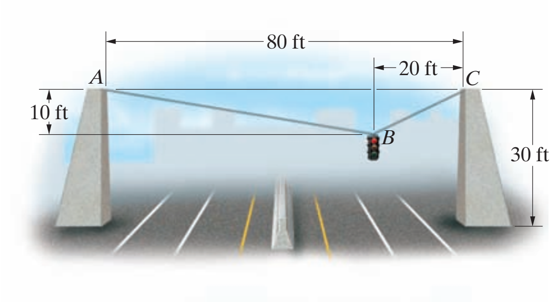
SOLUTION MANUAL FOR

ENGINEERING MECHANICS
STATICS

Fifth Edition

Bedford | Fowler

Problem 3.25 A traffic engineer wants to suspend a 200-lb traffic light above the center of the two right lanes of a four-lane thoroughfare as shown. Determine the tensions in the cables AB and BC.

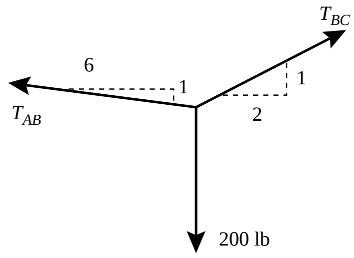


Solution:

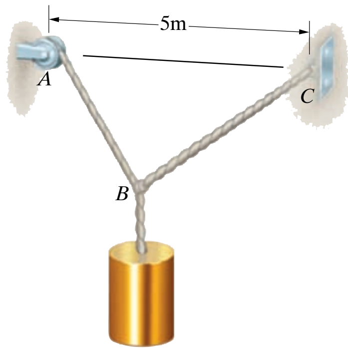
$$\sum F_x : -\frac{6}{\sqrt{37}}T_{AB} + \frac{2}{\sqrt{5}}T_{BC} = 0$$

$$\sum F_y : \frac{1}{\sqrt{37}}T_{AB} + \frac{1}{\sqrt{5}}T_{BC} - 200 \text{ lb} = 0$$

Solving: $\boxed{T_{AB} = 304 \text{ lb}, \; T_{BC} = 335 \text{ lb}}$



Problem 3.26 Cable AB is 3 m long and cable BC is 4 m long. The mass of the suspended object is 350 kg. Determine the tensions in cables AB and BC.

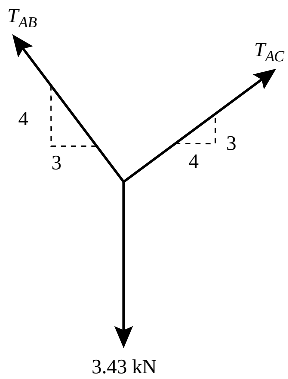


Solution:

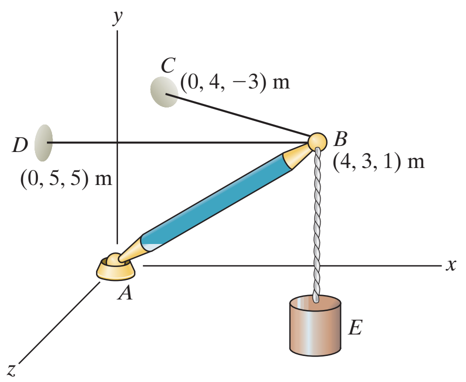
$$\sum F_x : -\frac{3}{5}T_{AB} + \frac{4}{5}T_{BC} = 0$$

$$\sum F_y : \frac{4}{5}T_{AB} + \frac{3}{5}T_{BC} - 3.43 \text{ kN} = 0$$

$\boxed{T_{AB} = 2.75 \text{ kN}, \; T_{BC} = 2.06 \text{ kN}}$



Problem 4.73 The tension in the cable BD is 1 kN. As a result, cable BD exerts a 1-kN force on the "ball" at B that points from B toward D. Determine the moment of this force about point A.



Solution: We have the force and position vectors

$$\mathbf{F} = \frac{1\text{ kN}}{6}(-4\mathbf{i} + 2\mathbf{j} + 4\mathbf{k}), \quad \mathbf{r} = \mathbf{AB} = (4\mathbf{i} + 3\mathbf{j} + \mathbf{k})\text{ m}$$

The moment is then

$$\boxed{\mathbf{M} = \mathbf{r} \times \mathbf{F} = (1.667\mathbf{i} - 3.33\mathbf{j} + 3.33\mathbf{k})\text{ kN-m}}$$

Problem 4.74* Suppose that the mass of the suspended object E in Problem 4.73 is 100 kg and the mass of the bar AB is 20 kg. Assume that the weight of the bar acts at its midpoint. By using the fact that the sum of the moments about point A due to the weight of the bar and the forces exerted on the "ball" at B by the three cables BC, BD, and BE is zero, determine the tensions in the cables BC and BD.

Solution: We have the following forces applied at point B.

$$\mathbf{F}_1 = -(100\text{ kg})(9.81\text{ m/s}^2)\mathbf{j}, \quad \mathbf{F}_2 = \frac{T_{BC}}{\sqrt{33}}(-4\mathbf{i} + \mathbf{j} - 4\mathbf{k}),$$

$$\mathbf{F}_3 = \frac{T_{BD}}{6}(-4\mathbf{i} + 2\mathbf{j} + 4\mathbf{k})$$

In addition we have the weight of the bar $\mathbf{F}_4 = -(20\text{ kg})(9.81\text{ m/s}^2)\mathbf{j}$

The moment around point A is

$$\mathbf{M}_A = (4\mathbf{i} + 3\mathbf{j} + \mathbf{k})\text{ m} \times (\mathbf{F}_1 + \mathbf{F}_2 + \mathbf{F}_3)$$

$$+ (2\mathbf{i} + 1.5\mathbf{j} + 0.5\mathbf{k})\text{ m} \times \mathbf{F}_4 = 0$$

Carrying out the cross products and breaking into components we find

$$M_x = 1079 - 2.26T_{BC} + 1.667T_{BD} = 0$$

$$M_y = 2.089T_{BC} - 3.333T_{BD} = 0$$

$$M_z = -4316 + 2.785T_{BC} + 3.333T_{BD} = 0$$

Only two of these three equations are independent. Solving we find

$$\boxed{T_{BC} = 886\text{ N}, \; T_{BD} = 555\text{ N}}$$

6.13 (*Continued*)

(4) *Joint A:*

$$\sum F_y = A_y - \frac{AC}{\sqrt{2}} = 0,$$

from which $AC = \frac{4\sqrt{2}}{3}F = 4\sqrt{2}$ kN (T).

$$\sum F_x = AB + \frac{AC}{\sqrt{2}} = 0,$$

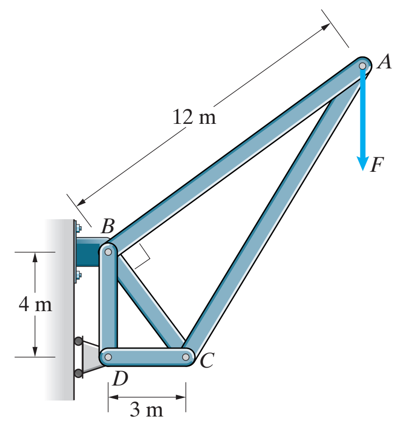
from which $AB = -\frac{4}{3}F = -4$ kN (C).

(5) *Joint C:*

$$\sum F_y = BC + \frac{AC}{\sqrt{2}} - F = 0,$$

from which $\boxed{BC = F - \frac{AC}{\sqrt{2}} = -\frac{1}{3}F = -1 \text{ kN } (C).}$

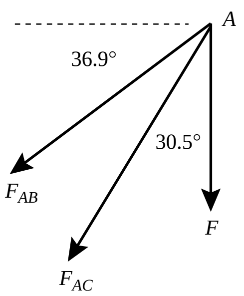
Problem 6.14 If you don't want the members of the truss to be subjected to an axial load (tension or compression) greater than 20 kN, what is the largest acceptable magnitude of the downward force F?



Solution: Start with joint A

$$\sum F_x : -F_{AB}\cos 36.9^\circ - F_{AC}\sin 30.5^\circ = 0$$

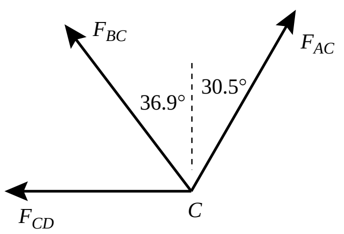
$$\sum F_y : -F_{AB}\sin 36.9^\circ - F_{AC}\cos 30.5^\circ - F = 0$$



Now work with joint C

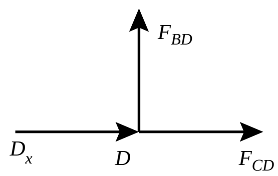
$$\sum F_x : -F_{CD} - F_{BC}\sin 36.9^\circ + F_{AC}\sin 30.5^\circ = 0$$

$$\sum F_y : F_{BC}\cos 36.9^\circ + F_{AC}\cos 30.5^\circ = 0$$



Finally examine joint D

$$\sum F_y : F_{BD} = 0$$



Solving we find

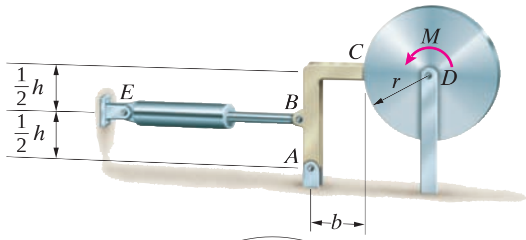
$$F_{AB} = 1.32F,\ F_{AC} = -2.08F,\ F_{CD} = -2.4F,$$

$$F_{BC} = 2.24F,\ F_{BD} = 0$$

The critical member is CD. Thus

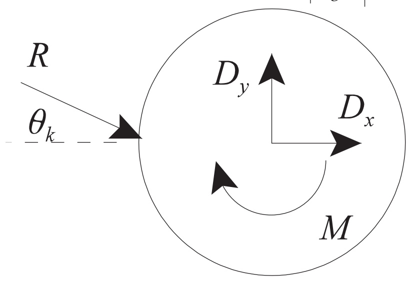
$$\boxed{2.4F = 20 \text{ kN} \Rightarrow F = 8.33 \text{ kN}}$$

Problem 9.22 In Example 9.2, what clockwise couple M would need to be applied to the disk to cause it to rotate at a constant rate in the clockwise direction?



Solution: Assume that the disk is rotating in the clockwise direction. From the free-body diagram of the disk,

$$\Sigma M_D : -M + (R \sin \theta_k) r = 0.$$

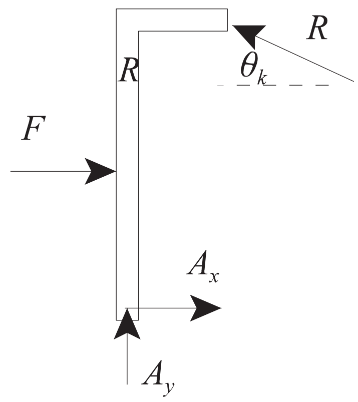


From the free-body diagram of the brake,

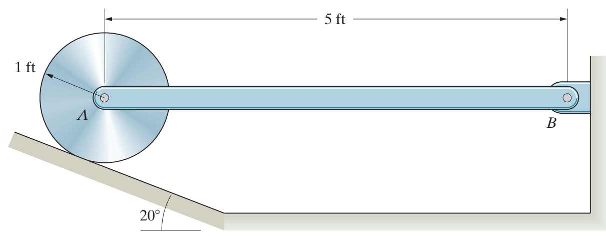
$$\Sigma M_A : -F(\tfrac{1}{2}h) + (R \cos \theta_k) h + (R \sin \theta_k) b = 0.$$

Solving these two equations yields

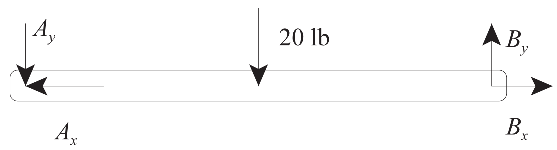
$$\boxed{M = \frac{\frac{1}{2}hrF\mu_k}{h + b\mu_k}.}$$



Problem 9.23 The homogeneous horizontal bar AB weighs 20 lb. The homogeneous disk weighs 30 lb. The coefficient of kinetic friction between the disk and the sloping surface is $\mu_k = 0.24$. What is the magnitude of the couple that would need to be applied to the disk to cause it to rotate at a constant rate in the clockwise direction?



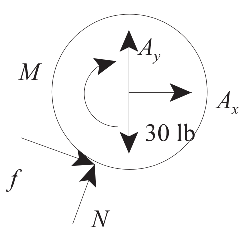
Solution: From the free-body diagram of the bar,



$\Sigma M_B : (20 \text{ lb})(2.5 \text{ ft}) + A_y(5 \text{ ft}) = 0$

$\Rightarrow A_y = -10$ lb.

From the free-body diagram of the disk.



$\Sigma F_x : A_x + N \sin 20^\circ + \mu_k N \cos 20^\circ = 0,$

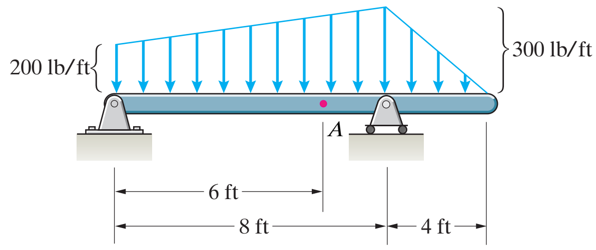
$\Sigma F_y : N \cos 20^\circ - \mu_k N \sin 20^\circ - 30 \text{ lb} = 0,$

$\Sigma M_A : -M + \mu_k N(1 \text{ ft}) = 0.$

Solving yields $A_x = -26.5$ lb, $N = 46.6$ lb, $M = 11.2$ ft-lb.

$\boxed{M = 11.2 \text{ ft-lb.}}$

Problem 10.13 Determine the internal forces and moment at A.

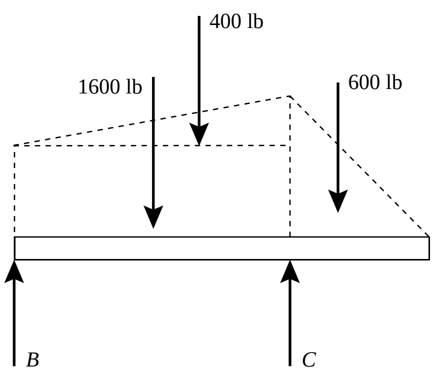


Solution: Use the whole body to find the reactions

$$\sum M_C : -B(8\text{ ft}) + (1600\text{ lb})(4\text{ ft})$$

$$+ (400\text{ lb})(2.67\text{ ft}) - (600\text{ lb})(1.33\text{ ft}) = 0$$

$$\Rightarrow B = 833\text{ lb}$$



Now examine the section to the left of the cut

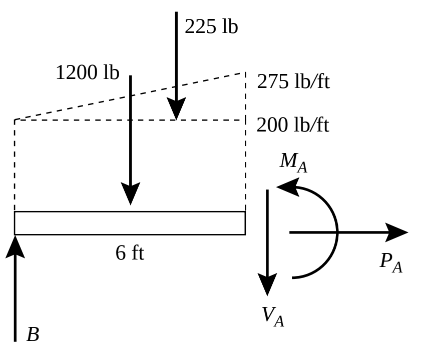
$$\sum F_x : P_A = 0$$

$$\sum F_y : B - 1200\text{ lb} - 225\text{ lb} - V_A = 0$$

$$\sum M_A : -B(6\text{ ft}) + (1200\text{ lb})(3\text{ ft})$$

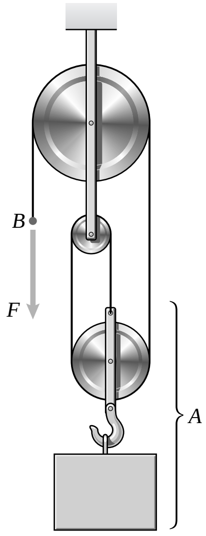
$$+ (225\text{ lb})(2\text{ ft}) + M_A = 0$$

Solving $\boxed{P_A = 0,\ \ V_A = -592\text{ lb},\ \ M_A = 950\text{ ft-lb}}$



Problem 11.49 The system is in equilibrium. The total weight of the suspended load and assembly A is 300 lb.

(a) By using equilibrium, determine the force F.
(b) Using the result of (a) and the principle of virtual work, determine the distance the suspended load rises if the cable is pulled downward 1 ft at B.



Solution:

(a) Isolate the assembly A. The sum of the forces:

$$\sum F_y = -W - 3F = 0,$$

where F is the tension in the cable, from which

$$F = \frac{W}{3} = 100 \text{ lb}.$$

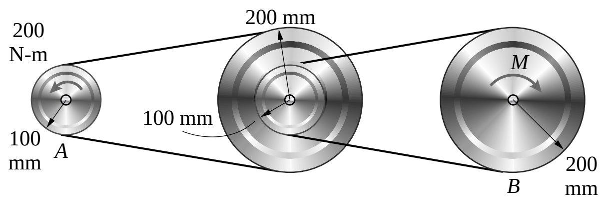
(b) Perform a virtual translation of the assembly A in the vertical direction. The virtual work: $\delta U = -W\delta y + F\delta x = 0$, from which

$$\frac{\delta x}{\delta y} = \frac{W}{F} = 3.$$

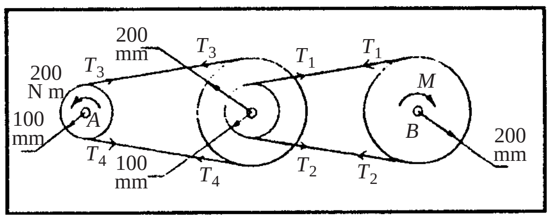
The ratio of translations of the assembly A and the point B is $\frac{1}{y_A} = 3$, from which $y_A = \frac{1}{3}$ ft

Problem 11.50 The system is in equilibrium.

(a) By drawing free-body diagrams and using equilibrium equations, determine the couple M.
(b) Using the result of (a) and the principle of virtual work, determine the angle through which pulley B rotates if pulley A rotates through an angle α.



Solution: The pulleys are frictionless and the belts do not slip. Denote the left pulley by A and the right pulley by B. Denote the upper and lower tensions in the belts at pulley A by T_3, T_4, at B by T_1, T_2.



(a) For pulley A: (1) $(T_3 - T_4)(0.1) = 200$ N m, For pulley B (2) $M = (T_1 - T_2)(0.2)$. For the center pulley, (3) $(T_1 - T_2)(0.1) = (T_3 - T_4)(0.2)$. Combine and solve: $M = (4)(200) = 800$ N m
(b) Perform a virtual rotation of the pulley A. The virtual work of the system is $\delta U = M_1\delta\alpha - M\delta\theta = 0$, from which

$$\frac{\delta\theta}{\delta\alpha} = \frac{M_1}{M} = \frac{200}{800} = \frac{1}{4},$$

from which $\theta = \frac{\alpha}{4}$