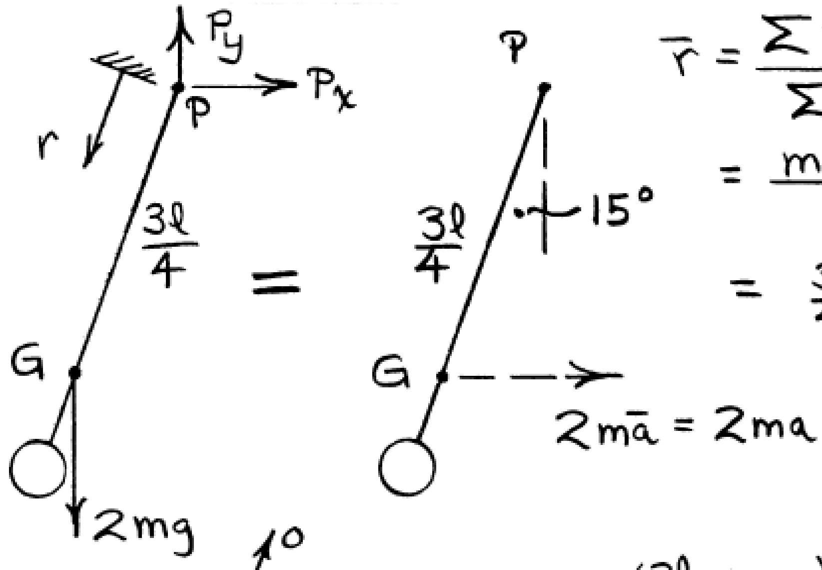
6/5

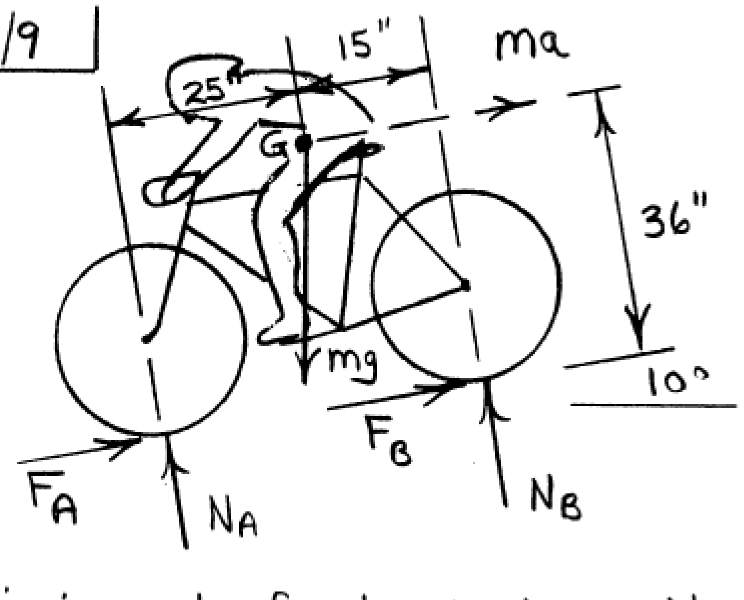


$$\bar{r} = \frac{\sum m_i r_i}{\sum m_i} = \frac{m(\ell/2) + m(\ell)}{m+m} = \frac{3}{4}\ell$$

$$\curvearrowleft + \; \sum M_P = \bar{I}\cancelto{0}{\alpha} + m\bar{a}d \; : \; 2mg\left(\frac{3\ell}{4}\sin 15^\circ\right) = 2ma\left(\frac{3\ell}{4}\cos 15^\circ\right)$$

$$\Rightarrow a = g\tan 15^\circ = \underline{0.268g}$$

6/9

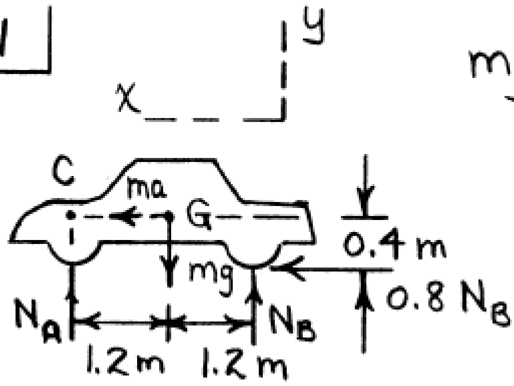


Tipping at front wheel : $N_B, F_B \rightarrow 0$

$$+\curvearrowleft \; \sum M_A = mad \; : \; mg\,(25\cos 10^\circ - 36\sin 10^\circ) = ma\,(36)$$

Solve to obtain $a = \underline{0.510g}$ ($\underline{16.43 \text{ ft/sec}^2}$)

6/11



$$mg = 1650(9.81) = 16.19(10^3)\ \text{N}$$

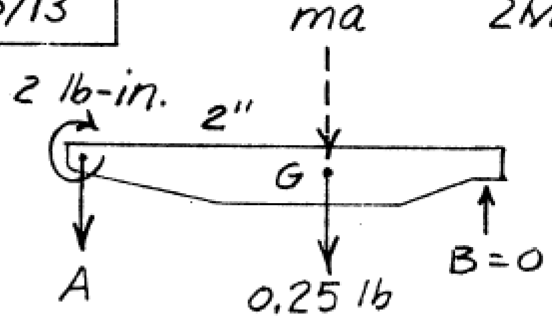
$$\circlearrowright + \Sigma M_C = ma d = 0: \quad N_B(2.4) - 0.8N_B(0.4) - 16.19(10^3)1.2 = 0$$

$$N_B = 9.34(10^3)\ \text{N or } \underline{N_B = 9.34\ \text{kN}}$$

$$\Sigma F_y = 0: \quad N_A + 9.34(10^3) - 16.19(10^3) = 0$$

$$N_A = 6.85(10^3)\ \text{N} \quad \text{or} \quad \underline{N_A = 6.85\ \text{kN}}$$

6/13



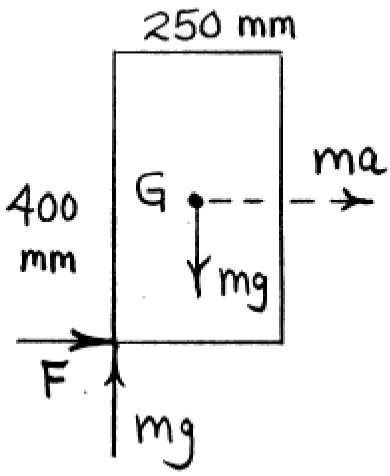
$$\Sigma M_A = ma d$$

$$2 + 0.25(2) = \frac{0.25}{32.2(12)} a(2)$$

$$a = 1932\ \text{in./sec}^2$$

$$\text{or} \quad \underline{a = 161\ \text{ft/sec}^2}$$

6/17



$$v = 1.2 + 0.9t^2\ \text{m/s}$$

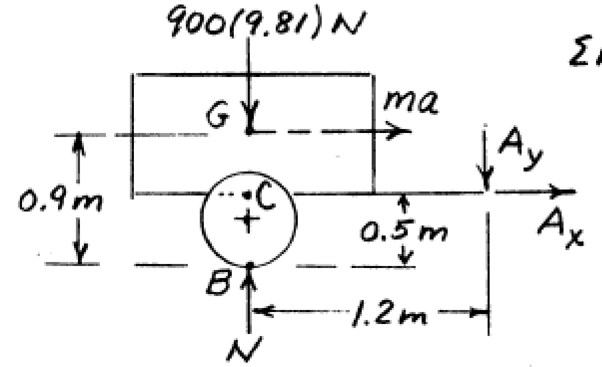
$$a = \dot{v} = 1.8t\ \text{m/s}^2$$

$$\circlearrowleft + \Sigma M_A = ma d:$$

$$mg\,\frac{250}{2} = m(1.8t)\left(\frac{400}{2}\right)$$

$$\underline{t = 3.41\ \text{s}}$$

6/20 $v^2 = 2as$, $a = \dfrac{v^2}{2s} = \dfrac{(60/3.6)^2}{2(30)} = 4.63\ m/s^2$

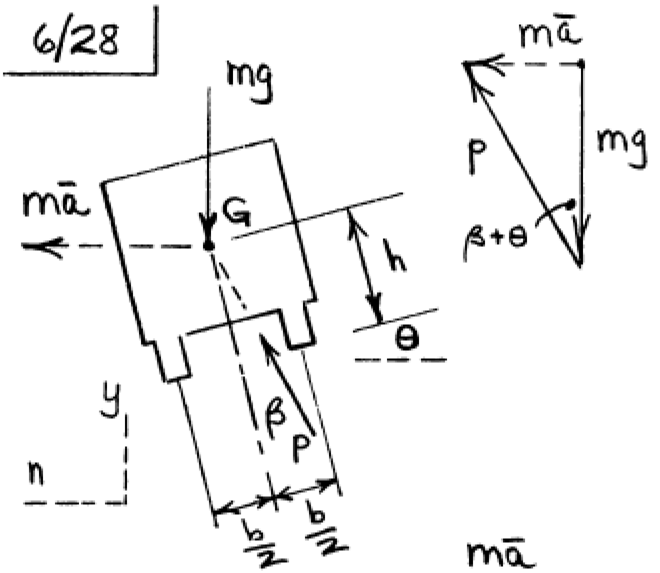


$\Sigma M_C = ma d$;

$1.2A_y = 900(4.63)(0.9 - 0.5)$

$\underline{A_y = 1389\ N}$

6/28



(a) For no tendency to slip, $\beta = 0$.

From diagram,

$\tan\theta = \dfrac{m\bar{a}}{mg} = \dfrac{v^2/r}{g}$

$$\underline{\theta = \tan^{-1}\frac{v^2}{gr}}$$

(b) $\tan(\beta+\theta) = \dfrac{m\bar{a}}{mg} = \dfrac{v^2/r}{g}$

$v^2 = gr\tan(\beta+\theta) = gr\dfrac{\tan\beta + \tan\theta}{1 - \tan\beta\tan\theta}$

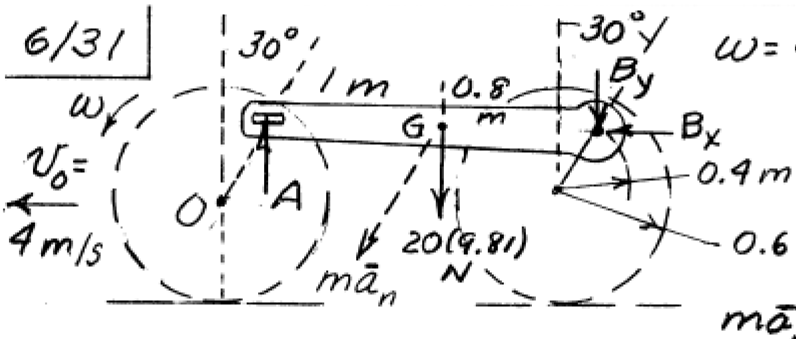
Slips first if $\mu < \dfrac{b/2}{h}$ & $\mu = \tan\beta$

So $$\underline{v^2 = gr\frac{\mu + \tan\theta}{1 - \mu\tan\theta}}$$

Tips first if $\mu > \dfrac{b/2}{h}$ & $\tan\beta = \dfrac{b}{2h}$:

$$\underline{v^2 = gr\frac{\frac{b}{2h} + \tan\theta}{1 - \frac{b}{2h}\tan\theta}}$$

6/31



$\omega = v/r = \frac{4}{0.6} = 6.67 \frac{rad}{s}$

$\alpha = 0\ ,\ \bar{a}_t = 0\ ,\ a_0 = 0$

$\bar{a}_n = a_{A/a_0} = r\omega^2$

$= 0.4(6.67)^2 = 17.78\ m/s^2$

$m\bar{a}_n = 20(17.78) = 356\ N$

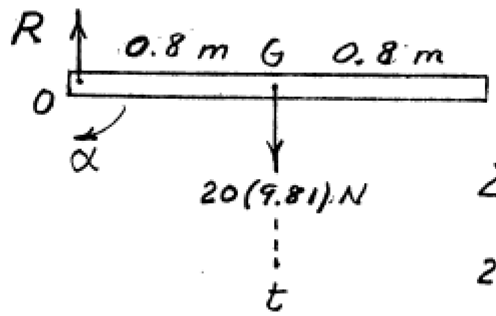
$\Sigma M_A = m\bar{a}d;\quad 1.8B_y + 20(9.81)(1.0) = 356\cos 30°(1.0)$

$B_y = 62.1\ N$

$\Sigma F_x = ma_x;\quad B_x = 356\sin 30° = 177.8\ N$

$B = \sqrt{B_x^2 + B_y^2};\quad B = \sqrt{(177.8)^2 + (62.1)^2} = \underline{188.3\ N}$

6/33



$\Sigma M_O = I_O\alpha$

$20(9.81)(0.8) = \frac{1}{3}(20)(1.6)^2\alpha$

$\alpha = 9.20\ rad/s^2$

$\Sigma F_t = m\bar{a}_t = m\bar{r}\alpha$

$20(9.81) - R = 20(0.8)(9.20)$

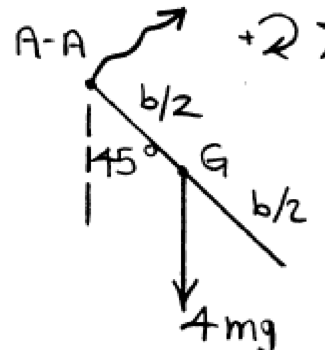
$\underline{R = 49.0\ N}$

6/38

$$I_{A-A} = 2\left(\tfrac{1}{3}mb^2\right) + mb^2 = \tfrac{5}{3}mb^2$$

$$I_{B-B} = \tfrac{1}{12}mb^2 + 2\left[\tfrac{1}{12}mb^2 + m\left(\left(\tfrac{b}{2}\right)^2 + \left(\tfrac{b}{2}\right)^2\right)\right] + \left[\tfrac{1}{12}mb^2 + mb^2\right] = \tfrac{7}{3}mb^2$$

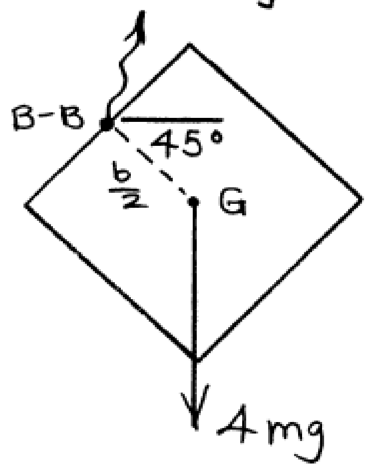
m = mass of each side



$$\overset{+}{\circlearrowright} \Sigma M_{A-A} = I_{A-A}\alpha :$$

$$4mg\,\frac{b}{2}\frac{\sqrt{2}}{2} = \frac{5}{3}mb^2\alpha$$

$$\underline{\alpha = \frac{3\sqrt{2}}{5}\frac{g}{b}}$$



$$\overset{+}{\circlearrowright} \Sigma M_{B-B} = I_{B-B}\alpha :$$

$$4mg\,\frac{b}{2}\frac{\sqrt{2}}{2} = \frac{7}{3}mb^2\alpha$$

$$\underline{\alpha = \frac{3\sqrt{2}}{7}\frac{g}{b}}$$

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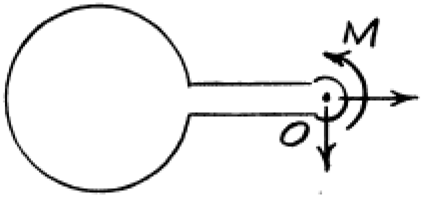
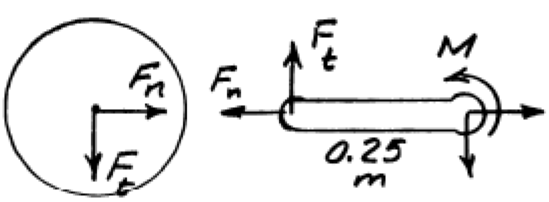


(a) Pin in place ; $\Sigma M_O = I_O\alpha$

$$30 = 43\left(\tfrac{1}{2}[0.2]^2 + [0.25]^2\right)\alpha$$

$$\underline{\alpha = 8.46 \text{ rad/s}^2}$$



(b) Pin removed

Arm: $F_t \approx M/r = \frac{30}{0.25} = 120$ N

Rotor: $\Sigma F_t = ma_t$

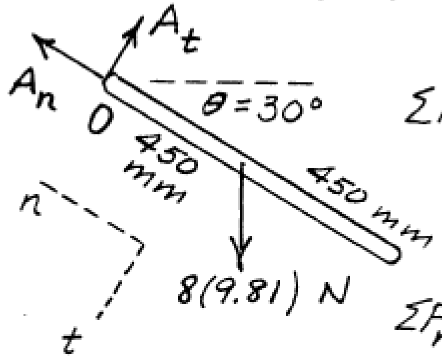
$$120 = 43\,(0.25\alpha)$$

$$\underline{\alpha = 11.16 \text{ rad/s}^2}$$

6/47

$\Sigma M_O = I_O\alpha$; $8(9.81)(0.450\cos 30°) = \frac{1}{3}8(0.900)^2\alpha$

$\alpha = 14.16\ rad/s^2$



$\Sigma F_t = m\bar{r}\alpha$; $8(9.81)\cos 30° - A_t = 8(0.450)(14.16)$

$A_t = 16.99\ N$

$\Sigma F_n = m\bar{r}\omega^2$; $A_n - 8(9.81)\sin 30° = 8(0.450)2^2$

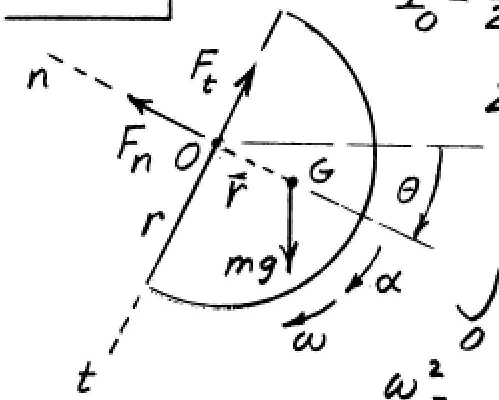
$\omega = \dot{\theta} = 2\ rad/s$

$A_n = 53.64\ N$

$$A = \sqrt{\overline{16.99}^2 + \overline{53.64}^2} = \underline{56.3\ N}$$

6/57

$I_O = \frac{1}{2}mr^2$; $\bar{r} = \frac{4r}{3\pi}$



$\Sigma M_O = I_O\alpha$; $mg\bar{r}\cos\theta = I_O\alpha$

$\alpha = mg\cos\theta\,\frac{\bar{r}}{I_O} = \frac{8}{3\pi}\frac{g}{r}\cos\theta$

$$\int_0^\omega \omega\,d\omega = \int_0^\theta \alpha\,d\theta$$

$$\frac{\omega^2}{2} = \frac{8}{3\pi}\frac{g}{r}\sin\theta\Big]_0^\theta, \quad \omega^2 = \frac{16}{3\pi}\frac{g}{r}\sin\theta$$

$\Sigma F_n = m\bar{r}\omega^2$; $F_n - mg\sin\theta = m\frac{4r}{3\pi}\frac{16}{3\pi}\frac{g}{r}\sin\theta$

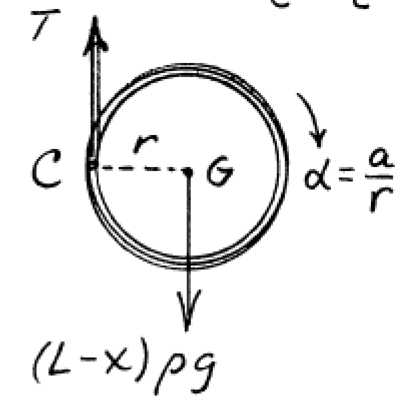
$$F_n = \left(\frac{64}{9\pi^2} + 1\right)mg\sin\theta = \underline{1.721\ mg\sin\theta}$$

$\Sigma F_t = m\bar{r}\alpha$; $mg\cos\theta - F_t = m\frac{4r}{3\pi}\frac{8}{3\pi}\frac{g}{r}\cos\theta$

$$F_t = \left(1 - \frac{32}{9\pi^2}\right)mg\cos\theta = \underline{0.640\ mg\cos\theta}$$

6/76 $\Sigma M_C = I_C \alpha$; $(L-x)\rho g r = 2(L-x)\rho r^2 \frac{a}{r}$

$a = g/2$ constant



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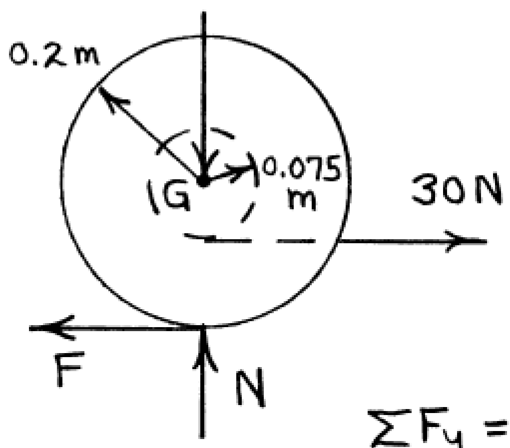
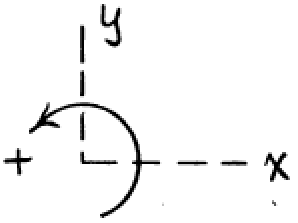


$\bar{k} = 0.175$ m

$\mu_s = 0.1$, $\mu_k = 0.08$



$\Sigma F_y = 0 \Rightarrow N = 25(9.81) = 245$ N

$\Sigma F_x = m\bar{a}_x$: $30 - F = 25a$ (1)

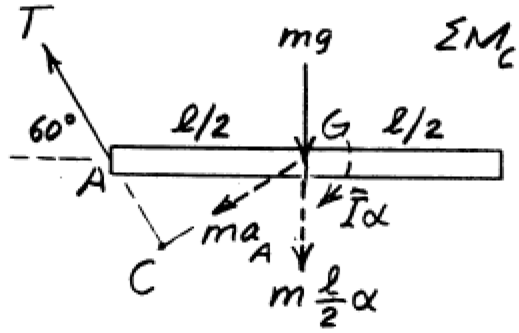
$\Sigma M_G = \bar{I}\alpha$: $30(0.075) - F(0.2) = 25(0.175)^2\alpha$ (2)

Assume rolling with no slip : $a = -r\alpha$ (3)

Solution of Eqs. (1)-(3) : $\begin{cases} a = 0.425 \text{ m/s}^2 \\ \alpha = -2.12 \text{ rad/s}^2 \\ F = 19.38 \text{ N} \end{cases}$

$F_{max} = \mu_s N = 0.1(245) = 24.5 \text{ N} > F$ (assumption OK)

6/91 3 unknowns, T, a_A, α. Moments about C eliminates two of them.



$$\Sigma M_C = \bar{I}\alpha + m\bar{a}d$$

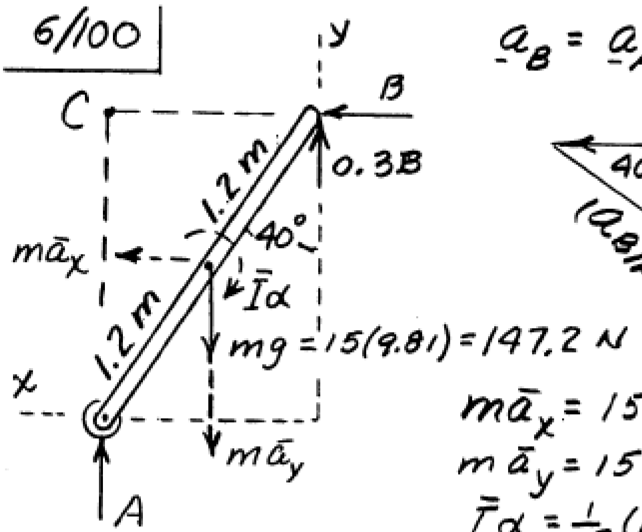
$$mg\frac{l}{2}\cos^2 30° = \frac{1}{12}ml^2\alpha + m\frac{l}{2}\alpha\left(\frac{l}{2}\cos^2 30°\right)$$

$$\alpha = \frac{18g}{13l}$$

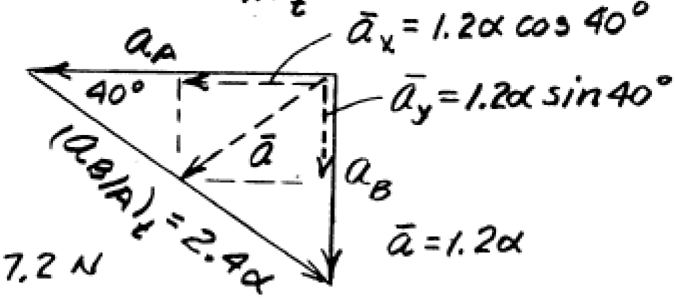
$$\Sigma M_G = \bar{I}\alpha;\quad T\frac{l}{2}\cos 30° = \frac{1}{12}ml^2\left(\frac{18g}{13l}\right),\quad \underline{T = \frac{2\sqrt{3}}{13}mg}$$

independent of l

6/100



$$\underset{-}{a}_B = \underset{-}{a}_A + (\underset{-}{a}_{B/A})_t$$



$$m\bar{a}_x = 15(1.2\alpha)\cos 40° = 13.79\alpha \quad N$$

$$m\bar{a}_y = 15(1.2\alpha)\sin 40° = 11.57\alpha \quad N$$

$$\bar{I}\alpha = \frac{1}{12}(15)(2.4)^2\alpha \quad = 7.2\alpha \quad N\cdot m$$

$$\Sigma M_C = \bar{I}\alpha + \Sigma m\bar{a}d$$

$$147.2(1.2\sin 40°) - 0.3B(2.4\sin 40°)$$
$$= 7.2\alpha + 13.79\alpha(1.2\cos 40°) + 11.57\alpha(1.2\sin 40°)$$

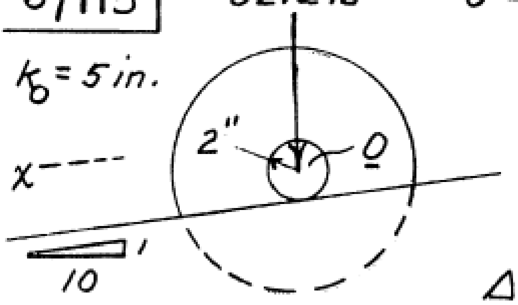
Simplify to $\alpha = 3.94 - 0.01607B$ ----(1)

$\Sigma F_x = m\bar{a}_x$; $B = 13.79\alpha$ ----------- (2)

Solve (1) & (2) & get $\alpha = 3.23$ rad/s²

$$a_A = 2.4\alpha\cos 40° = 2.4(3.23)\cos 40° = \underline{5.93 \text{ m/s}^2}$$

6/115 $k_O = 5$ in.



$\theta = \tan^{-1} 1/10$, $\sin\theta = 0.0995$

$U = \Delta T$

$U = 32.2(0.0995)(10)$
$= 32.04$ ft-lb

$\Delta T = \frac{1}{2} m v^2 + \frac{1}{2} I_O \omega^2 - 0$

$\Delta T = \frac{1}{2}\frac{32.2}{32.2} v^2 + \frac{1}{2}\frac{32.2}{32.2}\left(\frac{5}{12}\right)^2\left(\frac{v}{2/12}\right)^2 - 0 = \frac{29}{8} v^2$

Thus $32.04 = \frac{29}{8} v^2$, $v^2 = 8.839$, $\underline{v = 2.97 \text{ ft/sec}}$

6/119 $\Delta V_g = -200(9.81)(1.25) = -2453$ J

Each spring stretches a distance of 1.25 m so that $\Delta V_e = 2\left[\frac{1}{2} k (1.25)^2 - 0\right] = 1.563\,k$ J

$\Delta T = \frac{1}{2} I_O \omega^2 = \frac{1}{2}\, 200\left(\frac{1}{12}\overline{2.5}^2 + \overline{1.25}^2\right)\overline{1.5}^2 = 469$ J

$\Delta T + \Delta V_g + \Delta V_e = 0$; $469 - 2453 + 1.563k = 0$

$k = 1270$ N/m or $\underline{k = 1.270 \text{ kN/m}}$

6/133 $U' = \Delta T + \Delta V_g + \Delta V_e$ for entire system

$U' = 0$

$\Delta T = \frac{1}{2} I_O \omega^2 = \frac{1}{2}\left[\frac{1}{3}\frac{10}{32.2}\left(\frac{20}{12}\right)^2\right](1.5)^2 = 0.323$ ft-lb

$\Delta V_g = -Wh = -10\left(\frac{10}{12}\right) = -8.33$ ft-lb

$\Delta V_e = 2\left(\frac{1}{2} k x^2\right) = k\left(\frac{2}{12}\right)^2 = 0.0278k$

Thus $0 = 0.323 - 8.33 + 0.0278k$

$k = 288$ lb/ft or $\underline{k = 24.0 \text{ lb/in.}}$

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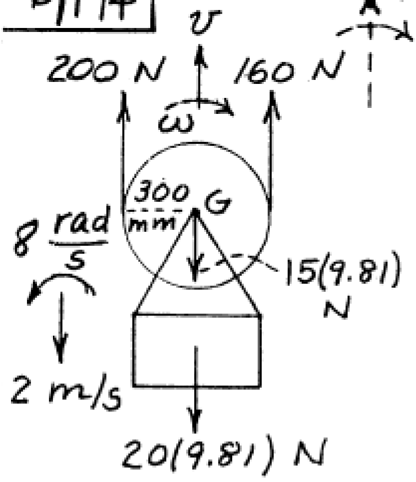

$\int \Sigma F\,dt = \Delta G$

$(360 - 35 \times 9.81)5 = 35(v - [-2])$

$\underline{v = 0.379 \text{ m/s up}}$

$\int \Sigma M_G\,dt = \Delta H_G$

$(200-160)0.3(5) = 15(0.25)^2(\omega - [-8])$

$\underline{\omega = 56.0 \text{ rad/s CW}}$

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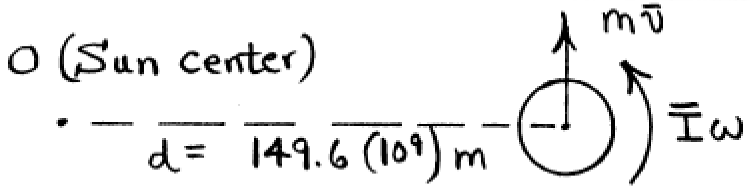

$\bar{H} = \bar{I}\omega = \frac{2}{5} m r^2 \left(\frac{2\pi}{\tau}\right)$

$= \frac{2}{5}(5.976 \cdot 10^{24})(6.371 \cdot 10^6)^2 \dfrac{2\pi}{23.9344(3600)}$

$= 7.08(10^{33}) \text{ kg}\cdot\text{m}^2/\text{s}$

$\bar{v} = \sqrt{\dfrac{G m_s}{d}} = \sqrt{\dfrac{6.673(10^{-11})(333{,}000)(5.976 \cdot 10^{24})}{149.6(10^9)}}$

$= 29\,800 \text{ m/s}$

$m\bar{v}d = 5.976(10^{24})(29\,800)(149.6 \cdot 10^9)$

$= 2.66(10^{40}) \text{ kg}\cdot\text{m}^2/\text{s}$

$\bar{H} = \bar{I}\omega + m\bar{v}d = \underline{2.66(10^{40}) \text{ kg}\cdot\text{m}^2/\text{s}}$

(The $\bar{I}\omega$ term is insignificant compared with the $m\bar{v}d$ term.)

6/184 Approximate the diver's body as a uniform slender bar in the first case and as a sphere in the second case. Conservation of angular momentum $H_1 = H_2$:

$$\frac{1}{12}\cancel{m}l^2 N_1 = \frac{2}{5}\cancel{m}r^2 N_2$$

$$\frac{1}{12}(2)^2(0.3) = \frac{2}{5}\left(\frac{0.7}{2}\right)^2 N_2$$

$$\underline{N_2 = 2.04 \text{ rev/s}}$$

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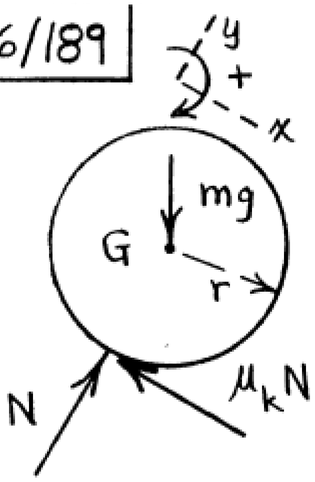


$$\int_0^t \Sigma F_y\, dt = m(v_y - v_{y_0}) = 0 \Rightarrow N = mg\cos\theta$$

$$\int_0^t \Sigma F_x\, dt = m(v_x - v_{x_0}):$$

$$(-\mu_k mg\cos\theta + mg\sin\theta)t = m(v - v_0) \quad (1)$$

$$\int_0^t \Sigma M_G\, dt = \bar{I}(\omega - \omega_0):$$

$$(\mu_k mg\cos\theta\, r)t = \frac{2}{5}mr^2\omega \quad (2)$$

We desire the time t when $v = r\omega$ (3)

Solution of Eqs. (1)–(3):

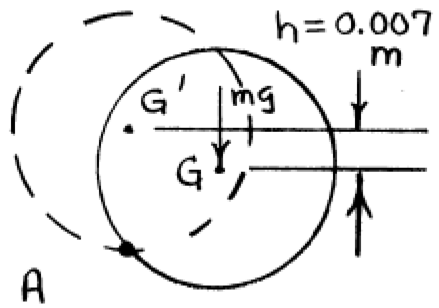
$$\begin{cases} t = \dfrac{2v_0}{g(7\mu_k\cos\theta - 2\sin\theta)} \\[2ex] v = \dfrac{5v_0\mu_k}{7\mu_k - 2\tan\theta} \\[2ex] \omega = \dfrac{5v_0\mu_k/r}{7\mu_k - 2\tan\theta} \end{cases}$$

For slipping to cease,

$7\mu_k\cos\theta > 2\sin\theta$

or $\mu_k > \frac{2}{7}\tan\theta$

6/205 Process II - roll about fixed point A



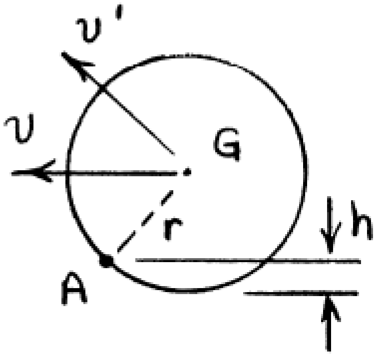
$$U_{1-2} = \Delta T$$

$$-mgh = \frac{1}{2}\left(\frac{3}{2}mr^2\right)\left(\omega'^2 - 0\right)$$

$$\omega' = \sqrt{\frac{4gh}{3r^2}} = \sqrt{\frac{4(9.81)(0.007)}{3(0.035)^2}}$$

$$= 8.65 \text{ rad/s}$$

Process I - impact at A



$$\Delta H_A = 0: \; mv(r-h) = I_A\omega'$$

$$= \left(\frac{3}{2}mr^2\right)\omega'$$

With $v = 0.5\Omega$:

$$\frac{1}{2}\Omega(r-h) = \frac{3}{2}r^2\omega'$$

$$\Omega = \frac{3r^2\omega'}{r-h} = \frac{3(0.035)^2(8.65)}{0.035 - 0.007} = \underline{1.135 \frac{\text{rad}}{\text{s}}}$$