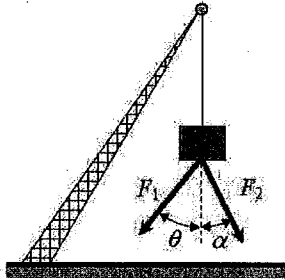
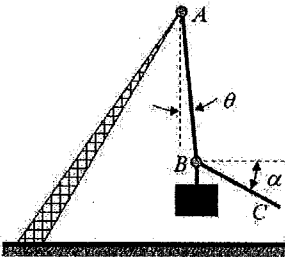


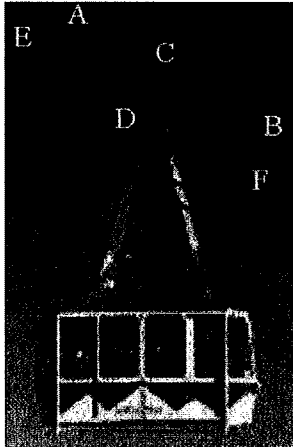
1. [4pt] A crate is being lowered from a main cable, while two smaller cables are used to steady its descent. Given that $F_1=335$ N, and $\theta=26$ degrees, determine the smallest possible magnitude of F_2 such that the resultant of forces F_1 and F_2 is vertical.



2. [2pt] What is the corresponding value of alpha?
3. [2pt] What is the corresponding magnitude of the resultant of F_1 and F_2 ?
4. [4pt] A weight of 3.1 kN is being held by two cables as shown. θ is 4 degrees, and α is 19 degrees. Determine the tension in cable AB.

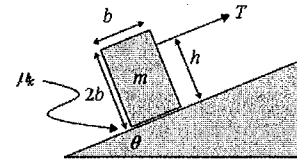


5. [3pt] Determine the tension in cable BC.
6. [9pt] The cabin of an aerial tramway (weighing 24.0 kN) is supported from cable AB by a set of frictionless wheels at C. The tramway itself is pulled upwards by cable DE, (cable DF has negligible tension). Cable segments AC and DE make an angle $\alpha=41.0$ degrees with the horizontal, while cable BC makes an angle $\beta=35.0$ degrees with the horizontal. What is the tension in support cable ACB?



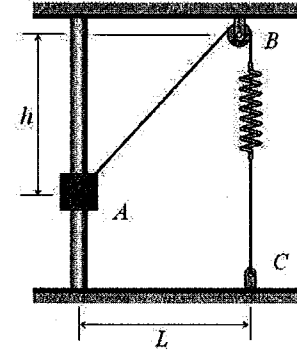
7. [5pt] What is the tension in the traction cable DE?

8. [6pt] Determine the magnitude of the tension T needed to ensure that the crate slides uphill with constant velocity. Given: $\theta=41$ deg, $b=0.8$ m, $m=55$ kg, and $\mu_k=0.02$.



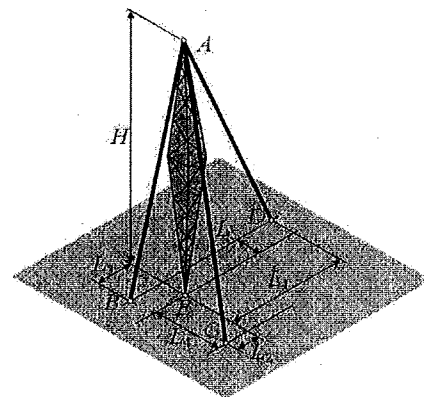
9. [6pt] Determine the maximum height h such that the block won't tip over while moving uphill at constant speed.
10. [4pt] Determine the magnitude of the tension such that the block will slide downhill with constant velocity.
11. [4pt] Determine the maximum height h such that the block won't tip over while moving downhill at constant speed.

12. [4pt] Collar A can slide on a frictionless vertical rod. The horizontal length L is 280 mm. The spring constant is 640 N/m, and the spring is unstretched when $h=310$ mm. The system is in equilibrium when $h=405$ mm. Determine the weight of the collar.



Written Assignment [6 pt]: Submit your work with commentary and a textbook-quality plot of $W(h)$, starting at 310 mm and ranging at least 200 mm.

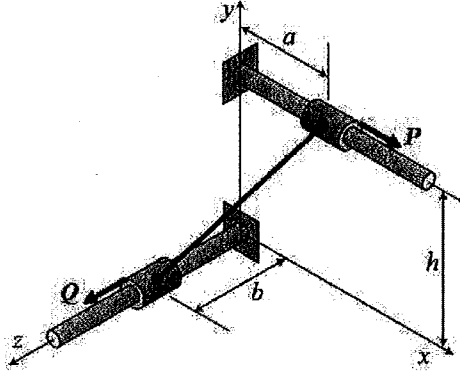
13. [4pt] The transmission tower AE is connected to the ground by the three cables AB, AC, and AD. The tension in cable AB is known to be 2750 N. The following lengths are known: $L_1=15.5$ m; $L_2=3.9$ m; $L_3=4.2$ m; $L_4=12.0$ m; $L_5=3.5$ m; and $H=15$ m. Determine the tension in cable AC.



14. [4pt] Determine the tension in cable AD.

Continued on next page...

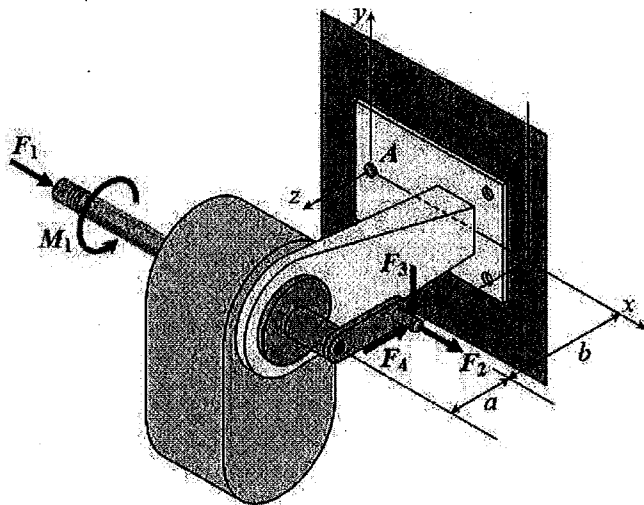
15. [3pt] The two collars shown can move freely on the frictionless rods, which are perpendicular to each other and separated by a distance $h = 5$ in. They are connected by a wire of length 8.5 in. At a certain instant, the collars are in equilibrium, the force Q is 50 lbf, and the distance a is 3.5 in. What is the tension in the wire?



16. [3pt] What is the required force P ?

17. [3pt] What is the required distance b ?

18. [2pt] To use a pencil sharpener, a student applies the force F_1 and the couple M_1 to the pencil, and force components F_2 , F_3 , and F_4 to the handle, as shown. These forces are equivalent to a force-couple system acting at point A having a force $F_A = 4.4 \text{ lbf } \hat{i} + F_{Ay} \hat{j} + (-0.9 \text{ lbf } \hat{k})$, and a couple $M_A = M_{Ax} \hat{i} + 2.5 \text{ lbf}\cdot\text{ft } \hat{j} + (-0.8 \text{ lbf}\cdot\text{ft } \hat{k})$. Given: $a = 2.2$ in., $b = 1.9$ in., $c = 4.7$ in., and $M_1 = 1.7 \text{ lbf}\cdot\text{ft}$. Determine the force F_3 (it will be positive if it acts in the direction shown).



19. [1pt] Determine F_{Ay} (it will be positive if it acts in the $+y$ direction).

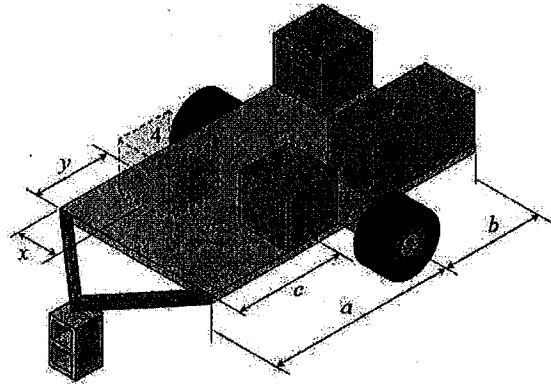
20. [2pt] Determine M_{Ax} .

21. [1pt] Determine F_4 .

22. [2pt] Determine F_2 .

23. [2pt] Determine F_1 .

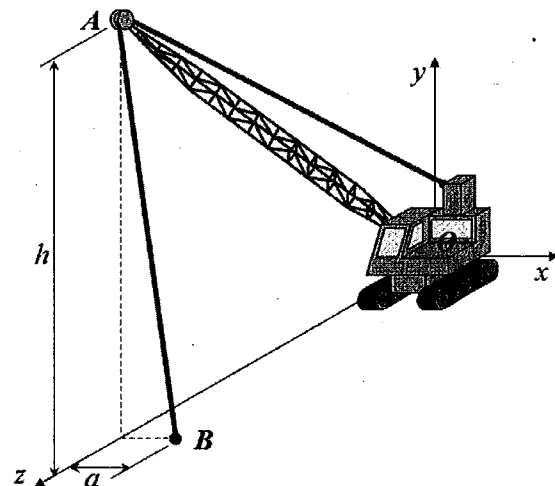
24. [1pt] Four crates of sand from an archaeological dig are to be loaded onto a flatbed trailer measuring $2\text{m} \times 4\text{m}$. There are three small boxes of size $0.6\text{m} \times 0.6\text{m} \times 0.6\text{m}$, and one large box of size $0.6\text{m} \times 0.6\text{m} \times 1.2\text{m}$. Two boxes are perfectly aligned to the back corners of the trailer, and one is aligned with the edge, as shown. The weights of the first three boxes are $W_1 = 200 \text{ N}$, $W_2 = 155 \text{ N}$, and $W_3 = 375 \text{ N}$. The fourth box is to be filled with sand and placed such that center of mass of all four crates is directly over the center of the axle. No part of crate 4 may overhang the trailer. Given: $a = 2.1\text{m}$, $b = 1.9 \text{ m}$, and $c = 1.6 \text{ m}$. What is the smallest possible weight of the fourth box?



25. [2pt] What is the distance x ?

26. [2pt] What is the distance y ?

27. [3pt] A crane is being used to lift a pallet at point B . The boom OA lies in the yz plane, and has a length of 22m . At the instant shown, the tension in cable AB is 3800 N . The height of the top of the boom is $h = 5.5 \text{ m}$, and the distance $a = 4.2 \text{ m}$. Determine the x -component of the moment exerted on the base of the crane (at point O) by the cable AB .



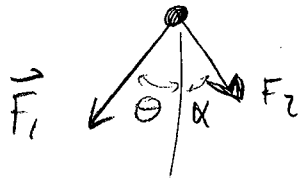
28. [3pt] Determine the y -component of the moment exerted on the base of the crane by cable AB .

29. [3pt] Determine the z -component of the moment exerted on the base of the crane by cable AB .

Applied, Assign #1

①

①



Given $(\vec{F}_1 + \vec{F}_2)_x = 0$ (vertical)

$$F_{1x} = -F_1 \sin \theta, \quad F_{2x} = +F_2 \sin \alpha, \quad \text{so}$$

$$F_2 = \frac{F_1 \sin \theta}{\sin \alpha}$$

Don't know α , but want F_2 min. F_2 min is when $\alpha = 90^\circ$

①

$$F_{2 \text{ min}} = F_1 \sin \theta$$

②

$$\alpha = 90^\circ$$

Finally, $R_x = F_{1x} + F_{2x} = 0$

$$R_y = F_{1y} + F_{2y} = F_{1y}$$

$$R = \sqrt{R_x^2 + R_y^2} = R_y = F_{1y}$$

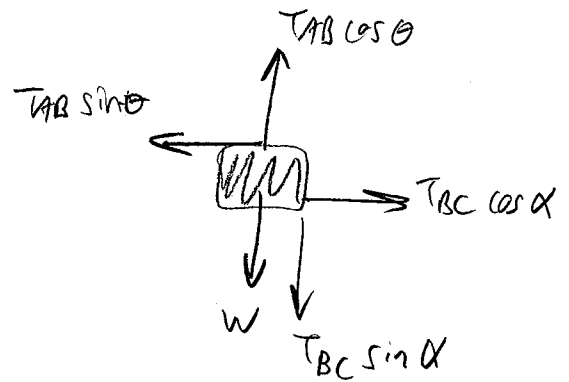
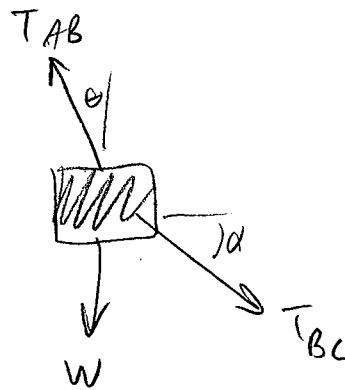
③

$$R = F_1 \cos \theta$$

Applied, Assign #1

②

④ Object is crate



$$\sum F_y = 0$$

$$T_{AB} \sin \theta = T_{BC} \cos \alpha$$

$$T_{BC} = \frac{T_{AB} \sin \theta}{\cos \alpha} \quad [!]$$

$$\sum F_y = 0 = T_{AB} \cos \theta - T_{BC} \sin \alpha - W = 0$$

④ Algebra \rightarrow

$$T_{AB} = \frac{W}{\cos \theta - \sin \theta \tan \alpha}$$

⑤ Algebra \rightarrow

$$T_{BC} = \frac{W \sin \theta}{\cos \alpha (\cos \theta - \sin \theta \tan \alpha)}$$

Applied, Assign #1

3

⑥ Object's car + inhabitants support system

Given: $T_{AC} = T_{BC}$ (same cable)

$$\sum F_x = 0$$

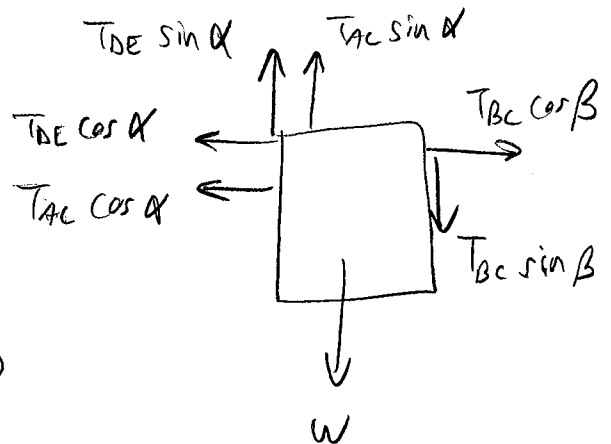
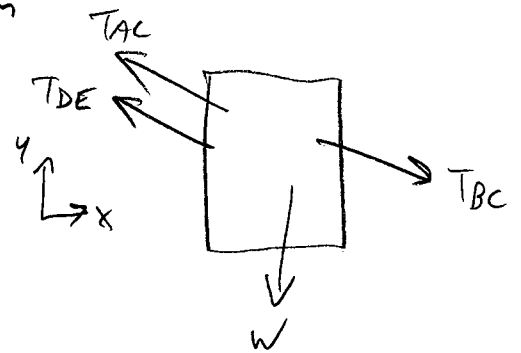
$$T_{BC} \cos \beta - T_{DE} \cos \alpha - T_{AC} \cos \alpha = 0$$

$$\rightarrow T_{DE} = -T_{AC} \left(\frac{\cos \alpha - \cos \beta}{\cos \alpha} \right) \quad [1]$$

$$\sum F_y = 0$$

$$T_{DE} \sin \alpha + T_{AC} \sin \alpha - T_{BC} \sin \beta - W = 0$$

Substitute from [1], Algebra \rightarrow



⑥

$$T_{AC} = \frac{W}{\sin \alpha - \sin \beta - \tan \alpha (\cos \alpha - \cos \beta)}$$

Note: $T_{AC} \gg W !!$

Also, from [1]

$$T_{DE} = \frac{W (\cos \beta - \cos \alpha)}{\cos \alpha (\sin \alpha - \sin \beta - \tan \alpha (\cos \alpha - \cos \beta))}$$

Applied assign #1

(4)

8) $\Sigma F_y = 0$

$$N = mg \cos \theta$$

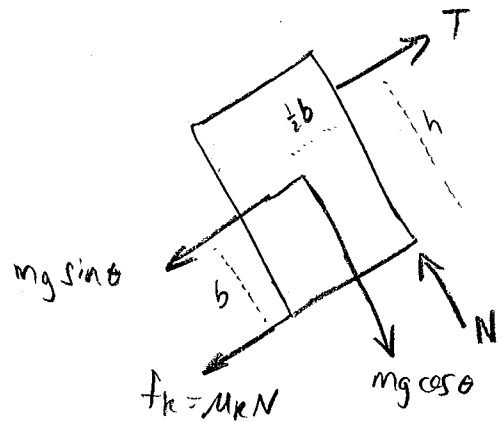
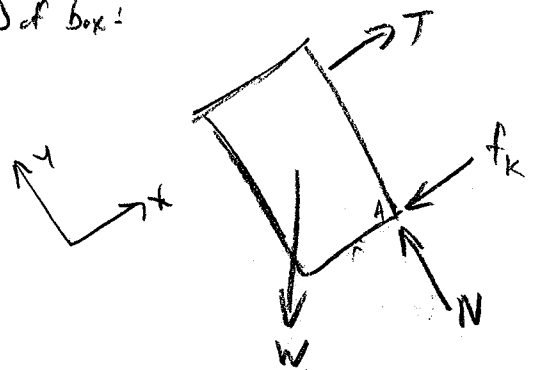
$$\Sigma F_x = 0 \quad (a=0 \text{ if } v=\text{const.})$$

$$T - mg \sin \theta - f_k = 0$$

$$T = mg \sin \theta + \mu_k mg \cos \theta$$

$$T = mg (\sin \theta + \mu_k \cos \theta)$$

FBD of box:



9) $\Sigma M_{A2} = 0$

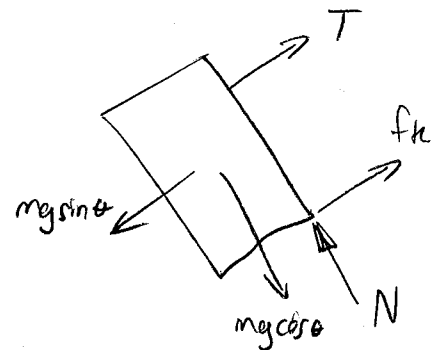
$$-T(h) + mg \sin \theta (b) + mg \cos \theta \left(\frac{b}{2}\right) = 0$$

$$h = \frac{mg b \left(\sin \theta + \frac{1}{2} \cos \theta \right)}{T} \rightarrow h = b \left(\frac{\sin \theta + \frac{1}{2} \cos \theta}{\sin \theta + \mu_k \cos \theta} \right)$$

c) In this case, friction is reversed.

$$T = mg (\sin \theta - \mu_k \cos \theta)$$

$$h = b \left(\frac{\sin \theta + \frac{1}{2} \cos \theta}{\sin \theta - \mu_k \cos \theta} \right)$$



Applied, Assign #1

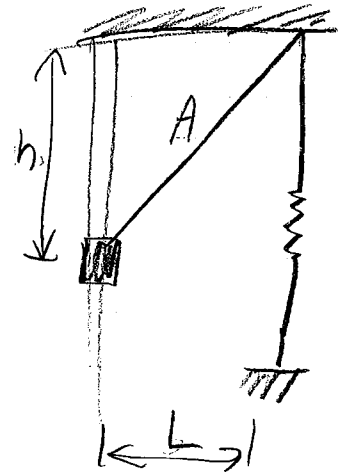
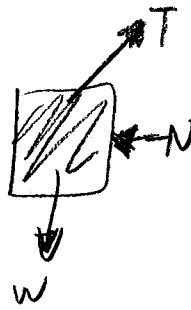
5

12) FBD is sliding collar

h_0 : spring is unstretched
 h_1 : block is in equilibrium

At equilibrium,

$$\sum F_y = 0 \rightarrow W = T_y = \frac{T h_1}{\sqrt{h_1^2 + L^2}}$$



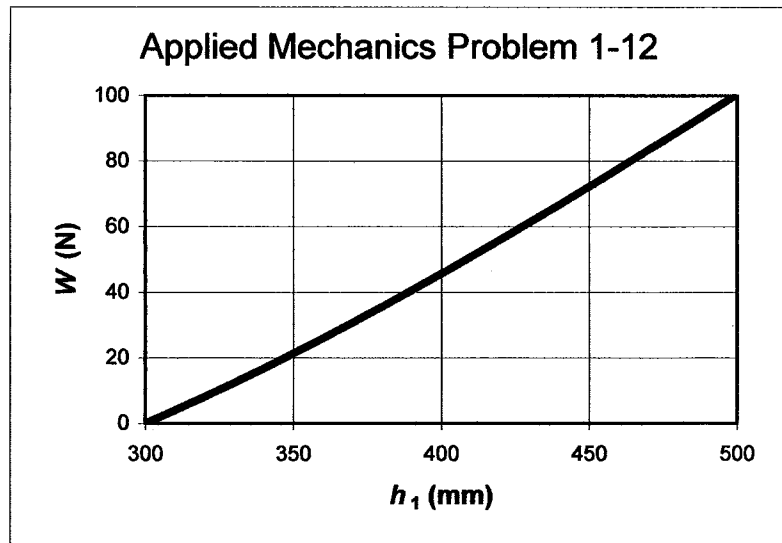
Here, $T = k \Delta y_{\text{spring}}$. What is Δy ?

At equilibrium, $A_1 = \sqrt{h_1^2 + L^2}$, and $\Delta y = A_1 - A_0 = \sqrt{h_1^2 + L^2} - \sqrt{h_0^2 + L^2}$

$$W = h_1 k \left[\frac{\sqrt{h_1^2 + L^2} - \sqrt{h_0^2 + L^2}}{\sqrt{h_1^2 + L^2}} \right]$$

Using $L = 260 \text{ mm}$
 $h_0 = 300 \text{ mm}$
 $k = 680 \text{ N/m}$

Here is the overall trend:

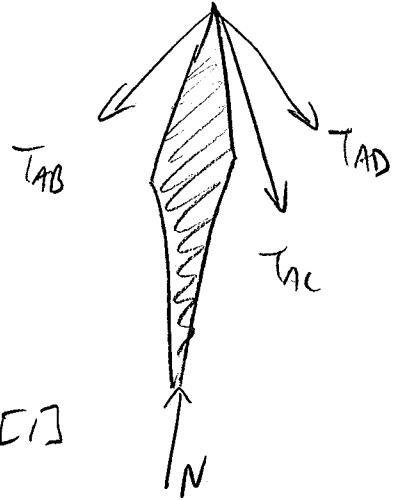


Applied, Assgn #1

6

13) FBD is the tower.

As always, $L_{AB} = \sqrt{L_{ABx}^2 + L_{ABy}^2 + L_{ABz}^2}$
and so on.



$$\sum F_x = 0 = -T_{ABx} + T_{ACx} - T_{ADx}$$

$$0 = -T_{AB} \frac{L_{ABx}}{L_{AB}} + T_{AC} \frac{L_{ACx}}{L_{AC}} - T_{AD} \frac{L_{ADx}}{L_{AD}} \quad [1]$$

$$\sum F_z = 0 = +T_{ABz} + T_{ACz} - T_{ADz}$$

$$0 = T_{AB} \frac{L_{ABz}}{L_{AB}} + T_{AC} \frac{L_{ACz}}{L_{AC}} - T_{AD} \frac{L_{ADz}}{L_{AD}} \quad [2]$$

Solving [1] and [2] simultaneously (or using solver)

$$T_{AD} = T_{AB} \frac{\frac{L_{ABx} L_{ACy}}{L_{AB} \cdot L_{ACx}} + \frac{L_{ABy}}{L_{AB}}}{\frac{L_{ADx} L_{ACy}}{L_{AD} L_{ACx}} - \frac{L_{ADy}}{L_{AD}}}$$

Using this with [1] gives

$$T_{AC} = \frac{L_{AC}}{L_{ACx}} \left(T_{AD} \frac{L_{ADx}}{L_{AD}} - T_{AB} \frac{L_{ABx}}{L_{AB}} \right)$$

Applied, Assign 1

(15)

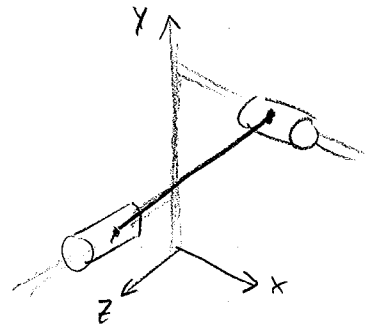
FBD of lower slider, in z-DIR, reveal:

(16)

$$T_z = Q$$

(17)

$$T \frac{b}{L} = Q \quad [1]$$



Similarly, for the upper slider $P = \frac{T a}{L} \quad [2]$

Finally, the pythagorean theorem tells us that $L^2 = a^2 + b^2 + h^2 \quad [3]$

Given: L, h, a, Q

From [3],

$$b = \sqrt{L^2 - a^2 - h^2}$$

From [1],

$$T = \frac{Q L}{b} =$$

$$T = \frac{Q L}{\sqrt{L^2 - a^2 - h^2}}$$

Finally, from [2],

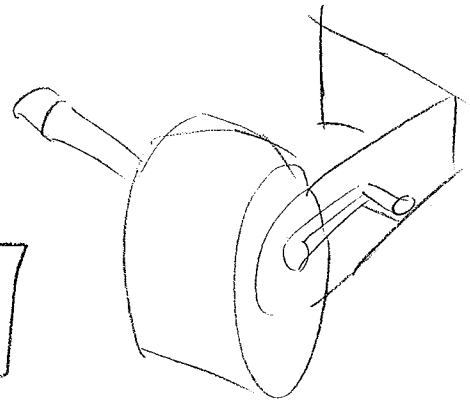
$$P = \frac{T a}{L}$$

$$P = \frac{Q a}{\sqrt{L^2 - a^2 - h^2}}$$

Applied, Assign 1

18 through 23

This is NOT a FBD problem.



- $M_{Az} = -F_3 \cdot c$

$$F_3 = -\frac{M_{Az}}{c}$$

- $F_{Ay} = -C_y$

- $M_{Ax} = M_1 + F_3 \cdot b$

- $F_{Az} = -F_4 \rightarrow F_4 = -F_{Az}$

- $M_{Ay} = F_1(a+b) + F_2b + F_4c \rightarrow$ two unknowns F_1, F_2

- $F_{Ax} = F_1 + F_2 \rightarrow F_1 = F_{Ax} - F_2$ plug into previous

$$M_{Ay} = (F_{Ax} - F_2)(a+b) + F_2b + F_4c$$

$$M_{Ay} = F_{Ax}(a+b) - F_2a + F_4c$$

Solve for $F_2 \rightarrow$

$$F_2 = \frac{F_{Ax}(a+b) - F_{Az} \cdot c - M_{Ay}}{a}$$

Finally, $F_1 = F_{Ax} - F_2$

$$F_1 = \frac{F_{Ax} \cdot b - F_{Az} \cdot c - M_{Ay}}{a}$$

Note: Given F_{Az} and M_{Az} are negative!

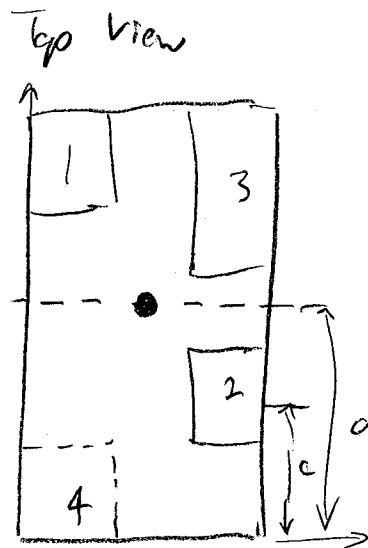
Applied, Assign 1

24 through 26

The smallest weight is when $x, y \rightarrow -\infty$.

But, we have two constraints:

- A) $x_{min} = \frac{H}{2} = 0.3m$
 B) $y_{min} = \frac{H}{2} = 0.3m$
- } box 4 no further than lower corner



Given: $x_{cm} = 1.0m$, $y_{cm} = a$

Center of Mass: $x_{cm} \cdot W_{TOT} = \sum x_i W_i$

X-DIR $(1m)(W_1 + W_2 + W_3 + W_4) = (0.3m)W_1 + (0.3m)W_4 + (1.7m)W_2 + (1.7m)W_3$

$$W_{4A} = W_3 + W_2 - W_1 \quad (\text{first criteria})$$

Y-DIR $(a)(W_1 + W_2 + W_3 + W_4) = (0.3)W_4 + 3.7W_1 + 3.4W_3 + cW_2$

$$W_{4B} = \frac{(3.7-a)W_1 + (3.4-a)W_3 + (c-a)W_2}{a-0.3} \quad (\text{second restriction})$$

Since we must satisfy both criteria, we have to choose W_4 = the larger of W_{4A} and W_{4B} .

$$W_4 = \max(W_{4A}, W_{4B})$$

For me, $W_{4A} = 370N$, and $W_{4B} = 358.42N$

$$W_4 = 370.0N$$

Clearly, this requires $x = 0.3m$ *, since that's how it was found.

Finally, $a \cdot W_{TOT} = yW_4 + 3.7W_1 + 3.4W_3 + cW_2$

$$y = \frac{(a-3.7)W_1 + (a-3.4)W_3 + (a-c)W_2 + aW_4}{W_4}$$

$$y = 0.359m$$

* your solution may require $y = 0.3m$ instead.

$$(27) \quad T_{AB} = 3500 \text{ N}$$

$$L_{OA} = 17 \text{ m}$$

$$L_{OAY} = h = 5.5 \text{ m}$$

$$L_{OAX} = 0$$

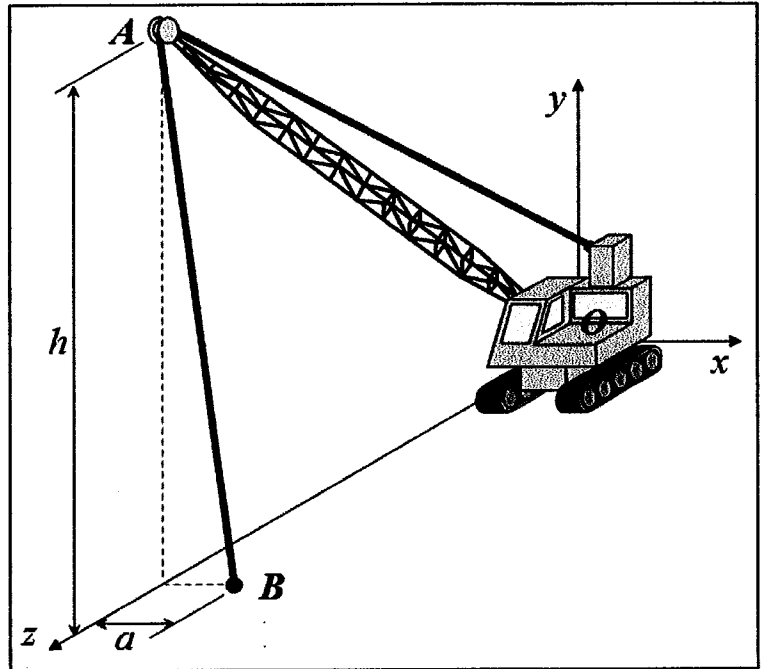
$$\therefore L_{OAZ} = 16.09 \text{ m}$$

$$L_{ABx} = 4 \text{ m} \quad (\text{"a"})$$

$$L_{ABY} = 5.5 \text{ m} \quad (\text{"h"})$$

$$L_{ABZ} = 0 \text{ m}$$

$$\therefore L_{AB} = 6.8007 \text{ m}$$



$$(27) \quad M_{Ox} = +T_{By} L_{OAZ} = \frac{T_{AB} L_{ABY}}{L_{AB}} L_{OAZ} = M_{Ox} = +45.5 \text{ kN}\cdot\text{m}$$

$$(28) \quad M_{Oy} = +T_{Bx} L_{OAZ} = \frac{T_{AB} L_{ABx}}{L_{AB}} L_{OAZ} = M_{Oy} = +33.1 \text{ kN}\cdot\text{m}$$

$$(29) \quad M_{Oz} = -T_{Bx} \cdot h = \frac{T_{AB} L_{ABx}}{L_{AB}} \cdot h = M_{Oz} = -11.3 \text{ kN}\cdot\text{m}$$