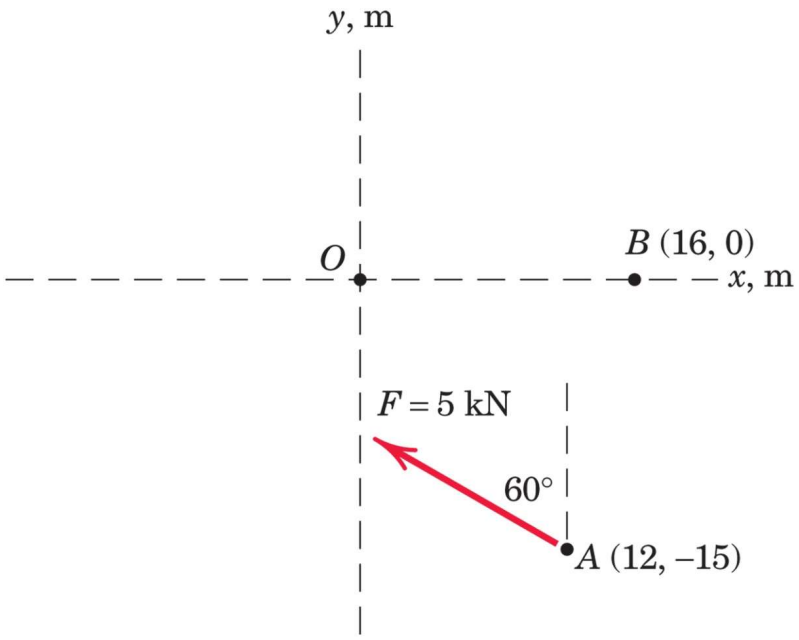
ENGINEERING MECHANICS - STATICS

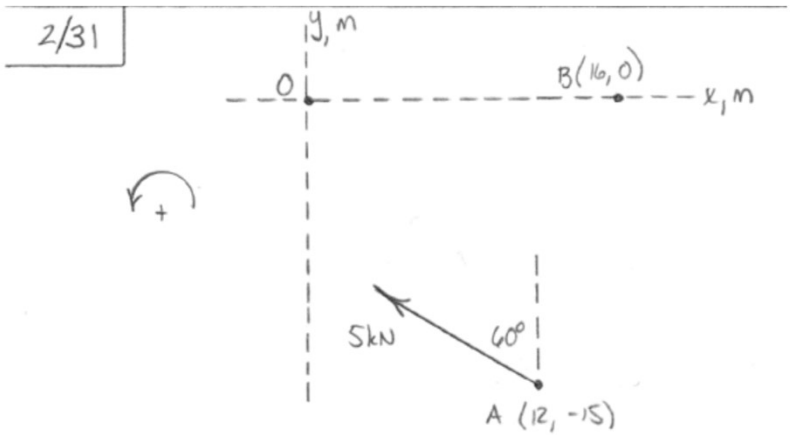
Vinay Papanna

Department of Mechanical Engineering

2/31) Determine the moments of the 5-kN force about point 0 and about point B.



2/31



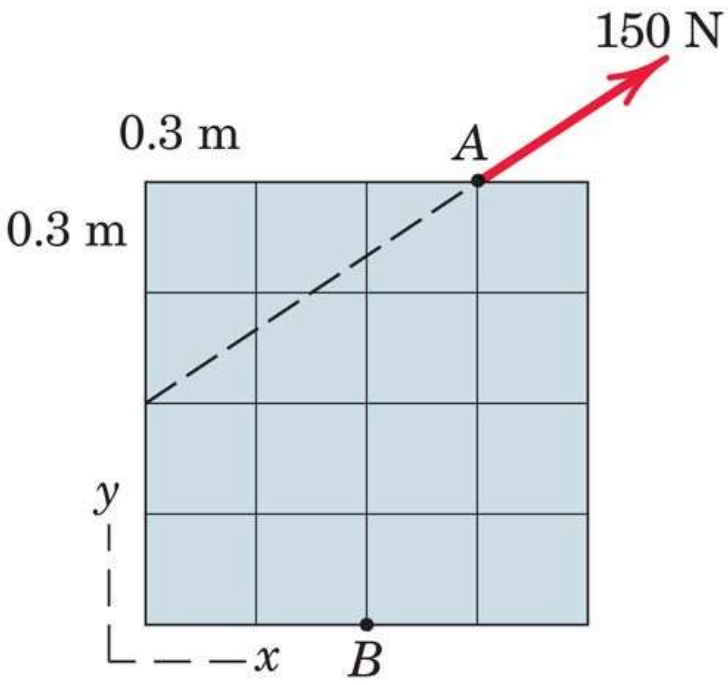
$$M_O = 5\cos 60^\circ(12) - 5\sin 60^\circ(15) = -35.0$$

$$\therefore \quad M_O = 35.0 \text{ kN·m} \quad \text{CW}$$

$$M_B = -5\cos 60^\circ(4) - 5\sin 60^\circ(15) = -75.0$$

$$\therefore \quad M_B = 75.0 \text{ kN·m} \quad \text{CW}$$

2/33) The rectangular plate is made up of 0.3-m squares as shown. A 150-N force is applied at point A in the direction shown. Calculate the moment of the force about point B.



$F_x = F\cos\theta$

$= 150\,\frac{3}{\sqrt{3^2+2^2}}$

$= 450/\sqrt{13}$ N

$F_y = F\sin\theta = 150\,\frac{2}{\sqrt{3^2+2^2}}$

$= 300/\sqrt{13}$ N

$\circlearrowright M_B = \frac{450}{\sqrt{13}}(0.6) + \frac{300}{\sqrt{13}}(0.6) = \frac{450}{\sqrt{13}}$ N·m

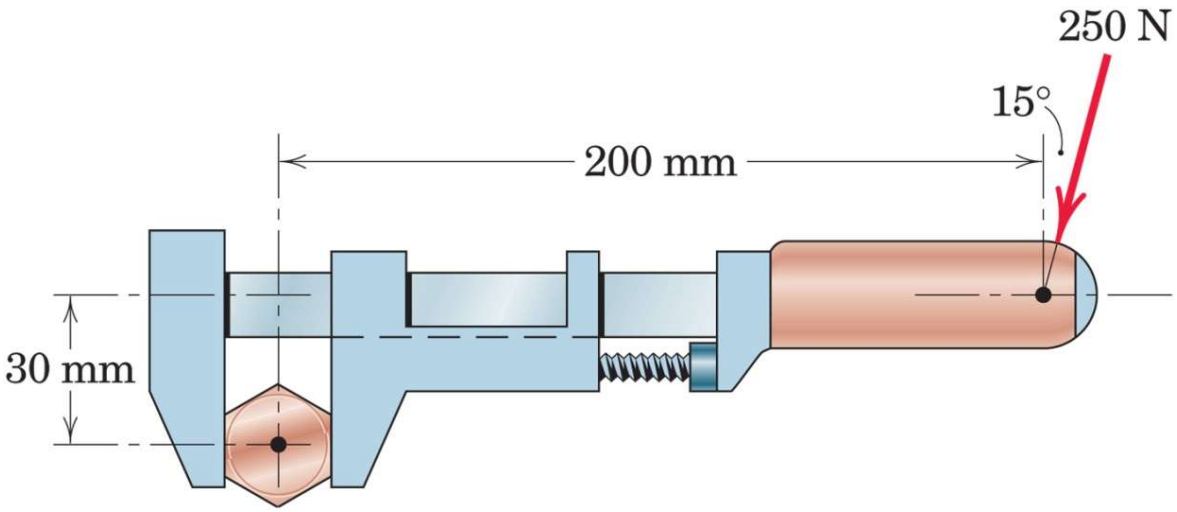
or $M_B = 124.8$ N·m CW

With $\theta = \tan^{-1}\frac{2}{3} = 33.7°$, $\underline{F} = 150(\cos 33.7°\,\underline{i} + \sin 33.7°\,\underline{j})$ N

With $\underline{r} = -0.6\,\underline{i} + 0.6\,\underline{j}$ m, $\underline{M}_B = \underline{r} \times \underline{F}$ yields

$\underline{M}_B = -124.8\,\underline{k}$ N·m, $\underline{M}_B = 124.8$ N·m, as before.

2/34) Calculate the moment of the 250-N force on the handle of the monkey wrench about the center of the bolt.

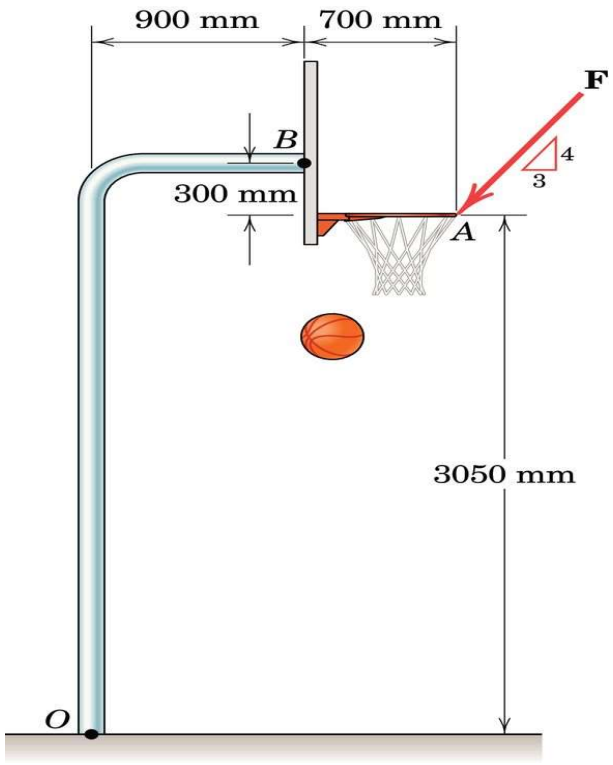


2/34

$+\circlearrowleft M_O = 250\cos 15°(0.200) - 250\sin 15°(0.030)$

$= 48.30 - 1.941 = 46.4\ \text{N·m}$

2/35) An experimental device imparts a force of magnitude F = 225 N to the front edge of the rim at A to simulate the effect of a slam dunk. Determine the moments of the force F about point 0 and about point B. Finally, locate, from the base at 0, a point C on the ground where the force imparts zero moment.



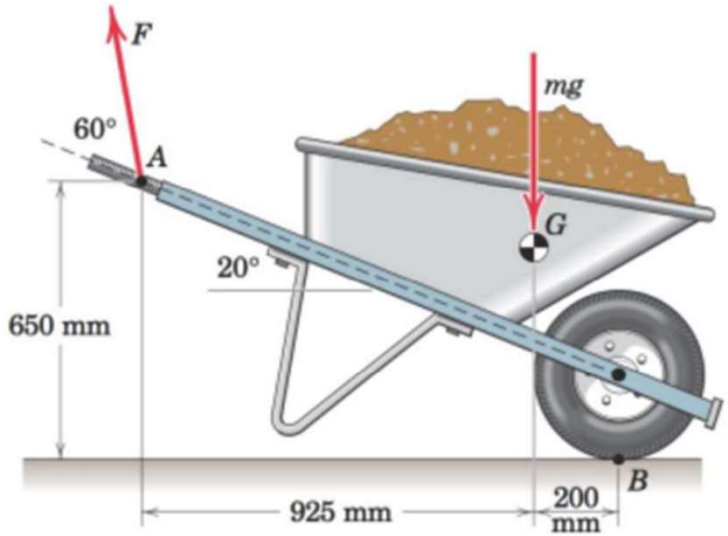
$$M_O = 3.05\left(\tfrac{3}{5}F\right) - 1.6\left(\tfrac{4}{5}F\right) = 123.8 \longrightarrow \underline{M_O = 123.8\ \text{N·m}\ \ \text{CCW}}$$

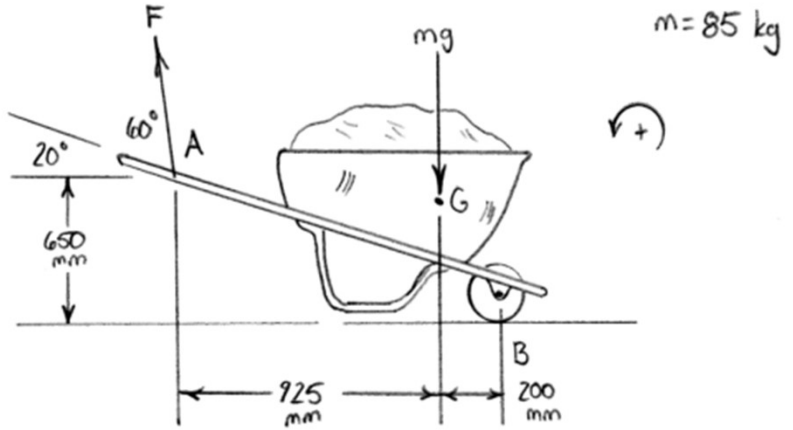
$$M_B = -0.3\left(\tfrac{3}{5}F\right) - 0.7\left(\tfrac{4}{5}F\right) = -166.5 \longrightarrow \underline{M_B = 166.5\ \text{N·m}\ \ \text{CW}}$$

$$M_C = 0 = 3.05\left(\tfrac{3}{5}F\right) - (1.6+d)\left(\tfrac{4}{5}F\right) \longrightarrow d = 0.688\ \text{m}$$

so... $\underline{d = 688\ \text{mm}\ \ \text{LEFT OF}\ \ O}$

2/36) A man exerts a force F on the handle of the stationary wheelbarrow at A. The weight of the wheelbarrow along with its load of dirt is 85 Kg with center of gravity at G. For the configuration shown, what forces F must the man apply at A to make the et moment about the tire contact point B equal to zero.

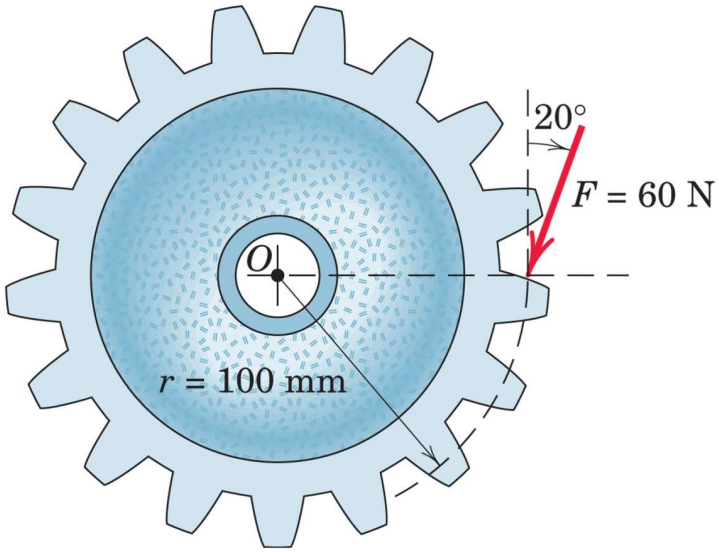




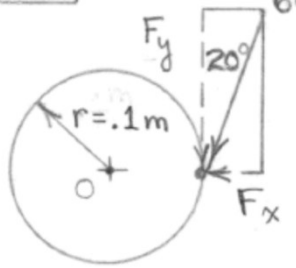
$$M_B = 0.2(85)(9.81) - F\sin 80^\circ\left(\frac{925+200}{1000}\right) + F\cos 80^\circ\left(\frac{650}{1000}\right) = 0$$

$$F = 167.6 \text{ N}$$

2/36) A force F of magnitude 60 N is applied to the gear. Determine the moment of F about point 0.



2/36

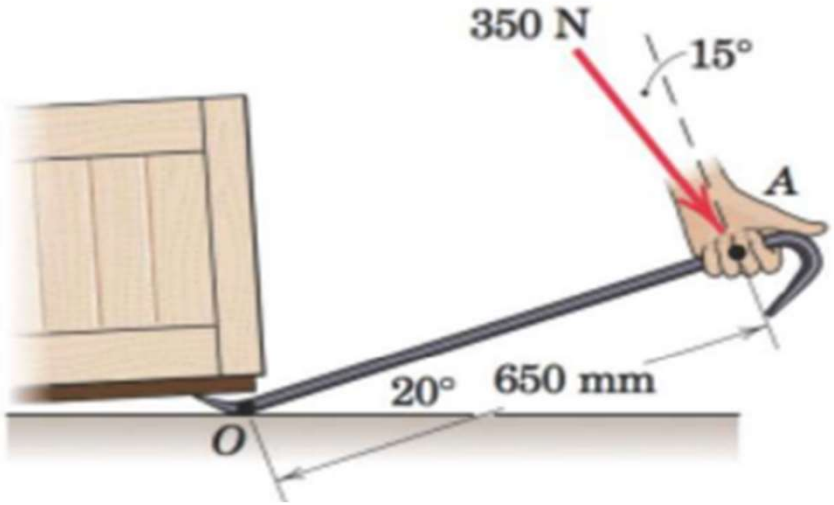


$+\circlearrowleft M_o = r F_y$

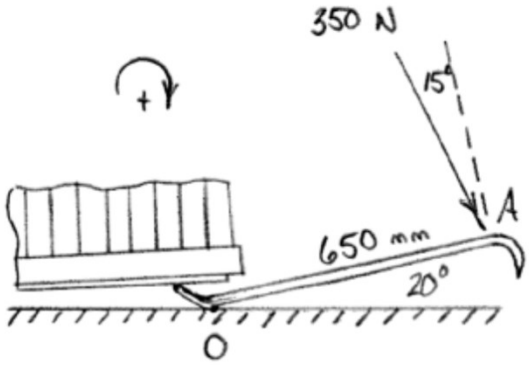
$= (0.1)(60 \cos 20°)$

$= 5.64 \text{ N·m}$

2/37) A man uses a crowbar to lift the corner of a hot tub for maintenance purposes. Determine the moment made by the 350 N force about point O. Neglect the small thickness of the crowbar.

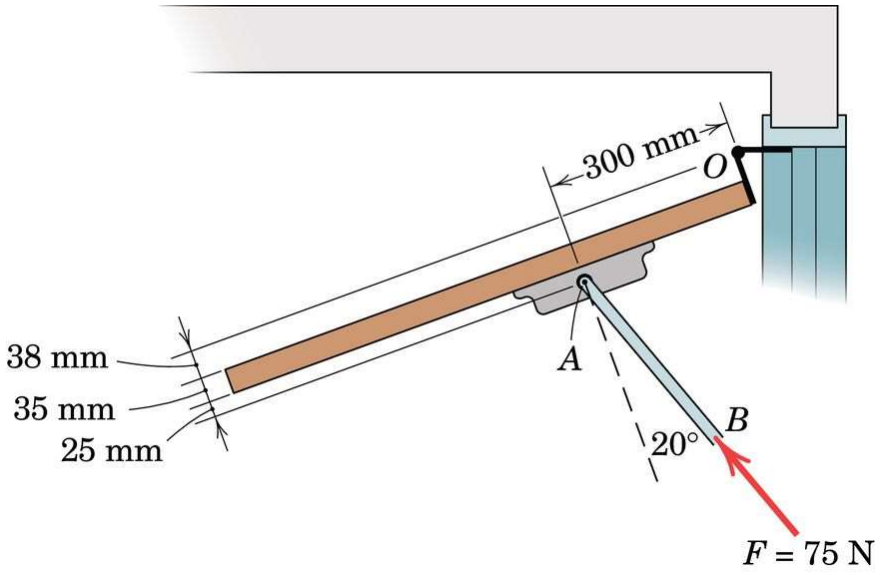


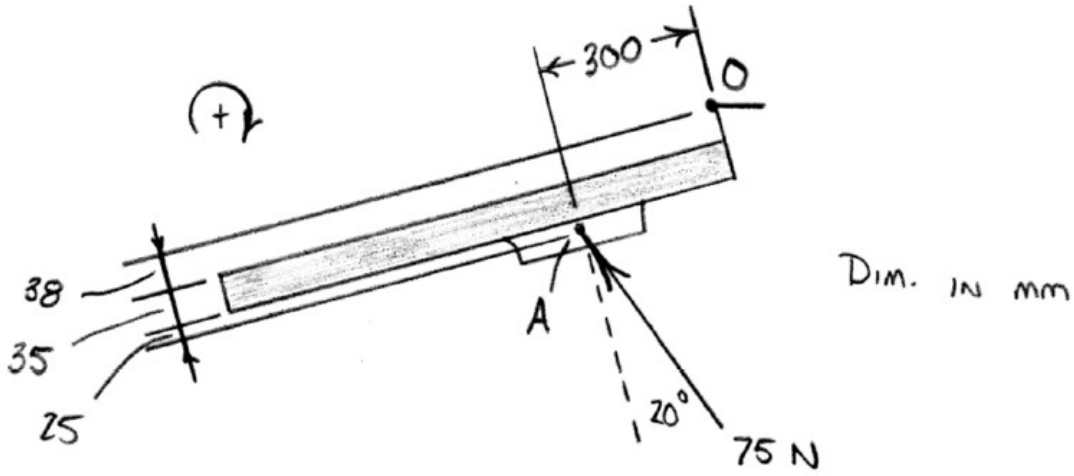
2/37



$M_O = 0.650\,(350 \cos 15^\circ) \rightarrow M_O = 220\ \text{N·m}\ \text{CW}$

2/38) An overhead view of a door is shown. If the compressive force F acting in the coupler arm of the hydraulic door closer is 75 N with the orientation shown, determine the moment of this force about the hinge axis o.

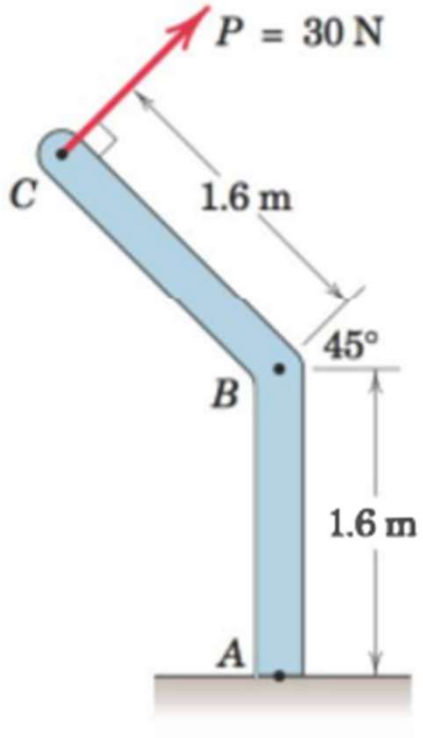




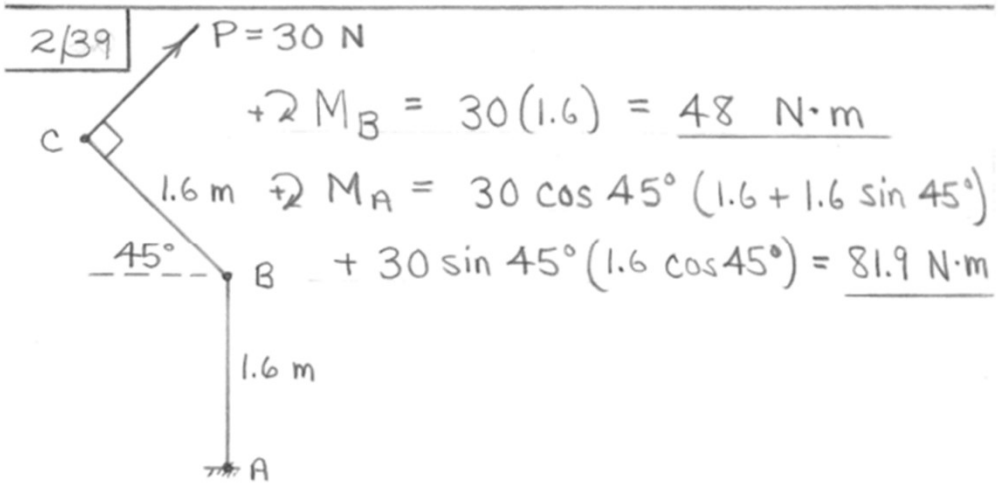
$$M_o = 0.300(75\cos 20^\circ) + \left(\frac{25+35+38}{1000}\right)(75\sin 20^\circ)$$

$$M_o = 23.7 \text{ N·m CW}$$

2/39) The 30 N force P is applied perpendicular to the portion BC of the bend bar. Determine the moment of P about point B and about point A.



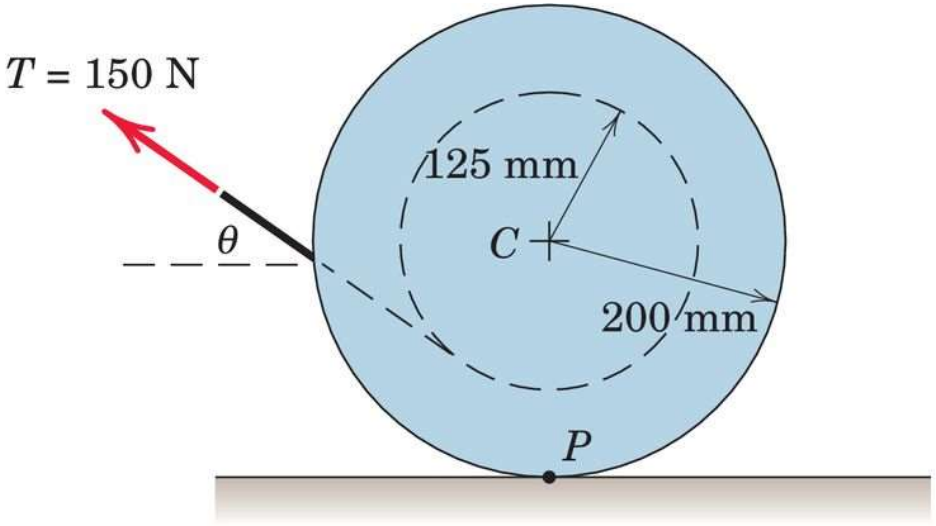
2/39



$+\circlearrowright M_B = 30(1.6) = 48 \text{ N·m}$

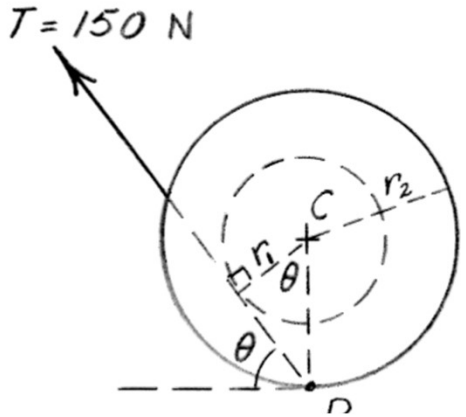
$+\circlearrowright M_A = 30\cos 45°\,(1.6 + 1.6\sin 45°) + 30\sin 45°\,(1.6\cos 45°) = 81.9 \text{ N·m}$

2/41) A 150-N pull T is applied to a cord, which is wound securely around the inner hub of the drum. Determine the moment of T about the drum center C. At what angle θ should T be applied so that the moment about the contact point P is zero?



$\circlearrowleft M_C = Tr_1 = 150(0.125)$

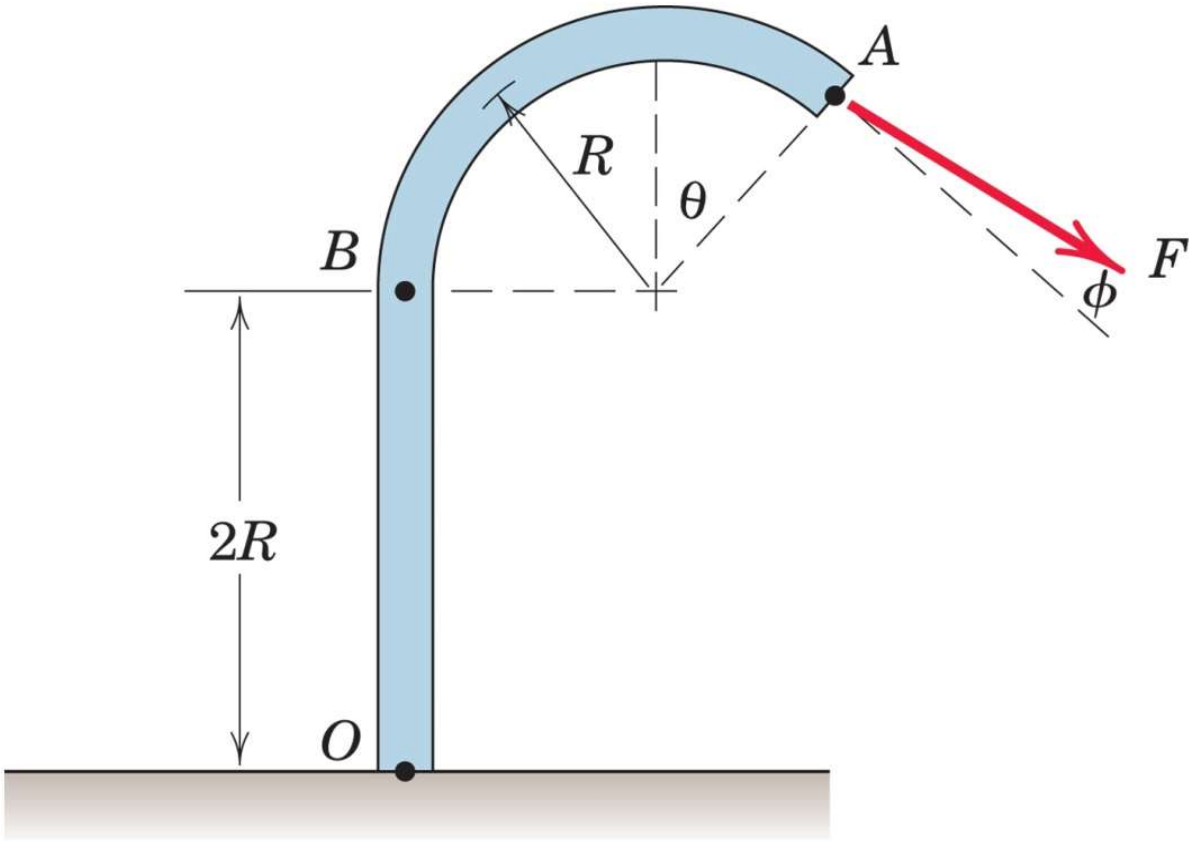
$= \underline{18.75 \text{ N·m CW}}$

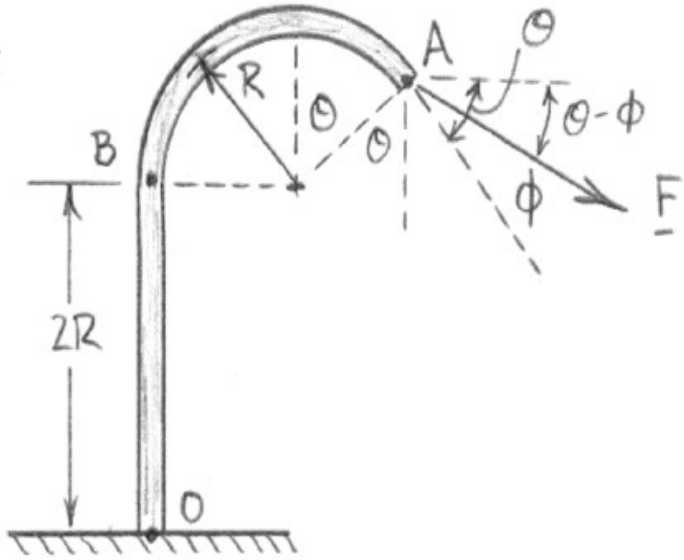


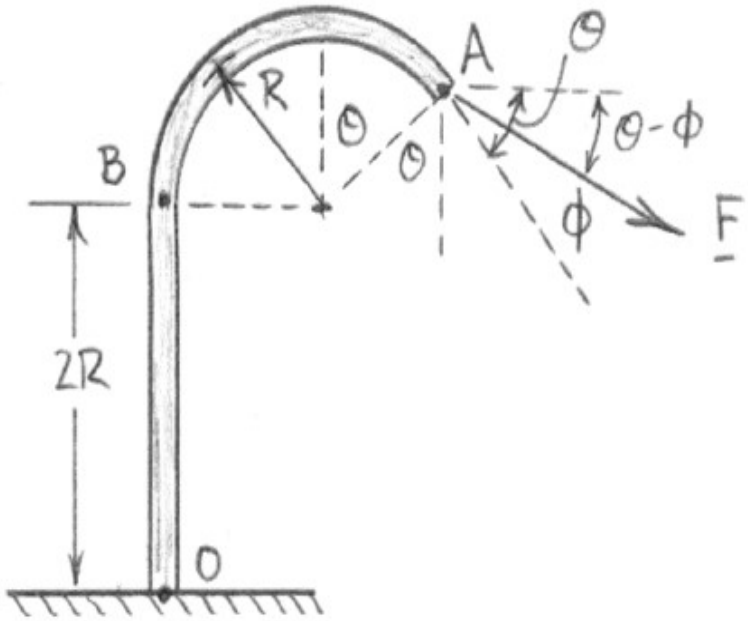
$\cos\theta = \frac{r_1}{r_2} = \frac{125}{200}$

$\underline{\theta = 51.3^\circ}$

2/43) Determine the general expressions for the moments of F about (a) point B and (b) point 0. Evaluate your expressions for F = 750 N, R = 2.4 m, θ= 30°, and ϕ = 15°.







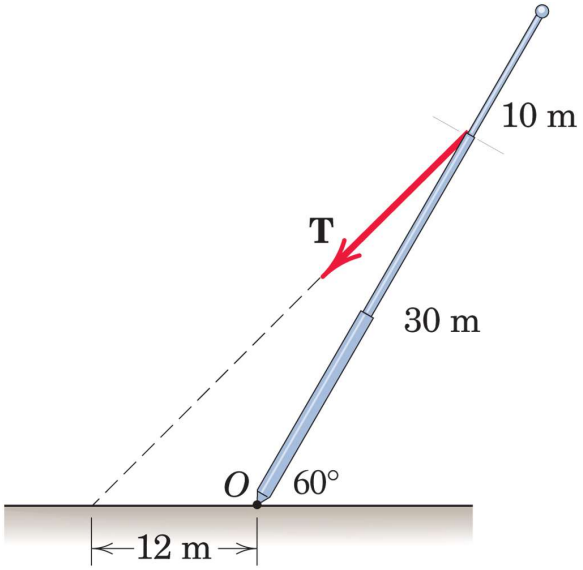
$$\begin{cases} M_B = F\sin(\theta-\phi)(R+R\sin\theta) + F\cos(\theta-\phi)(R\cos\theta) \\ \underline{M_B = FR[\cos\phi + \sin(\theta-\phi)]} \end{cases}$$

$$\begin{cases} M_O = F\sin(\theta-\phi)(R+R\sin\theta) + F\cos(\theta-\phi)(2R+R\cos\theta) \\ \underline{M_O = FR[2\cos(\theta-\phi) + \cos\phi + \sin(\theta-\phi)]} \end{cases}$$

IF $F = 750\ N$, $R = 2.4\ m$, $\theta = 30^\circ$, AND $\phi = 15^\circ$ ...

$$\begin{cases} \underline{M_B = 2200\ N\cdot m\ \ CW} \\ \underline{M_O = 5680\ N\cdot m\ \ CW} \end{cases}$$

2/46) In raising the pole from the position shown, the tension T in the cable must supply a moment about 0 of 72 kN-m . Determine T.



2/46

$$\theta = \tan^{-1}\frac{30(0.866)}{12+15} = 43.90^\circ$$

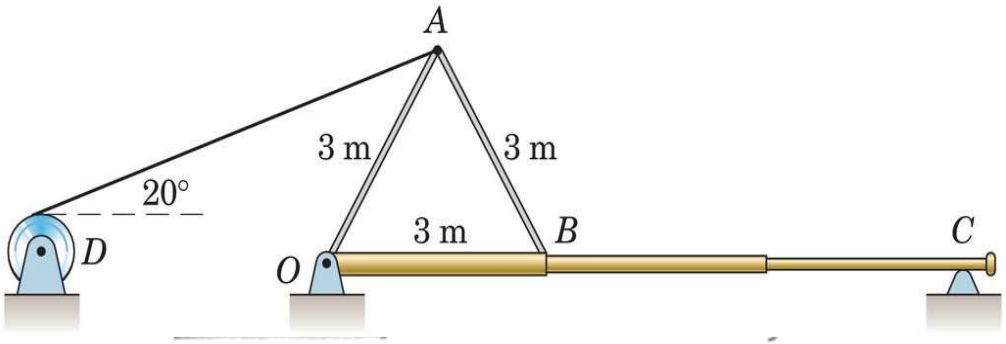
$$\alpha = 90^\circ - (30^\circ + 43.90^\circ) = 16.10^\circ$$

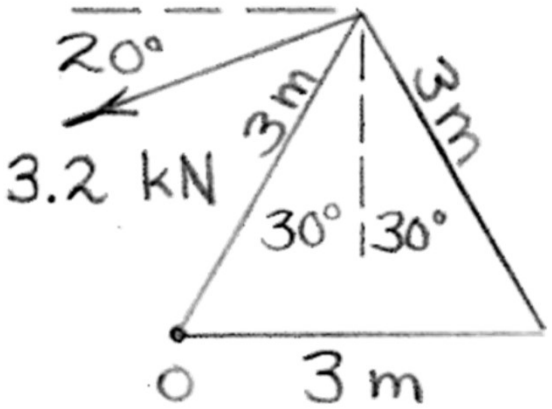
$$M_O = 72 \text{ kN·m}$$

$$= T \sin 16.10^\circ (30) = 8.32T$$

$$T = \frac{72}{8.32} = \underline{8.65 \text{ kN}}$$

2/49) In order to raise the flagpole OC, a light frame OAB is attached to the pole and a tension of 3.2 kN is developed in the hoisting cable by the power winch D. Calculate the moment M0 of this tension about the hinge point 0.



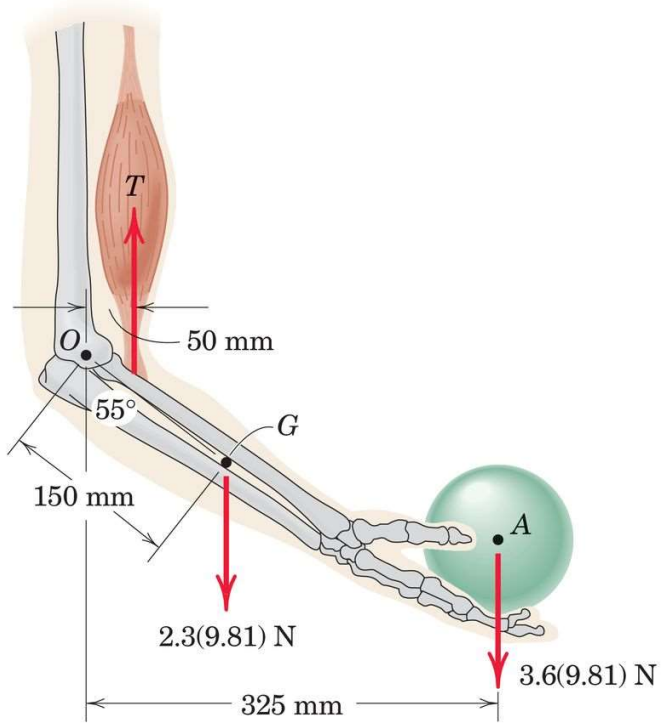


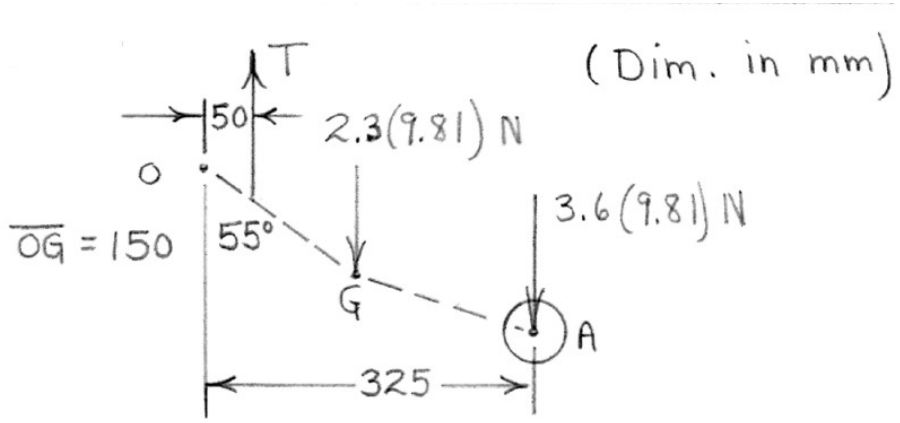
$M_o = 3.2 \cos 20° \, (3 \cos 30°)$

$- 3.2 \sin 20° \, (3 \sin 30°)$

$= \underline{6.17 \text{ kN·m} \quad \text{CCW}}$

2/50) Elements of the lower arm are shown in the figure. The mass of the forearm is 2.3 kg with center of mass at G. Determine the combined moment about the elbow pivot 0 of the weights of the forearm and the sphere. What must the biceps tension force be so that the overall moment about 0 is zero?





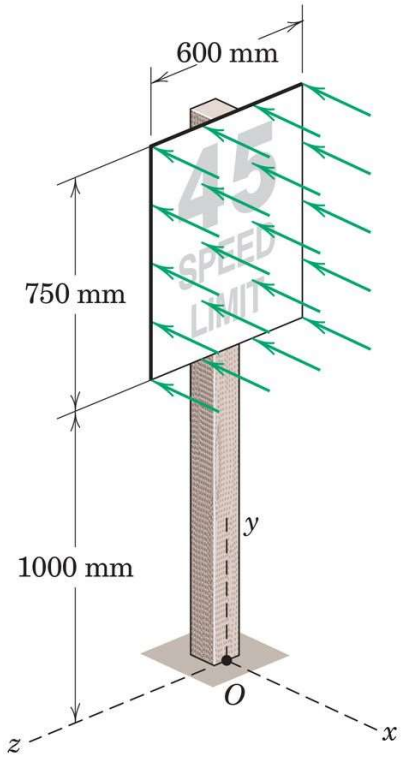
$\circlearrowleft M_O = 2.3(9.81)(0.150 \sin 55°) + 3.6(9.81)(0.325)$

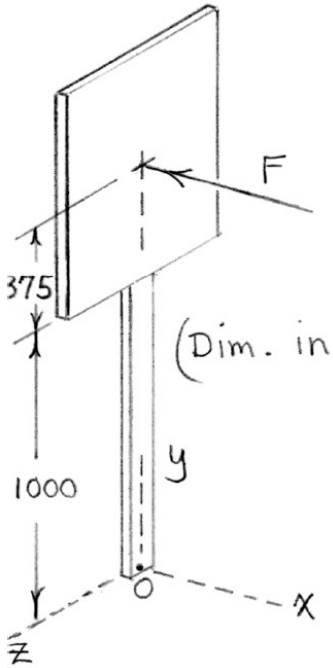
$= 14.25 \text{ N·m} \quad (CW)$

$\circlearrowleft \Sigma M_O = 0: \quad -T(0.050) + 14.25 = 0$

$T = 285 \text{ N}$

2/51) As the result of a wind blowing normal to the plane of the rectangular sign, a uniform pressure of 175 N/m2 is exerted in the direction shown in the figure. Determine the moment of the resulting force about point 0. Express your result as a vector using the coordinates shown.





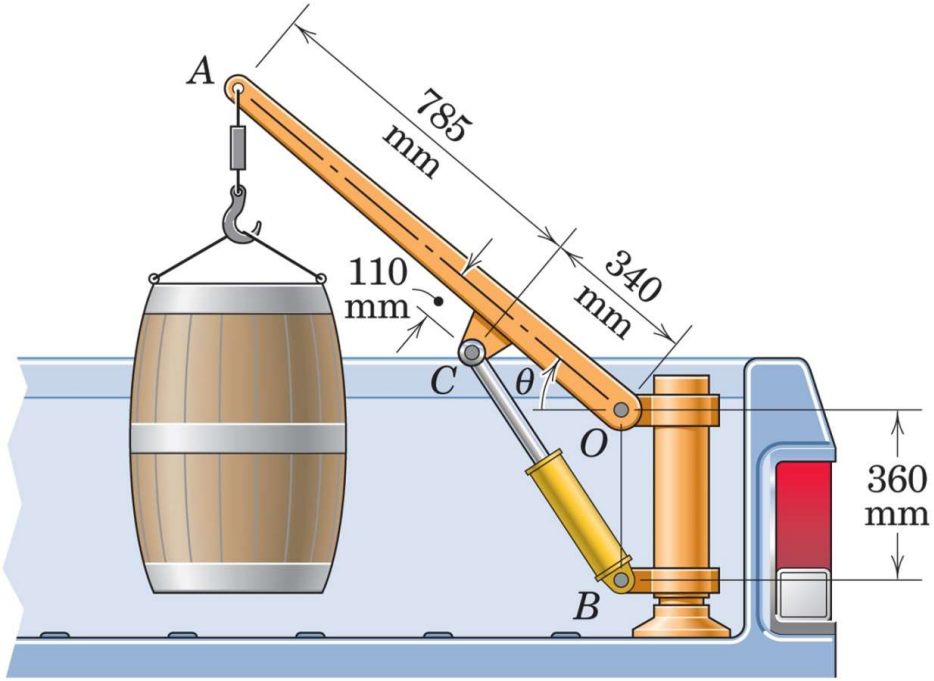
$$F = pA = 175(0.750)(0.6)$$

$$= 78.8 \text{ N}$$

$$\underline{M}_O = \underline{r} \times \underline{F} = 1.375\underline{j} \times (-78.8\underline{i})$$

$$= 108.3\underline{k} \text{ N·m}$$

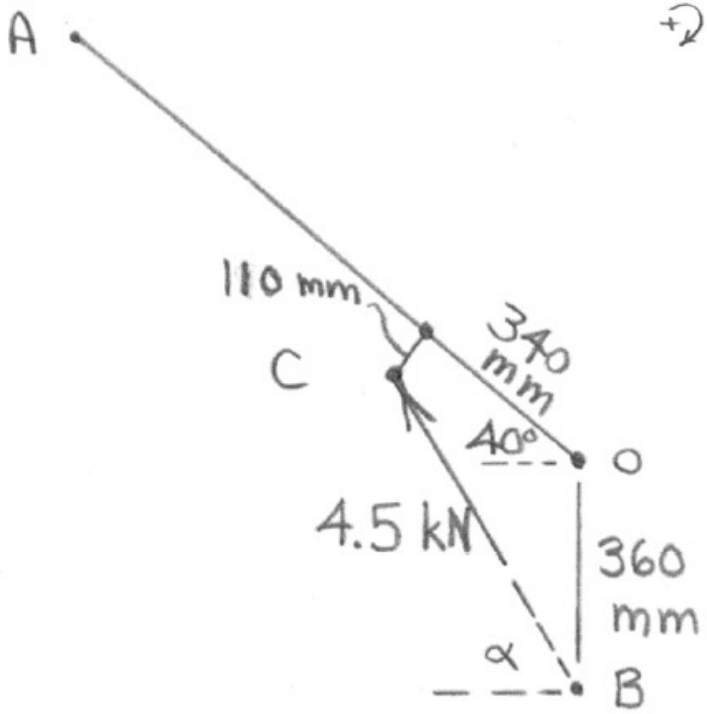
2/53) The small crane is mounted along the side of a pickup bed and facilitates the handling of heavy loads. When the boom elevation angle is $\theta = 40°$, the force in the hydraulic cylinder BC is 4.5 kN, and this force applied at point C is in the direction from B to C (the cylinder is in compression). Determine the moment of this 4.5-kN force about the boom pivot point 0.

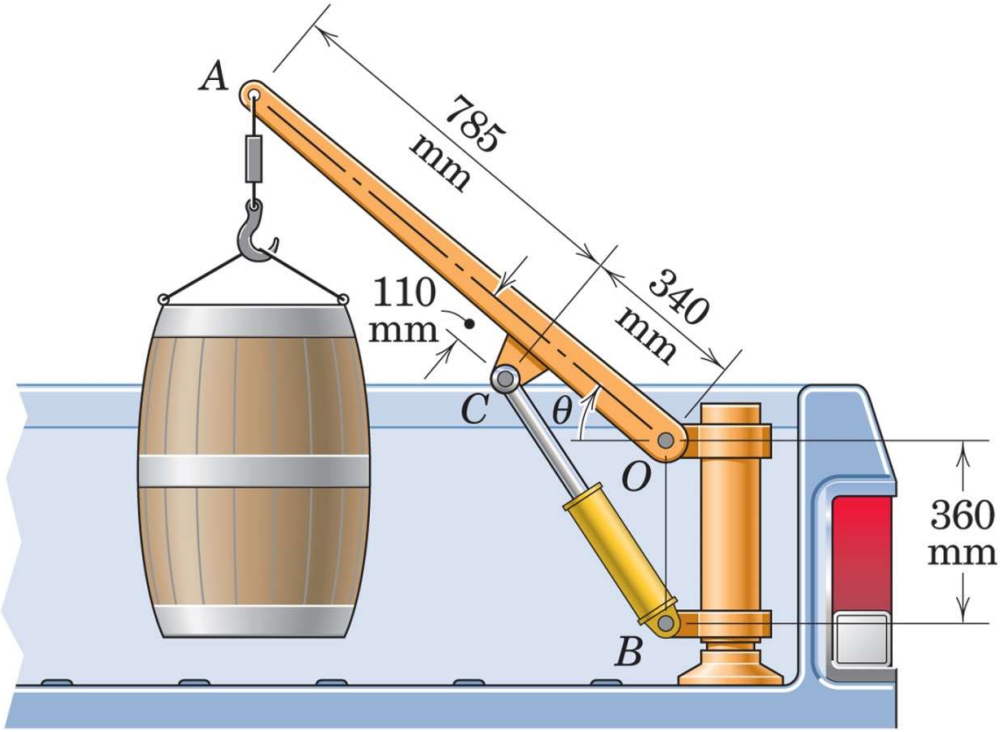


$$\alpha = \tan^{-1}\left[\frac{360 + 340\sin 40^\circ - 110\sin 50^\circ}{340\cos 40^\circ + 110\cos 50^\circ}\right]$$

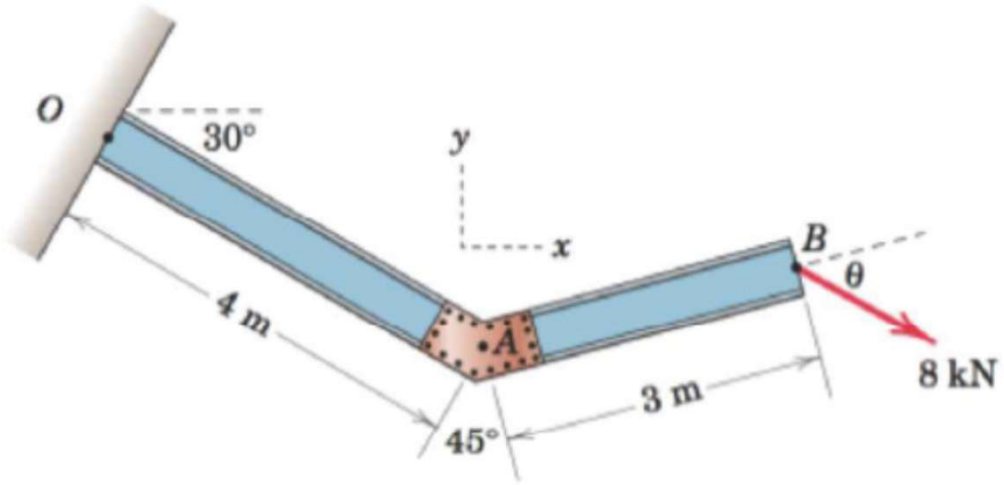
$$= 56.2^\circ$$

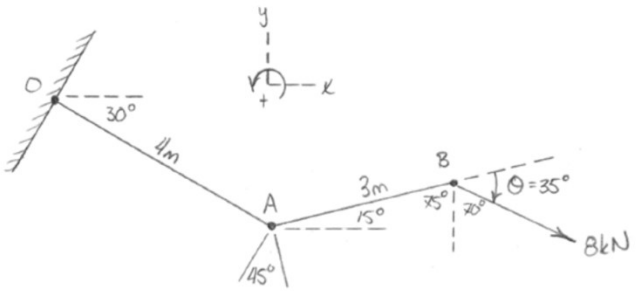
$$\circlearrowright M_O = 4.5\,(0.360\cos 56.2^\circ) = \underline{0.902\ \text{kN}\cdot\text{m CW}}$$





2/55) The bent cantilever beam is acted upon by an 8 kN force at B. If the angle θ = 350, determine (a) the moment M_o of the force about point O and (b) the moment M_a of the force about point O and (b) the moment M_a of the force about point A. What value(s) of θ ($0 < \theta > 360^0$) will result in the maximum possible moment about point O, and what is the magnitude of the moment at those orientations?





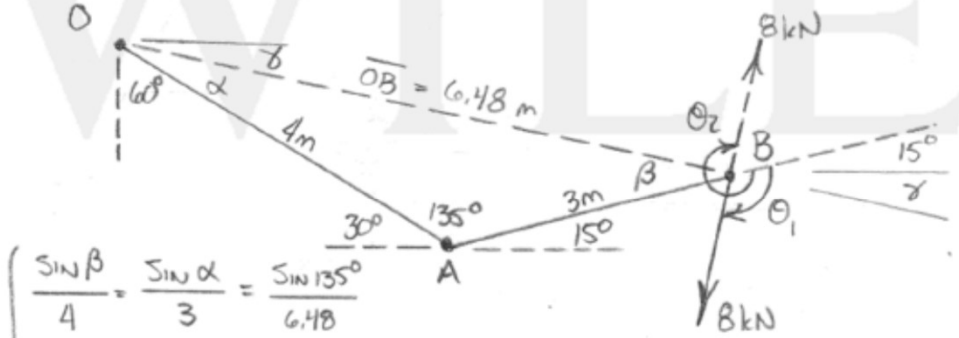
$$\underline{M}_O = \left[(4\cos 30^\circ + 3\cos 15^\circ)\underline{i} + (-4\sin 30^\circ + 3\sin 15^\circ)\underline{j}\right] \times \left(8\sin 70^\circ \underline{i} - 8\cos 70^\circ \underline{j}\right)$$

$$\therefore \quad \underline{M}_O = -8.21\ \underline{k}\ \text{kN·m}$$

$$\underline{M}_A = -8\sin 35^\circ (3)\,\underline{k} \longrightarrow \underline{M}_A = -13.77\ \underline{k}\ \text{kN·m}$$

• ANGLE TO FIND A MAXIMUM MOMENT AT O: THE FORCE MUST BE PERPENDICULAR TO LINE $\overline{OB}$.

$$\overline{OB} = \sqrt{4^2 + 3^2 - 2(4)(3)\cos 135^\circ} \longrightarrow \overline{OB} = 6.48\text{m}$$



$$\frac{\sin\beta}{4} = \frac{\sin\alpha}{3} = \frac{\sin 135^\circ}{6.48}$$

$$\beta = 25.9^\circ$$

$$\alpha = 19.11^\circ$$

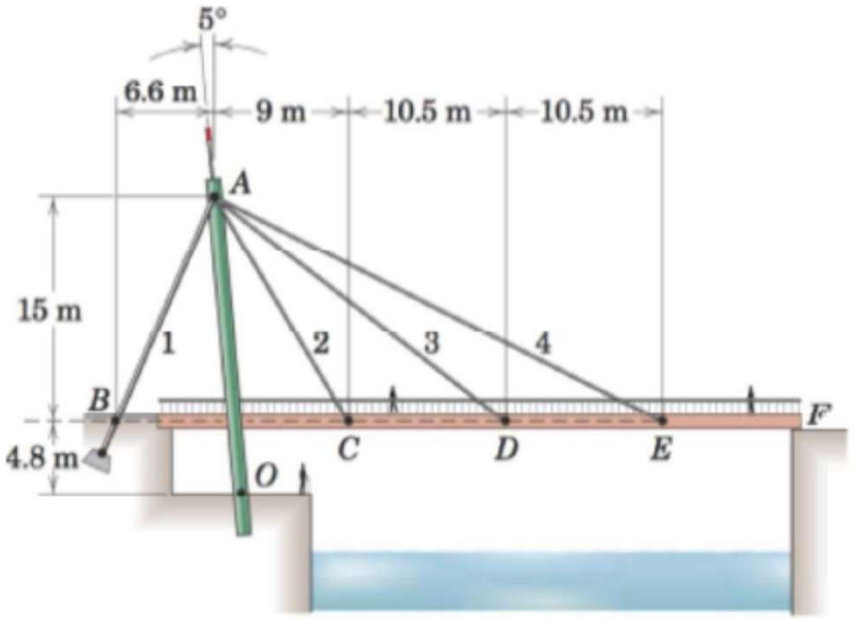
$$\gamma = 90^\circ - 60^\circ - 19.11^\circ = 10.89^\circ$$

$$\Theta_1 = 90^\circ + 15^\circ + 10.89^\circ \longrightarrow \Theta_1 = 115.9^\circ$$

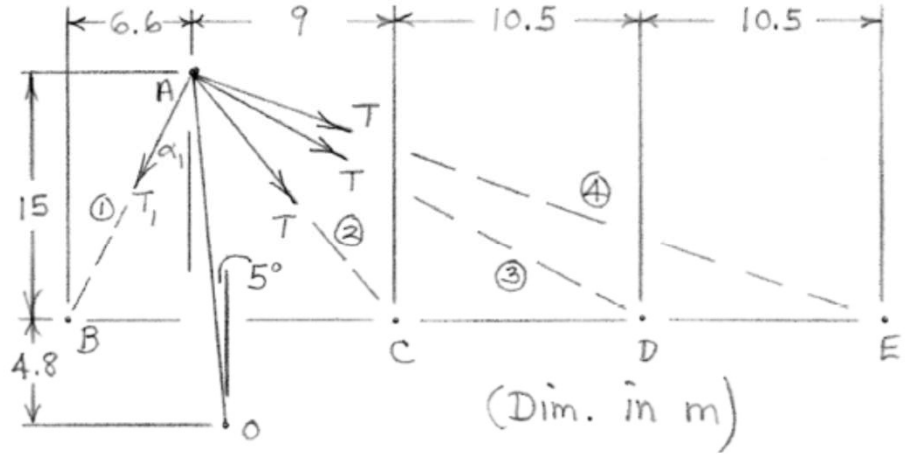
$$\Theta_2 = \Theta_1 + 180^\circ \longrightarrow \Theta_2 = 296^\circ$$

$$M_{MAX} = \overline{OB}\,F = 6.48(8) \longrightarrow M_{MAX} = 51.8\ \text{kN·m}$$

2/57) The asymmetrical support arrangement is chosen for a pedestrian bridge because conditions at the right end F do not permit a support tower and anchorages. During a test, the tensions in cables 1,3, and 4 are all adjusted to the same value T. If the combined moment of all four cable tensions about point O is to be zero, what should be the value T1 of tensions in cable 1?. Determine the corresponding value of the compression force P at O resulting from the four tensions applied at A. Neglect the weight of the tower.



2/57



$\alpha_1 = \tan^{-1}\frac{6.6}{15} = 23.7°$; Similarly, $\alpha_2 = 31.0°$;

$\alpha_3 = 52.4°$, $\alpha_4 = 63.4°$ (all relative to vertical)

$\curvearrowleft + \Sigma M_O = 0$: $[T_1 \sin(\alpha_1 + 5°) - T\sin(\alpha_2 - 5°)$

$-T\sin(\alpha_3 - 5°) - T\sin(\alpha_4 - 5°)]\frac{15+4.8}{\cos 5°} = 0$

$T_1 = 4.21T$

$+\downarrow \Sigma F = P = T_1\cos(\alpha_1 + 5°) + T[\cos(\alpha_2 - 5°)$

$+ \cos(\alpha_3 - 5°) + \cos(\alpha_4 - 5°)$

or $\underline{P = 5.79T}$ (with $T_1 = 4.21T$)

THANK YOU

VINAY PAPANNA
Department of Mechanical Engineering
vinayp@pes.edu