}53\,\vec{j}$$

$$\boxed{\vec{v}_D = (-0{,}6\,m/s)\,\vec{i} + (-0{,}53\,m/s)\,\vec{j} + (-0{,}71)\,m/s\,\vec{k}}$$

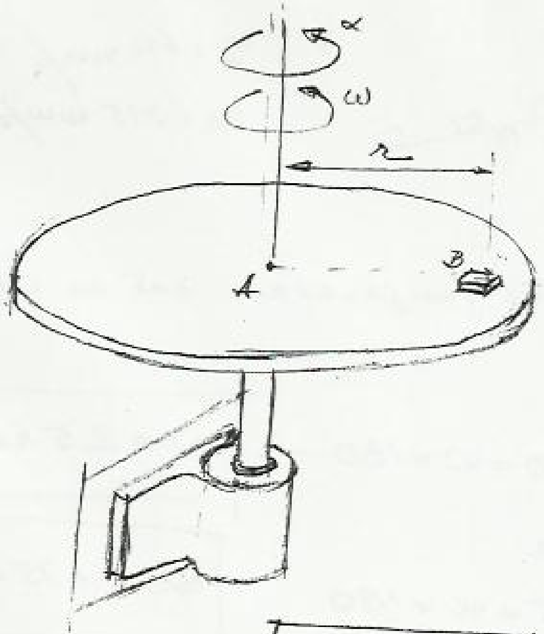
$$\vec{a}_D = \vec{\alpha} \wedge \vec{BD} + \vec{\omega} \wedge (\vec{\omega} \wedge \vec{BD}) \qquad \alpha = 0$$

$$\vec{a}_D = (4\vec{j} - 3\vec{k}) \wedge (-0{,}6\,\vec{i} - 0{,}53\,\vec{j} - 0{,}71\,\vec{k})$$

$$\vec{a}_D = +2{,}4\,\vec{k} - 2{,}84\,\vec{i} + 1{,}8\,\vec{j} - 1{,}59\,\vec{i}$$

$$\boxed{\vec{a}_D = (-4{,}43\,m/s^2)\,\vec{i} + (1{,}8\,m/s^2)\,\vec{j} + (2{,}4\,m/s^2)\,\vec{k}}$$

15.15



$a = 3\,m/s^2$

$t = 0 \Rightarrow \omega_0 = 0$

$\alpha = 4\,rad/s^2$

$r = 200\,mm$

$a_t = \alpha r$

$a_n = \omega^2 r$

$\omega = \cancel{\omega_0} + \alpha t$

$\omega = \alpha t$

$a_n = \alpha^2 r\, t^2$

$$a = \sqrt{a_t^2 + a_n^2}$$

$$a = \sqrt{\alpha^2 r^2 + (\alpha^2 r t^2)^2} \qquad \boxed{a = \alpha r \sqrt{1 + \alpha^2 t^4}}$$

$$3 = 4 \times 0{,}2 \sqrt{1 + 4^2 t^4}$$

$$3 = 0{,}8 \sqrt{1 + 16 t^4} \qquad 3{,}75 = \sqrt{1 + 16 t^4}$$

$$(3{,}75)^2 = 1 + 16 t^4 \qquad \boxed{t = 0{,}95\,s}$$

15.16

$\alpha = 0{,}5\,rad/s^2 \qquad r = 0{,}2\,m$

$$a = \alpha r \sqrt{1 + \alpha^2 t^4}$$

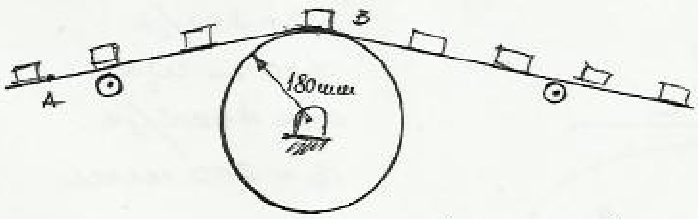
$$a = 0{,}1 \sqrt{1 + 0{,}25 t^4}$$

a) $t = 0 \qquad a_0 = 0{,}10\,m/s^2$

b) $t = 1\,s \qquad a_1 = 0{,}11\,m/s^2$

c) $t = 2\,s \qquad a_2 = 0{,}22\,m/s^2$

15.13-



$v_A = 450\ mm/s$ ←

$a_A = 315\ mm/s^2$ →

As velocidades e acelerações tangenciais são as mesmas para toda a correia.

a)

$v_B = v_A = 450\ mm/s$

$v_B = \omega r \qquad 450 = \omega \times 180$

$$\boxed{\omega = 2{,}5\ rad/s}$$

$a_{B_t} = a_A = 315\ mm/s^2$

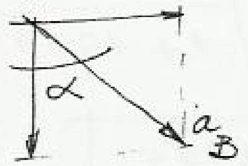
$a_{B_t} = \alpha r \qquad 315 = \alpha \times 180$

$$\boxed{\alpha = 1{,}75\ rad/s^2}$$

b) $\vec{a_B} = a_{B_t}\vec{u_t} + a_{B_n}\vec{u_n}$

$a_{B_t} = 315\ mm/s^2$ →

$a_{B_n} = \omega^2 r = 2{,}5^2 \times 180 = 1125\ mm/s^2$ ↓



$a_B = \sqrt{315^2 + 1125^2}$

$$\boxed{a_B = 1.168{,}27\ mm/s^2 \qquad a_B = 1{,}17\ m/s^2}$$

15,64°

$tg\alpha = \frac{315}{1125}$

15.14 $\omega = 3\ rad/s$ $\qquad a_B = 2\ m/s^2 \qquad r = 0{,}18\ m$

$a_B^2 = a_{B_t}^2 + a_{B_n}^2$

$a_{B_t} = \alpha r = 0{,}18\alpha$

$a_{B_n} = \omega^2 r = 3^2 \times 0{,}18 = 1{,}62\ m/s^2$

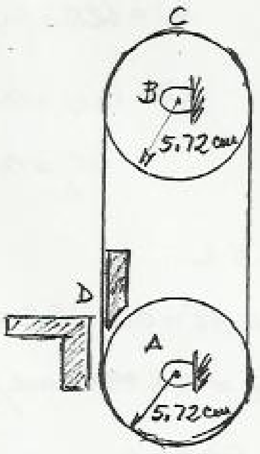
$a_B = 2\ m/s^2$

$2^2 = (0{,}18\alpha)^2 + 1{,}62^2$

$$\boxed{\alpha = \pm 6{,}52\ rad/s^2}$$

(sentido horário ou anti horário)

15.17-



$\omega_0 = 0$

$\alpha = 120\ rad/s^2$

Det. a_C.

a_D.

$t = 2s$

$\omega = \omega_0 + \alpha t$

$\omega = 0 + 120 \times 2$

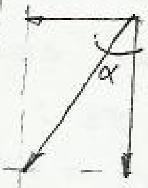
$\omega = 240\ rad/s$

$a_{C_t} = \alpha r = 120 \times 5,72 = 686,40\ cm/s^2 = 6,86\ m/s^2$

$a_{C_n} = \omega^2 r = 240^2 \times 5,72 = 329.472\ cm/s^2 = 3.294,72\ m/s^2$

$a_C = \sqrt{a_{C_t}^2 + a_{C_n}^2}$ $\quad a_C = \sqrt{6,86^2 + 3.294,72^2}$

$a_C = 3,29 \times 10^3\ m/s^2$ ↓



$tg\,\alpha = \frac{6,86}{3.294,72}$

$\alpha = 0,12°$

$a_D = a_{C_t} = 6,86\ m/s^2$ $\quad \boxed{a_D = 6,86\ m/s^2 \downarrow}$

15.18-

$\omega = 3450\ rpm$ $\quad 1\ rpm = \frac{2\pi}{60}\ rad/s = \frac{\pi}{30}\ rad/s$

$\omega = 115\pi\ rad/s$

a) $v_C = \omega r = 115\pi \times 5,72\ cm = 2066.54\ cm/s$.

$\boxed{v_C = 20,67\ m/s \leftarrow}$

$a_C = \omega^2 r = (115\pi)^2 \times 5,72 = 746.605,96\ cm/s^2$

$\boxed{a_C = 7.466\ m/s^2 \downarrow}$

b) CÁLCULO DE α! $\quad \omega = \omega_0 + \alpha t \quad 0 = 115\pi - \alpha \times 5 \quad \alpha = 72,26\ rad/s$

P/ $t = 4,5s$ $\quad \omega = 115\pi - 72,26 \times 4,5$

$\omega = 36,13\ rad/s$

$v_C = 36,13 \times 0,0572$

$\boxed{v_C = 2,07\ m/s \leftarrow}$

$a_n = \omega^2 r \quad a_n = 74,67\ m/s^2$

$a_t = \alpha r \quad a_t = 4,13\ m/s^2$

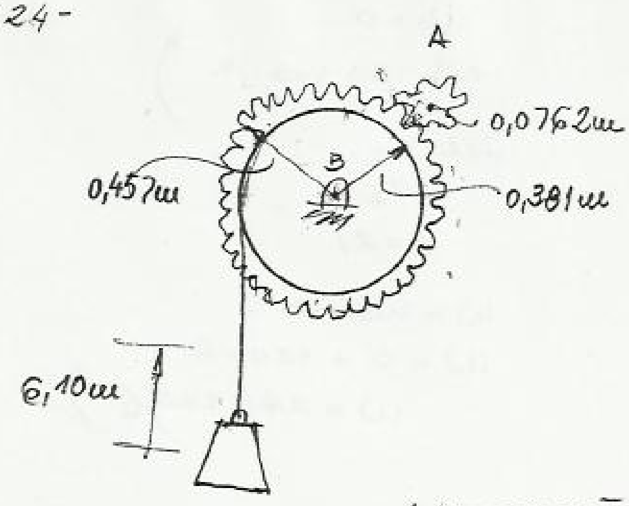
$a = \sqrt{74,67^2 + 4,13^2}$

$a_c = 74,78\ m/s^2$

86,8°

$\theta = 86,83$

15.24-



$\omega_0 = 0$ roda A

$\omega = 120\ rpm = 120 \times \frac{\pi}{30} = 4\pi\ rad/s$

$\omega = \omega_0 + \alpha t \qquad t = 5s$

$\alpha_A = 0,8\pi\ rad/s^2$

$a_t = \alpha r$

$a_t = 0,8\pi \times 0,0762 = \alpha_B \times 0,457$

$\alpha_B = 0,4191\ rad/s^2$.

ACELERAÇÃO NA CORDA.

$a = 0,4191 \times 0,381 \qquad a = 0,16\ m/s^2$

DESLOCAMENTO DO PESO EM 5s.

$\Delta s = \frac{1}{2} a t^2 \qquad \Delta s = \frac{1}{2} \times 0,16 \times 5^2$

$\Delta s = 2m$.

RESTA AO PESO DESLOCAR-SE 4,10m (6,10m - 2m)

A PARTIR DE 5s:

$\omega_A = 4\pi\ rad/s = cte.$

$v_t = \omega r \qquad v_t = 4\pi \times 0,0762 = \omega_B \times 0,457$

$\omega_B = 2,10\ rad/s.$

VELOCIDADE DA CORDA:

$v = \omega_B \times 0,381 = 0,798\ m/s.$

$\Delta s = vt \qquad 4,1 = 0,798\ t \qquad t = 5,14s.$

a) CÁLCULO DO Nº DE ROTAÇÕES DA ENGRENAGEM A

0 — 5s. $\theta_A = \frac{1}{2} \alpha_A t^2 \qquad \theta_A = \frac{1}{2} \times 0,8\pi \times 5^2$

$\theta_A = 31,42\ rad.$

5s — 10,14s. $\theta_A = \omega_A t \qquad \theta_A = 4\pi \times 5,14$

$\theta_A = 64,59\ rad$

$\theta_A = 31,42 + 64,59$

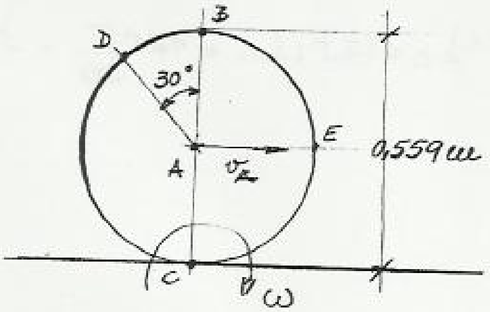
$\theta_A = 96,01\ rad$

$\boxed{\theta_A = 15,3\ rot.}$

b) $t = 5 + 5,14$

$\boxed{t = 10,14\ s}$

15.30 -



$v_A = 72,4\ km/h \rightarrow$

$$\omega = \frac{72,4}{3,6 \times \frac{0,559}{2}}$$

$\omega = 71,95\ rad/s$

$\vec{v}_B = \vec{v}_A + \vec{v}_{B/A} = 20,11\ m/s \rightarrow + 71,95 \times \frac{0,559}{2} \rightarrow$

$\boxed{v_B = 40,22\ m/s \rightarrow}$

$\vec{v}_C = \vec{v}_A + \vec{v}_{C/A} = 20,11\ m/s \rightarrow + 20,11\ m/s \leftarrow$

$\boxed{v_C = 0}$

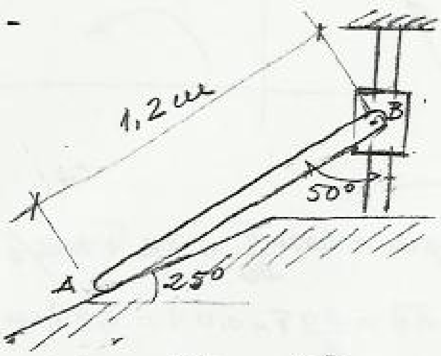
$\vec{v}_D = \vec{v}_A + \vec{v}_{D/A} = 20,11\ m/s \rightarrow + 71,95 \times \frac{0,559}{2}$ 30°

$\boxed{v_D = 38,85\ m/s \quad 15°}$

$\vec{v}_E = \vec{v}_A + \vec{v}_{E/A} = 20,11\ m/s \rightarrow + 71,95 \times \frac{0,559}{2} \downarrow$

$\boxed{v_E = 28,44\ m/s \quad 45°}$

15.31 -



$v_B = 1,8\ m/s \uparrow$

$\vec{v}_A = \vec{v}_B + \vec{v}_{A/B}$

$v_A = 1,8 + \omega \times 1,2$

25° $\quad \uparrow \quad$ 50°

Comp. $\rightarrow$:

$v_A \cos 25° = \omega \times 1,2 \cos 50°$

$v_A = 0,85\omega$

Comp. $\uparrow$:

$v_A \sin 25° = 1,8 - \omega \times 1,2 \sin 50°$

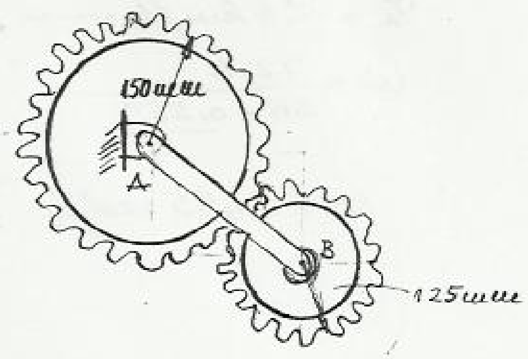
$0,85\omega \sin 25° + \omega \times 1,2 \sin 50° = 1,8$

$\boxed{\omega = 1,41\ rad/s}$

$v_A = 0,85\omega$

$\boxed{v_A = 1,20\ m/s \quad 25°}$

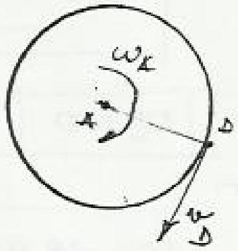
15.41-



$\omega_A = 150 \text{ rpm} = 150 \times \frac{\pi}{30} = 5\pi \text{ rad/s}$

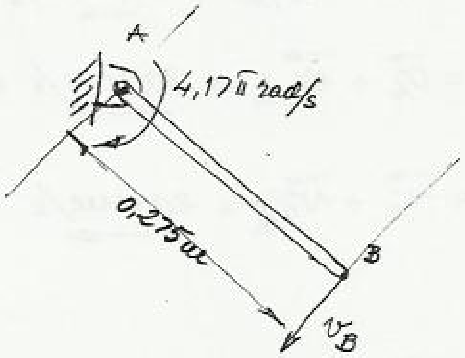
$\omega_{AB} = 125 \text{ rpm} = 125 \frac{\pi}{30} = 4{,}17\pi \text{ rad/s}$

RODA A:



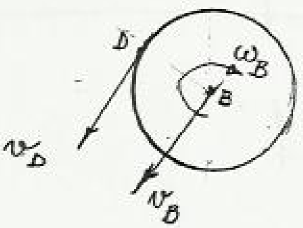
$v_D = \omega_A \times 0{,}15 = 2{,}36 \text{ m/s}$

BARRA AB



$v_B = 4{,}17\pi \times 0{,}275 = 3{,}60 \text{ m/s}$

RODA B.

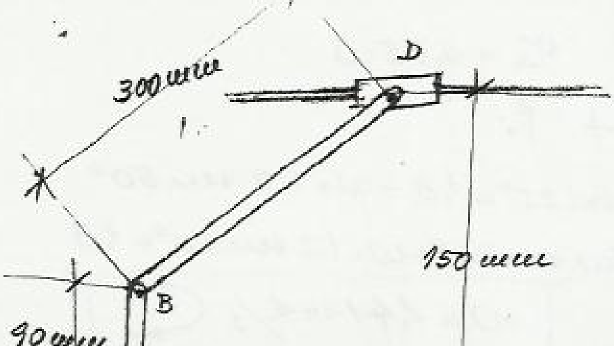


$\vec{v}_D = \vec{v}_B + \vec{v}_{D/B}$

$2{,}36 = 3{,}6 - \omega_B \cdot r_B$

$\boxed{\omega_B = 9{,}95 \text{ rad/s}}$

15.44 - $\theta = 0°$

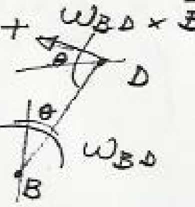


$\omega_{AB} = 200 \text{ rpm} = 200 \times \frac{\pi}{30} = \frac{20}{3}\pi \text{ rad/s}$

$v_B = \omega_{AB} \times \overline{AB} = \frac{20}{3}\pi \times 0{,}09 = 1{,}89 \text{ m/s}$

$\vec{v}_D = \vec{v}_B + \vec{v}_{D/B}$

$v_D = 1{,}89 + \omega_{BD} \times \overline{BD}$



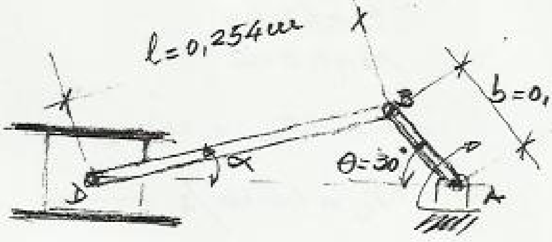
COMP. ↑:

$0 = \omega_{BD} \times 0{,}3 \operatorname{sen}\theta$ $\boxed{\omega_{BD} = 0}$

COMP. →

$v_D = 1{,}89$ $\boxed{v_D = 1{,}89 \text{ m/s}}$

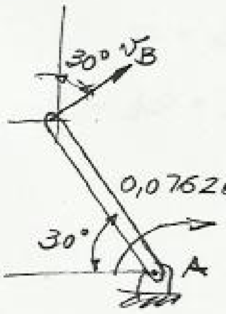
15.46 -



$\omega_{AB} = 750$ rpm

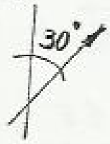
$\omega_{AB} = 25\pi$ rad/s

v_B :

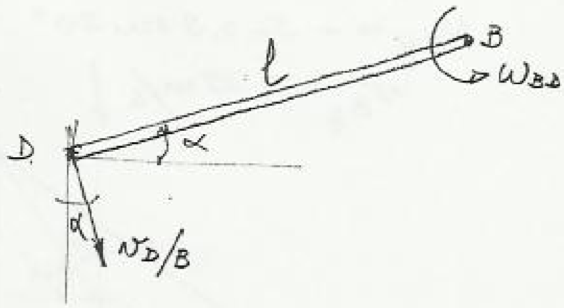


$v_B = 25\pi \times 0{,}0762$

$v_B = 5{,}98$ m/s



$$\frac{0{,}254}{\operatorname{sen} 30^\circ} = \frac{0{,}0762}{\operatorname{sen} \alpha} \qquad \alpha = 8{,}63^\circ$$



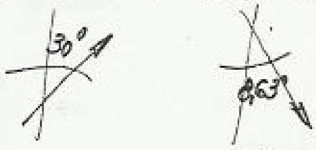
$v_{D/B} = \omega_{BD} \times l$

$v_{D/B} = 0{,}254\, \omega_{BD}$

$v_D = v_P$.

$$\vec{v}_D = \vec{v}_B + \vec{v}_{D/B}$$

$$v_D = 5{,}98 + 0{,}254\, \omega_{BD}$$



Comp. ↑:

$$0 = 5{,}98 \cos 30^\circ - 0{,}254\, \omega_{BD} \cos 8{,}63^\circ$$

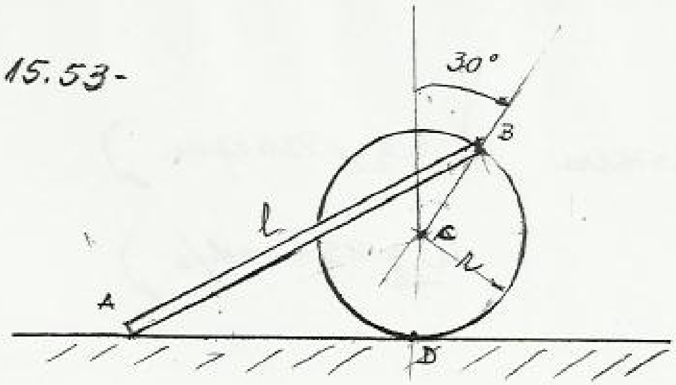
$$\boxed{\omega_{BD} = 20{,}64 \text{ rad/s}}$$

Comp. →:

$$v_D = 5{,}98 \operatorname{sen} 30^\circ + 0{,}254\, \omega_{BD} \operatorname{sen} 8{,}63^\circ$$

$$\boxed{v_D = 3{,}78 \text{ m/s} \rightarrow}$$

15.53-



$l = 1{,}2\ m$
$r = 0{,}3\ m$

Det. v_A e ω_{AB}

$v_C = 1{,}5\ m/s \rightarrow$

$v_D = 0$

$v_C = \omega_C \times r \qquad 1{,}5 = \omega_C \times 0{,}3$

$\omega_C = 5\ rad/s$

$\vec{v}_B = \vec{v}_C + \vec{v}_{B/C}$

$v_B = 1{,}5 + \omega_C \times 0{,}3$

Comp $\rightarrow$:

$v_{Bx} = 1{,}5 + 5 \times 0{,}3 \cos 30°$

$v_{Bx} = 2{,}80\ m/s \rightarrow$

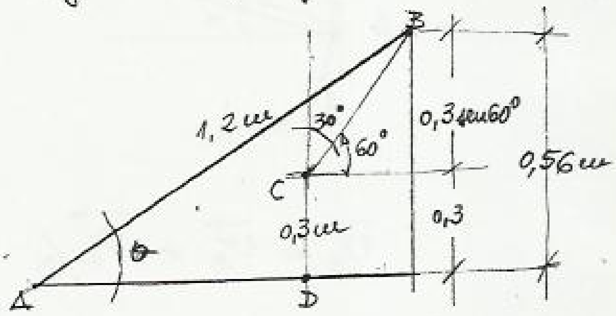
Comp $\uparrow$:

$-v_{By} = -5 \times 0{,}3 \sin 30°$

$v_{By} = 0{,}75\ m/s \downarrow$

$\vec{v}_A = \vec{v}_B + \vec{v}_{A/B}$

$v_A = v_B + \omega_{AB} \times \overline{AB}$



$\sin\theta = \frac{0{,}56}{1{,}2}$

$\theta = 27{,}81°$

Comp $\uparrow$:

$0 = -0{,}75 + 1{,}2\,\omega_{AB} \cos 27{,}81°$

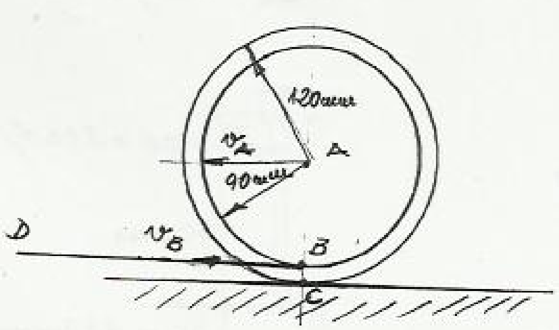
$$\boxed{\omega_{AB} = 0{,}71\ rad/s}$$

Comp. $\rightarrow$

$v_A = 2{,}8 - 1{,}2 \times 0{,}71 \sin 27{,}81°$

$$\boxed{v_A = 2{,}40\ m/s \rightarrow}$$

15.57 -



$v_D = v_B = 150\ mm/s$

$v_C = 0$

$C - C.I.$

$v_B = (120 - 90) \times \omega$

$150 = 30 \times \omega$

a) $\boxed{\omega = 5\ rad/s}$

b) $v_A = \omega r$

$v_A = \omega \times 120$

$v_A = 5 \times 120$

$\boxed{v_A = 600\ mm/s}$ ←

c) $v_A > v_D$

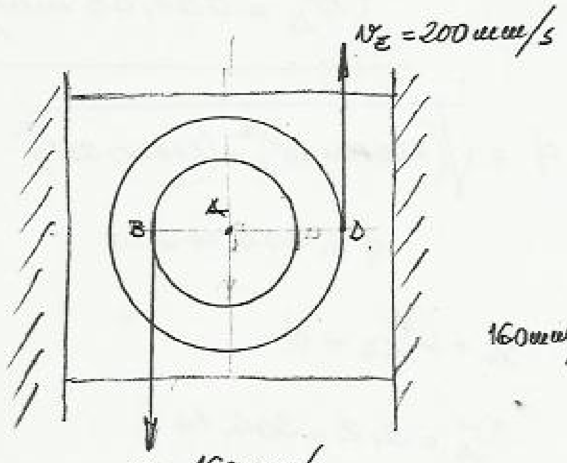
$\Delta s = v_{A/D} \cdot t$

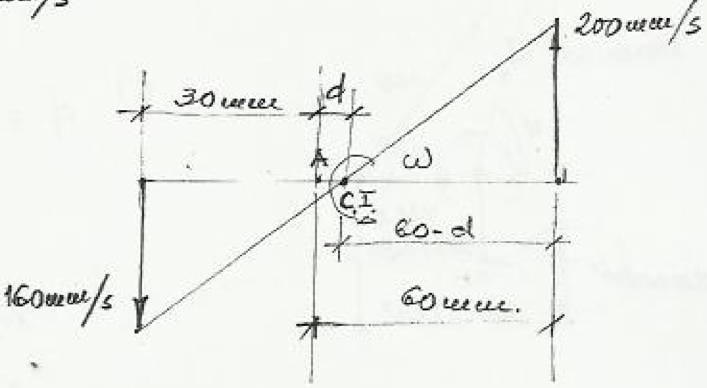
$\Delta s = (v_A - v_D) \times t$

$\Delta s = (600 - 150) \times 1$

$\boxed{\Delta s = 450\ mm.}$

15.58 -





$$\frac{160}{30+d} = \frac{200}{60-d} \qquad \frac{60-d}{30+d} = \frac{200}{160}$$

a) $60 - d = (30 + d)\,1{,}25$

$60 - d = 37{,}5 + 1{,}25\,d$

$60 - 37{,}5 = 2{,}25\,d$

$\boxed{d = 10\ mm}$

b) $v_{BLOCO} = v_A$

$v_A = \omega d \qquad \omega = \frac{160}{40} = 4\ rad/s$

$v_A = 4 \times 10$

$\boxed{v_A = 40\ mm/s}$ ↓

c) POLIA EXTERNA -

$v_{E/A} = 240\ mm/s$ ↑

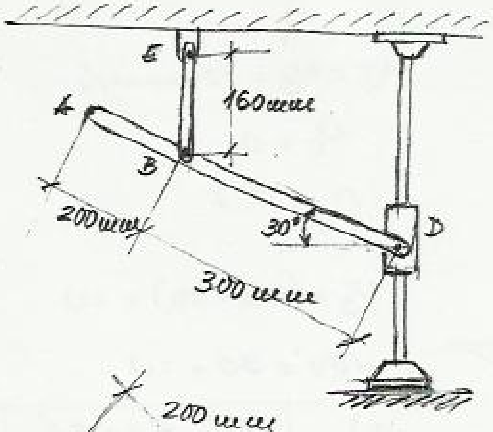
DESENROLA 240 mm F/s

POLIA INTERNA.

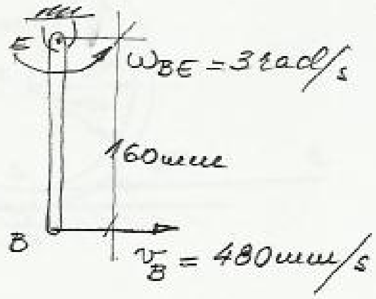
$v_{F/A} = 120\ mm/s$ ↓

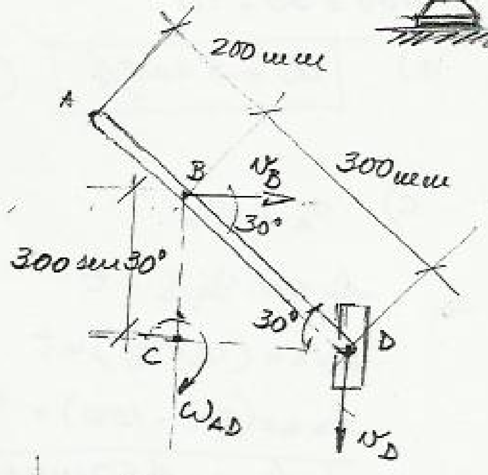
DESENROLA 120 mm F/s

15.59 -



$\omega_{BE} = 3\,rad/s$





$v_B = \omega_{AD} \times 300\,\text{sen}\,30°$

a) $\dfrac{480}{300\,\text{sen}\,30°} = \omega_{AD}$

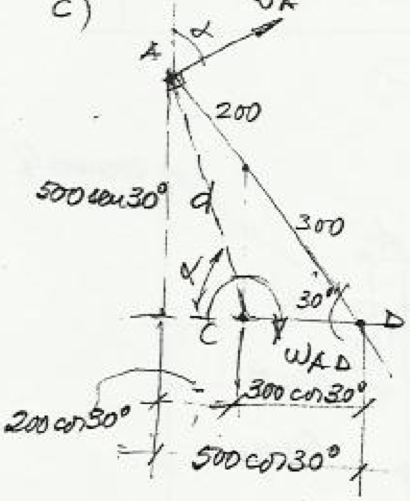
$\boxed{\omega_{AD} = 3{,}2\ rad/s}$

b) $v_D = \omega_{AD} \times 300 \cos 30°$

$v_D = 3{,}2 \times 300 \cos 30°$

$\boxed{v_D = 831{,}38\ mm/s}$

c)



c) $d = \sqrt{(500\,\text{sen}\,30°)^2 + (200 \cos 30°)^2}$

$d = 304{,}14\ mm.$

$v_A = \omega_{AD} \times d$

$v_A = 3{,}2 \times 304{,}14$

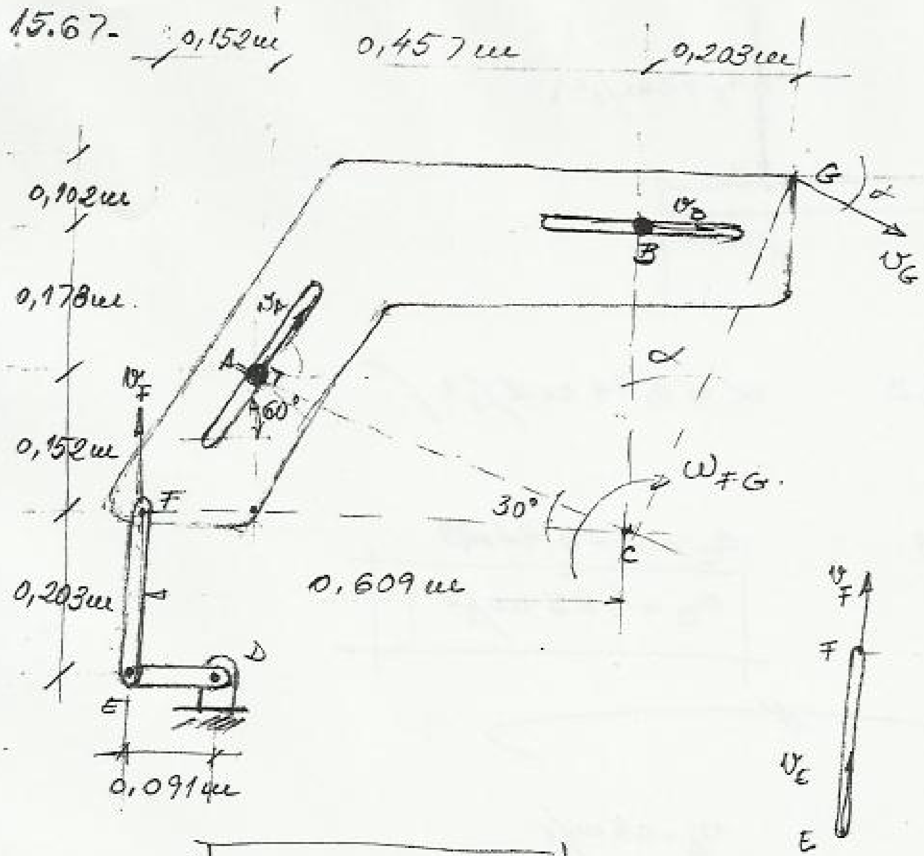
$\boxed{v_A = 973{,}24\ mm/s}$

$tg\,\alpha = \dfrac{500\,\text{sen}\,30°}{200 \cos 30°}$

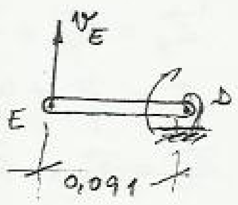
$tg\,\alpha = 1{,}44$

$\alpha = 55{,}29°$

15.67-



$\omega_{DE} = 8$ rad/s



$v_E = 0,728$ m/s

C.I → ∞

$\omega_{FE} = 0$

$v_F = v_E = 0,728$ m/s

a) $\boxed{v_F = 0,728 \text{ m/s}}$

b) $v_F = \omega_{FG} \times 0,609$

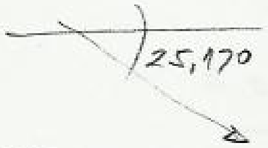
$0,728 = \omega_{FG} \times 0,609 \qquad \omega_{FG} = 1,195$ rad/s

$$\overline{CG} = \sqrt{(0,152+0,178+0,102)^2 + 0,203^2}$$

$\overline{CG} = 0,477$ m

$v_G = \omega_{FG} \times \overline{CG}$

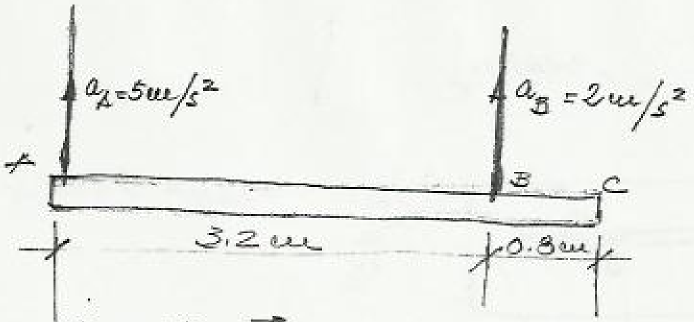
$v_G = 0,57$ m/s



$tg\alpha = \frac{0,203}{0,432}$

$\alpha = 25,17°$

15.79-



$\vec{a}_A = \vec{a}_B + \vec{a}_{A/B}$

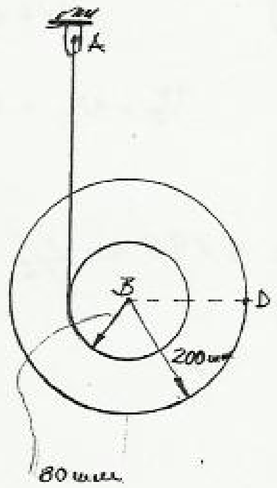
$\underset{\uparrow}{5} = \underset{\uparrow}{2} + \underset{\uparrow}{\alpha \times 3,2}$ $\qquad \alpha = 0,94\ rad/s^2$

$\vec{a}_C = \vec{a}_B + \vec{a}_{C/B}$

$\vec{a}_C = \underset{\uparrow}{2} + \underset{\downarrow}{\alpha \times 0,8}$ $\qquad a_C = 2 - 0,94 \times 0,8$

$\boxed{a_C = 1,25\ m/s^2 \uparrow}$

15.84.



$v_B = 0,6\ m/s$

$a_B = 2,4\ m/s^2$

$v_B = \omega r$

$0,6 = \omega \times 0,08$ $\qquad \omega = 7,5\ rad/s$

$a_B = \alpha r$

$2,4 = \alpha \times 0,08$ $\qquad \alpha = 30\ rad/s^2$

$\vec{a}_D = \vec{a}_B + \vec{a}_{D/B}$

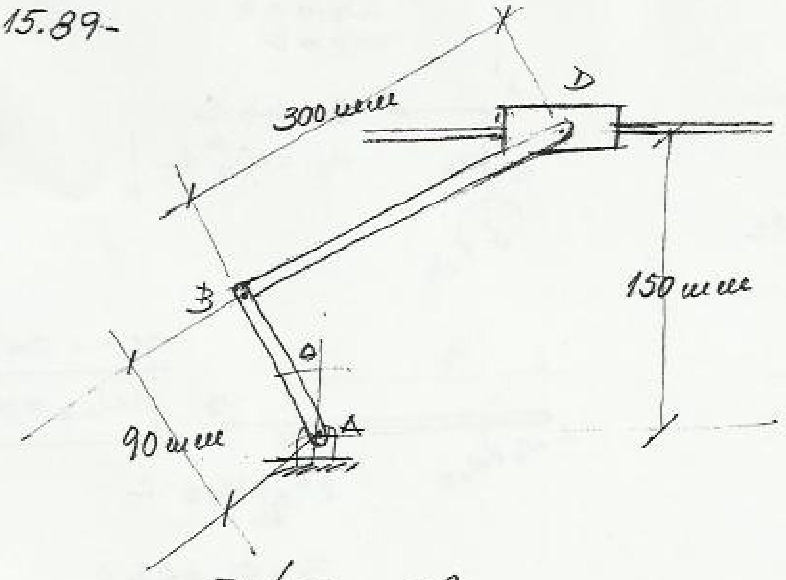
$\vec{a}_D = \underset{\downarrow}{a_B} + \underset{\downarrow}{\alpha \times 0,2} + \underset{\leftarrow}{\omega^2 0,2}$

$\vec{a}_D = \underset{\downarrow}{(2,4 + 30 \times 0,2)} + \underset{\leftarrow}{7,5^2 \times 0,2}$

$\vec{a}_D = \underset{\downarrow}{8,4} + \underset{\leftarrow}{11,25}$ $\qquad tg\,\alpha = \frac{8,4}{11,25}$ $\quad \alpha = 36,75°$

$\boxed{a_D = 14\ m/s^2 \quad 36,75°}$

15.89-

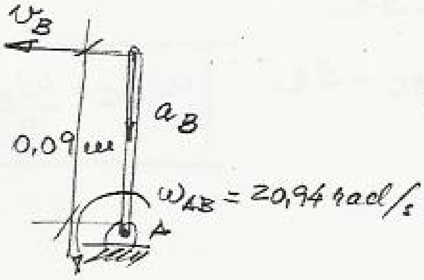


$\alpha_{AB} = 0$

$\omega_{AB} = 200$ rpm

$\omega_{AB} = 200 \times \dfrac{\pi}{30} = 20,94$ rad/s

P/ $\theta = 0°$



$v_B = \omega r = 20,94 \times 0,09 = 1,88$ m/s

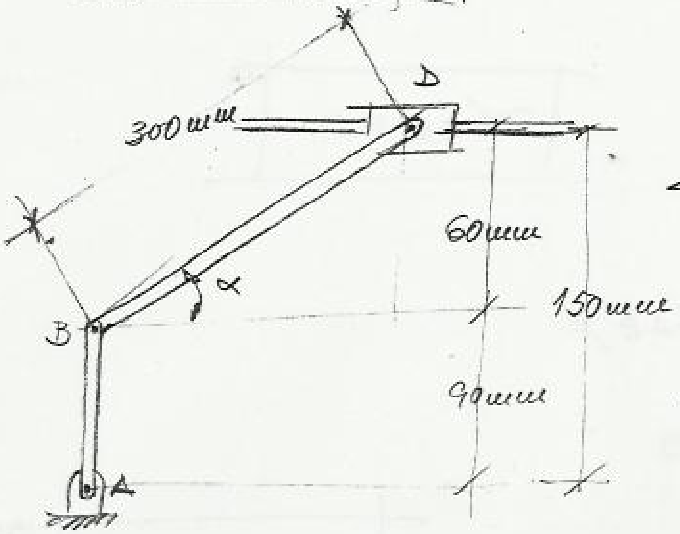
$a_B = \omega^2 r = 20,94^2 \times 0,09 = 39,46$ m/s²

$\vec{v}_D = \vec{v}_B + \vec{v}_{D/B}$ $\qquad v_D = v_B + \omega_{DB} \cdot \overline{BD}$

Comp ↑:

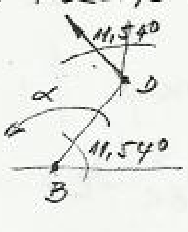
$0 = \omega_{BD} \cdot \overline{BD}\, \text{sen}\, \alpha$

$\boxed{\omega_{BD} = 0}$



$\vec{a}_D = \vec{a}_B + \vec{a}_{D/B}$

$a_D = 39,46 + \alpha \times 0,3$



Comp ↑:

$0 = -39,46 + \alpha \times 0,3 \cos 11,54°$

$\alpha = 134,26$ rad/s

Comp →:

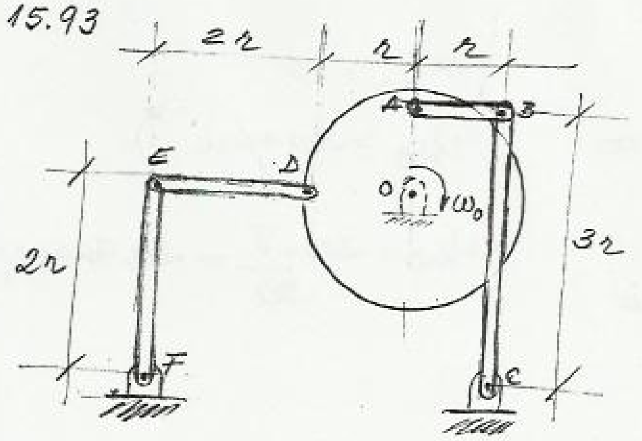
$-a_D = -\alpha \times 0,3\, \text{sen}\, 11,54°$

$\boxed{a_D = 8,06 \text{ m/s}^2}$

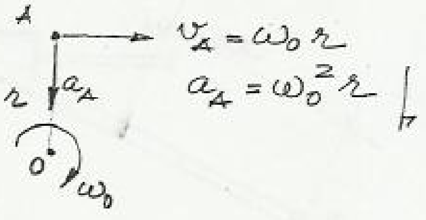
$\text{sen}\, \alpha = \dfrac{60}{300}$

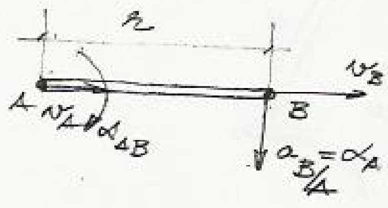
$\alpha = 11,54°$

15.93



$\omega_0 = cte.$
$\alpha_0 = 0$

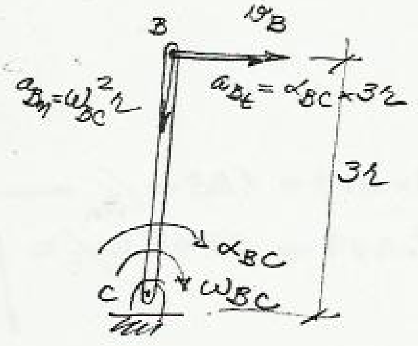




$CI \to \infty$

$$\boxed{\omega_{AB} = 0}$$

$v_B = v_A = \omega_0 r$



$v_B = \omega_{BC} \times 3r$

$\omega_0 r = \omega_{BC} \times 3r$

$$\boxed{\omega_{BC} = \frac{\omega_0}{3}}$$

$\vec{a}_B = \vec{a}_A + \vec{a}_{B/A}$

$\vec{a}_B = \vec{a}_A + \vec{a}_{B/A}$

$\alpha_{BC} \times 3r \rightarrow$, $\omega_{BC}^2 \times 3r \downarrow$ $\qquad \omega_0^2 r \downarrow \qquad \alpha_{AB} \cdot r \downarrow$

Comp $\rightarrow$:

$\alpha_{BC} \times 3r = 0$

$$\boxed{\alpha_{BC} = 0}$$

Comp. $\uparrow$:

$-\omega_{BC}^2 \times 3\cancel{r} = -\omega_0^2 \cancel{r} - \alpha_{AB} \cancel{r}$

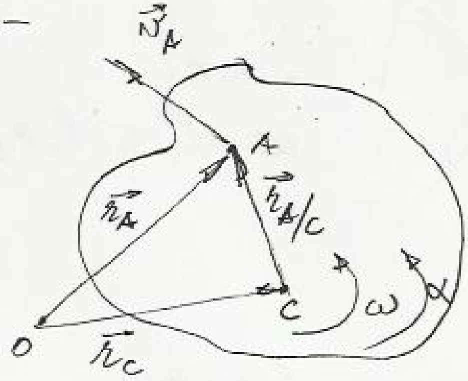
$\frac{3\omega_0^2}{9} - \omega_0^2 = \alpha_{AB}$

$\frac{\omega_0^2}{3} - \omega_0^2 = \alpha_{AB}$

$\alpha_{AB} = -\frac{2}{3}\omega_0^2$

$$\boxed{\alpha_{AB} = \frac{2}{3}\omega_0^2}$$

15.101 -



C — CENTRO INSTANTÂNEO DE ROTAÇÃO

$$\vec{v}_C = 0$$

$$\vec{r}_{A/C} = \vec{r}_A - \vec{r}_C$$

$$\vec{v}_A = \vec{v}_C + \vec{v}_{A/C}$$

$$\vec{v}_A = \vec{\omega} \wedge \vec{r}_{A/C}$$ (MULTIPLICANDO VETORIALMENTE POR $\vec{\omega}$)

$$\vec{\omega} \wedge \vec{v}_A = \vec{\omega} \wedge \vec{\omega} \wedge \vec{r}_{A/C}$$

$$\vec{\omega} = \omega \vec{k}$$

$$\vec{\omega} \perp \vec{r}_{C/A}$$

$$\vec{\omega} \wedge \vec{v}_A = -\omega^2 \vec{r}_{A/C}$$

$$\vec{\omega} \wedge \vec{v}_A = -\omega^2 (\vec{r}_A - \vec{r}_C)$$

$$\vec{r}_{A/C} = -\frac{\vec{\omega} \wedge \vec{v}_A}{\omega^2}$$

$$\boxed{\vec{r}_C = \vec{r}_A + \frac{\vec{\omega} \wedge \vec{v}_A}{\omega^2}}$$

$$\vec{a}_A = \vec{a}_C + \vec{a}_{A/C}$$

$$\vec{a}_C = 0$$

$$\vec{\omega} = \omega \vec{k}$$

$$\vec{\alpha} = \alpha \vec{k}$$

$$\vec{\alpha} \perp \vec{r}_{C/A}$$

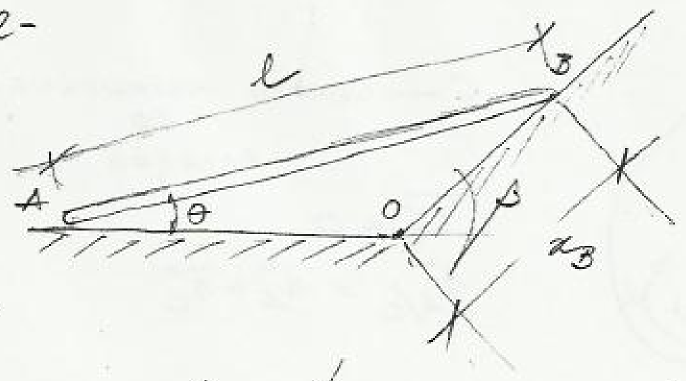
$$\vec{a}_A = \vec{\alpha} \wedge \vec{r}_{A/C} + \vec{\omega} \wedge \vec{\omega} \wedge \vec{r}_{A/C}$$

$$\vec{a}_A = \vec{\alpha} \wedge \left(\frac{-\vec{\omega} \wedge \vec{v}_A}{\omega^2}\right) + \vec{\omega} \wedge \vec{\omega} \wedge \left(\frac{-\vec{\omega} \wedge \vec{v}_A}{\omega^2}\right)$$

$$\vec{a}_A = \frac{\alpha \cancel{\omega} \vec{v}_A}{\omega^{\cancel{2}}} + (-\omega^2)\left(\frac{-\vec{\omega} \wedge \vec{v}_A}{\omega^2}\right)$$

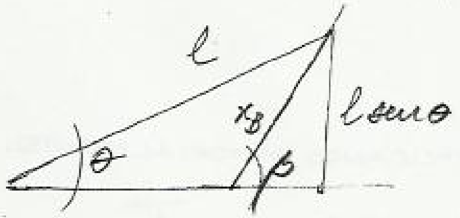
$$\boxed{\vec{a}_A = \frac{\alpha}{\omega} \vec{v}_A + \vec{\omega} \wedge \vec{v}_A}$$

15.102-



Det:

$\omega = f(v_B, l, \theta, \beta)$



$$\operatorname{sen}\beta = \frac{l \operatorname{sen}\theta}{x_B}$$

$$x_B = \frac{l \operatorname{sen}\theta}{\operatorname{sen}\beta}$$

$$v_B = \frac{d\, x_B}{dt} \qquad v_B = \frac{l \cos\theta\, \dot\theta}{\operatorname{sen}\beta} \qquad \dot\theta = \omega$$

$$v_B = \frac{l \cos\theta\, \omega}{\operatorname{sen}\beta}$$

$$\boxed{\omega = \frac{v_B \operatorname{sen}\beta}{l \cos\theta}}$$

15.103

Det. $\alpha = f(v_B, l, \theta, \beta)$

$$a_B = 0$$

$$\alpha = \frac{d\omega}{dt} \qquad \omega = \frac{\operatorname{sen}\beta}{l}\, v_B \cos^{-1}\theta$$

$$\frac{d\omega}{dt} = \frac{\operatorname{sen}\beta}{l}\left(\underbrace{\frac{dv_B}{dt}}_{0}\cos^{-1}\theta\right) + \frac{\operatorname{sen}\beta}{l}\left(v_B \cdot -\cos^{-2}\theta \cdot (-\operatorname{sen}\theta)\,\dot\theta\right)$$

$$a_B = \frac{dv_B}{dt} = 0$$

$$\dot\theta = \omega = \frac{v_B \operatorname{sen}\beta}{l \cos\theta}$$

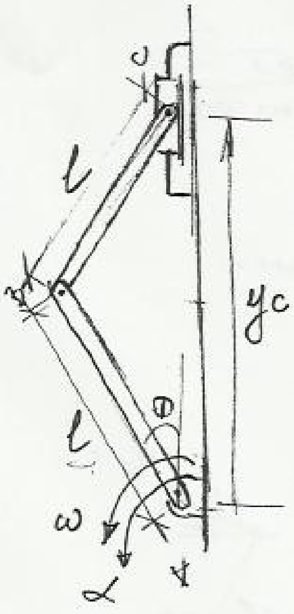
$$\alpha = \frac{\operatorname{sen}\beta}{l} \cdot \frac{v_B \operatorname{sen}\theta}{\cos^2\theta}\,\dot\theta$$

$$\boxed{\alpha = \left(\frac{v_B \operatorname{sen}\beta}{l}\right)^2 \frac{\operatorname{sen}\theta}{\cos^3\theta}}$$

15.107 -

$\omega = \dot{\theta}$

$\alpha = \ddot{\theta}$



$$y_C = 2l\cos\theta$$

$$v_C = \frac{dy_C}{dt} = -2l\,\mathrm{sen}\,\theta\,\dot{\theta}$$

$$v_C = -2l\,\mathrm{sen}\,\theta\,\omega$$

$$\boxed{v_C = 2l\omega\,\mathrm{sen}\,\theta \downarrow}$$

$$a_C = \frac{dv_C}{dt}$$

$$a_C = \frac{d}{dt}\left(-2l\,\mathrm{sen}\,\theta\,\dot{\theta}\right)$$

$$a_C = -2l\cos\theta\,\dot{\theta}\dot{\theta} + \left(-2l\,\mathrm{sen}\,\theta\,\ddot{\theta}\right)$$

$$\boxed{a_C = 2l\left(\alpha\,\mathrm{sen}\,\theta + \omega^2\cos\theta\right) \downarrow}$$

15.108 - $v_C = v_0$ Det. ω e α

$a_C = 0$

$$v_C = 2l\omega\,\mathrm{sen}\,\theta \qquad v_0 = 2l\omega\,\mathrm{sen}\,\theta$$

$$\boxed{\omega = \frac{v_0}{2l\,\mathrm{sen}\,\theta}}$$

$$a_C = -2l\left(\mathrm{sen}\,\theta\,\alpha + \omega^2\cos\theta\right)$$

$$a_C = 0$$

$$\mathrm{sen}\,\theta\,\alpha = -\omega^2\cos\theta$$

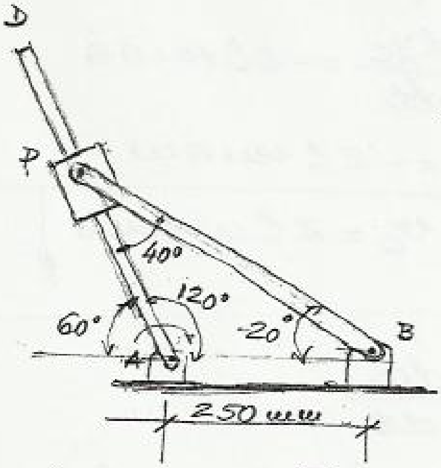
$$\alpha = -\left(\frac{v_0}{2l\,\mathrm{sen}\,\theta}\right)^2\frac{\cos\theta}{\mathrm{sen}\,\theta}$$

$$\alpha = -\left(\frac{v_0}{2l}\right)^2\frac{\cos\theta}{\mathrm{sen}^3\theta}$$

$$\boxed{\alpha = \left(\frac{v_0}{2l}\right)^2\frac{\cos\theta}{\mathrm{sen}^3\theta}}$$

15.115 -

$\omega_A = 8 \, rad/s$ ↻



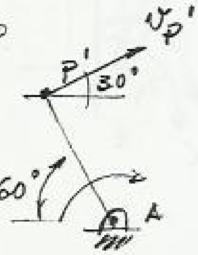
$$\frac{\overline{AB}}{\text{sen}\,40°} = \frac{\overline{AP}}{\text{sen}\,20°} = \frac{\overline{BP}}{\text{sen}\,120°}$$

$\overline{AB} = 250 \, mm$

$\overline{AP} = 133 \, mm.$

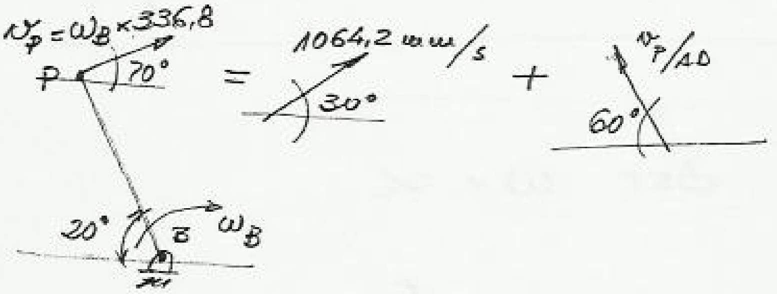
$\overline{BP} = 336{,}8 \, mm.$

P' — ponto da barra $\overline{AD}$ coincidente com P



$v_{P'} = \omega_A \times AP = 8 \times 133 = 1064.2 \, mm/s$

$\vec{v}_P = \vec{v}_{P'} + \vec{v}_{P/AD}$



Comp →:

$\omega_B \times 336{,}8 \cos 70° = 1064{,}2 \cos 30° - v_{P/AD} \cos 60°$

$115{,}19 \, \omega_B = 921{,}61 - v_{P/AD} \cos 60°$

$$\omega_B = \frac{921{,}61 - v_{P/AD} \cos 60°}{115{,}19}$$

$\omega_B = 8 - v_{P/AD} \times 0{,}0043$

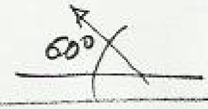
Comp. ↑:

$\omega_B \times 336{,}8 \,\text{sen}\, 70° = 1064{,}2 \,\text{sen}\, 30° + v_{P/AD} \,\text{sen}\, 60°$

$(8 - v_{P/AD} \times 0{,}0043) \times 336{,}8 \,\text{sen}\, 70° = 532{,}1 + 0{,}87 \, v_{P/AD}$

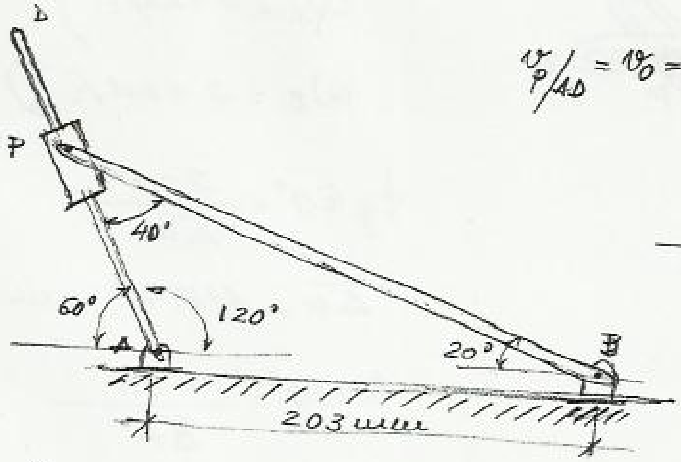
$2.531{,}91 - 1{,}36 \, v_{P/AD} = 532{,}1 + 0{,}87 \, v_{P/AD}$

$\boxed{v_{P/AD} = 896{,}41 \, mm/s}$

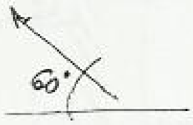


$\boxed{\omega_B = 4{,}15 \, rad/s}$ ↻

15.117-



$v_{P/AD} = v_0 = 305 \text{ mm/s}$



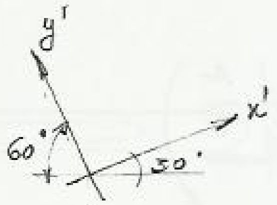
$$\frac{203}{\text{sen } 40^\circ} = \frac{\overline{BP}}{\text{sen } 120^\circ} = \frac{\overline{AP}}{\text{sen } 20^\circ}$$

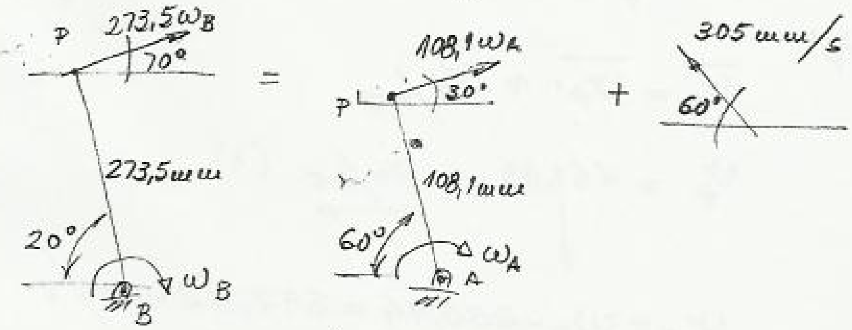
$\overline{AP} = 108{,}01 \text{ mm}$

$\overline{BP} = 273{,}50 \text{ mm}.$

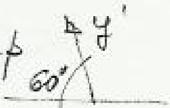
P': ponto da barra $\overline{AD}$ coincidente com P.

$$\vec{v}_P = \vec{v}_{P'} + \vec{v}_{P/AD}$$





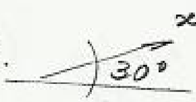
Comp



$273{,}5\,\omega_B \text{ sen } 40^\circ = 305$

$$\boxed{\omega_B = 1{,}73 \text{ rad/s}}$$

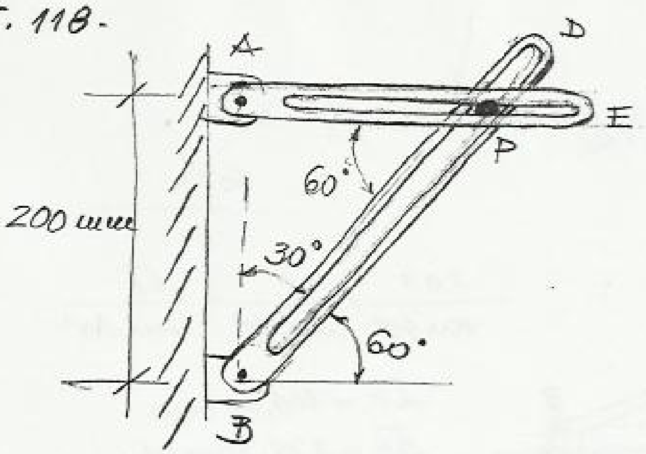
Comp.



$273{,}5\,\omega_B \cos 40^\circ = 108{,}1\,\omega_A$

$$\boxed{\omega_A = 3{,}36 \text{ rad/s}}$$

15.118-



$\omega_A = 4\ rad/s$ ↻

$\omega_B = 3\ rad/s$ ↻

$tg\,60° = \frac{200}{\overline{AP}}$

$\overline{AP} = 115,47\ mm$

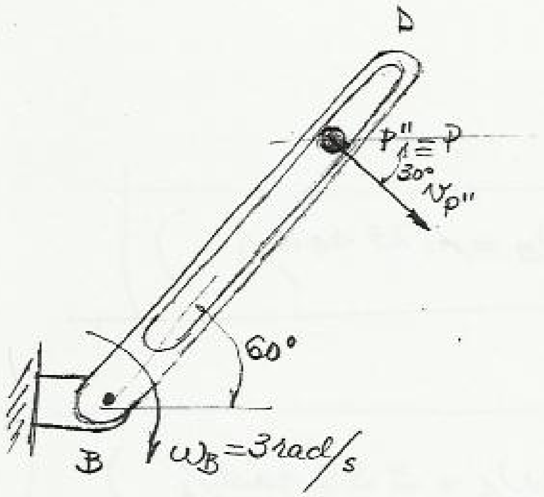
$\cos 30° = \frac{200}{\overline{BP}}$

$\overline{BP} = 230,94\ mm$

$v_{P'} = \omega_A \times 115,47 = 461,88\ mm/s \downarrow$

$\vec{v}_P = \vec{v}_{P'} + \vec{v}_{P/AE}$

$v_P = \underset{\downarrow}{461,88} + \underset{\rightarrow}{v_{P/AE}}$ (1)



$v_{P''} = \omega_B \times 230,94 = 692,82\ mm/s$ (30°)

$\vec{v}_P = \vec{v}_{P''} + \vec{v}_{P/BD}$

$v_P = \underset{30°}{692,82} + \underset{60°}{v_{P/BD}}$ (2)

IGUALANDO AS EQS. (1) E (2)

$\underset{\downarrow}{461,88} + \underset{\rightarrow}{v_{P/AE}} = \underset{30°}{692,82} + \underset{60°}{v_{P/BD}}$

Comp. ↑:

$-461,88 = -692,82\ sen\,30° - v_{P/BD}\ sen\,60°$

$v_{P/BD} = 133,33\ mm/s$

Comp. →:

$v_{P/AE} = 692,82 \cos 30° - v_{P/BD} \cos 60°$

$v_{P/AE} = 533,33\ mm/s \rightarrow$

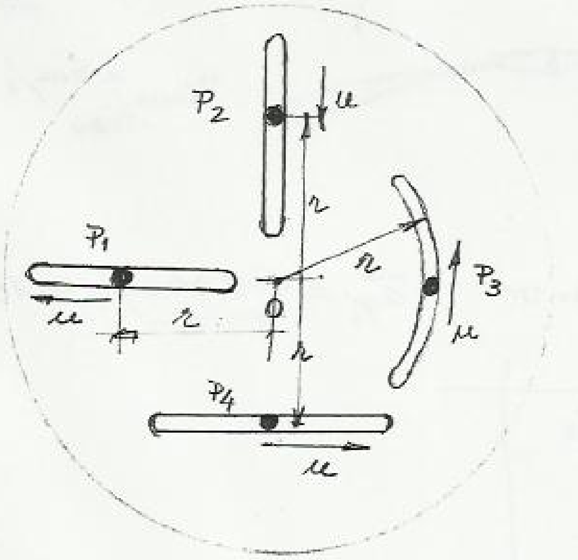
$\vec{v}_P = \vec{v}_{P'} + \vec{v}_{P/AE}$

$v_P = \underset{\downarrow}{461,88} + \underset{\rightarrow}{533,33}$

$\boxed{v_P = 705,53\ mm/s \quad 40,89°}$

15.120 -

ω ↻ $\qquad \omega = \underline{cte}$



P' — ponto do disco coincidente c/ cada ponto P_1, P_2, P_3, P_4

$$a_{P'} = r\omega^2$$

ACELERAÇÃO DO PINO EM RELAÇÃO AO DISCO:

P/ P_1, P_2, P_4 : $a_{P/D} = 0$

P/ P_3 : $a_{P/D} = \dfrac{u^2}{r}$

$a_C = 2\omega u$ P/ CADA PINO,
DIREÇÃO PERPENDICULAR À $\underline{u}$,
SENTIDO DE ROTAÇÃO DE ω (REGRA DA MÃO DIREITA)

$$\vec{a} = \vec{a}_{P'} + \vec{a}_{P/F} + \vec{a}_C$$

$\vec{a}_1 = [r\omega^2 \rightarrow] + [2\omega u \downarrow]$

$\vec{a}_2 = [r\omega^2 \downarrow] + [2\omega u \rightarrow]$

$\vec{a}_3 = [r\omega^2 \leftarrow] + [\frac{u^2}{r} \leftarrow] + [2\omega u \leftarrow]$

$\vec{a}_4 = [r\omega^2 \uparrow] + [2\omega u \uparrow]$

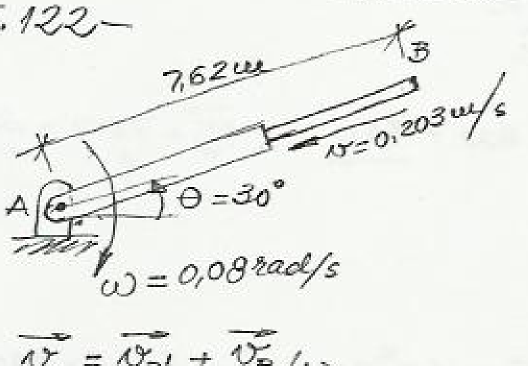
$\vec{a}_1 = r\omega^2 \vec{i} - 2\omega u \vec{j}$

$\vec{a}_2 = 2\omega u \vec{i} - r\omega^2 \vec{j}$

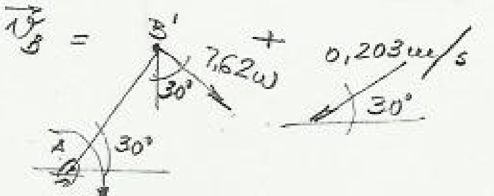
$\vec{a}_3 = -(r\omega^2 + \frac{u^2}{r} + 2\omega u)\vec{i}$

$\vec{a}_4 = (r\omega^2 + 2\omega u)\vec{j}$

15.122 -



$\vec{v}_B = \vec{v}_{B'} + \vec{v}_{B/AB}$



$v_{Bx} = 0,08 \times 7,62 \operatorname{sen} 30° - 0,203 \cos 30°$

$v_{By} = -0,08 \times 7,62 \cos 30° - 0,203 \operatorname{sen} 30°$

$v_{Bx} = 0,129$ m/s $\rightarrow$

$v_{By} = 0,629$ m/s $\downarrow$

$\boxed{v_B = 0,64 \text{ m/s} \quad 78,41°}$

$\vec{a}_B = \vec{a}_{B'} + \vec{a}_{B/AB} + \vec{a}_C$

$\vec{a}_B = \omega^2 \times 7,62 + 0 + 2\omega \times v$

30° $\qquad$ 30°

$a_{Bx} = -0,08^2 \times 7,62 \cos 30° - 2 \times 0,08 \times 0,203 \operatorname{sen} 30$

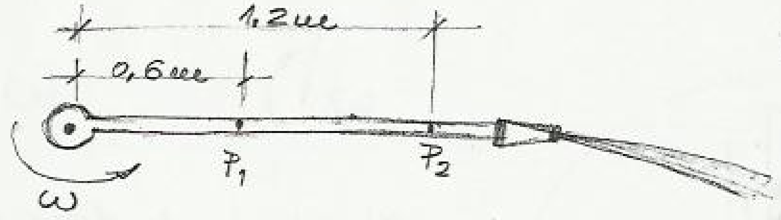
$a_{Bx} = 0,059$ m/s $\leftarrow$

$a_{By} = -0,08^2 \times 7,62 \operatorname{sen} 30° + 2 \times 0,08 \times 0,203 \cos 30$

$a_{By} = 0,0037$ m/s $\uparrow$

$\boxed{a_B = 0,0586 \text{ m/s}^2 \quad 3,59°}$

15.124-



$\omega = 150\,rpm = \frac{150\pi}{30} = 5\pi\ rad/s$

$v_{AGUA/TUBO} = 6m/s \rightarrow$

$\vec{a}_P = \vec{a}_{P'} + \vec{a}_{P/TUBO} + \vec{a}_C$

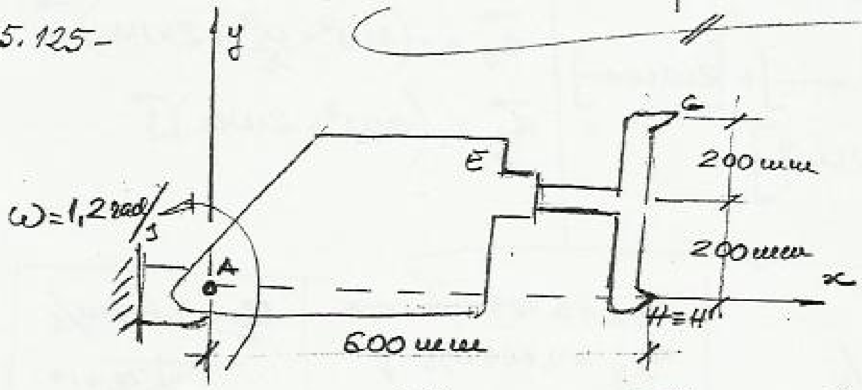
a) $\vec{a}_{P_1} = \underset{\leftarrow}{\omega^2 \times 0,6} + 0 + \underset{\uparrow}{2\omega \times v}$ $\vec{a}_{P_1} = \underset{\leftarrow}{148,04\,m/s} + \underset{\uparrow}{188,50\,m/s}$

$\boxed{a_{P_1} = 239,68\,m/s^2 \quad 51,86°}$

b) $\vec{a}_{P_2} = \underset{\leftarrow}{\omega^2 \times 1,2} + 0 + \underset{\uparrow}{2\omega \times v} \therefore \vec{a}_{P_2} = \underset{\leftarrow}{296,08\,m/s} + \underset{\uparrow}{188,50\,m/s}$

$\boxed{a_{P_2} = 351\,m/s^2 \quad 32,48°}$

15.125-



$v_{H/AE} = 300\,mm/s \rightarrow$

$a_{H/AE} = 0$

$\vec{v}_H = \vec{v}_{H'} + \vec{v}_{H/AE}$ $\vec{v}_H = \underset{\uparrow}{1,2 \times 600} + \underset{\rightarrow}{300}$ $\vec{v}_H = \underset{\uparrow}{720} + \underset{\rightarrow}{300}$

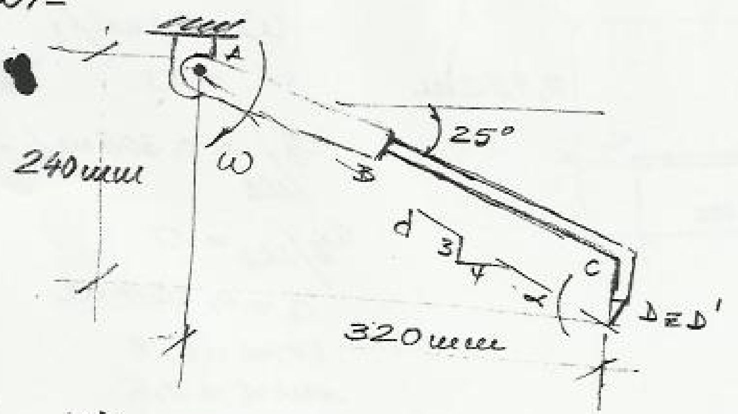
$\boxed{v_H = 780\,mm/s \quad 67,38°}$

$\vec{a}_H = \vec{a}_{H'} + \vec{a}_{H/AE} + \vec{a}_C$ $\vec{a}_H = \underset{\leftarrow}{1,2^2 \times 600} + 0 + \underset{\uparrow}{2 \times 1,2 \times 300}$

$\vec{a}_H = \underset{\leftarrow}{864} + \underset{\uparrow}{720}$

$\boxed{a_H = 1.124,68\,mm/s^2 \quad 39,8°}$

15.127



$\omega = 1{,}5\ rad/s$

$\alpha = 0$

$v_{D/AB} = 250\ mm/s$ (25°)

$a_{D/AB} = 0$

$d = 400\ mm$

$\cos\alpha = 0{,}8$

$\sin\alpha = 0{,}6$

a) $\vec{v}_D = \vec{v}_{D'} + \vec{v}_{D/AB}$

$\vec{v}_D = \omega \times 400 + 250\ mm/s$

$v_{Dx} = -1{,}5 \times 400 \sin\alpha - 250 \cos 25°$

$v_{Dy} = -1{,}5 \times 400 \cos\alpha + 250 \sin 25°$

$v_{Dx} = 586{,}58\ mm/s$ ←

$v_{Dy} = 374{,}35\ mm/s$ ↓

$$\boxed{v_D = 695{,}85\ mm/s \quad 32{,}5°}$$

b) $\vec{a}_D = \vec{a}_{D'} + \vec{a}_{D/AB} + \vec{a}_C$

$\vec{a}_D = \omega^2 \times 400 + 0 + 2\omega \times 250$

$a_{Dx} = -1{,}5^2 \times 400 \times \cos\alpha + 2 \times 1{,}5 \times 250 \sin 25°$

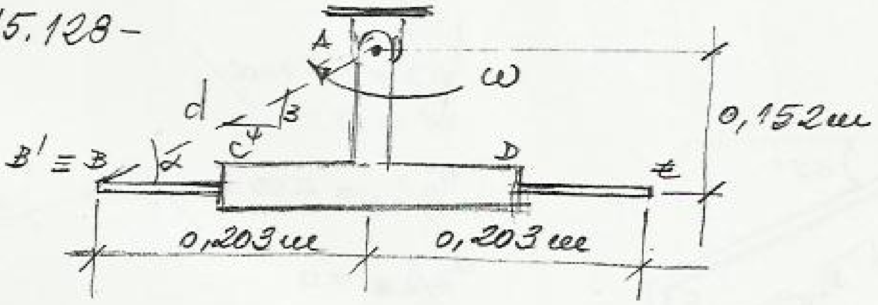
$a_{Dy} = 1{,}5^2 \times 400 \times \sin\alpha + 2 \times 1{,}5 \times 250 \cos 25°$

$a_{Dx} = 403{,}04\ mm/s^2$ ←

$a_{Dy} = 1.219{,}73\ mm/s^2$ ↑

$$\boxed{a_D = 1.284{,}59\ mm/s^2 \quad 71{,}71°}$$

15.128 -



$\omega = 3\ rad/s$

$\alpha = 0$

$v_{B/ACD} = 0,305\ m/s \rightarrow$

$a_{B/ACD} = 0$

$d = 0,254\ m$

$\cos\alpha = 0,8$

$\sin\alpha = 0,6$

a) $\vec{v}_B = \vec{v}_{B'} + \vec{v}_{B/ACD}$

$\vec{v}_B = \omega \times 0,254 + 0,305$

$v_{Bx} = -3 \times 0,254 \sin\alpha + 0,305$ $\qquad v_{Bx} = 0,152\ m/s \leftarrow$

$v_{By} = 3 \times 0,254 \cos\alpha$ $\qquad v_{By} = 0,610\ m/s \uparrow$

$$\boxed{v_B = 0,628\ m/s \quad 76°}$$

b) $\vec{a}_B = \vec{a}_{B'} + \vec{a}_{B/ACD} + \vec{a}_C$

$\vec{a}_B = \omega^2 \times 0,254 + 0 + 2 \times \omega \times 0,305$

$a_{Bx} = 3^2 \times 0,254 \times \cos\alpha$ $\qquad a_{Bx} = 1,83\ m/s^2 \rightarrow$

$a_{By} = 3^2 \times 0,254 \times \sin\alpha - 2 \times 3 \times 0,305$ $\qquad a_{By} = 0,46\ m/s^2 \downarrow$

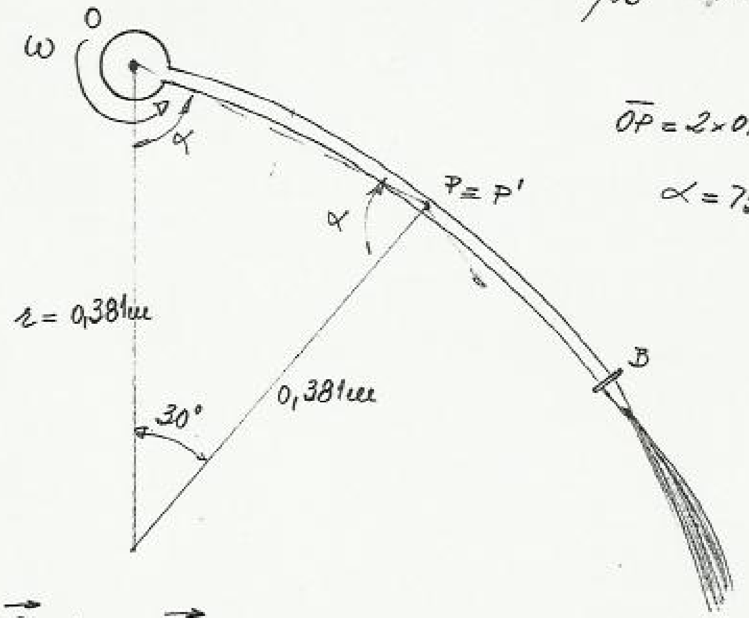
$$\boxed{a_B = 1,89\ m/s^2 \quad 14,11°}$$

15.134

$\alpha = 0$

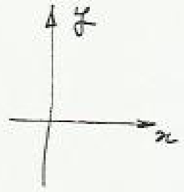
$\omega = 120\,rpm = \dfrac{120 \times \pi}{30} = 4\pi\ rad/s$

$v = v_{P/OB} = 12{,}2\ m/s$ ↘ 30°



$\overline{OP} = 2 \times 0{,}381 \sin\dfrac{30^\circ}{2} = 0{,}197\ m$

$\alpha = 75^\circ$



$\vec{a}_P = \vec{a}_{P'} + \vec{a}_{P/OB} + \vec{a}_C$

$\vec{a}_P = \omega^2 \times \overline{OP} + v^2/r + 2\omega v$

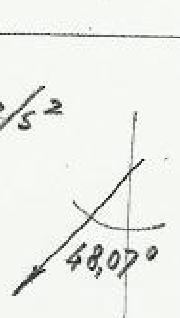
$a_{P_x} = -(4\pi)^2 \times 0{,}197 \times \sin 75^\circ - \dfrac{(12{,}2)^2}{0{,}381} \sin 30^\circ + 2 \times 4\pi \times 12{,}2 \sin 30^\circ$

$a_{P_x} = -72{,}07\ m/s^2$ $\qquad a_{P_x} = 72{,}07\ m/s^2$ ←

$a_{P_y} = (4\pi)^2 \times 0{,}197 \cos 75^\circ - \dfrac{(12{,}2)^2}{0{,}381} \cos 30^\circ + 2 \times 4\pi \times 12{,}2 \cos 30^\circ$

$a_{P_y} = -64{,}73\ m/s^2$ $\qquad a_{P_y} = 64{,}73\ m/s^2$ ↓

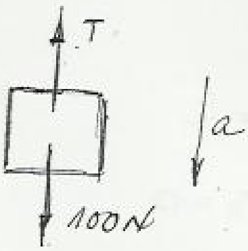
$\boxed{a_P = 96{,}87\ m/s^2}$



Cap. 12

12.3- BALANÇA DE MOLA -

ELEVADOR EM MOVIMENTO



$T = 90N$

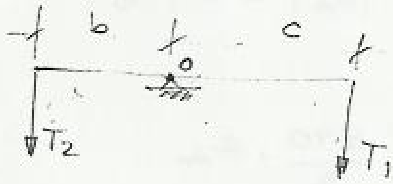
$R = m a$

$100 - T = \frac{100}{g} \cdot a$

$100 - 90 = \frac{100}{g} \cdot a$

$\boxed{a = 0{,}98 m/s^2}$

BALANÇA DE ALAVANCA



$\Sigma M_O = 0$

$c T_1 = b T_2$

$T_1 = \frac{b}{c} T_2 \qquad T_2 = \frac{c}{b} T_1$

ELEVADOR EM REPOUSO

$T_1 = 100 N \qquad T_2 = W$

$\boxed{T_2 = \frac{c}{b} T_1}$

$T_2 = \frac{c}{b} \times 100.$

CONSIDERANDO-SE OS BRAÇOS IGUAIS $\rightarrow T_2 = 100N \qquad W = 100N.$

ELEVADOR EM MOVIMENTO.

$100 - T_1 = \frac{100}{g} \cdot a$

$\boxed{T_1 = 100\left(1 - \frac{a}{g}\right)}$

$W' - T_2 = \frac{W'}{g} a$

$W' - \frac{W'}{g} a = T_2$

$\boxed{T_2 = W'\left(1 - \frac{a}{g}\right)}$

$T_2 = \frac{c}{b} T_1$

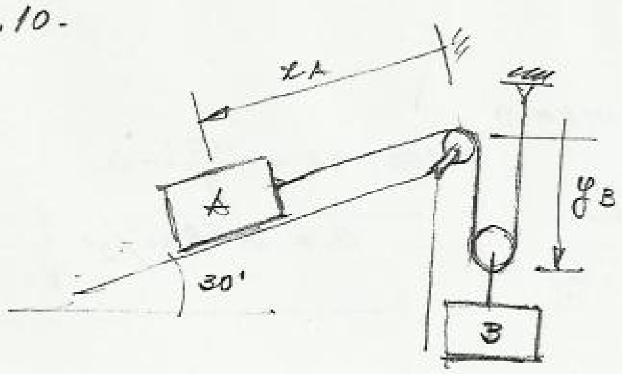
$\frac{c}{b}\left[100\left(\cancel{1 - \frac{a}{g}}\right)\right] = W'\left(\cancel{1 - \frac{a}{g}}\right)$

$W' = \frac{c}{b} 100 N.$

CONSIDERANDO-SE BRAÇOS IGUAIS.

$W' = 100 N.$

12.10-



$P_A = 890N$

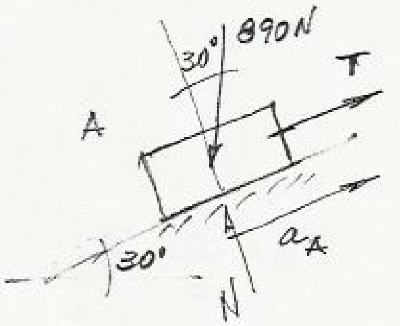
$P_B = 1557N$

$x_A + 2y_B = L$

$\frac{d}{dt} \quad v_A + 2v_B = 0$

$\frac{d}{dt} \quad a_A = -2a_B$

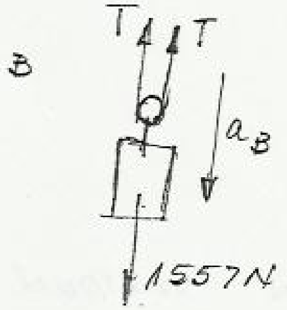
$|\vec{a}_A| = 2\,|\vec{a}_B|$



$T - 890\,\text{sen}\,30° = \frac{890}{g} \cdot a_A$

$|\vec{a}_A| = 2|\vec{a}_B|$

$T - 890\,\text{sen}\,30° = 2 \times \frac{890}{g}\, a_B \quad (1)$



$1557 - 2T = \frac{1557}{g}\, a_B$

$a_B = \frac{(1557 - 2T)}{1557} \times g \quad (2)$

Subst. (2) em (1):

$T - 890\,\text{sen}\,30° = 2 \times \frac{890}{\cancel{g}} \times \frac{(1557-2T)}{1557}\, \cancel{g}$

$T - 445 = 1780 - 2{,}29\,T$

$3{,}29T = 1780 + 445$

$\boxed{T = 677N}$

$a_B = \frac{(1557-2T)}{1557}\, g.$

$\boxed{a_B = 1{,}28\, m/s^2 \downarrow}$

$a_A = 2a_B$

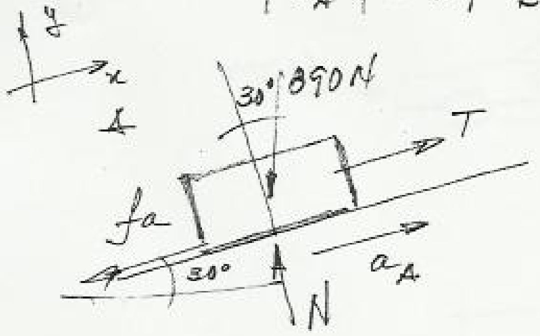
$\boxed{a_A = 2{,}56\, m/s^2 \; 30°}$

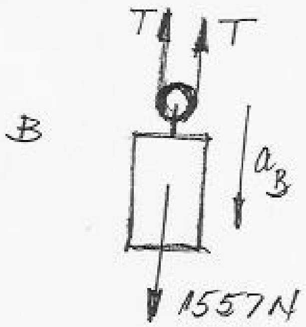
12.11 – DO PROBLEMA ANTERIOR

$$\vec{a}_A = -2\vec{a}_B$$

$$|\vec{a}_A| = 2|\vec{a}_B|$$

$\mu_c = 0{,}20$





CORPO A

$\Sigma F_y = 0$

$N = 890 \cos 30°$

$fa = \mu_c N \quad fa = 0{,}2 \times 890 \cos 30°$

$fa = 154{,}15\,N$

$\Sigma F_x = ma$

$$T - fa - 890 \operatorname{sen} 30° = \frac{890}{g} a_A$$

$$T - 599{,}15 = \frac{890}{g} a_A$$

$a_A = 2a_B$

$$T - 599{,}15 = \frac{1780}{g} a_B \quad (1)$$

P/ CORPO B

$$1557 - 2T = \frac{1557}{g} a_B$$

$$a_B = \frac{1557 - 2T}{1557} g \quad (2)$$

subst. (2) em (1)

$$T - 599{,}15 = \frac{1780}{\cancel{g}} \frac{1557 - 2T}{1557} \cancel{g}$$

$T - 599{,}15 = 1780 - 2{,}29T$

$3{,}29T = 2.379{,}15$

$$\boxed{T = 1.040{,}54\,N}$$

Subst. T em (2)

$a_B = -3{,}30\ m/s^2$

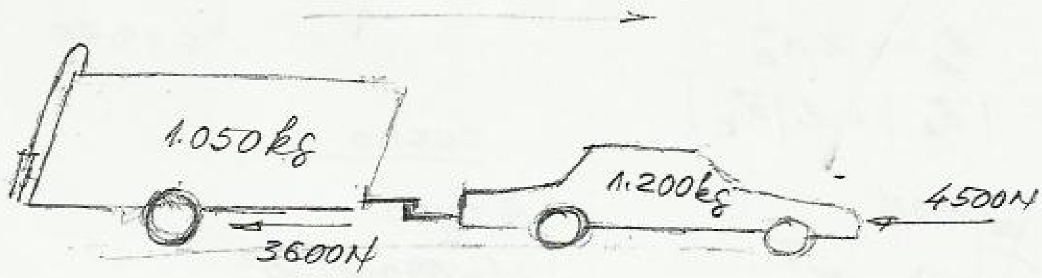
$$\boxed{a_B = 3{,}30\ m/s^2 \uparrow}$$

$a_A = -2a_B$

$a_A = -2(-3{,}3)$

$$\boxed{a = 6{,}6\ m/s^2 \quad 30°}$$

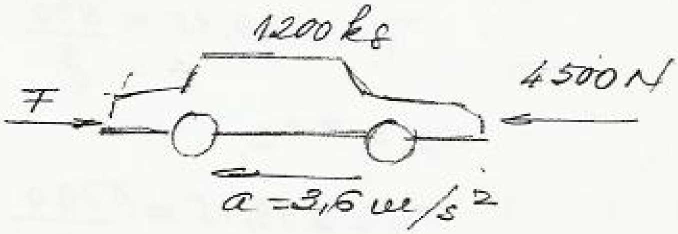
12.12-



$R = m\,a$

$8100 = 2250\,a$

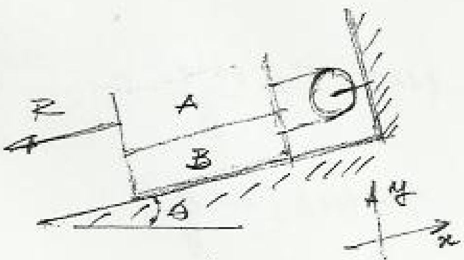
$$\boxed{a = 3{,}6\ m/s^2}$$



$4500 - F = 1200 \times 3{,}6$

$$\boxed{F = 180\,N}$$

12.14-



$\theta = 30°$

$m_A = 30\,kg$

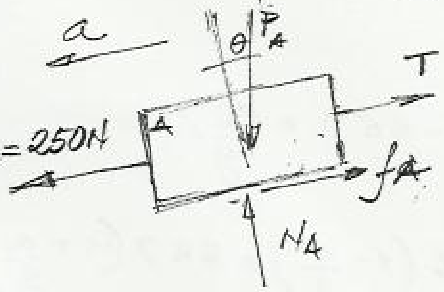
$m_B = 15\,kg$

$\mu_e = 0{,}15$

$\mu_c = 0{,}10$

Det. a_A

T



CORPO A -

$\Sigma F_y = 0$

$P_A \cos 30° = N_A \qquad N_A = 30g \cos 30°$

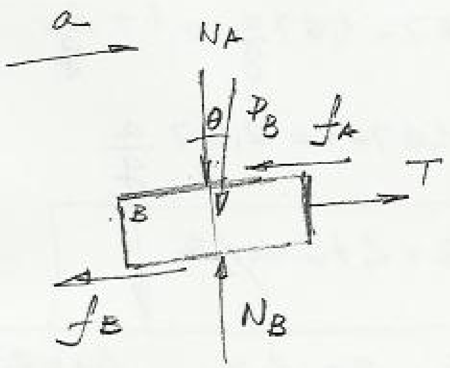
$f_A = 0{,}1 \times 30g \cos 30°$

$f_A = 3g \cos 30°$

$\Sigma F_x = m\,a$

$250 - T + 30g\,\text{sen}\,30° - f_A = 30 \times a$

$371{,}66 - T = 30a \quad (1)$



CORPO B -

$\Sigma F_y = 0$

$N_B = N_A + P_B \cos 30°$

$N_B = 30g \cos 30° + 15g \cos 30°$

$N_B = 45g \cos 30°$

$f_B = 0{,}1 \times 45g \cos 30° = 4{,}5g \cos 30°$

$\Sigma F_x = m\,a$

$T - P_B\,\text{sen}\,30° - f_A - f_B = 15a$

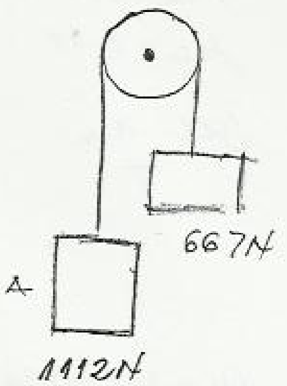
$T - 15g\,\text{sen}\,30° - 3g\cos 30° - 4{,}5g \cos 30° = 15a$

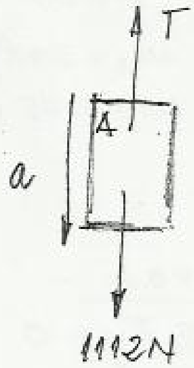
$T - 137{,}29 = 15a \quad (2)$

$$\begin{cases} 371{,}66 - T = 30a \\ -137{,}29 + T = 15a \end{cases} \quad \boxed{a = 5{,}21\,m/s^2 \ \swarrow 30°}$$

$$\boxed{T = 215{,}42\,N}$$

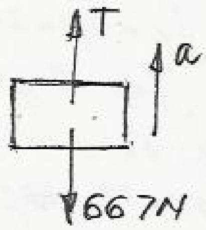
12.18 -





a) $1112 - T = \frac{1112}{g} \cdot a$

$T = 1112\left(1 - \frac{a}{g}\right)$



$T - 667 = \frac{667}{g} \times a$

$1112\left(1 - \frac{a}{g}\right) = 667\left(1 + \frac{a}{g}\right)$

$\frac{1112}{667}\left(1 - \frac{a}{g}\right) = 1 + \frac{a}{g}$

$1{,}67 - 1{,}67\frac{a}{g} = 1 + \frac{a}{g}$

$1{,}67 - 1 = 2{,}67\,\frac{a}{g}$

$\boxed{a = 2{,}45\ m/s^2 \downarrow}$

$t = 2s$

b) $v = v_0 + at$

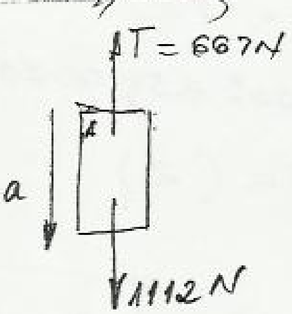
$v = 2{,}45 \times 2$

$\boxed{v = 4{,}90\ m/s \downarrow}$

c) $v^2 = v_0^2 + 2a\,\Delta x \qquad \Delta x = 2{,}44\ m$

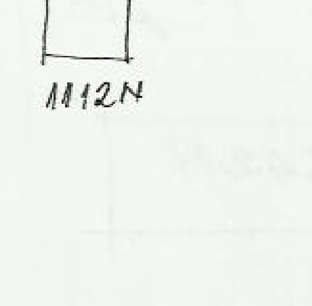
$v^2 = 2 \times 2{,}45 \times 2{,}44$

$\boxed{v = 3{,}46\ m/s \downarrow}$



a) $1112 - 667 = \frac{1112}{g} \cdot a$

$\boxed{a = 3{,}93\ m/s^2 \downarrow}$



b) $t = 2s.$

$v = v_0 + at$

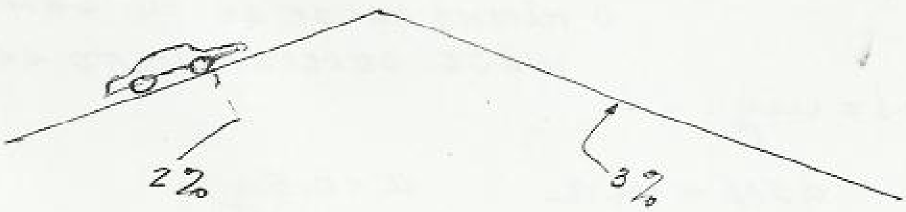
$v = 3{,}93 \times 2 \qquad \boxed{v = 7{,}86\ m/s \downarrow}$

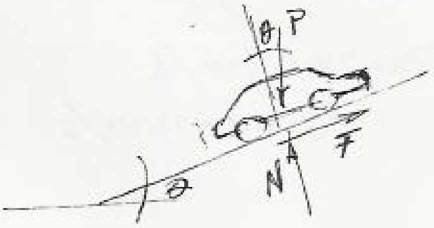
c) $\Delta x = 2{,}44\ m.$

$v^2 = 2 \times 3{,}93 \times 2{,}44$

$\boxed{v = 4{,}38\ m/s \downarrow}$

12.8.



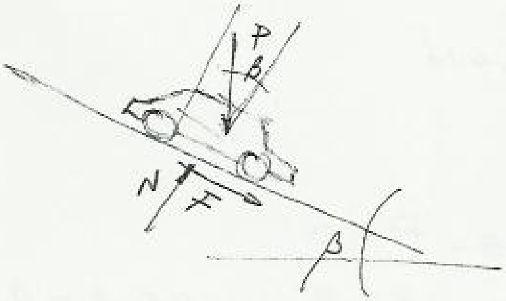


F é a força do motor

$tg\theta = 0{,}02 \qquad \theta = 1{,}15°$

$F - P\,sen\,\theta = 0 \implies v = \underline{cte}$

$F = mg\,sen\,\theta \qquad F = 0{,}02\,mg$



$tg\beta = 0{,}03 \qquad \beta = 1{,}71°$

$F + P\,sen\,\beta = m\,a$

$0{,}02\cancel{m}g + 0{,}03\cancel{m}g = \cancel{m}a$

$a = 0{,}05g$

$\boxed{a = 0{,}49\ m/s^2}$

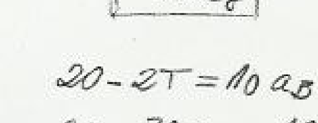
12.16

$x_B + 2x_A + (x_B - x_A) = L$

$2x_B + x_A = L$

$\frac{d^2}{dt^2} \qquad 2a_B + a_A = 0 \qquad \vec{a}_A = -2\vec{a}_B$

$|\vec{a}_A| = 2|\vec{a}_B|$

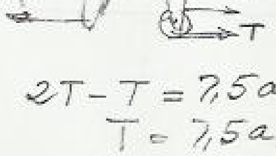


$20 - 2T = 10\,a_B$

$20 - 30\,a_B = 10\,a_B$

$20 = 40\,a_B$

$a_B = \frac{1}{2}\ m/s^2$



$2T - T = 7{,}5\,a_A$

$T = 7{,}5\,a_A$

$T = 15\,a_B$

$a_A = 1\ m/s^2$

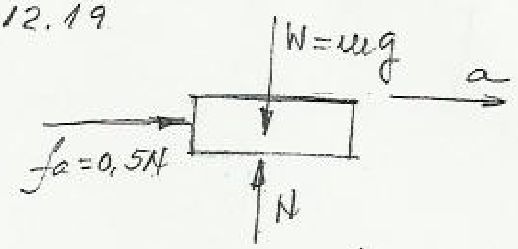
$v_A = a_A t$

$v_A = 1 \times 1{,}2$

$\boxed{v_A = 1{,}2\ m/s}$

$\boxed{v_B = 0{,}6\ m/s}$

12.19



CONSIDERANDO-SE QUE A CARGA ESTEJA NA IMINÊNCIA DE MOVIMENTO, CALCULAREMOS O MÁXIMO VALOR DE $\underline{a}$ SEM QUE HAJA DESLIZAMENTO DA CARGA.

$\Sigma F_y = 0 \quad N = mg$

$\Sigma F_n = ma \qquad 0{,}5N = ma \qquad a = 0{,}5g$

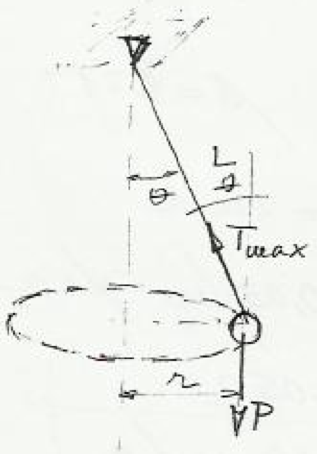
$0{,}5mg = ma \qquad a = 4{,}91\ m/s^2$

$v^2 = v_0^2 + 2a\Delta x \qquad v_0 = 72{,}4\ km/h$

$0 = 20{,}11^2 - 2 \times 4{,}91\ \Delta x \qquad v_0 = 20{,}11\ m/s$

$$\boxed{\Delta x = 41{,}19\ m}$$

12.35



$P = 22{,}2N$

$L = 1{,}22\ m$

$T_{max} = 53{,}4\ N$

$\Sigma F_y = 0$

$T_{max}\cos\theta - P = 0$

$\cos\theta = \dfrac{22{,}2}{53{,}4} \qquad \cos\theta = 0{,}41$

$$\boxed{\theta = 65{,}43°}$$

$\Sigma F_n = m a_n$

$T_{max}\,\text{sen}\,\theta = \dfrac{22{,}2}{g} \cdot a_n$

$53{,}4 \times \text{sen}\,65{,}43° = \dfrac{22{,}2}{g} \cdot \dfrac{v^2}{1{,}22\,\text{sen}\,65{,}43°}$

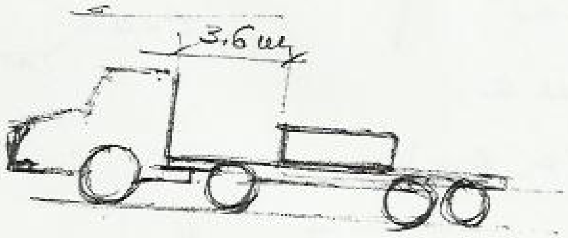
$a_n = \dfrac{v^2}{r}$

$r = L\,\text{sen}\,\theta$

$a_n = \dfrac{v^2}{L\,\text{sen}\,\theta}$

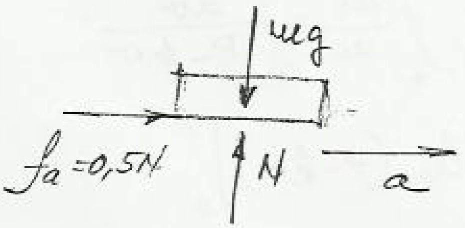
$$\boxed{v = 4{,}88\ m/s}$$

12.19



$\mu_e = 0,50$

$\mu_c = 0,40$



$0,5N = m\,a$

$0,5\cancel{m}g = \cancel{m}\,a$

$a = 0,5g \qquad a = 4,91\ m/s^2$

a – aceleração limite, o corpo está prestes ao deslizamento.

Cinemática:

$v^2 = v_0^2 + 2a\,\Delta x$

$v_0 = 72,4\ km/h = 20,11\ m/s$

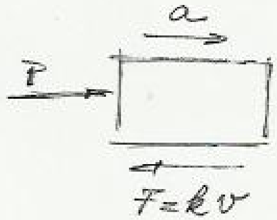
$v = 0$

$0^2 = \left(\frac{72,4}{3,6}\right)^2 - 2 \times 4,91\,\Delta x$

$$\boxed{\Delta x = 41,18\ m}$$

12.20.

12.26 -



$$\Sigma F_x = m a$$

$$P - kv = m a$$

$$a = \frac{1}{m}(P - kv)$$

$$t=0 \begin{cases} x=0 \\ v=0 \end{cases}$$

$$a = \frac{dv}{dt} \qquad \frac{1}{m}(P-kv) = \frac{dv}{dt} \qquad \int_0^t \frac{dt}{m} = \int_0^v \frac{dv}{P-kv}$$

$$\frac{1}{m} t = -\frac{1}{k}\int_0^v \frac{-k\,dv}{P-kv} \Rightarrow \frac{t}{m} = -\frac{1}{k} \ln(P-kv)\Big|_0^v$$

$$-\frac{kt}{m} = \ln(P-kv) - \ln P \longrightarrow -\frac{kt}{m} = \ln\frac{P-kv}{P}$$

$$\frac{P-kv}{P} = e^{-\frac{kt}{m}} \qquad P - kv = Pe^{-\frac{kt}{m}}.$$

$$kv = P\left(1 - e^{-\frac{kt}{m}}\right)$$

$$\boxed{v = \frac{P}{k}\left(1 - e^{-\frac{kt}{m}}\right)}$$

$$v = \frac{dx}{dt} \qquad \int e^u du = e^u$$

$$u = e^{-\frac{kt}{m}} \quad du = -\frac{k}{m} e^{-\frac{kt}{m}} dt$$

$$\int dx = \int v\,dt$$

$$\int_0^x dx = \frac{P}{k}\int_0^t \left(1 - e^{-\frac{kt}{m}}\right) dt$$

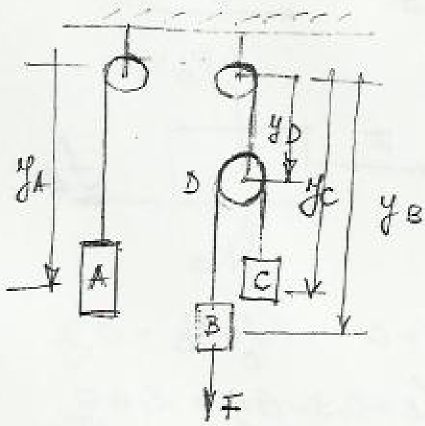
$$\int_0^x dx = \frac{P}{k}\left[\int_0^t dt + \frac{m}{k}\int_0^t -\frac{k}{m} e^{-\frac{kt}{m}} dt\right.$$

$$x = \frac{P}{k}\left[t + \frac{m}{k} e^{-\frac{kt}{m}}\Big|_0^t\right]$$

$$x = \frac{P}{k}\left[t + \frac{m}{k}\left(e^{-\frac{kt}{m}} - 1\right)\right]$$

$$x = \frac{P}{k}\left[t + \frac{m}{k}\left(e^{-\frac{kt}{m}} - 1\right)\right]$$

12.28-



$$y_A + y_D = L$$

$$y_B - y_D + y_C - y_D = L'$$

$$y_B + y_C - 2y_D = L'$$

$$y_D = \frac{1}{2}(y_B + y_C) + \frac{L'}{2}$$

$$y_A + \frac{1}{2}(y_B + y_C) = L''$$

$$\frac{d^2}{dt^2} \quad a_A + \frac{1}{2}(a_B + a_C) = 0$$

$$a_A = -\frac{1}{2}(a_B + a_C)$$

CORPO B

$$F + P_B - T = \frac{P_B}{g} \times a_B$$

$$F + 44{,}5 - T = \frac{44{,}5}{g} \times 1{,}22$$

$$F - T = -38{,}97 \quad (1)$$

CORPO B PERCORRE 2,44 m EM 2 s.

$$x_B = 0 + \frac{1}{2} a_B t^2$$

$$2{,}44 = \frac{1}{2} a_B \times 2^2$$

$$a_B = 1{,}22 \, m/s^2$$

$$P_B = 44{,}5 \, N$$

CORPO A $\quad P_A = 89 \, N$

$$a_B = -1{,}22 \, m/s^2$$

$$2T - 89 = \frac{89}{g} \times a_A$$

$$a_A = -\frac{1}{2}(a_B + a_C)$$

$$a_A = +0{,}61 - \frac{a_C}{2}$$

$$2T - 89 = \frac{89}{g}\left(+0{,}61 + \frac{a_C}{2}\right)$$

$$2T - 94{,}53 = -4{,}54 a_C \quad (2)$$

Subst. (3) em (2):

$$2T - 94{,}53 = -4{,}54(0{,}22T - 9{,}81)$$

$$2T - 94{,}53 = -T + 44{,}54$$

$$3T = 139{,}07$$

$$T = 46{,}35 \, N$$

CORPO C $\quad P_C = 44{,}5 \, N$

$$T - 44{,}5 = \frac{44{,}5}{g} \times a_C$$

$$a_C = 0{,}22T - 9{,}81 \quad (3)$$

Subst. T em (1)

$$F - 46{,}35 = -38{,}97$$

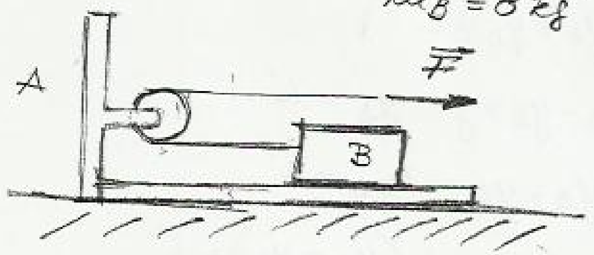
$$\boxed{F = 7{,}39 \, N}$$

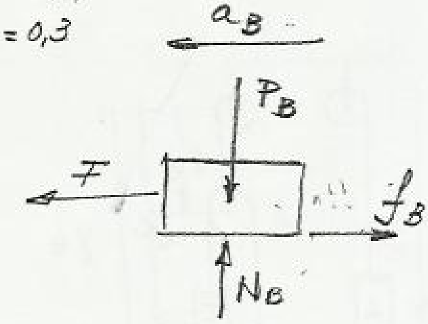
A TRAÇÃO NO CABO AD É 2T

$$T_{AD} = 2T = 92{,}70 \, N$$

$$\boxed{T_{AD} = 92{,}70 \, N}$$

12.29 $F = 30N$ $m_A = 12\,kg$ $m_B = 8\,kg$ $\mu_e = 0{,}4$ $\mu_c = 0{,}3$





$\Sigma F_y = 0 \quad N_B = P_B = 8g$

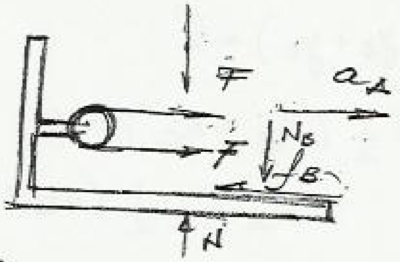
$f_B = 0{,}3 \times 8g = 2{,}4g$

$\Sigma F_x = ma$

$F - f_B = m_B \cdot a_B$

$30 - 2{,}4g = 8 \times a_B$

$a_B = 0{,}81\, m/s^2$ ←



$\Sigma F_x = ma$

$2F - f_B = m_A\, a_A$

$60 - 2{,}4g = 12\, a_A$

$a_A = 3{,}04\, m/s^2$ →

$\vec{a}_{B/A} = \vec{a}_B - \vec{a}_A$

→ (+)

$a_{B/A} = -0{,}81 - 3{,}04$

$a_{B/A} = -3{,}85\, m/s^2$

$a_{B/A} = 3{,}85\, m/s^2$ ←

$\Delta x_{B/A} = 400\, mm = 0{,}4\, m$

$v_{B/A}^2 = 2 \times a_{B/A}\, \Delta x_{B/A}$

$v_{B/A}^2 = 2 \times 3{,}85 \times 0{,}4$

$\boxed{v_{B/A} = 3{,}08\, m/s}$ →

12.30 – Se B NÃO ESCORREGA SOBRE O SUPORTE

$a_{B/A} = 0 \Longrightarrow a_B = a_A.$

$f_B = \mu_e N_B = 0{,}4 \times 8g = 3{,}2g$

$f_B - F = 8\, a_B$

$3{,}2g - F = 8\, a_B$

$a_B = a_A$

$3{,}2g - F = 8 a_A \ (1)$

CORPO A.

$2F - f_B = m_A\, a_A$

$2F - 3{,}2g = 12 a_A \ (2)$

Subst. (1) em (2).

$2F - 3{,}2g = \dfrac{3{,}2g - F}{8} \times 12$

$16F - 251{,}14 = 376{,}7 - 12F$

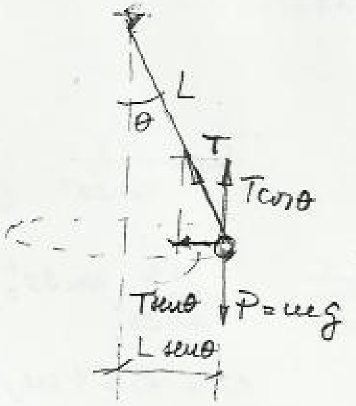
$28F = 627{,}84$

$\boxed{F = 22{,}42N}$

Subst. F em (2)

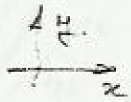
$\boxed{a_A = 1{,}12\, m/s^2}$ →

12.36-



$m = 3\,kg \qquad L = 800\,mm$

$v = 1{,}2\,m/s$



Det: θ e T.

$\Sigma F_y = 0$

$T\cos\theta = mg = 3g \quad (1) \Rightarrow T = \dfrac{3g}{\cos\theta}$

$\Sigma F_n = m\,a_n = m\dfrac{v^2}{r}$

$T\,\text{sen}\,\theta = \dfrac{3\times 1{,}2^2}{0{,}8\,\text{sen}\,\theta} = \dfrac{5.4}{\text{sen}\,\theta} \quad (2)$

subst. $T = \dfrac{3g}{\cos\theta}$ em (2):

$\dfrac{3g}{\cos\theta}\,\text{sen}\,\theta = \dfrac{5.4}{\text{sen}\,\theta} \Rightarrow 3g\,\text{sen}^2\theta = 5{,}4\cos\theta$

$\text{sen}^2\theta = 0{,}18\cos\theta \qquad 1-\cos^2\theta = 0{,}18\cos\theta$

$\cos^2\theta + 0{,}18\cos\theta - 1 = 0$

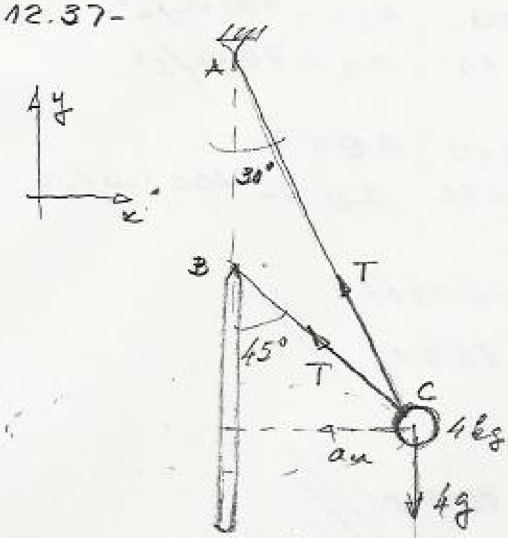
$\cos\theta = \dfrac{-0{,}18 \pm \sqrt{0{,}18^2 - 4\times 1\times(-1)}}{2} \qquad \cos\theta = \dfrac{-0{,}18 \pm 2{,}01}{2}$

$\boxed{\theta = 24{,}15^\circ}$

subst. θ em (1):

$T = \dfrac{3g}{\cos 24{,}15^\circ} \qquad \boxed{T = 32{,}25\,N}$

12.37-



$\Sigma F_y = 0$

$T\cos 30^\circ + T\cos 45^\circ = 4g \qquad T(\cos 30^\circ + \cos 45^\circ) = 4g$

$T = 24{,}94\,N$

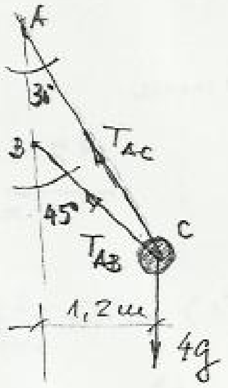
$\Sigma F_n = m\,a_n$

$T\,\text{sen}\,30^\circ + T\,\text{sen}\,45^\circ = 4\times\dfrac{v^2}{1{,}2}$

$v^2 = \dfrac{T(\text{sen}\,30^\circ + \text{sen}\,45^\circ)\times 1{,}2}{4}$

$\boxed{v = 3{,}00\,m/s}$

12.39-



1ª CONSIDERAÇÃO:

$T_{AB} = 0$

$\Sigma F_y = 0$

$T_{AC} \cos 30° = 4g \qquad T_{AC} = \frac{4g}{\cos 30°}$

$\Sigma F_n = m a_n$

$T_{AC} \operatorname{sen} 30° = 4 \times \frac{v^2}{1,2} \qquad \frac{\cancel{4}g}{\cos 30°} \operatorname{sen} 30° = \cancel{4} \times \frac{v^2}{1,2}$

$v^2 = 1,2 g \operatorname{tg} 30° \qquad v = 2,61\ m/s.$

2ª CONSIDERAÇÃO:

$T_{AC} = 0$

$\Sigma F_y = 0 \qquad T_{AB} \cos 45° = 4g \qquad T_{AB} = \frac{4g}{\cos 45°}$

$\Sigma F_n = m a_n \qquad T_{AB} \operatorname{sen} 45° = 4 \times \frac{v^2}{1,2} \qquad \frac{\cancel{4}g}{\cos 45°} \operatorname{sen} 45° = \cancel{4} \frac{v^2}{1,2}$

$v^2 = 1,2 g \operatorname{tg} 45° \qquad v = 3,43\ m/s$

$$\boxed{2,61\ m/s < v < 3,43\ m/s}$$

12.65-

$a_r = \ddot{r} - r\dot{\theta}^2 \qquad r = 25t^3 - 50t^2 \qquad \theta = t^3 - 4t$

$a_\theta = r\ddot{\theta} + 2\dot{r}\dot{\theta} \qquad \dot{r} = 75t^2 - 100t \qquad \dot{\theta} = 3t^2 - 4$

$\ddot{r} = 150t - 100 \qquad \ddot{\theta} = 6t$

$a_r = 150t - 100 - (25t^3 - 50t^2)(3t^2 - 4)^2 \qquad P/t=0 \quad a_r = -100\ m/s^2$

$P/t = 1s \quad a_r = 75\ m/s^2$

$a_\theta = (25t^3 - 50t^2) 6t + 2(75t^2 - 100t)(3t^2 - 4) \qquad P/t=0 \quad a_\theta = 0$

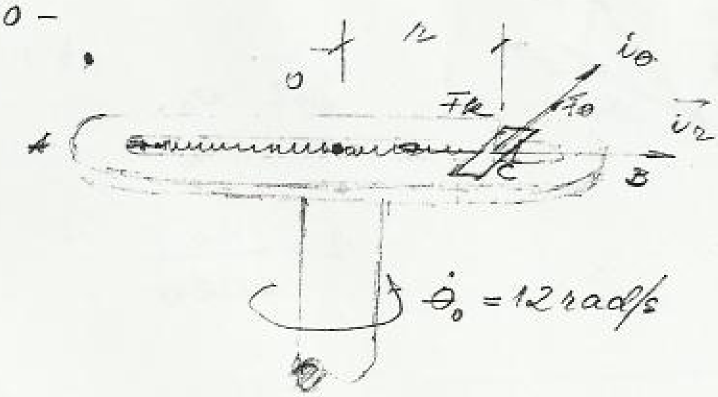
$P/t = 1s \quad a_\theta = -100\ m/s^2$

$m = 2\ kg$

$F_r = m a_r = 2 a_r \quad \begin{cases} t=0 & F_r = -200\ N \\ t=1s & F_r = 150\ N \end{cases}$

$F_\theta = m a_\theta = 2 a_\theta \quad \begin{cases} t=0 & F_\theta = 0 \\ t=1s & F_\theta = -200\ N \end{cases}$

12.70 -



$K = 36\ N/m$.

$r = 400\,mm = 0{,}4\,m$.

$\dot{\theta}_0 = 12\ rad/s = cte$

$v_r = 1{,}8\,m/s$ $\quad m_c = 200\,g$

Det:

a) a_r e a_θ

b) $\ddot{r}$

c) F_θ

a) MOLA NÃO DEFORMADA:

$r = 0$

Δx (deformação da mola) $\Rightarrow \Delta r = 0{,}4\,m$

$F_k = k\Delta r = 36 \times 0{,}4 = +14{,}4\,N$ $\qquad F_k = -F_r$

$F_r = m a_r$ $\qquad -14{,}4 = 0{,}2 \times a_r$

$$\boxed{a_r = -72\,m/s^2}$$

$a_\theta = r\ddot{\theta} + 2\dot{r}\dot{\theta}$

$\ddot{\theta} = 0 \Rightarrow \dot{\theta} = cte.$ $\qquad a_\theta = 2 \times 1{,}8 \times 12$

$\dot{r} = v_r = 1{,}8\,m/s$ $\qquad \boxed{a_\theta = 43{,}2\,m/s^2}$

b) aceleração do cursor relativa à peça AB $\Rightarrow \ddot{r}$

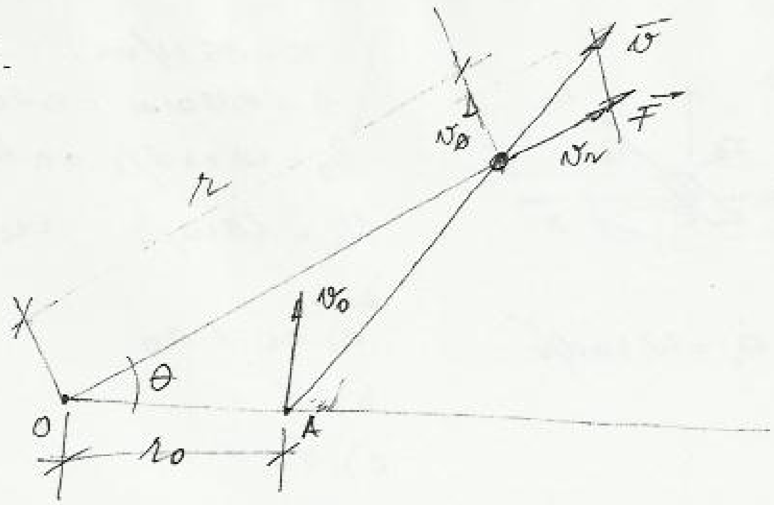
$a_r = \ddot{r} - r\dot{\theta}^2$ $\qquad \ddot{r} = a_r + r\dot{\theta}^2$

$\ddot{r} = -72 + 0{,}4 \times 12^2$ $\qquad \boxed{\ddot{r} = -14{,}4\,m/s^2}$

c) $F_\theta = m a_\theta$

$F_\theta = 0{,}2 \times 43{,}2$ $\qquad \boxed{F_\theta = 8{,}64\,N}$

12.74 -



Det. v_θ
v_r.

$r = \frac{r_0}{\cos 2\theta}$

CONSERVAÇÃO DO MOMENTO ANGULAR

$v_\theta \cdot r = v_0 r_0$

$v_\theta \cdot \frac{r_0}{\cos 2\theta} = v_0 \cancel{r_0}$

$$\boxed{v_\theta = v_0 \cos 2\theta}$$

$\vec v = \dot r \, \vec i_r + r \dot\theta \, \vec i_\theta$

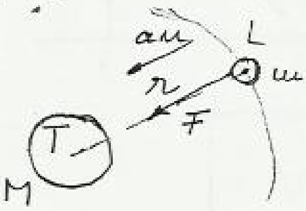
$v_\theta = r\dot\theta \qquad v_0 \cos 2\theta = \frac{r_0}{\cos 2\theta}\dot\theta \qquad \dot\theta = v_0 \frac{\cos^2 2\theta}{r_0}$

$r = \frac{r_0}{\cos 2\theta} = r_0 \cos^{-1} 2\theta \qquad \dot r = -r_0 \cos^{-2} 2\theta (-\text{sen}\, 2\theta)\, 2\dot\theta$

$\dot r = \frac{r_0 \,\text{sen}\, 2\theta}{\cos^2 2\theta}\, 2 \cdot \dot\theta = \frac{2 \cancel{r_0}\,\text{sen}\, 2\theta}{\cancel{\cos^2 2\theta}}\, v_0 \frac{\cancel{\cos^2 2\theta}}{\cancel{r_0}}$

$v_r = \dot r = 2 v_0 \,\text{sen}\, 2\theta \qquad \boxed{v_r = 2 v_0 \,\text{sen}\, 2\theta}$

12.78 -



$F = \frac{GMm}{r^2}$

$F = \frac{gR^2 m}{r^2}$

$\cancel{m}\, a_n = \frac{gR^2}{r^2}\cancel{m}$

$\frac{v^2}{\cancel{r}} = \frac{gR^2}{r^{\cancel{2}}}$

$P = \cancel{m} g = G\frac{M\cancel{m}}{R^2}$

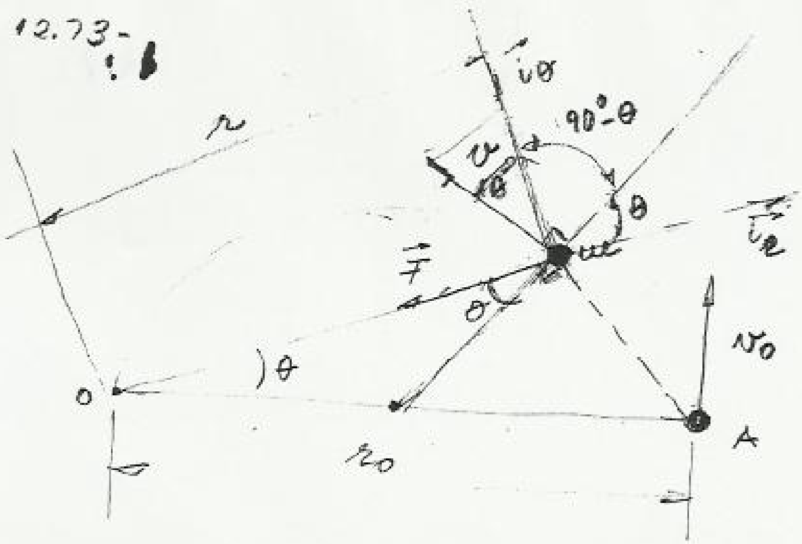
$GM = gR^2$

$v = \frac{2\pi r}{T}$

$\frac{2^2 \pi^2 r^2}{T^2} = \frac{gR^2}{r}$

$$\boxed{r^3 = \frac{gR^2T^2}{4\pi^2}}$$

12.73 -



$r = r_0 \cos\theta$

$r_0 = \dfrac{r}{\cos\theta}$

$\cos\theta = \dfrac{r}{r_0}$

MOV. SOB A AÇÃO DE FORÇA CENTRAL

— CONSERVAÇÃO DO MOMENTO ANGULAR —

$$(\vec{H}_0)_{antes} = (\vec{H}_0)_{depois}$$

$$\cancel{m} v_0 r_0 = \cancel{m} v r \cos\theta$$

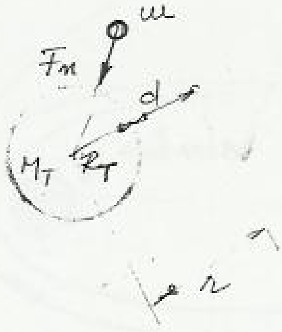
$$v_0 \cancel{r_0} = v . \cancel{r_0} \cos\theta \cos\theta$$

$$\boxed{v = \frac{v_0}{\cos^2\theta}} \qquad \boxed{v = \frac{v_0 r_0^2}{r^2}}$$

12.79 -

$F_n = m\,a_n$

$F_n = \dfrac{GMm}{r^2}$



$\dfrac{GM\cancel{m}}{r^{\cancel{2}}} = \cancel{m}\dfrac{v^2}{\cancel{r}}$

$v = \dfrac{2\pi r}{T}$ T - período

$GM = gR_T^2$

$\dfrac{GM}{r} = \dfrac{4\pi^2 r^2}{T^2}$ $r^3 = \dfrac{GMT^2}{4\pi^2} = g\dfrac{R_T^2 \cdot T^2}{4\pi^2}$

$T = 23h\ 56min = 86.160\ s$

$g = 9{,}81\ m/s^2$

$R_T = 6{,}37 \times 10^6\ m$

$r^3 = \dfrac{9{,}81 \times (6{,}37 \times 10^6)^2 \times (86160)^2}{4 \times \pi^2}$ $r = 42{,}14 \times 10^6\ m$

a) altitude d:

$d = r - R$ $d = 42{,}14 \times 10^6 - 6{,}37 \times 10^6$

$d = 35{,}77 \times 10^6\ m$

$d = 35.774\ km$

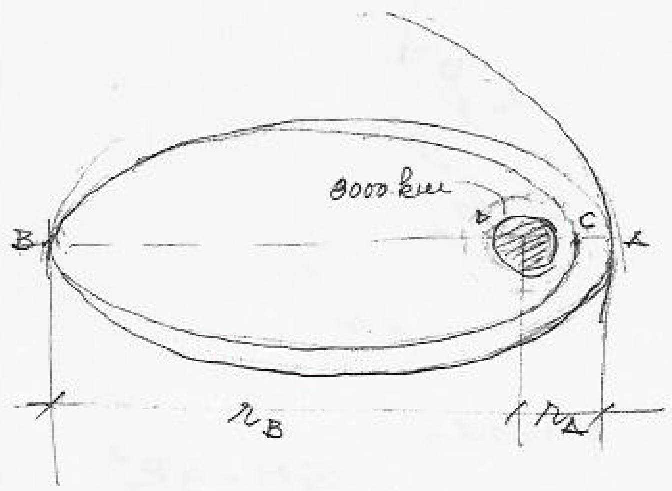
b) $v = \dfrac{2\pi r}{T}$

$v = \dfrac{2\pi \times 42{,}14 \times 10^6}{86160}$

$v = 3.073\ m/s$

$v = 11.063\ km/h$

12.82-



$r_C = 8000\ km$

$r_A = 12\times10^3\ km$

$r_B = 96\times10^3\ km.$

$GM_T = gR_T^2 = 9{,}81\frac{m}{s^2}\times(6{,}37\times10^6 m) =$

$GM_T = 3{,}98\times10^{14}\frac{m}{s^2}$

$v_B = 869\ m/s$

$v_A = 7400\ m/s$

$\Delta v_B = -146\ m/s.$

1º TRANSFERÊNCIA DE ÓRBITA

CONSERVAÇÃO DO MOMENTO ANGULAR:

$v_A r_A = v_B r_B$

$v_A \times 12\times10^3 = 869 \times 96\times10^3$

$v_A = 6.952\ m/s$

$\Delta v_A = -448\ m/s$

$\boxed{\Delta v_A = 448\ m/s}$

2º TRANSFERÊNCIA DE ÓRBITA

$v_B = 869 - 146 = 723\ m/s.$

VELOCIDADE DE C EM TORNO ~~DA~~ ÓRBITA CIRCULAR.

$v_C = \sqrt{\frac{GM_M}{r_C}}$

$GM_M = 0{,}82\ GM_T$

$GM_M = 0{,}82 \times 3{,}98\times10^{14}\ m^3/s^2$

$GM_M = 3{,}26\times10^{14}\ m^3/s^2$

$v_C = \sqrt{\frac{3.26\times10^{14}}{8\times10^6}}$

$v_C = 6.383{,}57\ m/s.$

$\Delta v_C = -2.292{,}43\ m/s$

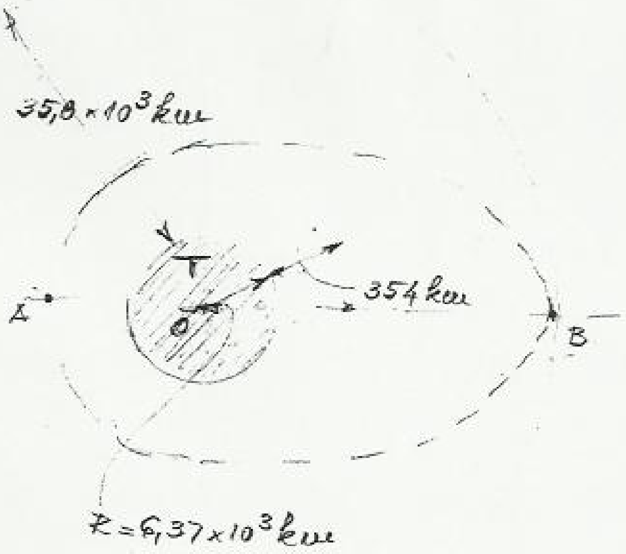
$r_C v_C = r_B v_B$

$8\times\cancel{10^3}\cdot v_C = 96\times\cancel{10^3}\times 723$

$v_C = 8.676\ m/s$

$\boxed{\Delta v_C = 2.292{,}43\ m/s}$

12.84



$r = (6{,}37\times10^3 + 354)\,\text{km}$

$F = \cancel{m}\,a_n = \dfrac{GM\cancel{m}}{r^2}$

$\dfrac{v^2}{\cancel{r}} = \dfrac{GM}{r^{\cancel{2}}} = \dfrac{gR_T}{r}$

VELOCIDADE CIRCULAR DE A:

$$v_A^2 = \frac{9{,}81\times(6{,}37\times10^6)^2}{(6{,}37\times10^6 + 354\times10^3)} \qquad v_A = 7.694{,}14\ \text{m/s}$$

VELOCIDADE ELÍPTICA DE A

$(v_A)_{el} = 2{,}41\ \text{km/s} \qquad (v_A)_{el} = 2410\ \text{m/s}.$

VELOCIDADE ELÍPTICA DE B:

CONSERVAÇÃO DO MOMENTO ANGULAR

$$r_A \cdot \cancel{m}(v_A)_{el} = r_B\,\cancel{m}(v_B)_{el}$$

$$(6{,}37\times10^6 + 354\times10^3)\times 2410 = (6{,}37\times10^6 + 35{,}8\times10^6)(v_B)_{el}.$$

$$(v_B)_{el} = 384{,}27\ \text{m/s}$$

VELOCIDADE CIRCULAR DE B.

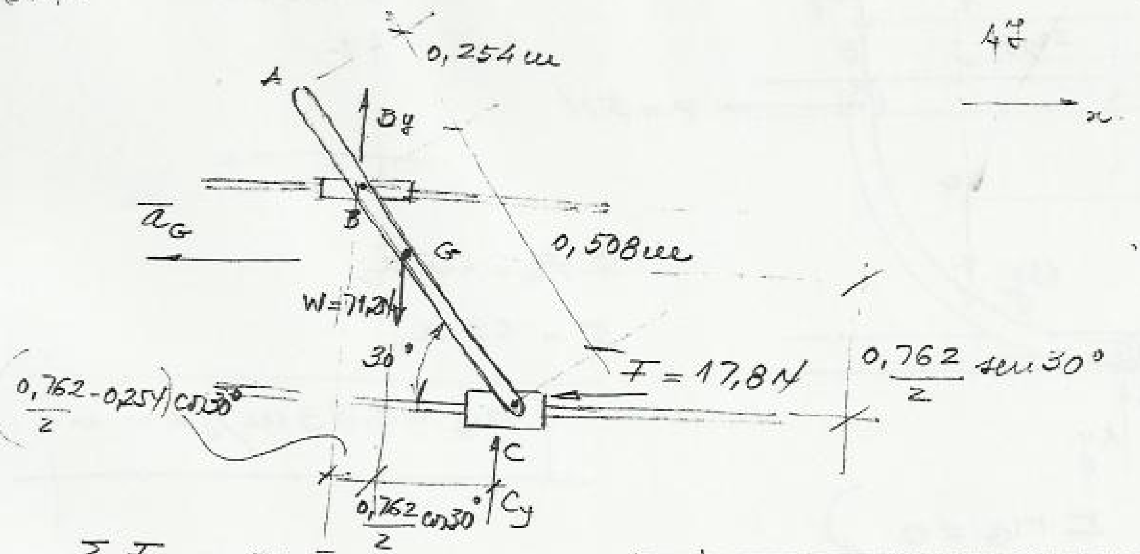
$$v_B^2 = \frac{9{,}81\times(6{,}37\times10^6)^2}{(6{,}37\times10^6 + 35{,}8\times10^6)} \qquad v_B = 3.072\ \text{m/s}$$

$\Delta v_B = 3.072 - 384{,}27$

$$\boxed{\begin{array}{c}\Delta v_B = 2.688\ \text{m/s}\\ \Delta v_B = 2{,}69\ \text{km/s}\end{array}}$$

Cap. 16

16.1 -



$\Sigma F_x = m\,\bar{a}_G$

$17,8 = \frac{71,2}{g} \times a_G$

$\boxed{a_G = 2,45\ m/s^2 \leftarrow}$

$\Sigma M_G = 0$

$C_y \times \frac{0,762}{2}\cos 30° - B_y\left(\frac{0,762}{2} - 0,254\right)\cos 30° - F \times \frac{0,762}{2}\,\text{sen}\,30° = 0$

$0,33\,C_y - 0,11\,B_y - 3,39 = 0$

$C_y = 10,28 + 0,33\,B_y$

$\Sigma F_y = 0$

$C_y + B_y - 71,2 = 0$

$10,28 + 0,33\,B_y + B_y = 71,2$

$\boxed{B_y = 45,69\,N}$ $\boxed{C_y = 25,51\,N}$

16.2 - $B_y = 35,6\,N \uparrow$ $B_y + C_y = 71,2$ $C_y = 35,6\,N \uparrow$

$\Sigma M_G = 0$

$0,33\,C_y - 0,11\,B_y - 0,19\,F = 0$

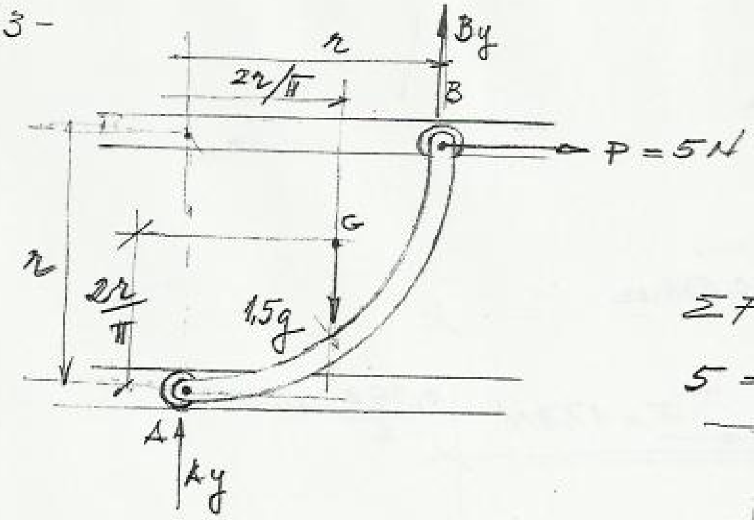
$\boxed{F = 41,11\,N \leftarrow}$

$\Sigma F_x = m\,\bar{a}_G$

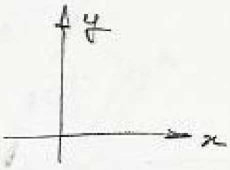
$41,11 = \frac{71,2}{g} \cdot \bar{a}_G$

$\boxed{\bar{a}_G = 5,66\ m/s^2 \leftarrow}$

16.3 -



$r = 0{,}3\,m$



$$\Sigma F_x = m\,\bar{a}_G$$

$$5 = 1{,}5\,a_G$$

$$\boxed{a_G = 3{,}33\,m/s^2 \rightarrow}$$

$$\Sigma M_G = 0$$

$$Ay \times \frac{2r}{\pi} - By\left(r - \frac{2r}{\pi}\right) + P\left(r - \frac{2r}{\pi}\right) = 0$$

$$0{,}19\,Ay - 0{,}81\,By + 4{,}05 = 0$$

$$Ay = 4{,}23\,By - 21{,}18$$

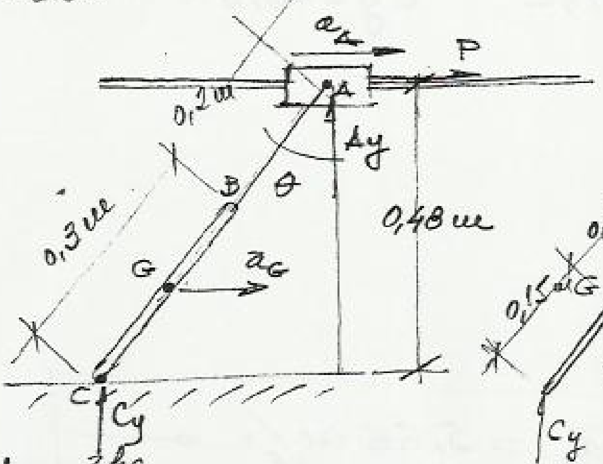
$$\Sigma F_y = 0$$

$$Ay + By = 1{,}5g \qquad 4{,}23\,By + By - 21{,}18 = 1{,}5g$$

$$\boxed{By = 6{,}86\,N}$$

$$\boxed{Ay = 7{,}86\,N}$$

16.5 -

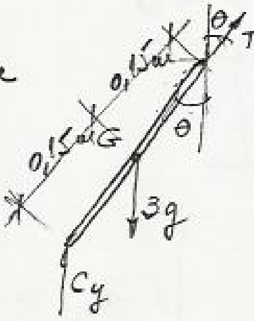


$m_{BC} = 3\,kg.$

CORDA E BARRA ALINHADAS:

$$\cos\theta = \frac{0{,}48}{0{,}5} \qquad \theta = 16{,}26°$$

$$a_G = a_A \quad \text{(TRANSLAÇÃO)}$$



$$\Sigma F_x = m\,\bar{a}_G$$

$$T\sin\theta = 3 \cdot a_G$$

$$T = 10{,}71\,a_G \qquad a_G = 2{,}86\,m/s^2$$

$$\boxed{a_A = 2{,}86\,m/s^2 \rightarrow}$$

$$\Sigma F_y = 0$$

$$T\cos\theta = 3g$$

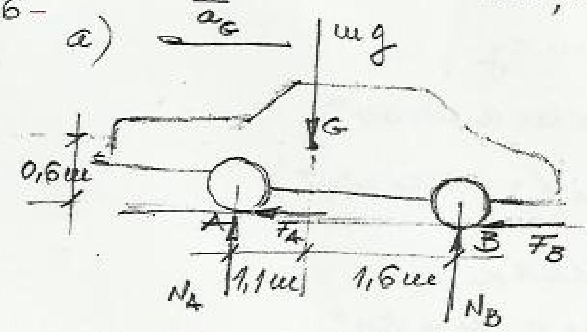
$$\boxed{T = 30{,}66\,N}$$

$$\Sigma M_G = 0$$

$$Cy = 0$$

16.6 - TRAÇÃO NAS QUATRO RODAS

a)



$\mu_e = 0{,}80$

$F_A = \mu_e N_A$

$F_B = \mu_e N_B$

$F_A + F_B = \mu_e (N_A + N_B)$

$\Sigma F_y = 0$

$N_A + N_B = mg$

$\Sigma F_x = m \bar{a}_G$

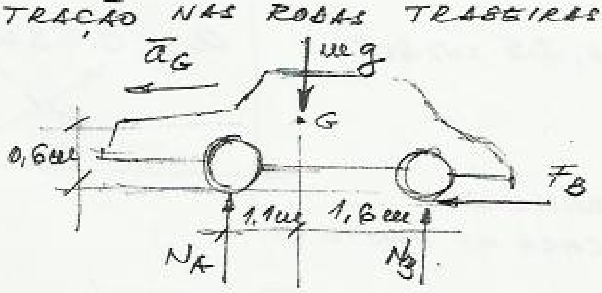
$F_A + F_B = m \bar{a}$

$\mu_e (N_A + N_B) = m \bar{a}$

$\mu_e (\cancel{m} g) = \cancel{m} \bar{a}$

$\bar{a}_G = \mu_e g$ $\boxed{\bar{a}_G = 7{,}85 \text{ m/s}^2 \leftarrow}$

b) TRAÇÃO NAS RODAS TRASEIRAS.



$\mu_e = 0{,}80$

$F_B = \mu_e N_B$

$\Sigma F_y = 0 \quad N_A + N_B = mg.$

$1{,}02 N_B + N_B = mg$

$N_B = \frac{mg}{2{,}02}$

$F_B = \frac{0{,}8}{2{,}02} mg$

$\Sigma M_G = 0$ (+)

$N_A \times 1{,}1 + F_B \times 0{,}6 - N_B \times 1{,}6 = 0$

$N_A \times 1{,}1 + \mu_e N_B \times 0{,}6 - 1{,}6 N_B = 0$

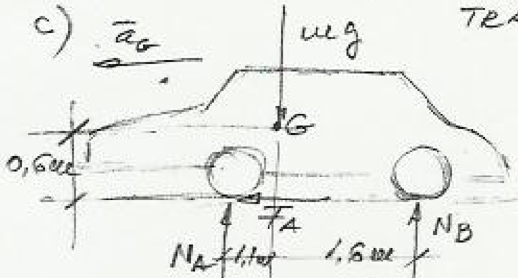
$N_A = 1{,}02 N_B$

$\Sigma F_x = m \bar{a}_G$

$\frac{0{,}8}{2{,}02} \cancel{m} g = \cancel{m} \bar{a}_G$

$\boxed{\bar{a}_G = 3{,}89 \text{ m/s}^2 \leftarrow}$

c) TRAÇÃO NAS RODAS DIANTEIRAS.



$F_A = \mu_e N_A = 0{,}8 N_A$

$\Sigma F_y = 0$

$N_A + N_B = mg$

$N_A + 0{,}98 N_A = mg$

$N_A = 0{,}51 mg$

$F_A = 0{,}8 \times 0{,}51 mg = 0{,}404 mg$

$\Sigma M_G = 0$ (+)

$N_A \times 1{,}1 + F_A \times 0{,}6 - N_B \times 1{,}6 = 0$

$N_A = 1{,}02 N_B$

$N_B = 0{,}98 N_A$

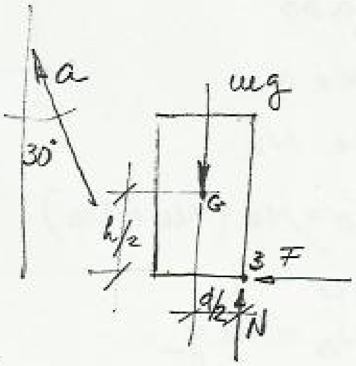
$\Sigma F_x = m \bar{a}_G$

$F_A = m \bar{a}_G$

$0{,}404 \cancel{m} g = \cancel{m} \bar{a}_G$

$\boxed{\bar{a}_G = 3{,}96 \text{ m/s}^2 \leftarrow}$

16.10 -



$$\Sigma F_y = m a_y$$

$$N - mg = m a \cos 30°$$

$$N = m(g + a \cos 30°)$$

$$\Sigma F_x = m a_x$$

$$F = m a \operatorname{sen} 30°$$

a) LATAS DESLIZANDO

$$F = \mu_c N \qquad \mu_c = \frac{\cancel{m} a \operatorname{sen} 30°}{\cancel{m}(g + a \cos 30°)}$$

$$0,25(g + a \cos 30°) = a \operatorname{sen} 30°$$

$$0,25 g = a(\operatorname{sen} 30° - 0,25 \cos 30°)$$

$$\boxed{a = 8,65 \, m/s^2}$$

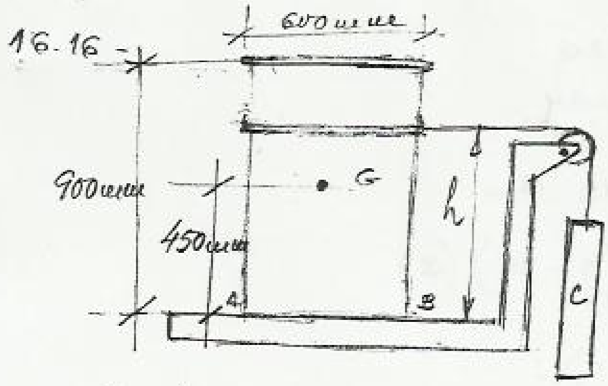
b) NA SITUAÇÃO DE TOMBAMENTO A NORMAL ESTÁ APLICADA NO PONTO B.

$$\Sigma M_G = 0 \; (\circlearrowleft +) \qquad F = 0,25 N$$

$$N \times \frac{d}{\cancel{2}} = F \frac{h}{\cancel{2}} \qquad \frac{N}{F} = \frac{h}{d} \qquad \frac{N}{0,25 N} = \frac{h}{d}$$

$$\boxed{\frac{h}{d} = 4}$$

16.16 -



$m_b = 125\ kg$

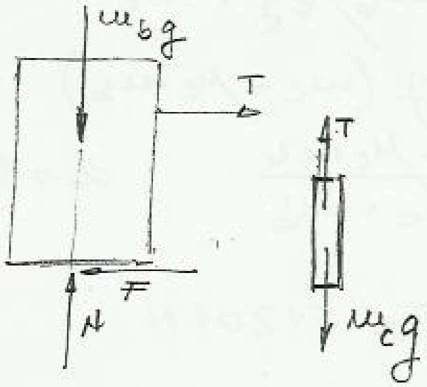
$m_c = 60\ kg$

$\mu_e = 0{,}35$

$\mu_c = 0{,}30$

1) VERIFICAÇÃO DO ESTADO DE DESLIZAMENTO.

ASSUMIMOS O REPOUSO (IMINÊNCIA DE MOVIMENTO) E DETERMINAMOS O VALOR MÍNIMO DE m_C P/ ESTA SITUAÇÃO.



P/ O BARRIL

$\Sigma F_x = 0 \qquad F = T$

$\Sigma F_y = 0 \qquad N = m_b g$

$F = \mu_e N$

$F = \mu_e m_b g = T$

P/ O CILINDRO $\quad \Sigma F_y = 0$

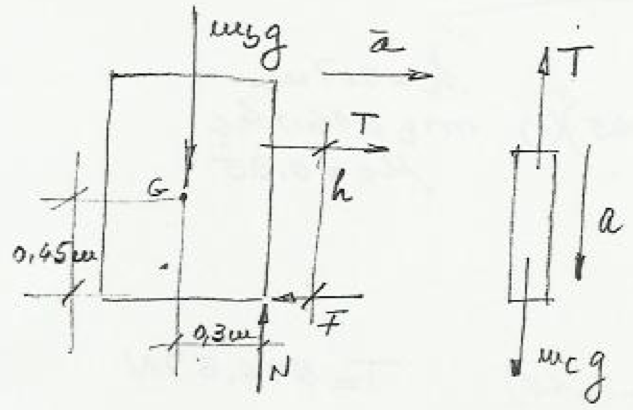
$T = m_c g$

$\mu_e m_b \cancel{g} = m_c \cancel{g} \qquad m_c = \mu_e m_b$

$m_c = 0{,}35 \times 125 \qquad m_c = 43{,}75\ kg$

COMO $m_C = 60\ kg > 43{,}75\ kg$ — O CORPO ESTÁ DESLIZANDO.

ASSUMINDO O DESLIZAMENTO E A IMINÊNCIA DE TOMBAMENTO.



P/ O BARRIL

$F = \mu_c N \qquad \Sigma F_y = 0 \quad N = m_b g$

$F = \mu_c m_b g$

$\Sigma F_x = m_b \bar{a}$

$T - F = m_b a$

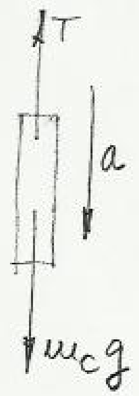
$T - \mu_c m_b g = m_b a$

$T = m_b(\mu_c g + a) \ (1)$

$\Sigma M_G = 0$ +↻

$T(h - 0{,}45) + F \times 0{,}45 - N \times 0{,}3 = 0$

$T(h - 0{,}45) = m_b g(0{,}3 - \mu_c \times 0{,}45) \ (2)$



P/O CILINDRO

$$\Sigma F_y = m a_y$$

$$m_c g - T = m_c \cdot a$$

$$T = m_c (g-a) \quad (3)$$

Subst. (3) em (1):

$$m_c (g-a) = m_b (\mu_c g + a)$$

$$m_c g - m_c a = m_b \mu_c g + m_b a$$

$$a (m_b + m_c) = g (m_c - \mu_c m_b)$$

$$a = g \frac{m_c - \mu_c m_b}{m_c + m_b} \qquad a = 1{,}19 \; m/s^2 \longrightarrow$$

$$T = m_c (g-a)$$

$$T = 60 (9{,}81 - 1{,}19) \qquad T = 517{,}01 \; N$$

Subst o valor de T em (2)

$$517{,}01 (h - 0{,}45) = 125 \times 9{,}81 (0{,}3 - 0{,}3 \times 0{,}45) \qquad h = 0{,}841 \; m$$

P/ QUE O BARRIL NÃO TOMBE.

$$\boxed{h \leq 0{,}841 \; m}$$

16.17- DO PROBLEMA ANTERIOR:

$$h = 0{,}7 \; m$$
$$m_b = 160 \; kg$$
$$\mu_c = 0{,}35$$

$$T (h - 0{,}45) = m_b g (0{,}3 - \mu_c \times 0{,}45) \quad (1)$$

$$T = m_c (g - a) \quad (2)$$

$$T = m_b (\mu_c g + a) \quad (3)$$

Eq (1):

$$T (0{,}7 - 0{,}45) = 160 \times 9{,}81 (0{,}3 - 0{,}35 \times 0{,}45) \qquad T = 894{,}67 \; N$$

Subst T em eq. (3)

$$894{,}67 = 160 (0{,}35 \times 9{,}81 + a) \qquad a = 2{,}16 \; m/s^2.$$

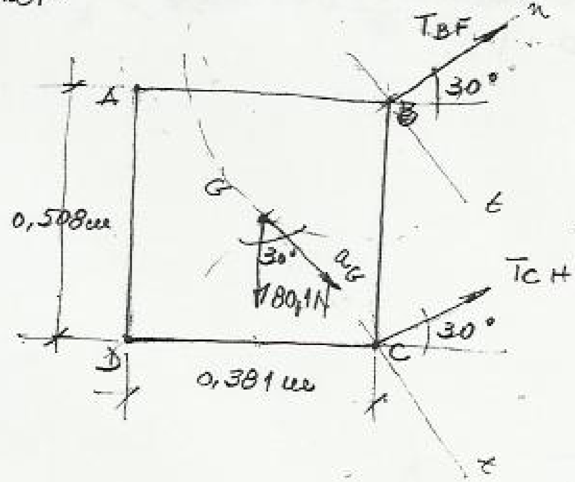
Subst. a e T em eq (2)

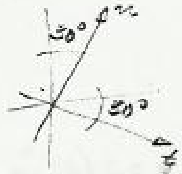
$$894{,}67 = m_c (9{,}81 - 2{,}16) \qquad m_c = 116{,}95 \; kg.$$

VALOR MÁXIMO DE m_c.
(IMINÊNCIA DE TOMBAMENTO)

$$\boxed{m_c \leq 116{,}95 \; kg}$$

16.21- IMEDIATAMENTE APÓS O CABO AE TER SIDO CORTADO.





$$\Sigma F_t = m a_t$$

$$\cancel{80{,}1}\cos 30° = \frac{\cancel{80{,}1}}{g} \times a_G$$

$$a_G = g\cos 30°$$

a) $\boxed{a_G = 8{,}50\ m/s^2 \searrow 30°}$

b) $\Sigma F_n = 0$

$$T_{BF} + T_{CH} - 80{,}1\,\text{sen}\,30° = 0$$

$$T_{BF} + T_{CH} = 40{,}05\ N \quad (1)$$

$\Sigma M_G = 0$ ↻+

$$T_{BF}\cos 30° \times \frac{0{,}508}{2} - T_{BF}\,\text{sen}\,30° \times \frac{0{,}381}{2} - T_{CH}\cos 30° \times \frac{0{,}508}{2} - T_{CH}\,\text{sen}\,30° \times \frac{0{,}381}{2} = 0$$

$$0{,}125\,T_{BF} = 0{,}315\,T_{CH}$$

$$T_{BF} = 2{,}527\,T_{CH} \quad (2)$$

Subst. (2) em (1):

$$2{,}527\,T_{CH} + T_{CH} = 40{,}05$$

$$\boxed{T_{CH} = 11{,}35\ N}$$

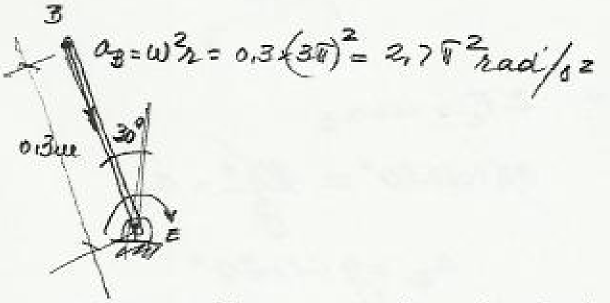
$$\boxed{T_{BF} = 28{,}69\ N}$$

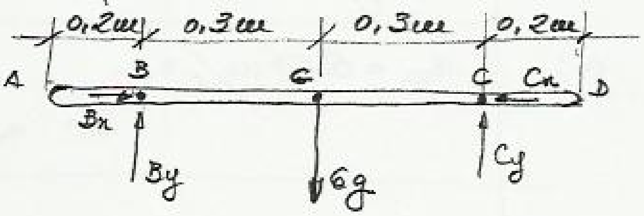
16.23-

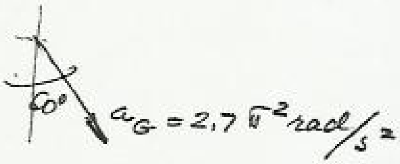
$\omega_{BE} = \omega_{CF} = 90\,rpm = \frac{90 \times \pi}{30} = 3\pi\ rad/s$

$\alpha = 0$

$\bar{a}_G = a_B = a_C$







$\Sigma M_G = 0$

$B_y = C_y$

$\Sigma F_y = m a_{Gy}$

$B_y - 6g + C_y = -6 \cdot 2.7\pi^2 \cos 60°$

$B_y + C_y = -21{,}08$

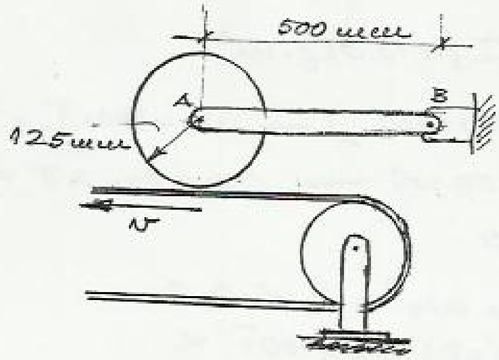
$2B_y = -21{,}08$

$B_y = -10{,}54N$

$$\boxed{\begin{array}{l} B_y = 10{,}54N \downarrow \\ C_y = 10{,}54N \downarrow \end{array}}$$

16.34-

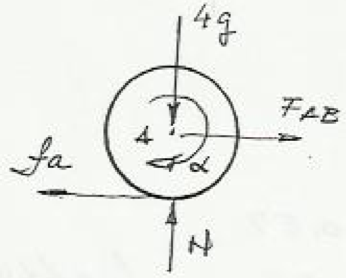
a)



$\bar{I}_A = \frac{1}{2} m r^2$

$m = 4\,kg$

$\mu_c = 0,40$



$\Sigma F_y = 0$

$N = 4g$

$f_a = \mu_c N$

$f_a = 0,4 \times 4g$

$f_a = 1,6g$

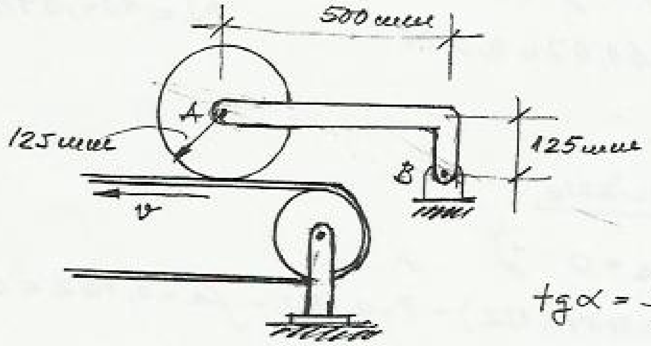
$\Sigma M_A = \bar{I}_A \alpha$

$f_a \times \cancel{r} = \frac{m r^{\cancel{2}}}{2} \alpha$

$1,6g = \frac{4 \times 0,125}{2} \alpha$

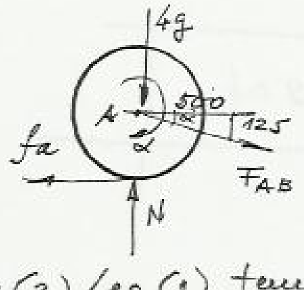
$$\boxed{\alpha = 62,78\ rad/s^2}$$

b)



$tg\alpha = \frac{125}{500}$ $\cos\alpha = 0,97$

$sen\alpha = 0,24$



$\Sigma F_x = 0$

$F_{AB} \cos\alpha = f_a$ (1)

$\Sigma F_y = 0$

$N - F_{AB}\, sen\alpha - 4g = 0$

$F_{AB}\, sen\alpha = N - 4g$ (2)

DIVIDINDO eq(2)/eq(1) temos:

$tg\alpha = \frac{N - 4g}{f_a}$

$f_a = \mu_c N$

$0,25 = \frac{N - 4g}{0,4N}$

$N = 43,60N$

$f_a = 17,44N$

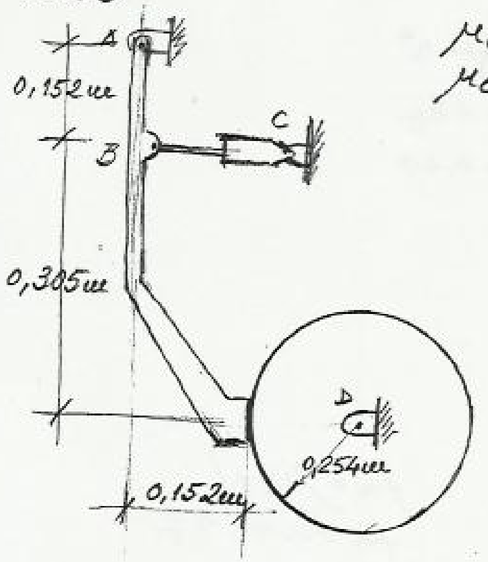
$\Sigma M_A = \bar{I}_A \alpha$

$f_a \times \cancel{r} = \frac{m r^{\cancel{2}}}{2} \alpha$

$\frac{17,44 \times 2}{4 \times 0,125} = \alpha$

$$\boxed{\alpha = 69,76\ rad/s^2}$$

16.38-



$\mu_e = 0,40$

$\mu_c = 0,30$

$I_D = 18,3\ kg.m^2$

$\omega_0 = 180\ rpm \Rightarrow \omega_0 = 180 \times \frac{\pi}{30} = 6\pi\ rad/s$

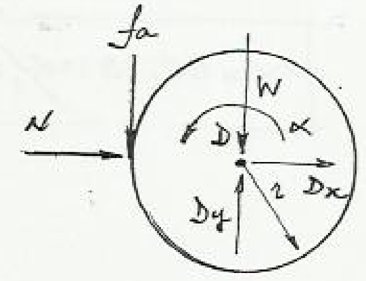
$\Delta\theta = 50\ rot \Rightarrow \Delta\theta = 50 \times 2\pi = 100\pi\ rad$

$\omega_f = 0$

$\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$

$0 = (6\pi)^2 + 2 \times 100\pi . \alpha$

$-\frac{36\pi}{200} = \alpha \qquad \alpha = 0,57\ rad/s^2$



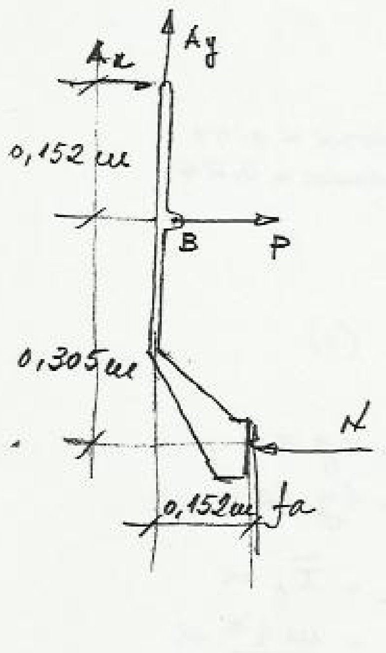
$\Sigma M_D = \bar{I}_D \alpha$

$fa \times r = 18,3 \times 0,57$

$fa = \frac{18,3 \times 0,57}{0,254} \qquad fa = 41,07\ N$

$fa = \mu_c \times N \qquad N = 136,89\ N$

$41,07 = 0,3\ N$



EQUILÍBRIO

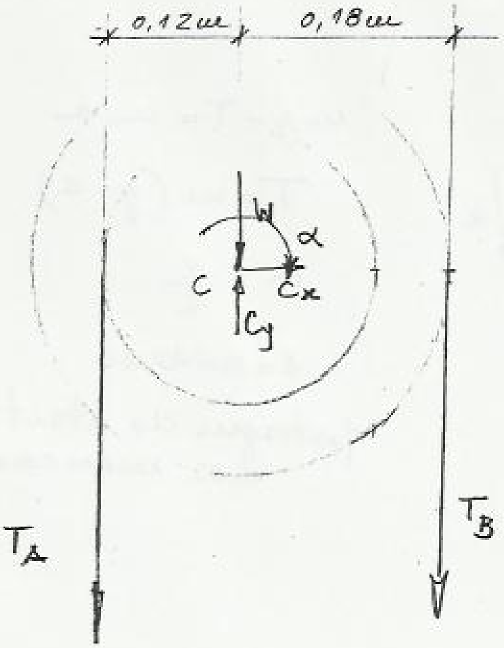
$\Sigma M_A = 0$

$N \times (0,305 + 0,152) - P \times 0,152 - fa \times 0,152 = 0$

$\frac{136,89 \times 0,457 - 41,07 \times 0,152}{0,152} = P$

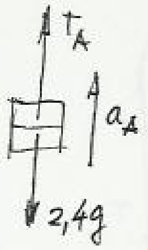
$\boxed{P = 368\ N}$

16.42 -



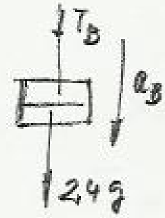
$a_A = 0,12\alpha$
$a_B = 0,18\alpha$

$\Sigma F = ma$



$T_A - 2,4g = 2,4 \cdot a_A$

$T_A = 2,4(g + 0,12\alpha)$



$2,4g - T_B = 2,4a_B$

$T_B = 2,4(g - 0,18\alpha)$

$I_c = m k_c^2$

$I_c = 6 \times 0,135^2$

$I_c = 0.109\ kgm^2$

a) $\Sigma M_C = \bar{I}_c \alpha$

$T_B \times 0,18 - T_A \times 0,12 = 0,1094 \times \alpha$

$2,4(g - 0,18\alpha) \times 0,18 - 2,4(g + 0,12\alpha) \times 0,12 = 0,1094\alpha$

$2,4g(0,18 - 0,12) - 2,4(0,18^2 + 0,12^2)\alpha = 0,1094\alpha$

$$\boxed{\alpha = 6,37\ rad/s^2}$$

b) $a_A = 0,12\alpha$

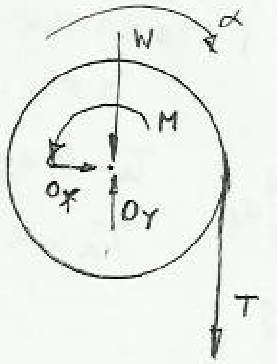
$a_A = 0.76\ m/s^2$

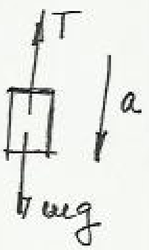
$v_A = v_0 + a_A t$

$v_A = 0,76 \times 2,5$

$$\boxed{v_A = 1,91\ m/s}$$

16.44-





$mg - T = ma$

$T = m(g-a)$

$\alpha = \frac{a}{r}$

$r = 0{,}610\,m$

M ⇒ torque do atrito nos mancais.

$\Sigma M_O = \bar{I}\alpha$

$T \times r - M = \bar{I}\alpha$

$m(g-a)\times r - M = \bar{I}\alpha$

$m(g-a)\times r - M = \bar{I}.\frac{a}{r}$

1º caso: $m_1 = \frac{89N}{g}$ $\Delta y = 3{,}05\,m$ $t = 4{,}6\,s.$

$\Delta y = \frac{1}{2}at^2$ $a_1 = 0{,}29\,m/s^2$

2º caso: $m_2 = \frac{178N}{g}$ $\Delta y = 3{,}05\,m$ $t = 3{,}1\,s$

$\Delta y = \frac{1}{2}at^2$ $a_2 = 0{,}63\,m/s^2$

P/ A PRIMEIRA SITUAÇÃO:

$\frac{89}{g}(g - 0{,}29)\times 0{,}610 - M = \bar{I}\,\frac{0{,}29}{0{,}610} \Rightarrow 52{,}69 - M = 0{,}475\,\bar{I}\ (1)$

P/ A SEGUNDA SITUAÇÃO:

$\frac{178}{g}(g - 0{,}63)\times 0{,}610 - M = \bar{I}\,\frac{0{,}63}{0{,}610} \longrightarrow 101{,}61 - M = 1{,}033\,\bar{I}\ (2)$

FAZENDO eq (2) − eq (1):

$101{,}61 - 52{,}69 = (1{,}033 - 0{,}475)\bar{I}$

$$\boxed{\bar{I} = 87{,}67\ kg.m^2}$$

16.45 - DO PROBLEMA 16.44

$$m(g-a)\times r - M = \bar{I}\,\frac{a}{r}$$

DESPREZANDO O ATRITO $\Rightarrow M = 0$

$$\bar{I} = m_v \bar{k}^2$$

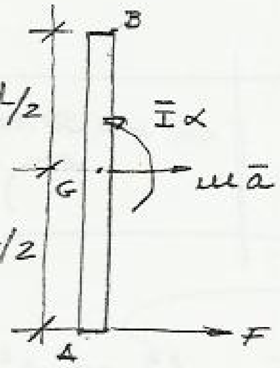
$$m(g-a)\times r = m_v \bar{k}^2 \frac{a}{r}$$

$$mgr - mar = m_v \bar{k}^2 \frac{a}{r}$$

$$mgr^2 = (m_v \bar{k}^2 + m r^2)\,a$$

$$\boxed{a = \frac{m g r^2}{(m_v \bar{k}^2 + m r^2)}}$$

16.59 -



L = 900 mm.

$$I_G = \frac{mL^2}{12}$$

m = 1,25 kg

L = 900 mm

F = 3 N

$$\Sigma F_x = m a_x$$

$$F = m\bar{a}$$

$$3 = 1{,}25\,\bar{a}$$

$$\boxed{\bar{a} = 2{,}4\ m/s^2 \rightarrow}$$

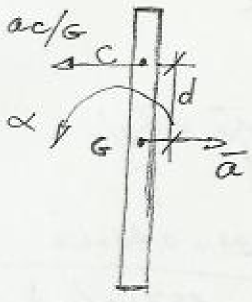
$$\Sigma M_G = \bar{I}\alpha$$

$$F \times \frac{L}{2} = \frac{mL^2}{12}\alpha$$

$$3 \times 0{,}45 = \frac{1{,}25 \times 0{,}9^2}{12}\alpha$$

$$\boxed{\alpha = 16\ rad/s^2}$$

PONTO $\underline{C}$ DE ACELERAÇÃO NULA



$$\vec{a}_C = \vec{a}_G + \vec{a}_{C/G}$$

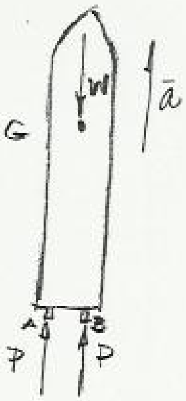
$$a_C = \bar{a} - \alpha d$$

$$a_C = 0$$

$$0 = 2{,}4 - 16 \times d$$

$$\boxed{d = 0{,}15\ m}$$

16.61- COM OS DOIS MOTORES FUNCIONANDO



$W = 1{,}11 \times 10^5\ N$

$\bar{a} = 13{,}7\ m/s^2$

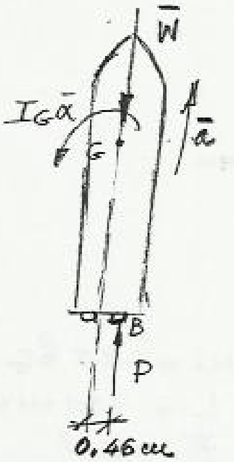
$2P - W = m\,\bar{a}$

$2P - 1{,}11 \times 10^5 = \frac{1{,}11 \times 10^5}{9{,}81} \times 13{,}7$

$2P = 266.015\ N$

$P = 1{,}33 \times 10^5\ N$

COM SOMENTE O MOTOR B FUNCIONANDO.



$P - W = m\,\bar{a}$

$1{,}33 \times 10^5 - 1{,}11 \times 10^5 = \frac{1{,}11 \times 10^5}{g}\,\bar{a}$

$$\boxed{\bar{a} = 1{,}95\ m/s^2 \uparrow}$$

$\bar{I}_G = \frac{m l^2}{12}$ $\quad \bar{I}_G = \frac{1{,}11 \times 10^5 \times 14{,}6^2}{9{,}81 \times 12} = 2{,}01 \times 10^5\ kg\,m^2$

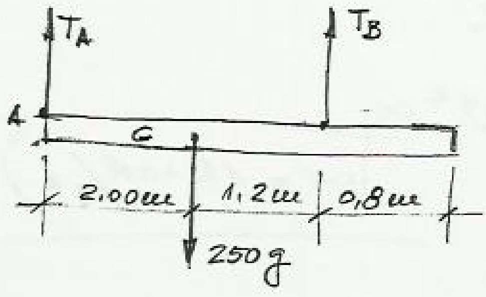
$\Sigma M_G = I_G\,\alpha$

$P \times 0{,}46 = \bar{I}_G\,\alpha$

$1{,}33 \times 10^5 \times 0{,}46 = 2{,}01 \times 10^5\,\alpha$

$$\boxed{\alpha = 0{,}30\ rad/s^2 \curvearrowleft}$$

16.62-



$T_A = 1000\ N$

$T_B = 1800\ N$

$\bar{I} = \frac{m l^2}{12} = \frac{250 \times 4^2}{12} = 333{,}33\ kg\,m^2$

$\Sigma F_y = m\,a_y$

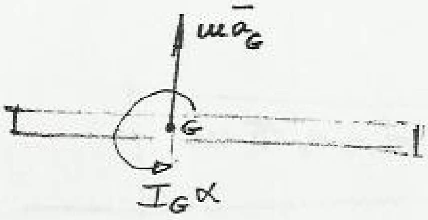
$T_B + T_A - 250g = 250 \cdot \bar{a}_G$

$\bar{a}_G = 1{,}39\ m/s^2 \uparrow$

$\Sigma M_G = I_G\,\alpha$

$T_B \times 1{,}2 - T_A \times 2{,}00 = \bar{I}\,\alpha$

$\alpha = 0{,}48\ rad/s$ ↻



$\vec{a}_A = \vec{a}_G + a_{A/G}$

$\vec{a}_B = \vec{a}_G + \vec{a}_{B/G}$

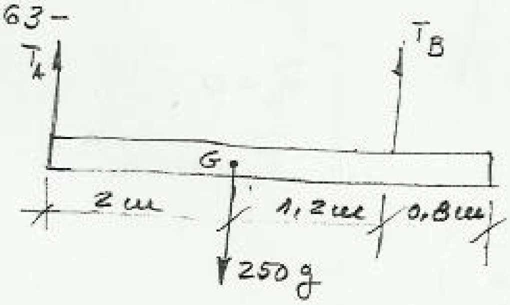
$a_A = 1{,}39 - 0{,}48 \times 2$

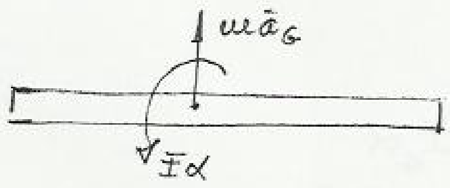
$$\boxed{a_A = 0{,}43\ m/s^2 \uparrow}$$

$a_B = 1{,}39 + 0{,}48 \times 1{,}2$

$$\boxed{a_B = 1{,}97\ m/s^2 \uparrow}$$

16.63-





$\bar{I} = 333,33 \ kg \cdot m^2$

$a_B = 0,5 \ m/s^2 \uparrow$

$a_A = 2 \ m/s^2 \uparrow$

$\vec{a}_A = \vec{a}_G + \vec{a}_{A/G}$ $\quad$ $\vec{a}_B = \vec{a}_G + \vec{a}_{B/G}$.

$\underset{\uparrow}{2} = \underset{\uparrow}{a_G} - \underset{\downarrow}{2\alpha}$ (1) $\quad$ $\underset{\uparrow}{0,5} = \underset{\uparrow}{a_G} + \underset{\uparrow}{1,2\alpha}$ (2)

Fazendo eq (1) - eq (2):

$2 - 0,5 = -2\alpha - 1,2\alpha$ $\quad$ $\alpha = -0,47$

$\boxed{\alpha = 0,47 \ rad/s^2}$

$2 = a_G - 2\alpha$.

$2 = a_G - (-0,47) \times 2$ $\quad$ $\boxed{a_G = 1,06 \ m/s^2 \uparrow}$

$\Sigma F_y = m a_y$

$T_A + T_B - 250g = 250 \cdot 1,06$

$T_A + T_B = 2.717,5 \ N$ (3)

$\Sigma M_G = I_G \alpha$

$2T_A - 1,2T_B = 333,33 \times 0,47$

$2T_A - 1,2T_B = 156,67$ (4)

Subst (3) em (4):

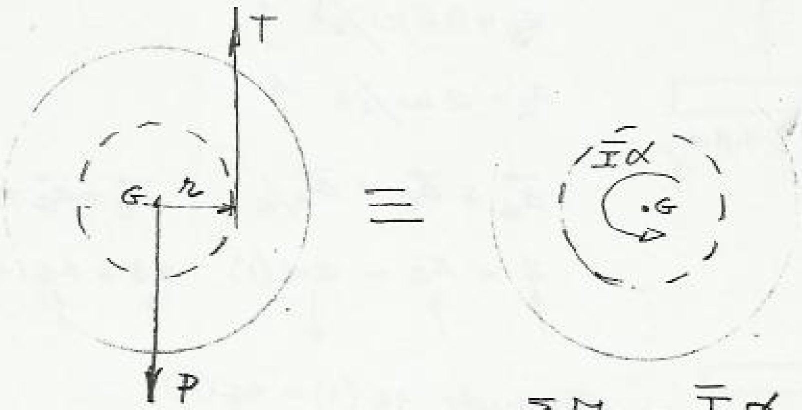
$2(2.717,5 - T_B) - 1,2T_B = 156,67$.

$-3,2T_B = -5.278,33$

$\boxed{T_B = 1.649,48 \ N}$

$\boxed{T_A = 1.068,02 \ N}$

16.66.



$\bar{a}_G = 0$

$\bar{I}_G = m\bar{k}^2$

$\Sigma F_y = m a_y$

$T - P = 0$

$\boxed{T = P}$

$\Sigma M_G = \bar{I}_G \alpha$

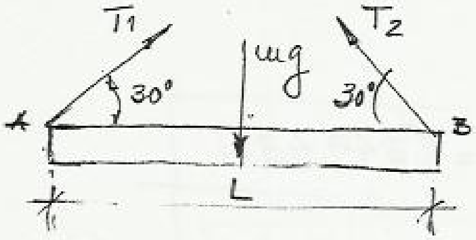
$T \cdot r = m \bar{k}^2 \cdot \alpha$

$\cancel{P} \cdot r = \frac{\cancel{P}}{g} \bar{k}^2 \cdot \alpha$

$\boxed{\alpha = g r / \bar{k}^2}$

16.71

$\bar{I}_G = \frac{mL^2}{12}$



$\Sigma F_y = 0$

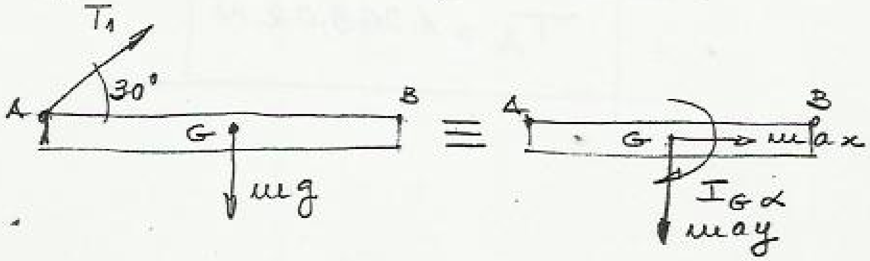
$T_1 \operatorname{sen} 30° + T_2 \operatorname{sen} 30° = mg$

$2 T_1 \operatorname{sen} 30° = mg$

$T_1 = mg$

$\Sigma F_x = 0$

$T_1 = T_2$



$\Sigma F_x = m\bar{a}_x$

$T_1 \cos 30° = m\bar{a}_x$

$\cancel{m} g \frac{\sqrt{3}}{2} = \cancel{m}\bar{a}_x$

$\bar{a}_x = \frac{\sqrt{3}}{2} g \longrightarrow$

$\Sigma F_y = m\bar{a}_y$

$mg - mg \operatorname{sen} 30° = m\bar{a}_y$

$\cancel{m} g - \frac{\cancel{m} g}{2} = \cancel{m}\bar{a}_y$

$\bar{a}_y = g/2 \downarrow$

$\Sigma M_G = I_G \alpha$

$T_1 \operatorname{sen} 30° \times \frac{L}{2} = \frac{mL^2}{12}\alpha$

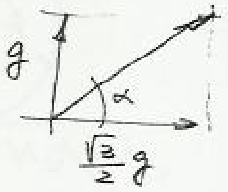
$\cancel{m} g \times \frac{1}{2} \times \frac{\cancel{L}}{2} = \frac{\cancel{m} L^{\cancel{2}}}{12}\alpha$

$\boxed{\alpha = \frac{3g}{L}}$

16.71 (cont.)

$$\vec{a}_A = \vec{a}_G + \vec{a}_{A/G}$$

$$\vec{a}_A = \left(\underset{\longrightarrow}{\frac{\sqrt{3}}{2} g} + \underset{\downarrow}{g/2} \right) + \underset{\uparrow}{\alpha \cdot \frac{L}{2}}$$



Comp $\longrightarrow$:

$$(a_A)_x = \frac{\sqrt{3}}{2} g \longrightarrow$$

$$a_A = \left(\sqrt{\left(\frac{\sqrt{3}}{2}\right)^2 + 1^2} \right) g$$

$$tg\alpha = \frac{1}{\frac{\sqrt{3}}{2}}$$

Comp $\uparrow$

$$(a_A)_y = -g/2 + \frac{3g}{\cancel{L}} \cdot \frac{\cancel{L}}{2}$$

$$\boxed{a_A = 1{,}32 g \ m/s^2 \quad \nearrow 49{,}11^\circ}$$

$$\alpha = 49{,}11'$$

$$(a_A)_y = g \uparrow$$

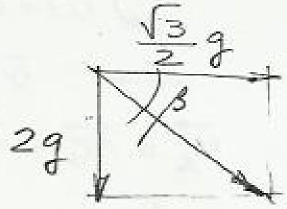
$$\vec{a}_B = \vec{a}_G + \vec{a}_{B/G}$$

$$\vec{a}_B = \left(\underset{\longrightarrow}{\frac{\sqrt{3}}{2} g} + \underset{\downarrow}{g/2} \right) + \underset{\downarrow}{\alpha \frac{L}{2}}$$

$$a_B = \left(\sqrt{\left(\frac{\sqrt{3}}{2}\right)^2 + 2^2} \right) g$$

Comp $\rightarrow$:

$$(a_B)_x = \frac{\sqrt{3}}{2} g \longrightarrow$$



Comp $\uparrow$;

$$(a_B)_y = -g/2 - \frac{3g}{\cancel{L}} \cdot \frac{\cancel{L}}{2}$$

$$tg\beta = \frac{2}{\sqrt{3}/2}$$

$$(a_B)_y = -2g$$

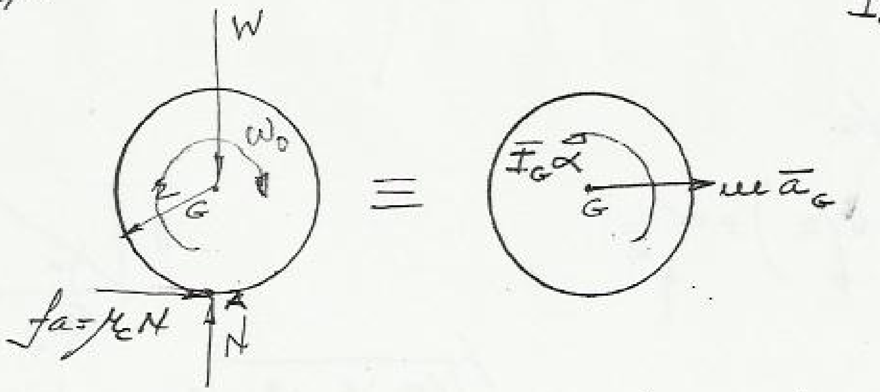
$$\beta = 66{,}59^\circ$$

$$(a_B)_y = 2g \downarrow$$

$$\boxed{a_B = 2{,}18 g \ m/s^2 \quad \searrow 66{,}59^\circ}$$

16.74 -

$$\bar{I}_G = \frac{2}{5} m r^2$$



$\Sigma F_y = 0 \quad N = W \quad f_a = \mu_c N \rightarrow f_a = \mu_c W$

$\Sigma F_x = m a_x$

$f_a = m \bar{a}_G \qquad \mu_c \cancel{W} = \frac{\cancel{W}}{g} \bar{a}_G \qquad \boxed{\bar{a}_G = \mu_c g \rightarrow}$

$\Sigma M_G = \bar{I}_G \alpha$

$f_a \times \cancel{r} = \frac{2}{5} m r^{\cancel{2}} \alpha$

$\mu_c \cancel{W} = \frac{2}{5} \frac{\cancel{W}}{g} r \alpha \qquad \boxed{\alpha = \frac{5}{2} \mu_c \frac{g}{r} \circlearrowright}$

CINEMÁTICA:

$\circlearrowright + \quad \omega = \omega_0 - \alpha t = \omega_0 - \frac{5}{2} \mu_c \frac{g}{r} t \quad (1)$

$\xrightarrow{+} \quad \bar{v} = \bar{a} t = \mu_c g t = v_G \quad (2)$

$\vec{v}_A = \vec{v}_G + \vec{v}_{A/G}$

$v_A = \mu_c g t - \omega r$

$v_A = \mu_c g t - \left(\omega_0 - \frac{5}{2} \mu_c \frac{g}{r}\right) r$

$v_A = \frac{7}{2} \mu_c g t - \omega_0 r$

a) INÍCIO DO ROLAMENTO $v_A = 0 \rightarrow t = t_1$

$0 = \frac{7}{2} \mu_c g t_1 - \omega_0 r$

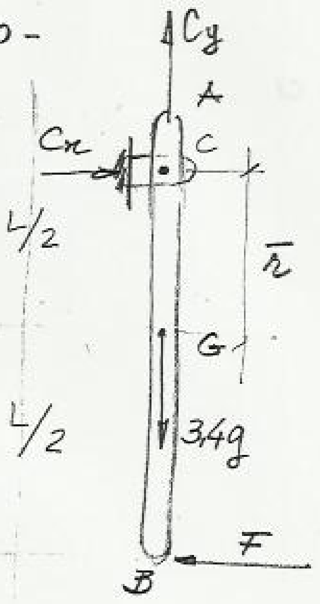
$$\boxed{t_1 = \frac{2}{7} \frac{\omega_0 r}{\mu_c g}}$$

b) SUBST. t_1 NAS EQS. (1) E (2) TEMOS:

$\omega = \omega_0 - \frac{5}{\cancel{2}} \cancel{\mu_c} \frac{\cancel{g}}{\cancel{r}} \times \frac{\cancel{2}}{7} \frac{\omega_0 \cancel{r}}{\cancel{\mu_c g}} \qquad \boxed{\omega = \frac{2}{7} \omega_0 \circlearrowright}$

$\bar{v} = \cancel{\mu_c g} \times \frac{2}{7} \frac{\omega_0 r}{\cancel{\mu_c g}} \qquad \boxed{\bar{v} = \frac{2}{7} \omega_0 r \rightarrow}$

16.80 -



$\bar{r} = \frac{L}{4}$

$L = 0{,}914\,m$

$m = 3{,}4\,kg$

$F = 11{,}1\,N$

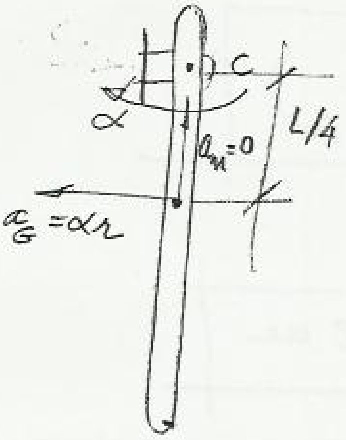
a) $M_C = I_C \alpha$

$F \times \left(\frac{L}{2} + \frac{L}{4}\right) = \left(\frac{1}{12} m L^2 + m \times \left(\frac{L}{4}\right)^2\right) \cdot \alpha$

$F \times \frac{3}{4} \cancel{L} = \frac{28 m}{192} L^{\cancel{2}} \times \alpha$

$11{,}1 \times \frac{3}{4} = \frac{28 \times 3{,}4}{192} \times 0{,}914\, \alpha$

$\boxed{\alpha = 18{,}37\, rad/s}$



$\Sigma F_x = m a_x$

$F - C_x = m \cdot \alpha \bar{r}$

$11{,}1 - C_x = 3{,}4 \times 18{,}37 \times 0{,}229$

$C_x = -3{,}20\,N$

$\boxed{C_x = 3{,}20\,N \rightarrow}$

$\Sigma F_y = 0$

$-3{,}4g + C_y = 0$

$C_y = 3{,}4g$

$\boxed{C_y = 33{,}35\,N \uparrow}$

16.81 - DO PROBLEMA ANTERIOR:

$$F - C_x = m \alpha \bar{r} \qquad C_x = 0$$

$$F = m \alpha \bar{r} \qquad \alpha = \frac{F}{m \bar{r}}$$

$$\Sigma M_O = I_O \alpha$$

$$F \times \left(\frac{L}{2} + \bar{r} \right) = m \left(\frac{L^2}{12} + \bar{r}^2 \right) \alpha$$

$$\cancel{F} \times \left(\frac{L}{2} + \bar{r} \right) = \cancel{m} \left(\frac{L^2}{12} + \bar{r}^2 \right) \cdot \frac{\cancel{F}}{\cancel{m} \bar{r}}$$

$$\frac{L}{2} \bar{r} + \cancel{\bar{r}^2} = \frac{L^2}{12} + \cancel{\bar{r}^2}$$

$$\frac{\cancel{L}}{\cancel{2}} \bar{r} = \frac{L^{\cancel{2}}}{\cancel{12}_6} \qquad \boxed{\bar{r} = \frac{L}{6}}$$

$$\alpha = \frac{F}{m \bar{r}} \qquad \boxed{\alpha = \frac{6F}{mL}}$$

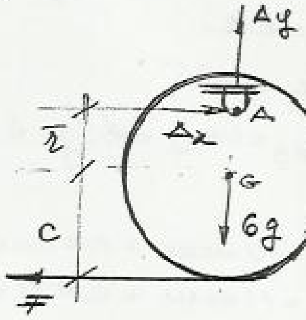
P/ $L = 0{,}914\ m$
$m = 3{,}4\ kg$
$F = 11{,}1\ N$

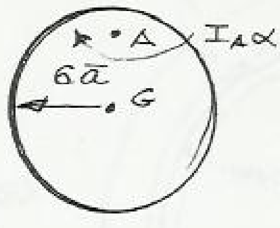
$$\boxed{\bar{r} = 0{,}152\ m}$$

$$\boxed{\alpha = 21{,}43\ rad/s^2}$$

16.82-

$c = 160\ mm$
$m = 6\ kg$
$F = 20\ N$
$\bar{r} = \frac{3}{4} c = 120\ mm$





a) $M_A = I_A \alpha$

$M_A = \left(\frac{mc^2}{2} + m\bar{r}^2\right)\alpha$

$F(\bar{r}+c) = m\left(\frac{c^2}{2} + \bar{r}^2\right)\alpha$

$$\boxed{\alpha = 34{,}31\ rad/s^2}$$

b) $\Sigma F_y = 0$

$A_y = 6g \rightarrow \boxed{A_y = 58{,}86N \uparrow}$

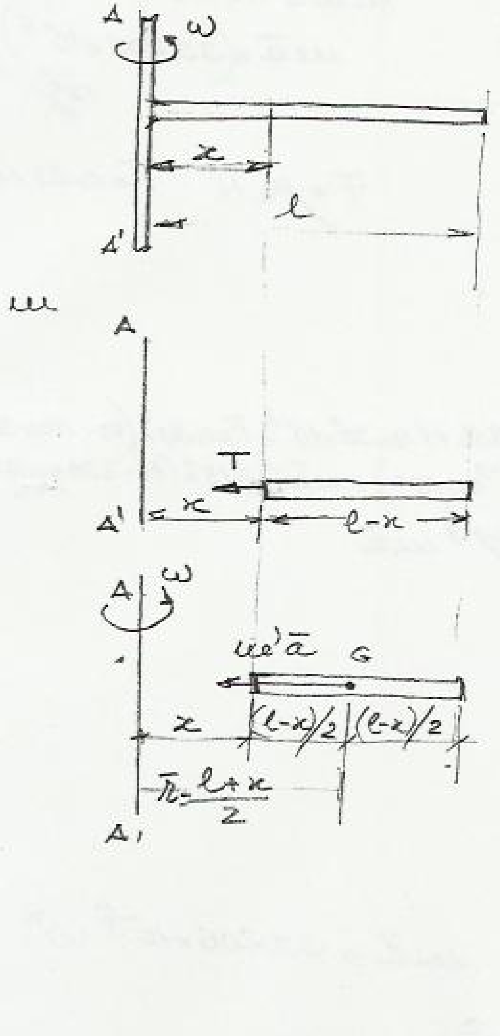
$\Sigma F_x = m\bar{a}_x$

$F - A_x = 6 \times (\alpha \times \bar{r})$

$A_x = F - 6 \times (\alpha \times \bar{r})$

$A_x = -4{,}70 \rightarrow \boxed{A_x = 4{,}70N \rightarrow}$

16.85-



$\omega = cte.$

$\frac{m'}{l-x} = \frac{m}{l} \qquad m' = m\frac{l-x}{l}$

$\bar{a} = a_n = \omega^2 \bar{r}$

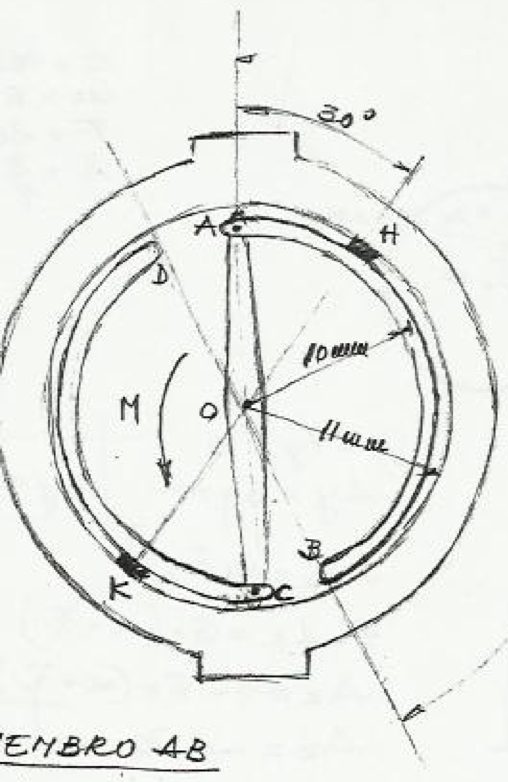
$\Sigma F_x = m\bar{a}_x$

$T = m'\bar{a}$

$T = m\frac{l-x}{l} \cdot \omega^2 \frac{l+x}{2}$

$$\boxed{T = \frac{m\omega^2}{2}\left(l^2 - x^2\right)}$$

16.39-



150°

$\omega = 3000\ rpm = 3000\,\frac{\pi}{30} = 100\pi\ rad/s$

$\omega = cte.$

$\mu_c = 0{,}35$

$m_{AB} = m_{CD} = 4{,}5g = 4{,}5\times10^{-3}\,kg$

$r = 10\,mm = 0{,}01\,m$

$OH = 11\,mm = 0{,}011\,m$

$2\beta = 150°$

$\beta = 75° \quad \beta = \frac{75\pi}{180}\,rad$

$\bar{r} = r\,\frac{sen\,\beta}{\beta} \rightarrow \bar{r} = 0{,}0074\,m$

$\bar{r} = 7{,}38\times10^{-3}\,m$

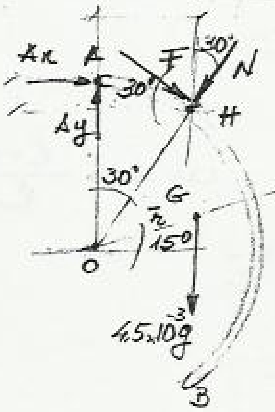
$\bar{a} = \omega^2\,\bar{r}$

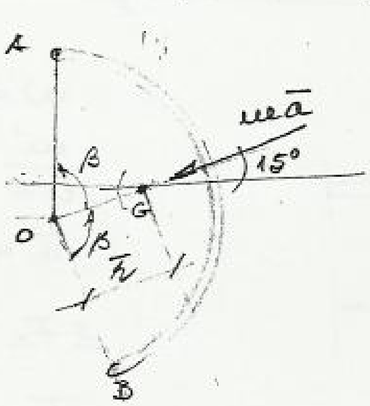
$m\bar{a} = 4{,}5\times10^{-3}\times\bar{r}\cdot\omega^2$

$m\bar{a} = (33{,}206\times10^{-6})\,\omega^2 \quad \cancel{15°}$

$F = \mu_c N \quad F = 0{,}35N$

MEMBRO AB





$\Sigma M_A = (\Sigma M_A)\,ef.$

$4{,}5\cdot9{,}81\times10^{-3}\times7{,}38\times10^{-3}\cos15° + N\,sen\,30°\times(10-11\cos30°)\times10^{-3} + F\,sen\,30°\times11\,sen\,30°\times10^{-3} - F\cos30°\,(10-11\cos30°)\times10^{-3} +$
$+ N\cos30°\cdot11\,sen\,30°\times10^{-3} = m\bar{a}\,(sen\,15°\times7{,}38\times10^{-3}\cos15°) + m\bar{a}\,(\cos15°\times(10-7{,}38\,sen\,15°)\times10^{-3})$

$5N\times\cancel{10^{-3}} + 2{,}3397F\times\cancel{10^{-3}} + 0{,}3258\times\cancel{10^{-3}} = 9{,}659\times\cancel{10^{-3}}\,m\bar{a}$

$F = 0{,}35N \quad N = \frac{F}{0{,}35}$

$5\times\frac{F}{0{,}35} + 2{,}3397F + 0{,}3258 = 9{,}659\,m\bar{a}$

$16{,}6254F = 9{,}659\,m\bar{a} - 0{,}3258$

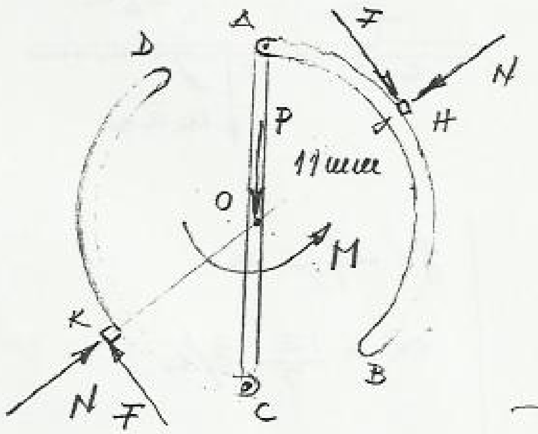
$F = 0{,}58\,m\bar{a} - \underbrace{0{,}02}_{\to0}$

DESPREZANDO O 2º MEMBRO

$F = 0{,}58\,m\bar{a} \qquad m\bar{a} = 33{,}206\times10^{-6}\cdot\omega^2$

$F = 19{,}292\times10^{-6}\,\omega^2$

CONSIDERANDO AMBOS OS MEMBROS:



$\alpha = 0 \qquad \bar{a} = 0$

$\Sigma M_0 = 0$

$M - 2F \times 11 \times 10^{-3} = 0$

$M = 2F \times 11 \times 10^{-3}$

$M = 2 \times 19{,}292 \times 11 \times 10^{-9} \omega^2$

$\boxed{M = 424{,}42 \times 10^{-9} \omega^2}$

P/ $\omega = 100\pi$ rad/s.

$M = 0{,}042$ Nm $\quad \boxed{M = 41{,}89 \times 10^{-3} \text{ Nm}}$

$\boxed{M = 41{,}89 \text{ N.mm}}$

16.90. DO PROBLEMA ANTERIOR:

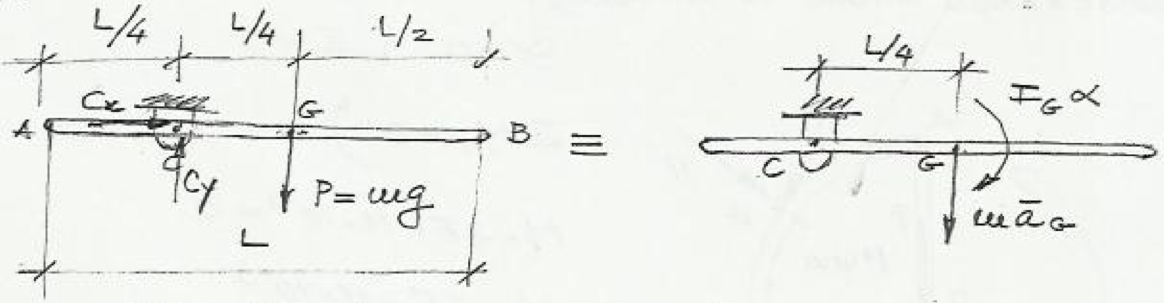
$M = 424{,}42 \times 10^{-9} \omega^2$ Nm

$M = 50$ Nmm $= 50 \times 10^{-3}$ Nm.

$\dfrac{50 \times 10^{-3}}{424{,}42 \times 10^{-9}} = \omega^2 \qquad \boxed{\omega = 343{,}23 \text{ rad/s}}$

$\boxed{\omega = 3.278 \text{ rpm}}$

16.91 -



$$\Sigma M_C = I_C \alpha$$

$$P \times L/4 = \left(I_G + m\left(\frac{L}{4}\right)^2\right)\alpha$$

$$\cancel{m}g\, L/4 = \left(\frac{\cancel{m}L^2}{12} + \frac{\cancel{m}L^2}{16}\right)\alpha$$

$$g\frac{\cancel{L}}{\cancel{4}} = L^{\cancel{2}}\left(\frac{1}{\cancel{12}_{3}} + \frac{1}{\cancel{16}_{4}}\right)\alpha$$

$$g = \frac{7L}{12}\alpha$$

$$\alpha = \frac{12}{7} g/L$$

a) $a_B = CB \times \alpha$

$$a_B = \left(L - \frac{L}{4}\right) \times \frac{12}{7}\frac{g}{L} = \frac{3}{\cancel{4}}\cancel{L} \times \frac{\cancel{12}^{3}}{7}\frac{g}{\cancel{L}}$$

$$\boxed{a_B = \frac{9}{7} g \downarrow}$$

b) $\Sigma F_x = m\, a_{G_x} = 0$

$$\boxed{C_x = 0}$$

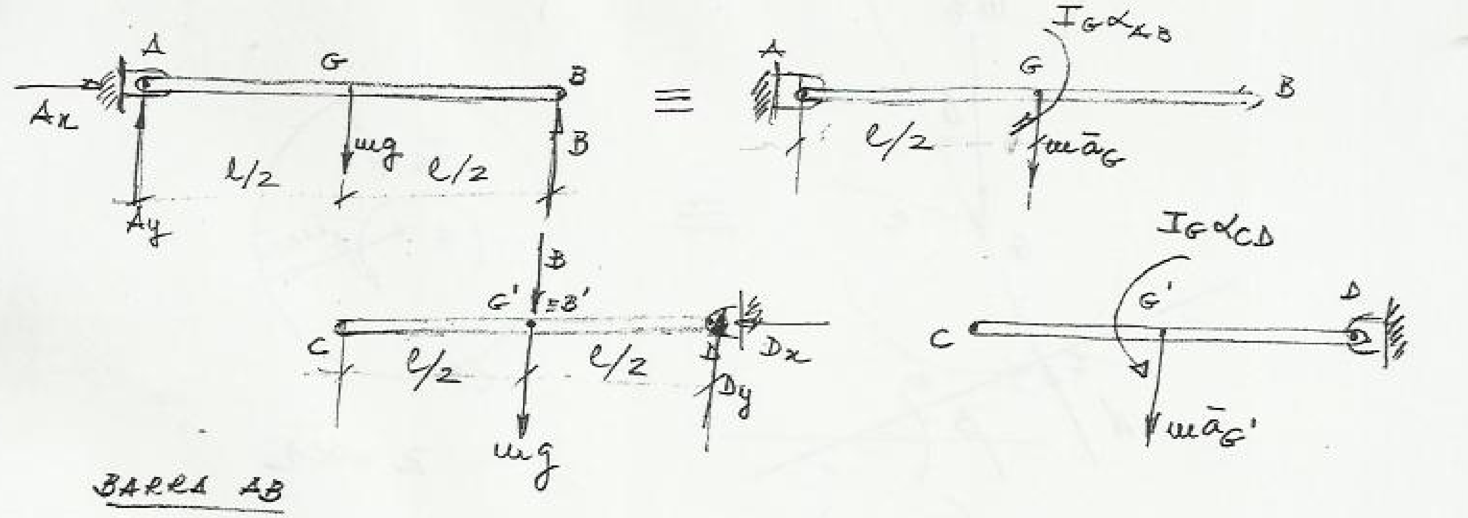
$$\Sigma F_y = m a_{Gy} \Longrightarrow P - C_y = m\bar{a}_G = m.\alpha \times \frac{L}{4}$$

$$mg - C_y = m\frac{\cancel{L}}{4} \times \frac{\cancel{12}}{7}\frac{g}{\cancel{L}}$$

$$C_y = mg - \frac{3}{7} mg \qquad C_y = \frac{4}{7} mg$$

$$\boxed{C_y = \frac{4}{7} P \uparrow}$$

16.101-



BARRA AB

$\omega_{AB} = 0$

$\Sigma M_A = I_A \alpha_{AB}$ (+)

$$mg\frac{l}{2} - Bl = \left[\frac{ml^2}{12} + m\left(\frac{l}{2}\right)^2\right]\alpha_{AB} \qquad B = \frac{mg}{2} - \frac{ml}{3}\alpha_{AB} \quad (1)$$

BARRA CD

$\omega_{CD} = 0$

$\Sigma M_D = I_D \alpha_{CD}$ (+)

$$mg\frac{l}{2} + B\frac{l}{2} = \left[\frac{ml^2}{12} + m\left(\frac{l}{2}\right)^2\right]\alpha_{CD} \qquad B = 2\left(\frac{ml}{3}\alpha_{CD} - \frac{mg}{2}\right) \quad (2)$$

FAZENDO EQ (1) = EQ. (2)

$$\frac{\cancel{m}g}{2} - \frac{\cancel{m}l}{3}\alpha_{AB} = 2\left(\frac{\cancel{m}l}{3}\alpha_{CD} - \frac{\cancel{m}g}{2}\right)$$

$$\frac{g}{2} + g = \left(\frac{2}{3}\alpha_{CD} + \frac{1}{3}\alpha_{AB}\right)l$$

$$2\alpha_{CD} + \alpha_{AB} = \frac{9}{2}\frac{g}{l} \quad (3)$$

CINEMÁTICA:

$a_B = a_{B'}$

$$\alpha_{AB} \times l = \alpha_{CD} \times \frac{l}{2} \Rightarrow \alpha_{AB} = \frac{\alpha_{CD}}{2} \quad (4)$$

SUBST. (4) EM (3):

$$2\alpha_{CD} + \frac{\alpha_{CD}}{2} = \frac{9}{2}\frac{g}{l}$$

$$\frac{5}{2}\alpha_{CD} = \frac{9}{2}g/l$$

$$\alpha_{CD} = \frac{9}{5}g/l$$

$$\alpha_{CD} = 1{,}8g/l \quad (5)$$

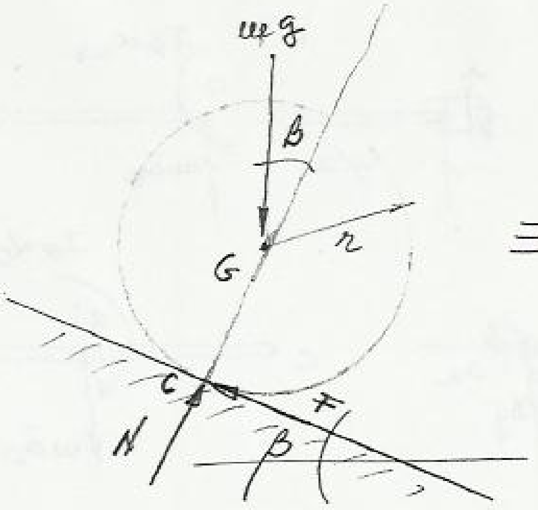
a) $a_C = \alpha_{CD} \times l$ $\boxed{a_C = 1{,}8g\downarrow}$

b) SUBST. $\alpha_{CD} = 1{,}8g/l$ EM (2) TEMOS:

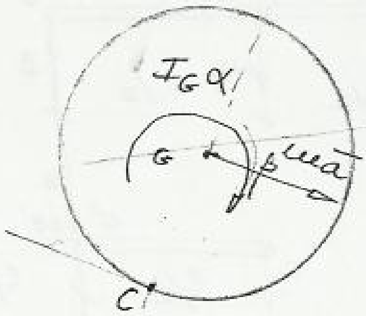
$$B = 2\left(\frac{ml}{3} \times \frac{1{,}8g}{l} - \frac{mg}{2}\right)$$

$$B = \left(\frac{3{,}6}{3} - 1\right)mg \qquad \boxed{B = 0{,}2mg\uparrow}$$

16.107-



$\equiv$



$\bar{a} = \alpha r$

$\Sigma M_c = I_c \alpha$

$\Sigma M_c = (\Sigma M_c)ef.$

$mg \operatorname{sen}\beta \times r = I_G\alpha + m\bar{a} \times r$

$\cancel{m}g \operatorname{sen}\beta \times r = (\cancel{m}\bar{k}^2 + \cancel{m}r^2)\alpha$

$$\alpha = \frac{r \operatorname{sen}\beta g}{\bar{k}^2 + r^2}$$

$\bar{a} = \alpha r$

$$\boxed{\bar{a} = \frac{r^2}{\bar{k}^2 + r^2} g \operatorname{sen}\beta}$$

16.115-

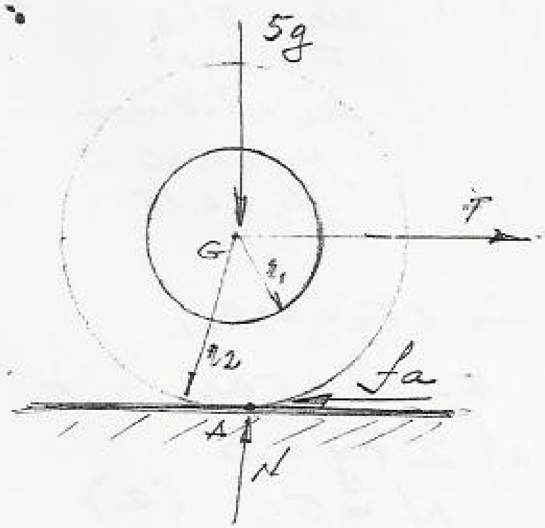


DIAGRAMA DO CORPO LIVRE

|||

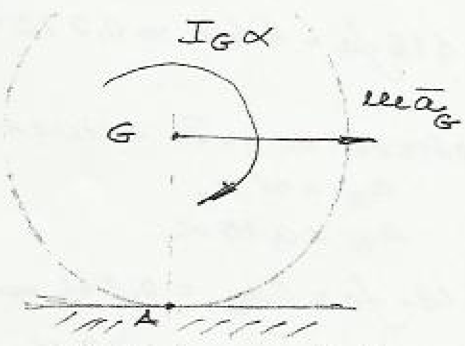


DIAGRAMA DAS FORÇAS RESULTANTES

$r_1 = 80\,mm$

$r_2 = 160\,mm$

$m = 5\,kg$

$k_G = 120\,mm$

$F = 18\,N$

$\mu_e = 0{,}20$

$\mu_c = 0{,}15$

$\Sigma F_x = m\,a_{Gx}$

$F - fa = 5 a_G \quad (1)$

$\Sigma F_y = 0$

$N = 5g \quad (2)$

$\Sigma M_G = I_G\,\alpha$

$fa \times 0{,}16 = 5 \times 0{,}12^2 \alpha \quad (3)$

1) ASSUMINDO A HIPÓTESE DE NÃO DESLIZAMENTO

$a_G = \alpha r \qquad a_G = 0{,}16\,\alpha$

$18 - fa = 5 \times 0{,}16\,\alpha$

$0{,}16\,fa = 0{,}072\alpha \Rightarrow \alpha = 2{,}22\,fa$

$18 - fa = 0{,}8 \times 2{,}22\,fa$

$fa = 6{,}48\,N \qquad fa_{max} = \mu_e N = 0{,}2 \times 5 \times 9{,}81 = 9{,}81\,N$

$fa < fa_{max}$

O CORPO NÃO DESLIZA.

$\alpha = 2{,}22\,fa \qquad \alpha = 2{,}22 \times 6{,}48$

$\boxed{\alpha = 14{,}4\,rad/s^2}$

$a_G = 0{,}16\,\alpha \qquad \boxed{a_G = 2{,}30\,m/s^2 \longrightarrow}$

16.116 -

$r_1 = 80\,mm$
$r_2 = 160\,mm$
$m = 5\,kg$
$F = 18\,N$
$k_G = 120\,mm$
$\mu_e = 0{,}20$
$\mu_c = 0{,}15$

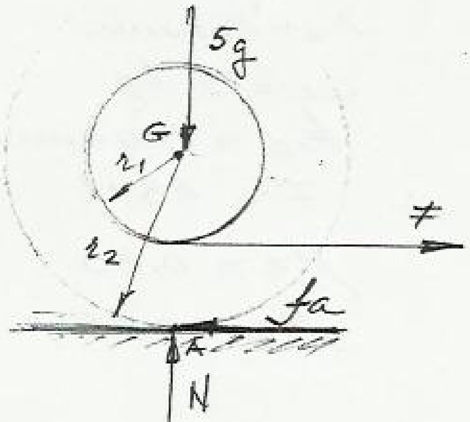


DIAGRAMA DO CORPO LIVRE

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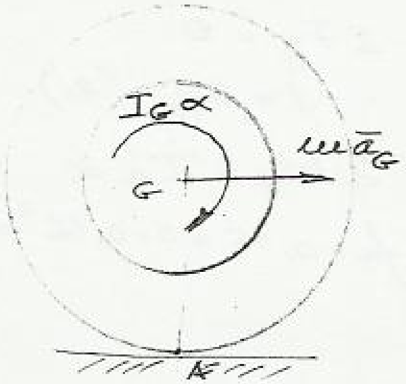


DIAGRAMA DAS FORÇAS RESULTANTES

$\xrightarrow{+} \Sigma F_x = m a_{G_x}$

$F - fa = 5 a_G \quad (1)$

$+\uparrow \Sigma F_y = 0$

$N = 5g \quad (2)$

$(+) \Sigma M_G = I_G \alpha$

$fa \times r_2 - F \times r_1 = 5 \times 0{,}12^2 \alpha$

$0{,}16 fa - 1{,}44 = 0{,}072 \alpha \quad (3)$

1) HIPÓTESE DE NÃO DESLIZAMENTO

$a_G = \alpha r$

$a_G = 0{,}16 \alpha$

$18 - fa = 5 a_G = 0{,}8 \alpha \Rightarrow \alpha = \frac{18 - fa}{0{,}8}$

$0{,}16 fa - 1{,}44 = 0{,}072 \alpha$

$0{,}16 fa - 1{,}44 = 0{,}072 \frac{18 - fa}{0{,}8} \Rightarrow fa = 12{,}24\,N$

$fa = 12{,}24\,N$

$fa_{max} = 0{,}20 \times 5 \times 9{,}81\,N$

$fa_{max} = 9{,}81\,N$

$fa > 9{,}81\,N$

CONCLUSÃO: O CILINDRO ROLA DESLIZANDO.

2). ASSUMINDO A CONDIÇÃO DE DESLIZAMENTO.

$fa = \mu_c N \quad fa = 0{,}15 \times 5 \times 9{,}81 \Rightarrow fa = 7{,}34\,N$

$0{,}16 fa - 1{,}44 = 0{,}072 \alpha$

$0{,}16 \times 7{,}34 - 1{,}44 = 0{,}072 \alpha$

$\alpha = -3{,}65\,rad/s^2$

$\boxed{\alpha = 3{,}65\,rad/s^2}$

$18 - fa = 5 a_G$

$18 - 7{,}34 = 5 a_G$

$\boxed{a_G = 2{,}13\,m/s^2}$

16.109 - DO PROBLEMA 16.107, TEMOS:

$$\bar{a} = \frac{r^2}{r^2 + \bar{k}^2}\, g \operatorname{sen} \beta$$

$\beta = 15^\circ$

$r = 25\,mm$

$\bar{k} = 400\,mm$

$$\bar{a} = \frac{0{,}025^2}{0{,}025^2 + 0{,}4^2}\, 9{,}81 \times \operatorname{sen} 15^\circ$$

$\bar{a} = 0{,}0099\,m/s^2$ $\qquad \bar{a} = 9{,}88\,mm/s^2$

$$\Delta \bar{x} = \frac{1}{2}\,\bar{a}\,t^2$$

P/ $t = 15\,s$ $\qquad \Delta \bar{x} = \frac{1}{2} \times 9{,}88 \times 15^2$ $\qquad \Delta \bar{x} = 1.111{,}44\,mm$

$$\boxed{\Delta \bar{x} = 1{,}11\,m}$$

//

16.130.

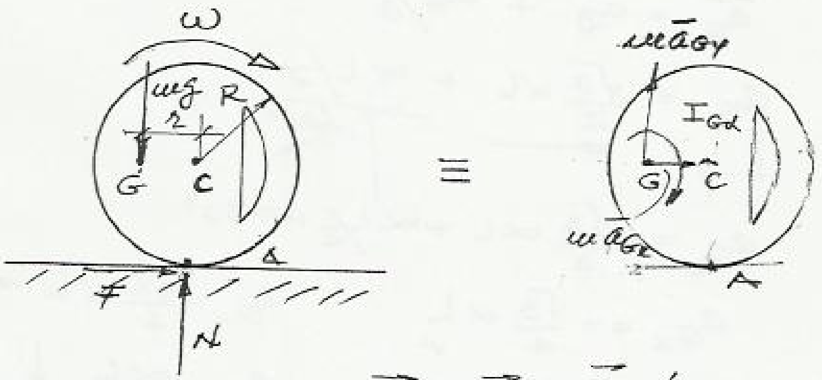
$m = 5\,kg$

$R = 0{,}30\,m$

$r = 0{,}10\,m$

$\bar{k}_G = 0{,}15\,m$

$\omega = 8\,rad/s$

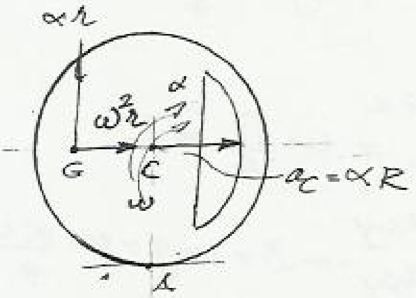


$$\vec{a}_G = \vec{a}_C + \vec{a}_{G/C}$$

$$\vec{a}_G = \underset{\rightarrow}{\alpha R} + \underset{\uparrow}{\alpha r} + \underset{\rightarrow}{\omega^2 r}$$

$$a_{Gx} = \alpha R + \omega^2 r$$

$$a_{Gy} = \alpha r$$



$$\Sigma M_A = (\Sigma M_A)\,efet.$$

$$-mg \times r = I_G \alpha + m a_{Gx} \times R + m \bar{a}_{Gy} \times r$$

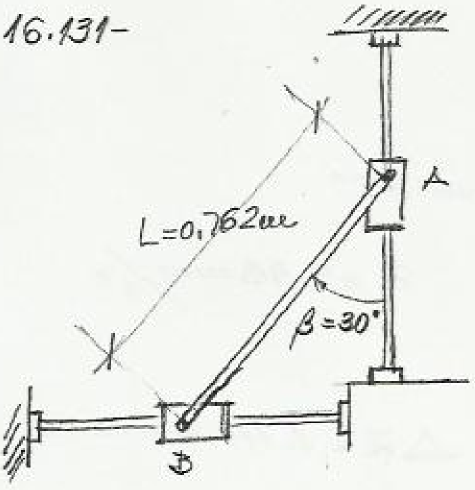
$$-\cancel{m} g \times r = \cancel{m} \bar{k}_G^2 . \alpha + \cancel{m}(\alpha R + \omega^2 r) \times R + \cancel{m}\, \alpha r . r$$

$$-g r = \alpha\left(\bar{k}_G^2 + R^2 + r^2\right) + \omega^2 r . R$$

$$\frac{-(g + \omega^2 R)\, r}{k_G^2 + R^2 + r^2} = \alpha \qquad \alpha = -23{,}68\,rad/s^2$$

$$\boxed{\alpha = 23{,}68\,rad/s^2}$$

16.131-

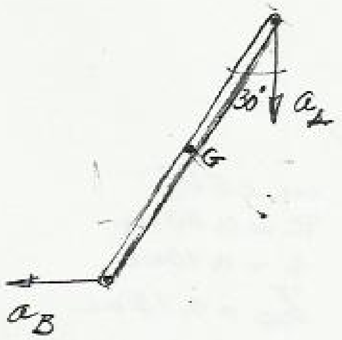


$m = 2{,}72\ kg$
$\omega_0 = 0$

$\vec{a}_A = \vec{a}_B + \vec{a}_{A/B}$

$a_A = a_B + a_{A/B}$

$30°$ αL



$a_B = \alpha L \cos 30° = \frac{\sqrt{3}}{2}\alpha L$ ←

$\vec{a}_G = \vec{a}_B + \vec{a}_{G/B}$

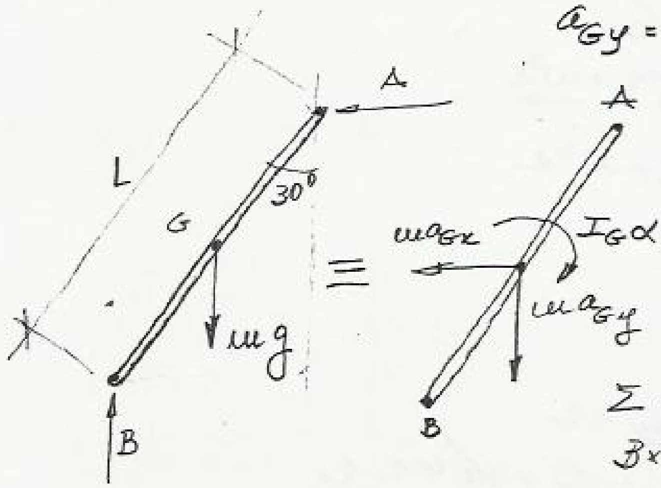
$a_G = \frac{\sqrt{3}}{2}\alpha L + \alpha L/2$

$30°$

$a_{Gx} = -\frac{\sqrt{3}}{2}\alpha L + \alpha \frac{L}{2}\cos 30°$

$a_{Gx} = -\frac{\sqrt{3}}{4}\alpha L$ $\qquad a_{Gx} = \frac{\sqrt{3}}{4}\alpha L$ ←

$a_{Gy} = -\alpha \frac{L}{2}\,\text{sen}\,30°$ $\qquad a_{Gy} = \frac{\alpha L}{4}$ ↓



$\Sigma F_x = m a_{Gx}$

$A = m a_{Gx} = m \frac{\sqrt{3}}{4}\alpha L$

$\Sigma F_y = m a_{Gy}$

$mg - B = m a_{Gy} \Rightarrow B = mg - m\frac{\alpha L}{4}$

$\Sigma M_G = I_G \alpha$

$B \times \frac{L}{2}\,\text{sen}\,30° - A \times \frac{L}{2}\cos 30° = \frac{mL^2}{12}\alpha$

$\left(\cancel{m}g - \cancel{m}\frac{\alpha}{4}L\right)\frac{\cancel{L}}{2}\,\text{sen}\,30° - \cancel{m}\frac{\sqrt{3}}{4}\alpha \frac{L}{2}\cos 30° = \frac{mL^2}{12}\alpha$

$g\frac{\text{sen}\,30°}{2} = \alpha\left(\frac{L}{12} + \frac{L}{16} + \frac{3}{8}L\right)$ $\qquad \boxed{\alpha = 6{,}18\ rad/s^2}$

$A = m\frac{\sqrt{3}}{4}\alpha L$

$\boxed{A = 5{,}55\ N}$ ←

$B = mg - m\frac{\alpha L}{4}$

$\boxed{B = 23{,}48\ N}$ ↑