

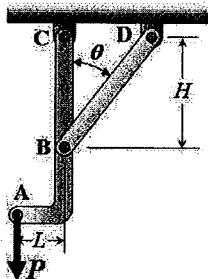
1. [3pt] Two forces are applied to the hook as shown. The magnitudes of the forces are $F_1 = 70$ N, and $F_2 = 55$ N. If $\alpha = 29^\circ$, what is β such that the resultant of the two forces is horizontal?



2. [2pt] What is the magnitude of the corresponding resultant of these two forces?

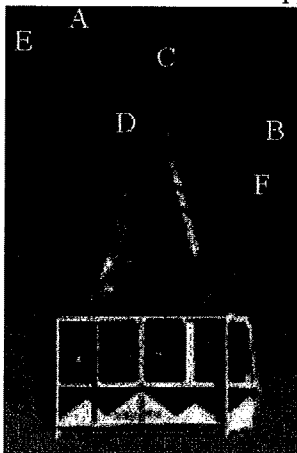
3. [2pt] Both β and F_2 are now changed so that F_2 is the smallest possible value for which the resultant is horizontal. What is the new value of F_2 ?

4. [3pt] Member BD exerts a force of magnitude 1600 N on member ABC that is directed along the line BD (i.e., similar to the tension in a rope). If $\theta = 34^\circ$, $H = 96$ cm, and $L = 57$ cm, what is the magnitude of the horizontal component of the force in member BD?



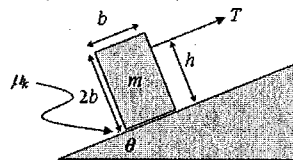
5. [3pt] Knowing that there is no net torque about point C acting on member ABC, determine the magnitude of the force P.

6. [7pt] The cabin of an aerial tramway (weighing 19.5 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 $\alpha = 40.5^\circ$ with the horizontal, while cable BC makes an angle $\beta = 33.5^\circ$ with the horizontal. What is the tension in support cable ACB?



7. [4pt] What is the tension in the traction cable DE?

8. [5pt] Determine the magnitude of the tension T needed to ensure that the crate slides uphill with constant velocity. Given: $\theta = 55^\circ$, $b = 0.4$ m, $m = 130$ kg, and $\mu_k = 0.06$.

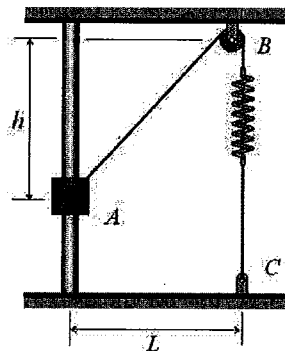


9. [5pt] Determine the maximum height h such that the block won't tip over while moving uphill at constant speed.

10. [3pt] Determine the magnitude of the tension such that the block will slide downhill with constant velocity.

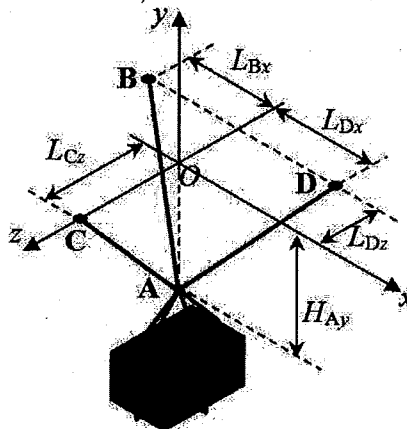
11. [3pt] Determine the maximum height h such that the block won't tip over while moving downhill at constant speed.

12. [4pt] Collar A can slide on a frictionless vertical rod. The horizontal length L is 260 mm. The spring constant is 600 N/m, and the spring is unstretched when $h = 295$ mm. The system is in equilibrium when $h = 380$ mm. Determine the weight of the collar.



Written Assignment [10 pt]: Submit your work with commentary and a textbook-quality plot of $W(h)$, starting at 295 mm and ranging at least 200 mm.

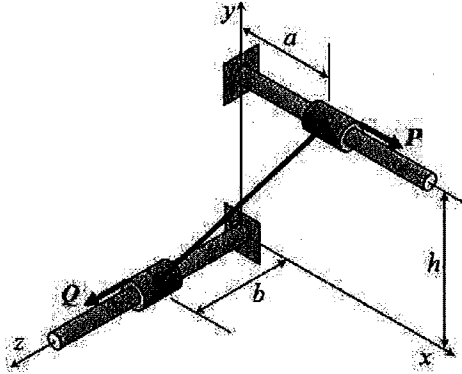
13. [4pt] Three cables are used to support a crate (held at point A below the origin) from the ceiling (points B, C, and D). Given $L_{Bx} = 0.9$ m, $L_{Dx} = 1.1$ m, $L_{Cz} = 0.7$ m, $L_{Dz} = 0.5$ m, and $H_{Ay} = 1.6$ m. If the tension in cable AB is 1500 N, what is the tension in cable AC?



14. [4pt] What is the weight of the crate?

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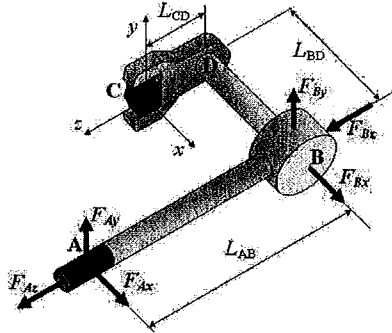
15. [3pt] The two collars shown can move freely on the frictionless rods, which are perpendicular to each other and separated by a distance $h = 5.5$ in. They are connected by a wire of length 9.5 in. At a certain instant, the collars are in equilibrium, the force Q is 60 lbf, and the distance a is 6.5 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] A crowfoot wrench is used to loosen the rusty bolt at C . The mechanic holds the wrench at A and B , exerting forces there. As a result, the bolt at C experiences some net force and some net moment. The net force at C is known to be $(-48 \hat{i} + 0 \hat{j} + 19 \hat{k})\text{N}$, and the net moment at C is known to be $(25 \hat{i} + 0 \hat{j} + 0 \hat{k})\text{Nm}$. Also, the component $F_{Az} = 10\text{N}$. Determine the component F_{Ax} , given: $L_{AB} = 240\text{mm}$, $L_{BD} = 175\text{mm}$, and $L_{CD} = 46\text{mm}$.



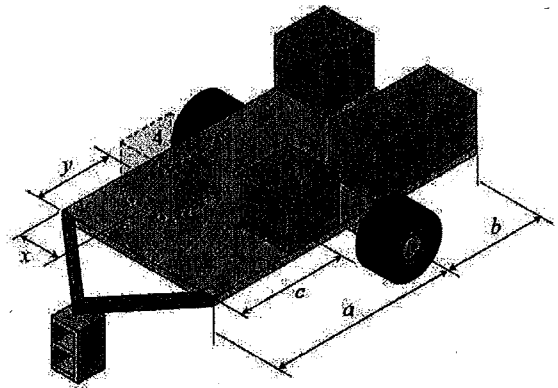
19. [2pt] Determine the component F_{Ay} .

20. [2pt] Determine the component F_{Bx} .

21. [2pt] Determine the component F_{By} .

22. [2pt] Determine the component F_{Bz} .

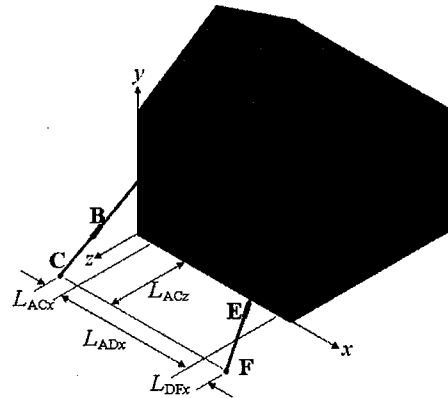
23. [4pt] Four crates of sand from an archaeological dig are to be loaded onto a flatbed trailer measuring $2\text{m} \times 4\text{m}$. There are three small boxes of size $0.6\text{m} \times 0.6\text{m} \times 0.6\text{m}$, and one large box of size $0.6\text{m} \times 0.6\text{m} \times 1.2\text{m}$. 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 $W_1 = 200\text{N}$, $W_2 = 175\text{N}$, and $W_3 = 425\text{N}$. 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 $c = 1.7\text{m}$. What is the smallest possible weight of the fourth box?



24. [3pt] What is the distance x ?

25. [3pt] What is the distance y ?

26. [3pt] A farmer uses cables AC and DF with turnbuckles B and E to plumb one side of his barn. The total moment about the x -axis of the two cables is $4740\text{ft}\cdot\text{lb}$, and the tension in cable AC is 265lb . Given: $L_{ACx} = 0.8\text{ft}$; $L_{DFx} = 2.4\text{ft}$; $L_{ADx} = 20.0\text{ft}$; $L_{ACz} = 13.0\text{ft}$; $HA = 12.0\text{ft}$; and $HD = 14.5\text{ft}$. Determine the tension in cable DF .



27. [3pt] Determine the net moment of the two cables about the y axis.

28. [3pt] Determine the net moment of the two cables about the z axis.

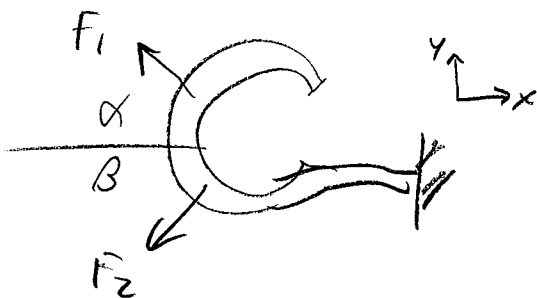
Assign 1

① $\sum F_y = 0$

$$F_1 - F_2 = 0$$

$$F_1 \sin \alpha - F_2 \sin \beta = 0$$

$$\beta = \arcsin\left(\frac{F_1 \sin \alpha}{F_2}\right)$$



② $\vec{F}_{TOT} = \vec{F}_1 + \vec{F}_2$ $F_{TOT,x} = -F_1 \cos \alpha - F_2 \cos \beta$

$$F_{TOT,y} = 0 \quad (\text{given})$$

So $|F_{TOT}| = F_1 \cos \alpha + F_2 \cos \beta$

③ For this part, F_2 is vertically down. ($\beta = 90^\circ$)

$$F_2 = F_1 \sin \alpha$$

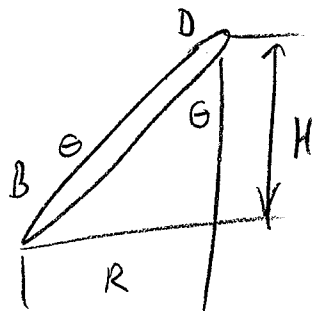
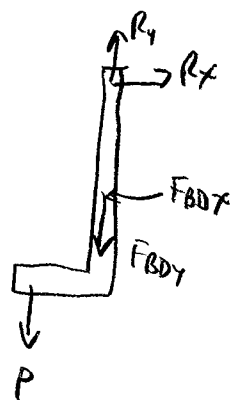
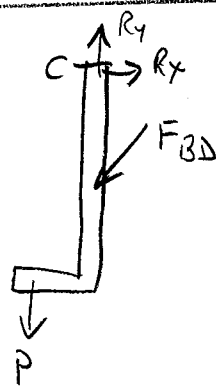
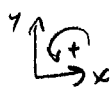
④ OBJECT IS ABC

$$R = H \tan \theta$$

Similar triangles:

$$\frac{F_{BDx}}{F_{BD}} = \frac{R}{\sqrt{R^2 + H^2}}$$

$$F_{BDx} = \frac{R \cdot F_{BD}}{\sqrt{R^2 + H^2}}$$



⑤ $\sum M_c = 0$
 $+ P \cdot L - F_{BDx} \cdot H = 0$

$$P = \frac{F_{BDx} \cdot H}{L}$$

Applied, Assign #1

3

⑥ Object's car + inhabitants + support system

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

$$\sum F_x = 0$$

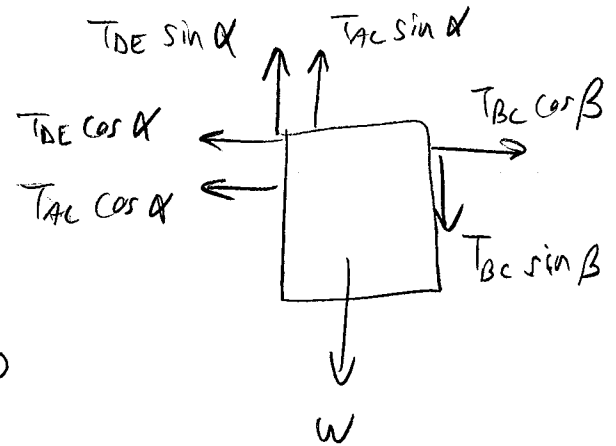
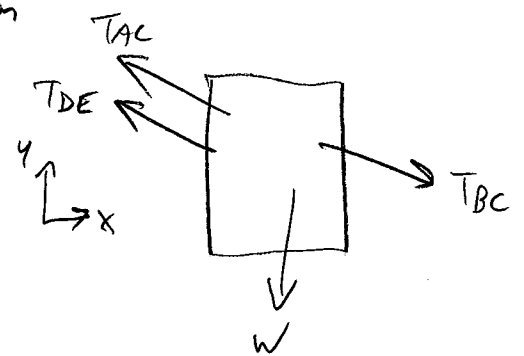
$$T_{BC} \cos \beta - T_{DE} \cos \alpha - T_{AC} \cos \alpha = 0$$

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

$$\sum F_y = 0$$

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

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) $\Sigma F_y = 0$

$N = mg \cos \theta$

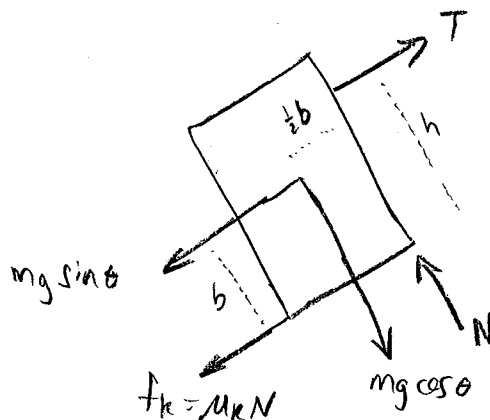
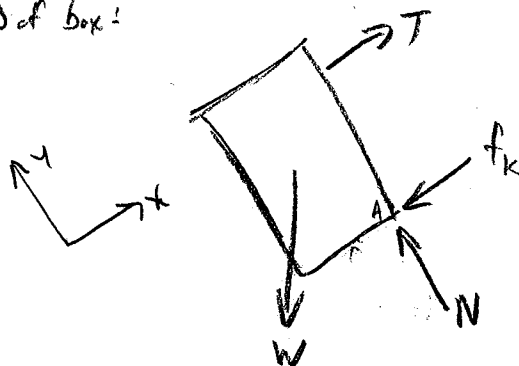
$\Sigma F_x = 0$ ($a = 0$ if $v = \text{const.}$)

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

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

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

FBD of box:



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

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

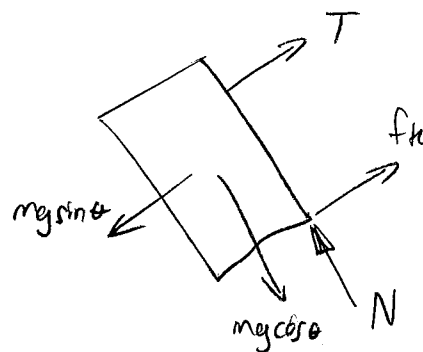
9) $h = \frac{mg b (\sin \theta + \frac{1}{2} \cos \theta)}{T}$

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

c) In this case, friction is reversed.

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

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



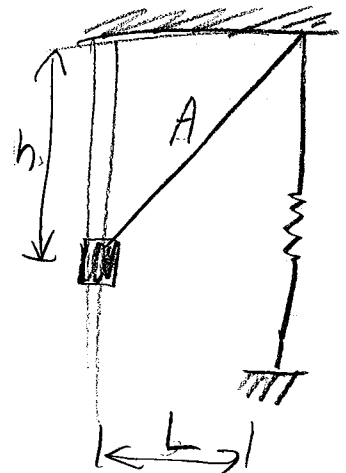
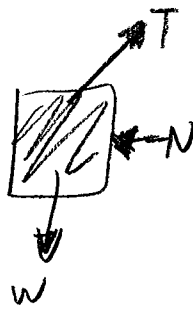
Applied, Assign #1

5

12) FBD is sliding collar

h_0 : spring is unstretched
 h_1 : block is in equilibrium

At equilibrium,



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

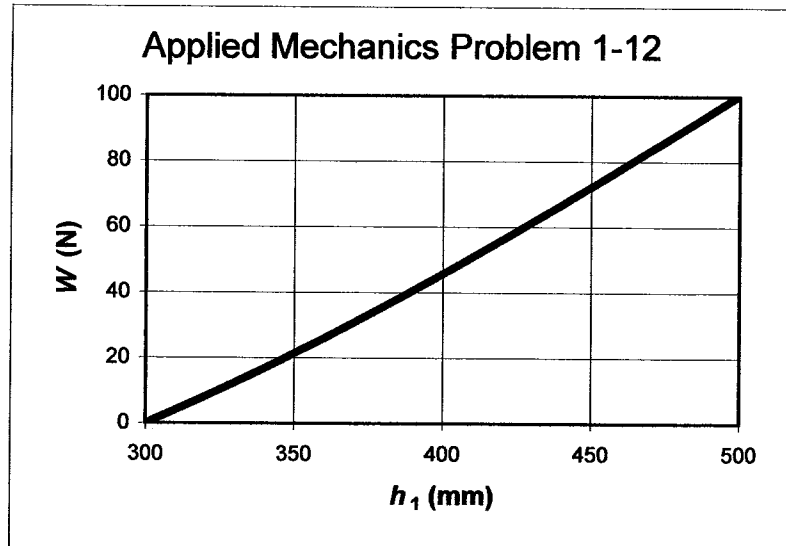
Here, $T = k \Delta y_{\text{spring}}$. What is Δy ?

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

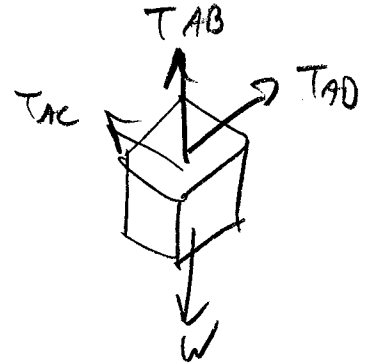
$$W = h_1 k \left[\frac{\sqrt{h_1^2 + L^2} - \sqrt{h_0^2 + L^2}}{\sqrt{h_1^2 + L^2}} \right]$$

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

Here is the overall trend:



$$\begin{array}{l}
 \textcircled{13} \quad L_{ABx} = 0.9 \text{ m} \\
 L_{ABy} = 1.6 \text{ m} \\
 L_{ABz} = 0.5 \text{ m} \\
 L_{AB} = 1.9026 \text{ m} \\
 T_{AB} = 1500 \text{ N} \\
 \text{Object} = \text{crate}
 \end{array}
 \left|
 \begin{array}{l}
 L_{ACx} = 0 \\
 L_{ACy} = 1.6 \text{ m} \\
 L_{ACz} = 0.7 \text{ m} \\
 L_{AC} = 1.7464 \text{ m}
 \end{array}
 \right.
 \begin{array}{l}
 L_{ADx} = 1.1 \text{ m} \\
 L_{ADy} = 1.6 \text{ m} \\
 L_{ADz} = 0.5 \text{ m} \\
 L_{AD} = 2.005 \text{ m}
 \end{array}$$



$$\sum F_x = 0$$

$$-T_{ABx} + T_{ADx} = 0$$

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

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

$$T_{AD} = 1293 \text{ N}$$

$$\sum F_z = 0$$

$$+T_{ACz} - T_{ABz} - T_{ADz} = 0$$

$$T_{AC} \frac{L_{ACz}}{L_{AC}} = T_{AB} \frac{L_{ABz}}{L_{AB}} + T_{AD} \frac{L_{ADz}}{L_{AD}}$$

$$T_{AC} = 1787.5 \text{ N}$$

$$\textcircled{14} \quad \sum F_y = 0$$

$$W = T_{ABy} + T_{ACy} + T_{ADy}$$

$$W = T_{AB} \left(\frac{L_{ABy}}{L_{AB}} \right) + T_{AC} \left(\frac{L_{ACy}}{L_{AC}} \right) + T_{AD} \left(\frac{L_{ADy}}{L_{AD}} \right)$$

$$W = 3931 \text{ N}$$

Applied, Assign 1

(15)

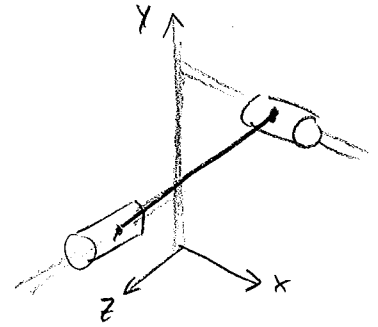
FBD of lower slider, in z-DIR, reveals:

(16)

$$T_z = Q$$

(17)

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



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

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

Given: L, h, a, Q

From [3],

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

From [1],

$$T = \frac{QL}{b} =$$

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

Finally, from [2],

$$P = \frac{Ta}{L}$$

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

$$\textcircled{18} \quad \begin{aligned} F_{\text{on bolt}} &= -48\hat{i} + 0\hat{j} + 19\hat{k} \rightarrow F_{\text{on wrench}} = 48\hat{i} - 19\hat{k} \\ M_{\text{on bolt}} &= 25\hat{i} + 0\hat{j} + 0\hat{k} \rightarrow M_{\text{on wrench}} = -25\hat{i} \end{aligned}$$

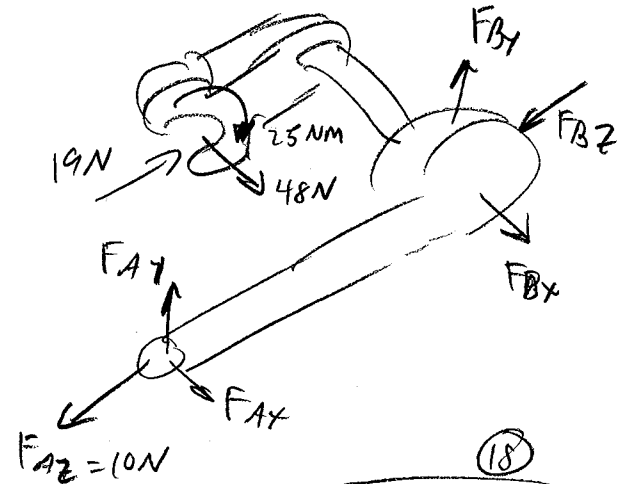
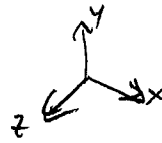
OBJECT = wrench

$$F_{Az} = 10\text{ N}$$

$$L_{AB} = 240\text{ mm}$$

$$L_{BD} = 175\text{ mm}$$

$$L_{CD} = 46\text{ mm}$$



$$\Sigma F_z = 0 = +10\text{ N} - 19\text{ N} + F_{Bz}$$

$$\textcircled{22} \quad F_{Bz} = +9\text{ N}$$

$$\Sigma M_{By} = 0 = F_{Ax} \cdot L_{AB} - 19\text{ N} \cdot L_{BD} + 48\text{ N} \cdot L_{CD} = 0 \rightarrow F_{Ax} = +4.65\text{ N}$$

$$\Sigma F_x = 0 \rightarrow 48\text{ N} + F_{Ax} + F_{Bx} = 0 \rightarrow \textcircled{20} \quad F_{Bx} = -52.65\text{ N}$$

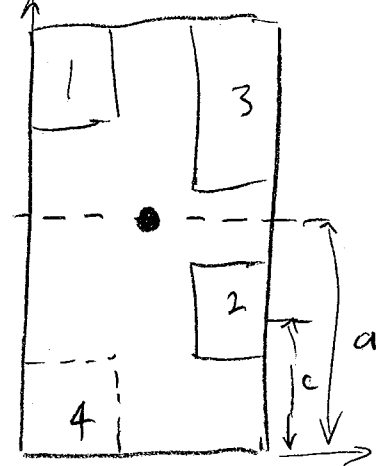
$$\Sigma M_{Bx} = 0 = -F_{Ay} \cdot L_{AB} - 25\text{ Nm} = 0 \rightarrow \textcircled{19} \quad F_{Ay} = -104.2\text{ N}$$

$$\Sigma F_y = 0 = F_{Ay} + F_{By} = 0 \rightarrow \textcircled{21} \quad F_{By} = +104.2\text{ N}$$

Applied, Assign 1

23 through 25 $a = 2.1\text{m}$ $b = 1.9\text{m}$ $c = 1.6\text{m}$

Top view



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

BUT, we have two constraints:

A) $x_{min} = \frac{H}{2} = 0.3\text{m}$
 B) $y_{min} = \frac{H}{2} = 0.3\text{m}$

} box 4 no further than lower corner

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

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

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

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

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

$W_{4B} = \frac{(3.7-a)W_1 + (3.4-a)W_3 + (c-a)W_2}{a-0.3}$ (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, $W_{4A} = 370\text{N}$, and $W_{4B} = 358.42\text{N}$

$W_4 = 370.0\text{N}$

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

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

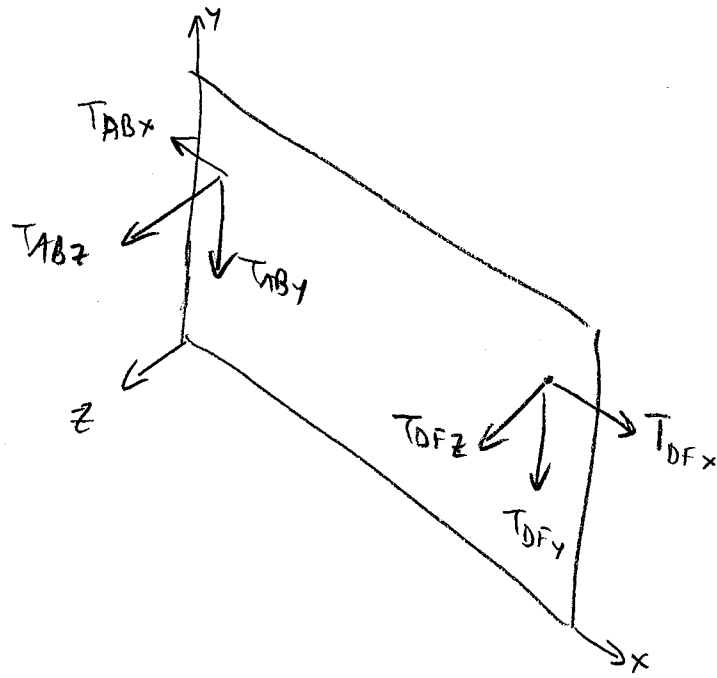
$y = \frac{(a-3.7)W_1 + (a-3.4)W_3 + (a-c)W_2 + aW_4}{W_4}$

$y = 0.359\text{m}$

* your solution may require $y = 0.3\text{m}$ instead.

$$\begin{aligned} \textcircled{26} \quad \Sigma M_x &= +4740 \text{ ft}\cdot\text{lb} \\ T_{AC} &= 265 \text{ lb} = T_{AB} \\ L_{ACx} &= 0.8 \text{ ft} \\ L_{ACy} &= H_A = 12 \text{ ft} \\ \underline{L_{ACz} &= 13 \text{ ft}} \\ L_{AC} &= 17.7099 \text{ ft} \end{aligned}$$

$$\begin{aligned} L_{DFx} &= 2.4 \text{ ft} \\ L_{DFy} &= 14.5 \text{ ft} = H_D \\ \underline{L_{DFz} &= 13 \text{ ft}} \\ L_{DF} &= 19.6217 \text{ ft} \end{aligned}$$



$$\begin{aligned} \Sigma M_x &= 4740 = T_{DFz} \cdot H_A + T_{ABz} \cdot H_A \\ 4740 &= T_{DF} \frac{L_{DFz}}{L_{DF}} H_D + T_{AB} \frac{L_{ABz}}{L_{AB}} H_A \rightarrow T_{DF} = 250.42 \text{ lb} \end{aligned}$$

$$\begin{aligned} \textcircled{27} \quad \Sigma M_y &= -T_{ABz} \cdot L_{ACx} - T_{DFz} \cdot (L_{ADx} + L_{ACx}) \\ &= -T_{AB} \frac{L_{ABz}}{L_{AB}} L_{ACx} - T_{DF} \frac{L_{DFz}}{L_{DF}} (L_{ADx} + L_{ACx}) \quad [L_{ADx} = 20 \text{ ft}] \\ &= -155.62 \text{ ft}\cdot\text{lb} - 3450.95 \text{ ft}\cdot\text{lb} \end{aligned}$$

$$\Sigma M_y = -3606 \text{ ft}\cdot\text{lb}$$

$$\begin{aligned} \textcircled{28} \quad \Sigma M_z &= T_{ABx} \cdot H_A - T_{ABy} \cdot L_{ACx} - T_{DFx} \cdot H_D - T_{DFy} \cdot (L_{ACx} + L_{ADx}) \\ &= T_{AB} \frac{L_{ABx}}{L_{AB}} H_A - T_{AB} \frac{L_{ABy}}{L_{AB}} L_{ACx} - T_{DF} \frac{L_{DFx}}{L_{DF}} H_D - T_{DFy} (L_{ACx} + L_{ADx}) \\ &= +143.65 \text{ ft}\cdot\text{lb} - 143.65 \text{ ft}\cdot\text{lb} - 444.13 \text{ ft}\cdot\text{lb} - 3849 \text{ ft}\cdot\text{lb} \end{aligned}$$

$$\Sigma M_z = -4293 \text{ ft}\cdot\text{lb}$$