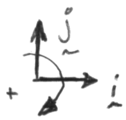
MAE 325 Fall 1999

Assignment 2: Due Wed 9/8/99

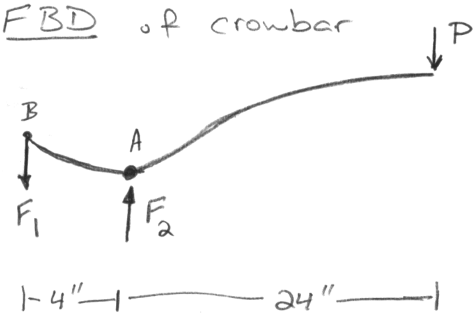
(1)



Find: Tension in the spike

b such that the spike does not bend.

FBD of crowbar



from FBD of crowbar:

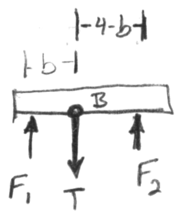
$\sum \underset{\sim}{F} \Rightarrow \{-F_1 \underset{\sim}{j} + F_2 \underset{\sim}{j} - P \underset{\sim}{j} = 0\}$

$\{\ \} \cdot \underset{\sim}{j} \Rightarrow \quad -F_1 + F_2 - P = 0 \qquad (1)$

$\sum M_A \Rightarrow \{-4 \cdot F_1 \underset{\sim}{k} + 24 P \underset{\sim}{k} = 0\}$

$\{\ \} \cdot \underset{\sim}{k} \Rightarrow \quad 4F_1 = 24P \quad \Rightarrow \quad \boxed{F_1 = 6P \qquad F_1 = 180 \text{ lbf}}$

FBD of board



using (1) $\boxed{F_2 = F_1 + P \qquad F_2 = 210 \text{ lbf}}$

from FBD of board:

$\sum \underset{\sim}{F} \Rightarrow \{F_1 \underset{\sim}{j} + F_2 \underset{\sim}{j} - T_j = 0\}$

$\{\ \} \cdot \underset{\sim}{j} \Rightarrow \quad \boxed{T = F_1 + F_2 \qquad T = 390 \text{ lbf}}$

To prevent bending

$\sum M_B \Rightarrow \{b F_1 \underset{\sim}{k} - (4-b) F_2 \underset{\sim}{k} = 0\}$

$\{\ \} \cdot \underset{\sim}{k} \Rightarrow \quad b F_1 = (4-b) F_2 = 0$

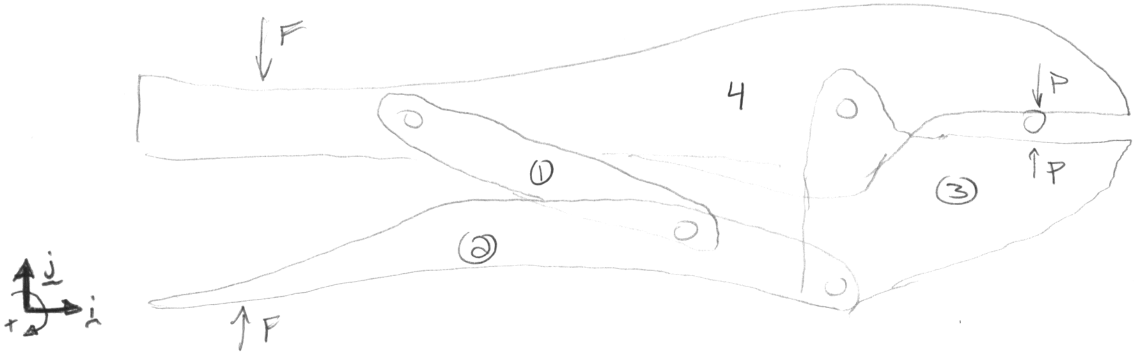
$$b = \frac{4 F_2}{F_1 + F_2} = \frac{840}{390}$$

$\boxed{b = 2.15 \text{ in}}$

3

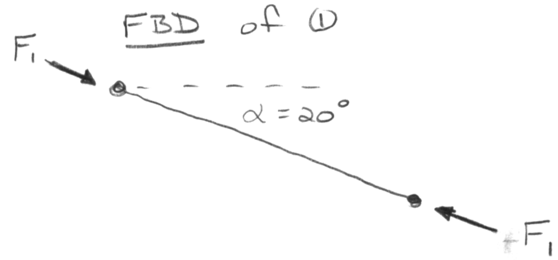
Find: Forces on each pin and member w/ $P = 4000N$

F to keep it clamped



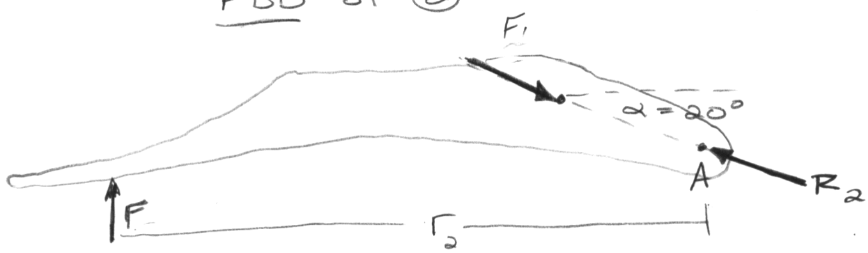
Break wrench into components:

FBD of 1



two force member: Forces equal and opposite

FBD of 2



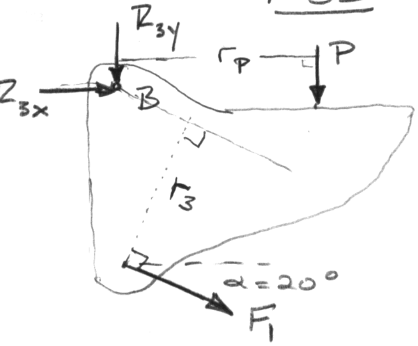
$\sum M_A \Rightarrow r_2 F \underset{\sim}{k} = 0$ (F_1 acts through A)

or $\boxed{F = 0}$

$\sum \underset{\sim}{F} \Rightarrow F_1 - R_2 = 0$

$\boxed{R_2 = F_1}$

FBD of (3)



$\Sigma M_B \Rightarrow \{ r_p P \underset{\sim}{k} - r_3 F_1 \underset{\sim}{k} = 0 \}$

$\{ \ \} \cdot \underset{\sim}{k} \Rightarrow \quad r_p P = r_3 F_1$

$$F_1 = \frac{r_p}{r_3} P$$

from drawing!

$r_p = 2.6 \text{ cm}$

$r_3 = 2.175 \text{cm}$

so: $\boxed{F_1 = 4781.61 \text{ N}}$

$\Sigma \underset{\sim}{F} \cdot \underset{\sim}{i} \Rightarrow \quad \cos\alpha \, F_1 + R_{3x} = 0$

$\boxed{R_{3x} = - 4493.24 \text{ KN}}$

$\Sigma F \cdot \underset{\sim}{j} \Rightarrow \quad -\sin\alpha \, F_1 - P - R_{3y} = 0$

$\boxed{R_{3y} = - 5635.41 \text{ N}}$

Forces R_{3x} and R_{3y} act in the opposite direction on member (4)

Note: Your answers may be slightly different due to differences in measuring, however $F = 0$ for any measurement.

(4)

Find: T when (a) weight moves up at steady speed
(b) weight moves down at steady speed

Given: $W = 100$ lbf $r = 0.2$ in $R = 2$ in $\mu = 0.3$

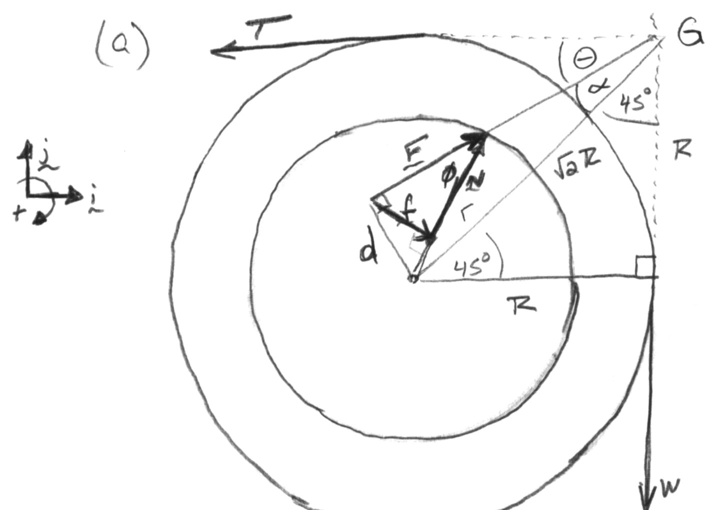
unlubricated bearing

axle cannot rotate

pulley fits loosely on axle

FBD

(a)



$$\underset{\sim}{F} = \underset{\sim}{f} + \underset{\sim}{N} \qquad (1)$$

Friction Force

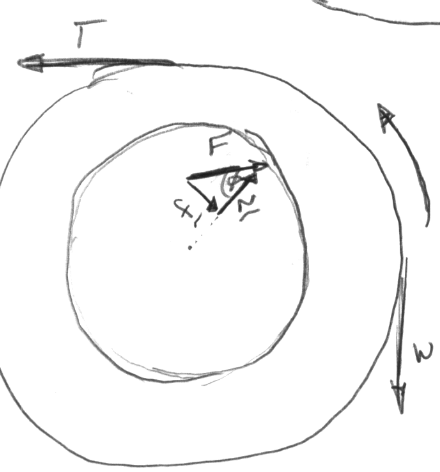
Normal Force

The lines of the 3 forces (T, W, F) intersect at a single point and are coplanar ("3 Force Body")

$$\tan \phi = \mu \qquad (2)$$

$$d = r \sin \phi \qquad (3)$$

$$\sin \alpha = \frac{d}{\sqrt{2}R} \qquad (4)$$



combining (3) and (4) and solving for α:

$$\alpha = \sin^{-1}\left(\frac{r \sin \phi}{\sqrt{2}R}\right) \qquad (5)$$

$$\Theta = \frac{\pi}{2} - \left(\alpha + \frac{\pi}{4}\right) = \frac{\pi}{4} - \alpha \qquad (6)$$

combining (5) and (6):

$$\Theta = \frac{\pi}{4} - \sin^{-1}\left(\frac{r \sin \phi}{\sqrt{2}R}\right) \qquad (7)$$

$$\sum \underset{\sim}{F} \Rightarrow \{-T\,\underset{\sim}{i} - W\,\underset{\sim}{j} + F\cos\theta\,\underset{\sim}{i} + F\sin\theta\,\underset{\sim}{j} = \underset{\sim}{0}\}$$

$$\{\ \}\cdot\underset{\sim}{i} \Rightarrow \quad -T + F\cos\theta = 0 \qquad (8)$$

$$\{\ \}\cdot\underset{\sim}{j} \Rightarrow \quad -W + F\sin\theta = 0 \qquad (9)$$

from (9): $F = \dfrac{W}{\sin\theta}$ (10)

Subs. (10) into (8):

$$T = \frac{W}{\sin\theta}\cos\theta = \frac{W}{\tan\theta}$$

$$T = \frac{W}{\tan\left[\frac{\pi}{4} - \sin^{-1}\left(\frac{r\sin\phi}{\sqrt{2}\,R}\right)\right]}$$

$$\boxed{T = 104.15 \text{ lbf}}$$

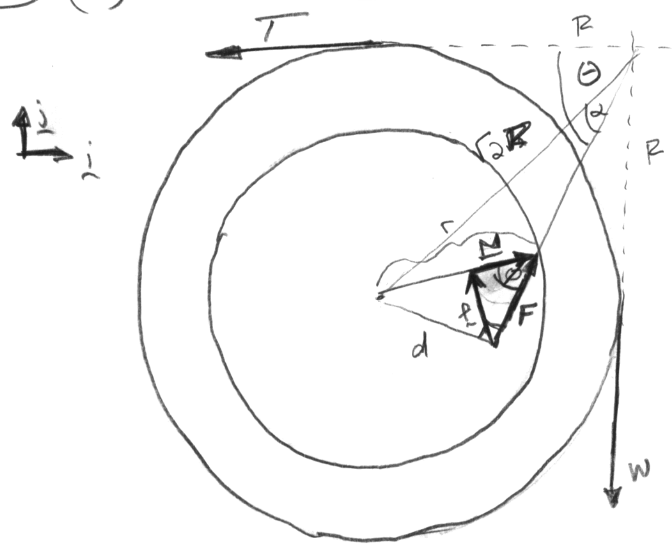
Note: if $\mu \to \infty$ then $\phi = \frac{\pi}{2}$ and $\sin\phi = 1$

so $T = \dfrac{W}{\tan\left[\frac{\pi}{4} - \sin^{-1}\left(\frac{r}{\sqrt{2}R}\right)\right]} = 115.26 \text{ lbf}$

for ∞ friction !!

(4) (b)

FBD



as in part (a)

$$\underset{\sim}{F} = \underset{\sim}{f} + \underset{\sim}{N}$$

$$\tan\phi = \mu$$

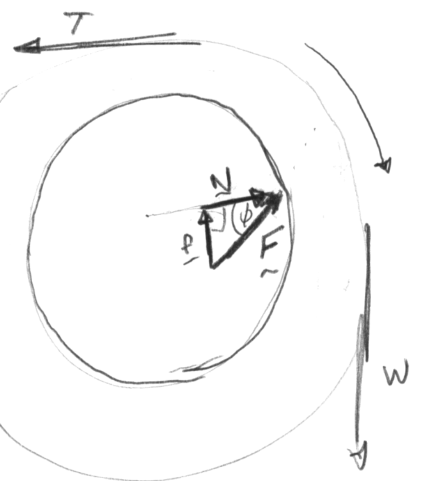
$$d = r\sin\phi$$

$$\alpha = \sin^{-1}\left(\frac{r\sin\phi}{\sqrt{2}R}\right)$$

$$\theta = \frac{\pi}{4} + \alpha \qquad (11)$$

subs. α ;

$$\theta = \frac{\pi}{4} + \sin^{-1}\left(\frac{r\sin\phi}{\sqrt{2}R}\right)$$



$$\Sigma \underset{\sim}{F} \Rightarrow \left\{ -T\underset{\sim}{i} - W\underset{\sim}{j} + F\cos\theta\,\underset{\sim}{i} + F\sin\theta\,\underset{\sim}{j} = \underset{\sim}{0} \right\}$$

→ same as (a) so :

$$T = \frac{W}{\tan\theta} = \frac{W}{\tan\left[\frac{\pi}{4} + \sin^{-1}\left(\frac{r\sin\phi}{\sqrt{2}R}\right)\right]}$$

$$\boxed{T = 96.02 \text{ lbf}}$$

Note: if $\mu \to \infty$ $\quad \phi = \frac{\pi}{2} \quad \sin\phi = 1$

then $T = 86.76$ lbf

p. 108

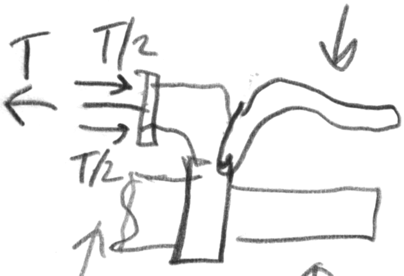
Problems w/ example:

1. F_{b1} does not necessarily equal F_{b2}. In the case of a rider seated on the bike at a standstill it may, but deceleration would cause additional force to be placed on the handlebar so $F_{b1} > F_{b2}$

2. When the cable was cut for the FBD a force was added from the cable, but none from the cable housing. The cable housing is in compression.

In fact, if you assume that the cable and housing have no bending strength/stiffness $\Rightarrow$ net cable+housing tension $= 0 \Rightarrow$ housing compression = cable tension.

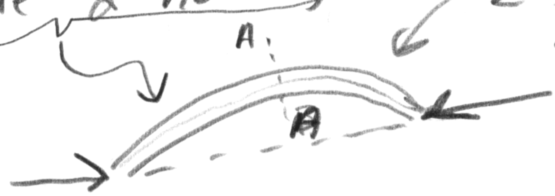
handle FBD (pg 109) should look like this



no forces or couples here! (they turn out to be zero)

Look at FBD of carved piece of cable & housing

2 force body w/ no couples



Now cut at A-A

$\Rightarrow$

$\Rightarrow$ no equilib. unless forces are zero

$\Rightarrow$ no net tension in housing/cable combo.