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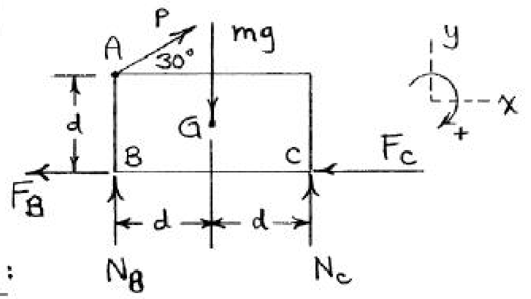

Slips:

$$\Sigma F_x = 0: \; -F_B - F_C + P\cos 30° = 0 \qquad (1)$$

$$\Sigma F_y = 0: \; N_B + N_C + P\sin 30° - mg = 0 \qquad (2)$$

With $F_B = \mu_s N_B$ & $F_C = \mu_s N_C$, combine (1) & (2) to obtain $P = \dfrac{\mu_s mg}{\mu_s \sin 30° + \cos 30°}$

With $\mu_s = 0.5$, $P = P_{slip} = \underline{0.448 mg}$

Tips ($N_B, F_B \to 0$):

$$\Sigma M_G = 0: \; (P\cos 30°)d + (P\sin 30°)(2d) - mg(d) = 0$$

$$\Rightarrow P = \frac{mg}{\cos 30° + 2\sin 30°} = \underline{0.536 mg = P_{tip}}$$

For these conditions, slipping would occur first.

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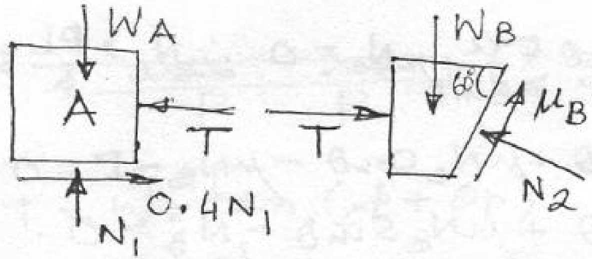
$\therefore N_1 = 5491.03\,N$

$\Sigma F_x = 0;\quad P + 0.25N_1 + 0.2N_2\cos 60^\circ - N_2\cos 30^\circ = 0 \quad \therefore \underline{P = 323.86\,N}$

2.



$\phi_B = 15^\circ \quad \therefore \mu_B = \tan\phi_B = 0.268$

<u>For block B:</u> $\Sigma F_y = 0;$

$N_2\sin 30^\circ + 0.268N_2\sin 60^\circ - W_B = 0.$

$\therefore N_2 = 2185.5\,N$

$\Sigma F_x = 0,\quad T - N_2\cos 30^\circ + 0.268N_2\cos 60^\circ = 0 \quad \therefore T = 1599.85\,N$

<u>For Block A</u>, $\Sigma F_x = 0;\ 0.4N_1 - T = 0 \quad \therefore N_1 = 3999.62\,N$

$\Sigma F_y = 0;\ N_1 - W_A = 0 \quad \therefore W_A = 3999.62\,N$

$\approx \underline{4000\,N}$

3. <u>Front wheel drive</u>:

$\Sigma F_t = 0;\ F - P\sin\theta = 0;\ \Sigma F_n = 0;\ N - P\cos\theta = 0.$

For impending condition, $\mu = \frac{F}{N} = \frac{P\sin\theta}{P\cos\theta} = \tan\theta$

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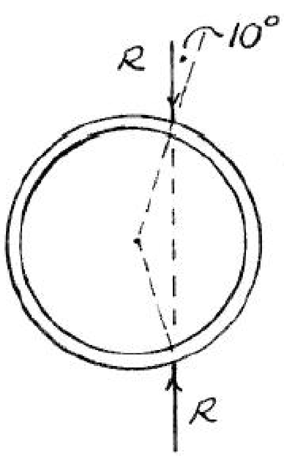

$$\mu_{s_{min}} = \tan \phi = \tan 10^\circ$$

$$= \underline{0.176}$$

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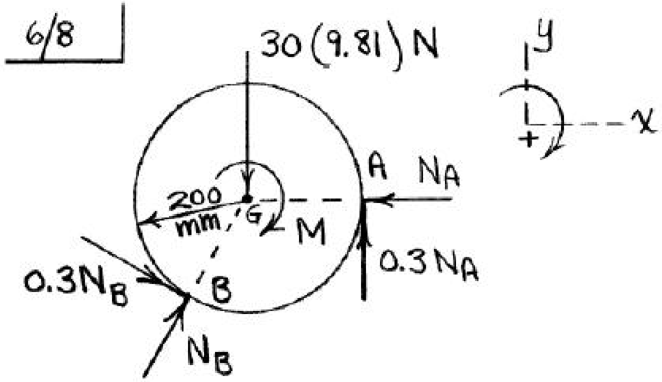
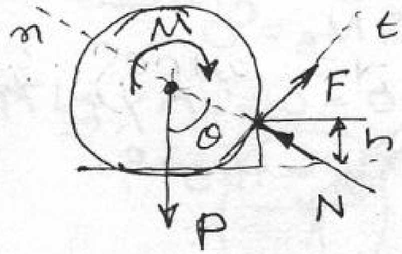


$$\begin{cases} \Sigma M_G = 0: & M - 0.3(N_A + N_B)\,0.2 = 0 \quad (1) \\ \Sigma F_x = 0: & N_B \sin 30^\circ + 0.3 N_B \cos 30^\circ - N_A = 0 \quad (2) \\ \Sigma F_y = 0: & N_B \cos 30^\circ - 0.3 N_B \sin 30^\circ - 30(9.81) \\ & + 0.3 N_A = 0 \quad (3) \end{cases}$$

Solution of Eqs. (1)–(3): $\begin{cases} N_B = 312 \text{ N} \\ N_A = 237 \text{ N} \\ M = 32.9 \text{ N·m} \end{cases}$

$\approx 4000\,N$

3. Front wheel drive :



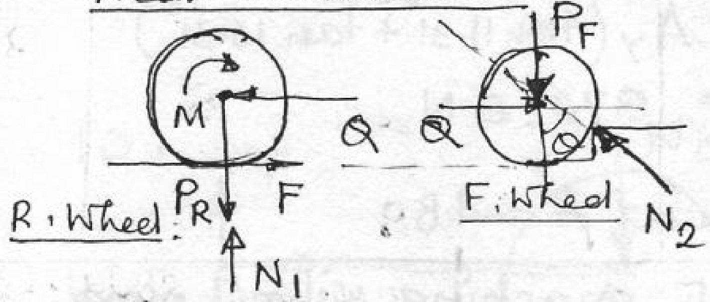
$\Sigma F_t = 0$; $F - P\sin\theta = 0$; $\Sigma F_n = 0$; $N - P\cos\theta = 0$.

For impending condition, $\mu = \frac{F}{N} = \frac{P\sin\theta}{P\cos\theta} = \tan\theta$

$\tan\theta = 0.85$, ∴ $\theta = 40.365^\circ$

∴ $h = r - r\cos\theta = \underline{66.7\,mm}$

Rear Wheel drive



$P_R = 0.2W$, Q = Force exerted by the chasis, on each wheel.

$\Sigma F_y = 0$; $N_1 - P_R = 0$ ∴ $N_1 = 0.2W$ ∴ $F = 0.17W$

$\Sigma F_x = 0$; $F - Q = 0$ ∴ $Q = F = 0.17W$

$$\left.\begin{aligned} &\Sigma F_y = 0;\ P_F - N_2\cos\theta = 0 \\ &\Sigma F_x = 0;\ Q - N_2\sin\theta = 0 \end{aligned}\right\}\ \text{Front wheel.}$$

∴ $\tan\theta = \frac{Q}{P_F} = \frac{0.17W}{0.3W} = 0.5667$, ∴ $\theta = 29.54^\circ$

∴ $h = r - r\cos\theta = \underline{36.4\,mm}$.

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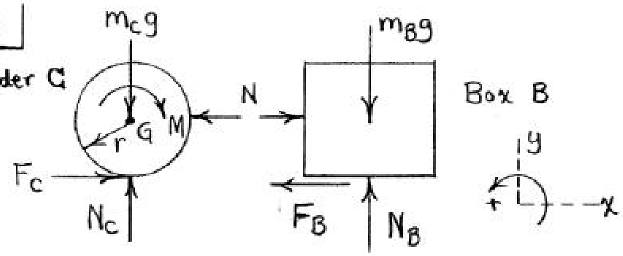


Assume that box slips but cylinder does not.

$F_B = (\mu_s)_B N_B$.

$$B \begin{cases} \Sigma F_x = 0: & N - F_B = 0 & (1) \\ \Sigma F_y = 0: & N_B - m_B g = 0 & (2) \end{cases}$$

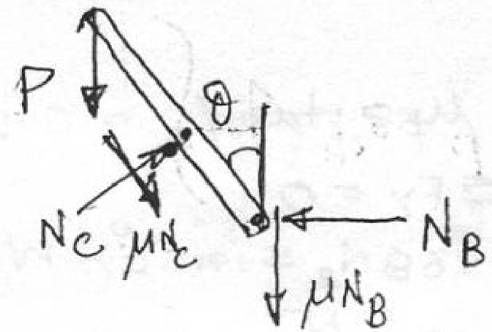
So $N_B = m_B g$, $N = F_B = (\mu_s)_B m_B g$

$$C \begin{cases} \Sigma F_x = 0: & F_c - N = 0 & (3) \\ \Sigma F_y = 0: & N_c - m_c g = 0 & (4) \\ \Sigma M_G = 0: & F_c r - M = 0 & (5) \end{cases}$$

$$M = F_c r = N r = (\mu_s)_B m_B g r$$
$$= 0.5(3)(9.81)(0.2) = \underline{2.94 \text{ N}\cdot\text{m}}$$

$$F_c = N = (\mu_s)_B m_B g = (0.5)(3)(9.81) = 14.72 \text{ N}$$
$$< (F_c)_{max} = (\mu_s)_c m_c g = (0.4)(6)(9.81) = 23.5 \text{ N}$$

5. Impending motion of B upward:



$\Sigma M_B = 0$; $\quad PL\sin\theta - \dfrac{a}{\sin\theta} \times N_c = 0 \quad \therefore N_c = \dfrac{PL}{a}\sin^2\theta.$

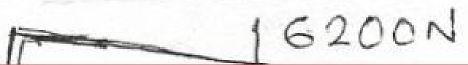
$\Sigma F_y = 0$; $\quad N_c\sin\theta - \mu N_c\cos\theta - \mu N_B - P = 0.$

$\Sigma F_x = 0 \quad N_c\cos\theta + \mu N_c\sin\theta - N_B = 0.$

solving, $\dfrac{L}{a} = 13.63$ for reverse direction, frictional forces are opposite, again $\dfrac{L}{a} = 3.461$.

$\therefore$ range is $3.46 \leq \dfrac{L}{a} \leq 13.63$

6.



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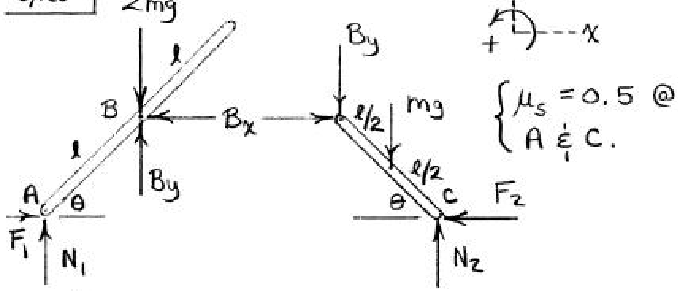

$$AB \begin{cases} \Sigma F_x = 0: \quad F_1 - B_x = 0 & (1) \\ \Sigma F_y = 0: \quad N_1 + B_y - 2mg = 0 & (2) \\ \Sigma M_A = 0: \quad B_x(\ell \sin\theta) + B_y(\ell\cos\theta) - 2mg(\ell\cos\theta) = 0 & (3) \end{cases}$$

$$BC \begin{cases} \Sigma F_x = 0: \quad B_x - F_2 = 0 & (4) \\ \Sigma F_y = 0: \quad -B_y - mg + N_2 = 0 & (5) \\ \Sigma M_C = 0: \quad mg\left(\frac{\ell}{2}\cos\theta\right) + B_y(\ell\cos\theta) - B_x(\ell\sin\theta) = 0 & (6) \end{cases}$$

Assume first slippage at A: $F_1 = 0.5N_1$. Solve seven equations to obtain $\underline{\theta = 63.4°}$, $F_2 = 0.625\,mg$, & $N_2 = 1.75\,mg$. Note $F_2 < F_{2max} = 0.875\,mg$.

Then assume first slippage at B: $F_2 = 0.5N_2$. Obtain $\theta = 55.0°$, $F_1 = 0.875\,mg$ & $N_1 = 1.25\,mg$. Note $F_1 > F_{1max} = 0.625\,mg$. So A slips first.

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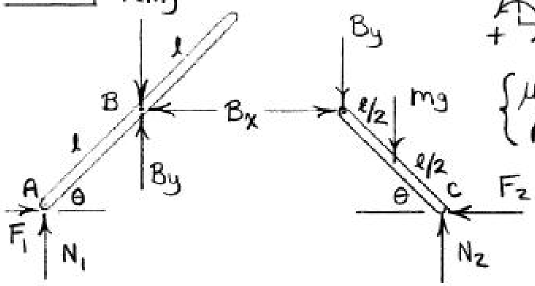

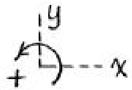

$\left\{ \mu_s = 0.5 \right.$ @ A & C.

AB
$$\begin{cases} \Sigma F_x = 0: \quad F_1 - B_x = 0 & (1) \\ \Sigma F_y = 0: \quad N_1 + B_y - 2mg = 0 & (2) \\ \Sigma M_A = 0: \quad B_x(l \sin\theta) + B_y(l\cos\theta) - 2mg(l\cos\theta) = 0 & (3) \end{cases}$$

BC
$$\begin{cases} \Sigma F_x = 0: \quad B_x - F_2 = 0 & (4) \\ \Sigma F_y = 0: \quad -B_y - mg + N_2 = 0 & (5) \\ \Sigma M_C = 0: \quad mg(\frac{l}{2}\cos\theta) + B_y(l\cos\theta) - B_x(l\sin\theta) = 0 & (6) \end{cases}$$

Assume first slippage at A: $F_1 = 0.5 N_1$. Solve seven equations to obtain $\underline{\theta = 63.4°}$, $F_2 = 0.625\,mg$, & $N_2 = 1.75\,mg$. Note $F_2 < F_{2max} = 0.875\,mg$.

Then assume first slippage at B: $F_2 = 0.5 N_2$. Obtain $\theta = 55.0°$, $F_1 = 0.875\,mg$ & $N_1 = 1.25\,mg$. Note $F_1 > F_{1max} = 0.625\,mg$. So A slips first.

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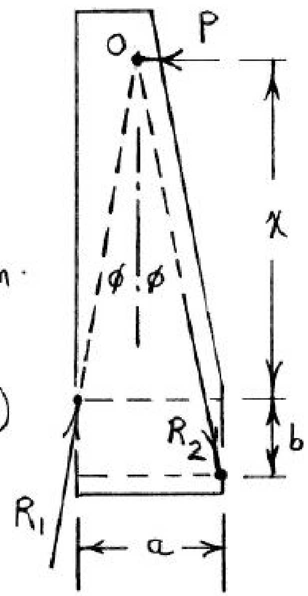
For equilibrium, the forces must be concurrent at O and $\phi = \tan^{-1}\mu_s$ for impending motion with $x = x_{min}$.

$a = x\tan\phi + (x+b)\tan\phi$

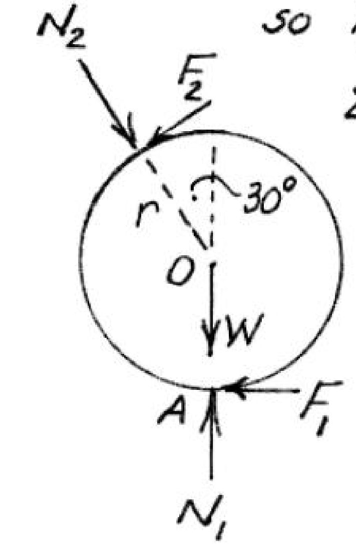
$= x\mu_s + (x+b)\mu_s = \mu_s(2x+b)$

$$x = \frac{a - b\mu_s}{2\mu_s}$$



6/37 Lower roller; $\Sigma M_O = 0$; $F_1 = F_2$ But $N_1 > N_2$

so F_2 reaches limiting value $\mu_s N_2$ before F_1.

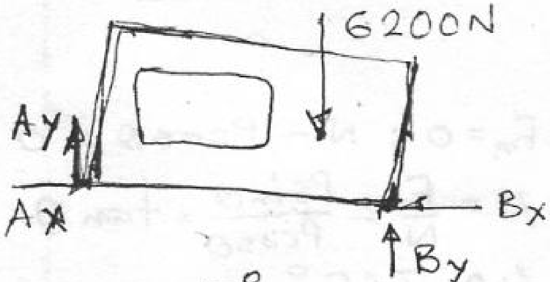


$$\Sigma M_A = 0;\ \mu_s N_2 \left(r + \frac{\sqrt{3}}{2} r\right) - N_2 \frac{r}{2} = 0$$

$$\text{so } \mu_s = \frac{r/2}{r + \frac{\sqrt{3}\,r}{2}} = \frac{0.5}{1 + 0.866} = \underline{0.268}$$

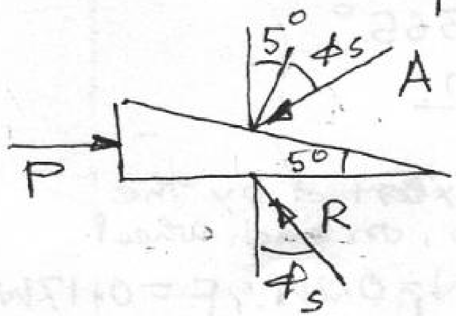
$3.46 \leq \frac{L}{a} \leq 13.63$

6.

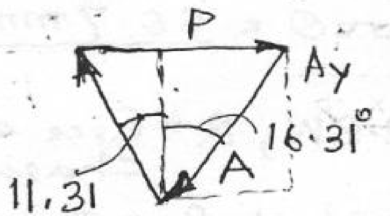


Just at the entry of the peg, from F.B.D of the machine base, $\Sigma M_B = 0$

$-6200 \times 50 + A_y \times 1750 = 0 \therefore A_y = 1771.4N$



$\mu_s = 0.2 \therefore \phi_s = \tan^{-1}\mu_s = 11.31°$



$\therefore P = A_y(\tan 11.31° + \tan 16.31°)$

$= 872.6\ N$

Total maximum friction force at A and B:

$F = \mu_s W = 1240N$. Since $P < F$, machine will not move.

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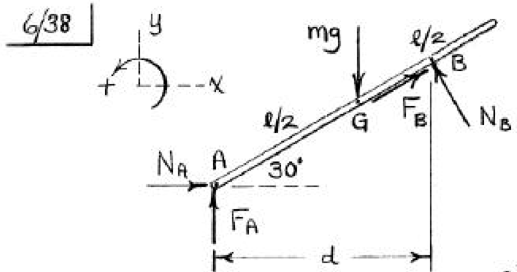

FBD assumes slipping CCW $\left\{ \text{We expect } \frac{l}{2} > \frac{d}{\cos 30°} \right.$!

$$\begin{cases} \Sigma F_x = 0: \; N_A + F_B \cos 30° - N_B \sin 30° = 0 \\ \Sigma F_y = 0: \; F_A + F_B \sin 30° + N_B \cos 30° - mg = 0 \\ \Sigma M_A = 0: \; -mg \frac{l}{2} \cos 30° + N_B \frac{d}{\cos 30°} = 0 \end{cases}$$

Limiting friction: $F_A = \mu_s N_A$, $F_B = \mu_s N_B$

Solve 5 equations to obtain

$$\begin{cases} N_A = 0.1362\,mg & F_A = 0.0545\,mg \\ N_B = 0.887\,mg & F_B = 0.355\,mg \end{cases} \quad l = 2.37d$$

For slipping CW, reverse F_A & F_B on FBD and first two equations & obtain

$$N_A = 2.58\,mg \quad F_A = 1.034\,mg$$
$$N_B = 3.05\,mg \quad F_B = 1.222\,mg \qquad l = 8.14d$$

For equilibrium: $\underline{2.37 \leq \frac{l}{d} \leq 8.14}$

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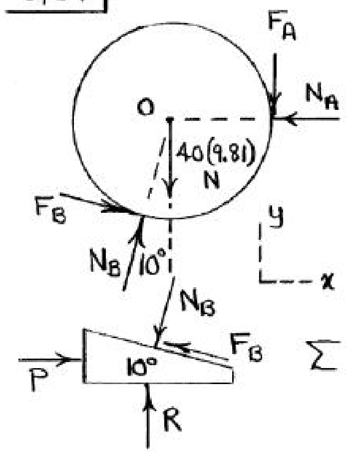

By inspection $N_A < N_B$, so slipping occurs first at A. Thus $F_A = 0.25 N_A$

Cylinder: $\Sigma M_o = 0$:

$F_B r - F_A r = 0$, $F_B = F_A = 0.25 N_A$

$\Sigma F_y = 0$: $N_B \cos 10° - F_A \sin 10° - 40(9.81) - F_A = 0$

or $N_B \cos 10° - (0.25 N_A) \sin 10° - 40(9.81) - 0.25 N_A = 0$ (a)

$\Sigma F_x = 0$: $N_B \sin 10° + F_B \cos 10° - N_A = 0$

or $N_B \sin 10° + (0.25 N_A) \cos 10° - N_A = 0$ (b)

Solve (a) & (b): $N_A = 98.6$ N, $N_B = 428$ N; $\underline{F_B = F_A = 24.6 \text{ N}}$

Wedge: $\Sigma F_x = 0$: $P - 24.6 \cos 10° - 428 \sin 10° = 0$, $\underline{P = 98.6 \text{ N}}$

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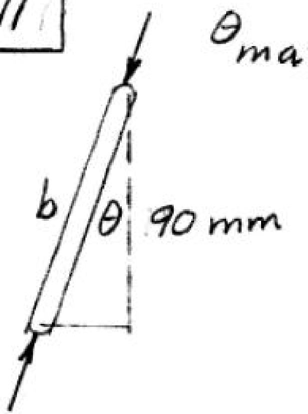

$$\theta_{max} = \phi = \tan^{-1}\mu = \tan^{-1} 0.40 = 21.80°$$

$$b = 90/\cos 21.80° = \underline{96.9 \text{ mm}}$$

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6/124 For the slab

$\Sigma F_x = 0: \mu_k N \cos\alpha - N \sin\alpha = 0$

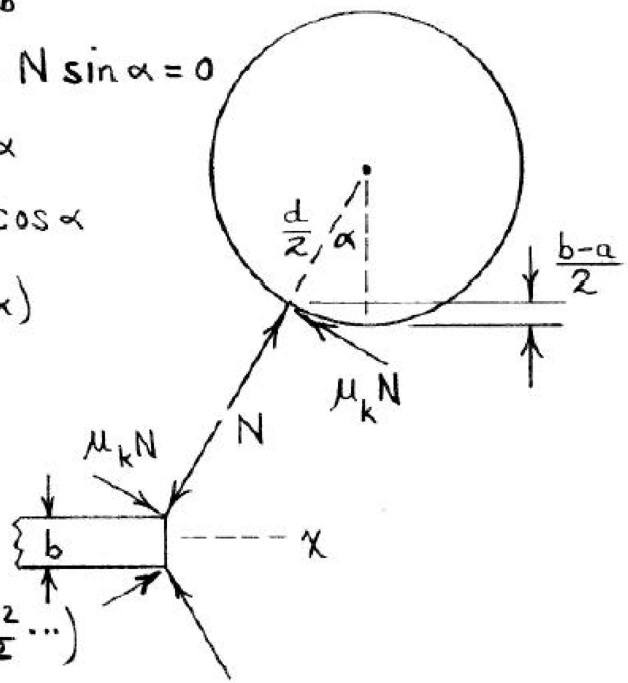
$$\mu_k = \tan\alpha$$

$$\frac{d}{2} + \frac{a}{2} = \frac{b}{2} + \frac{d}{2}\cos\alpha$$

$$b = a + d(1 - \cos\alpha)$$

For small α,

$$\begin{cases} \cos\alpha \cong 1 - \frac{\alpha^2}{2} + \cdots \\ \tan\alpha \cong \alpha \end{cases}$$



So $b = a + d\left(1 - 1 + \frac{\alpha^2}{2} \cdots\right)$

$$= \underline{a + \frac{\mu_k^2 d}{2}}$$

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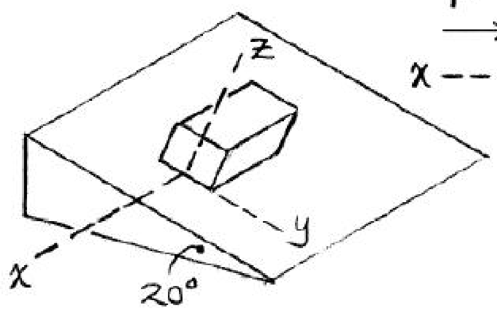

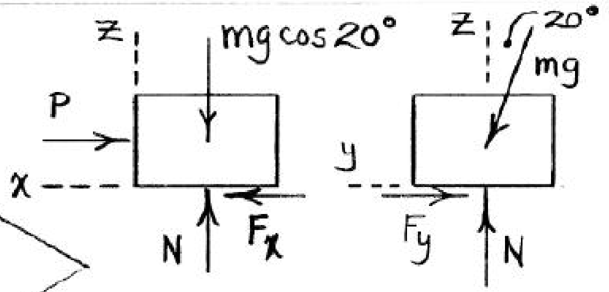

$$(x-z)\begin{cases} \Sigma F_z = 0: \; N - 8(9.81)\cos 20° = 0, & N = 73.7 \text{ N} \\ \Sigma F_x = 0: \; F_x - P = 0, & F_x = P \end{cases}$$

$$(y-z)\left\{ \Sigma F_y = 0: \; -F_y + 8(9.81)\sin 20° = 0, \quad F_y = 26.8 \text{ N} \right.$$

$$F = \sqrt{F_x^2 + F_y^2} = \mu_s N: \; \sqrt{P^2 + 26.8^2} = 0.5(73.7)$$

$$\underline{P = 25.3 \text{ N}}$$

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$$\frac{mg}{P} = e^{\mu\beta}, \quad \frac{mg}{mg/6} = e^{\mu\left(\frac{5}{4}2\pi\right)}$$

$$\frac{5}{2}\pi\mu = \ln 6 = 1.792, \quad \mu = \frac{2(1.792)}{5\pi} = \underline{0.228}$$

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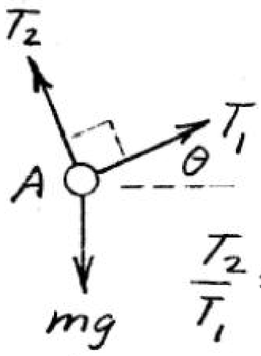

Equilibrium of A gives

$T_1 = mg \sin\theta$

$T_2 = mg \cos\theta$

$$\frac{T_2}{T_1} = e^{\mu\beta}, \quad \frac{mg\cos\theta}{mg\sin\theta} = e^{3\pi\mu/2}$$

For $\theta = 20°$, $\quad \text{ctn}\, 20° = e^{3\pi\mu/2} = 2.747$

or $\mu = \dfrac{2}{3\pi} \ln 2.747 = \underline{0.214}$

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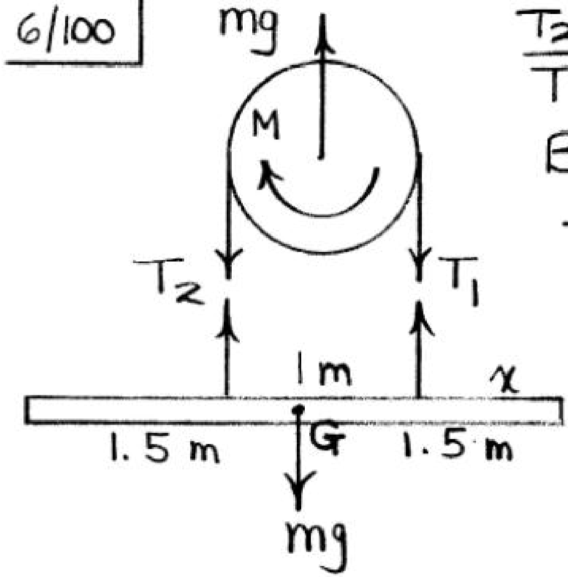


$$\frac{T_2}{T_1} = e^{\mu\beta} = e^{0.25\pi} = 2.19$$

Beam : $\Sigma M_G = 0$:

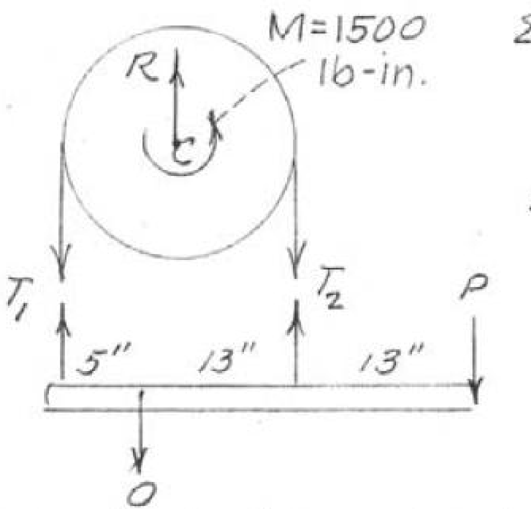
$$T_2\,(1 + x - 1.5) = T_1\,(1.5 - x)$$

Combine to get

$$\frac{1.5 - x}{x - 0.5} = 2.19$$

$$\underline{x = 0.813 \text{ m}}$$

6/104 $T_2/T_1 = e^{\mu\beta} = e^{0.20\pi} = 1.874$ ----(a)



$\Sigma M_C = 0;\ (T_2 - T_1)\,9 = 1500$

$T_2 - T_1 = 166.7$ ----(b)

Lever: $\Sigma M_O = 0;\ 26P + 5T_1 - 13T_2 = 0$ ---(c)

Combine (a) & (b) & get

$T_2 = 1.874(T_2 - 166.7)$, $T_2 = 357$ lb.

$T_1 = 357 - 166.7 = 190.7$ lb

Substitute in (c) & get

$26P + 5(190.7) - 13(357) = 0$, $\underline{P = 142.0 \text{ lb}}$

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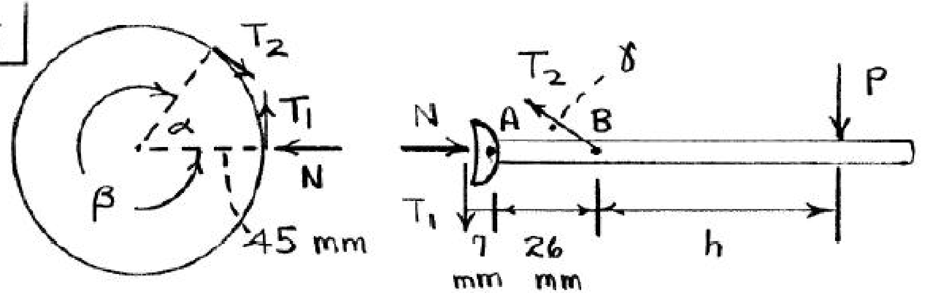

$$\cos\alpha = \frac{45}{45+7+26}, \quad \alpha = 54.8^\circ, \quad \gamma = 180-90-\alpha = 35.2^\circ$$

$$\beta = 360-\alpha = 305^\circ \text{ or } 5.33 \text{ rad}$$

$$\frac{T_2}{T_1} = e^{\mu\beta} = e^{0.25(5.33)} = 3.79 \qquad (a)$$

Bar: $\Sigma M_P = 0: \; T_1(h+7+26) - T_2 \sin\gamma\,(h) = 0$

$$\text{or} \quad \frac{T_2}{T_1} = \frac{h+33}{0.577h} \qquad (b)$$

From (a) & (b), $\underline{h = 27.8 \text{ mm}}$

(For actual wrench, $h \cong 100$ mm)