ENGINEERING MECHANICS

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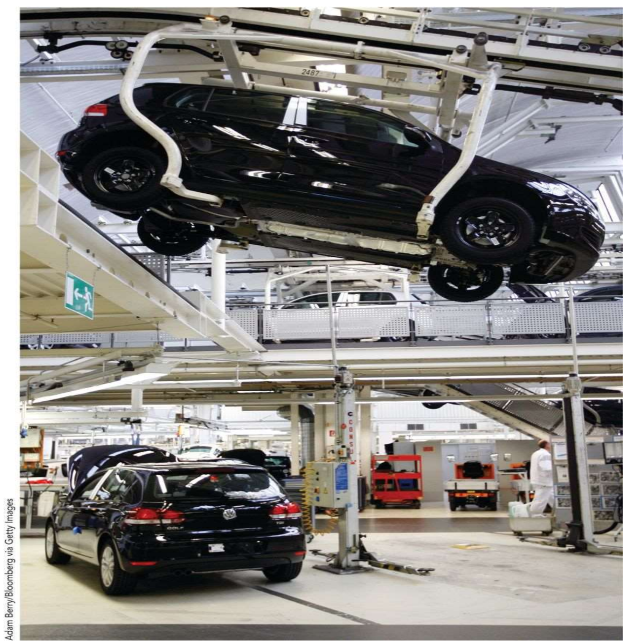
ENGINEERING MECHANICS

Unit: 2
Equilibrium and Beams



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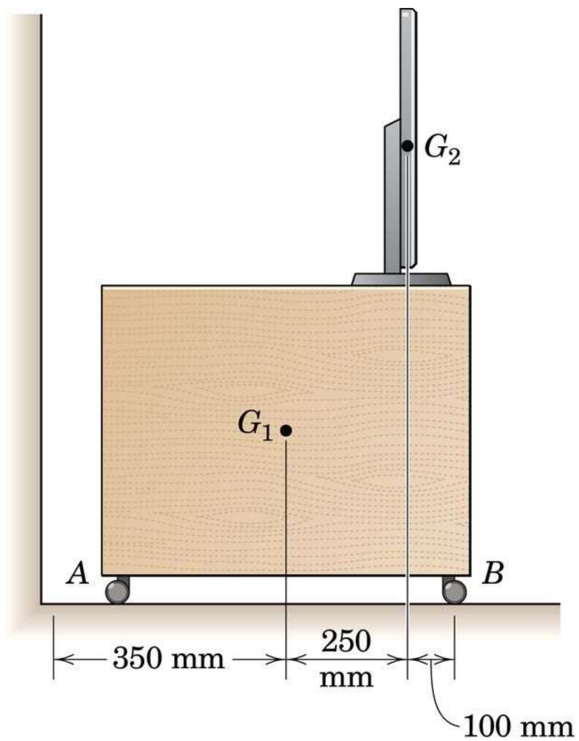
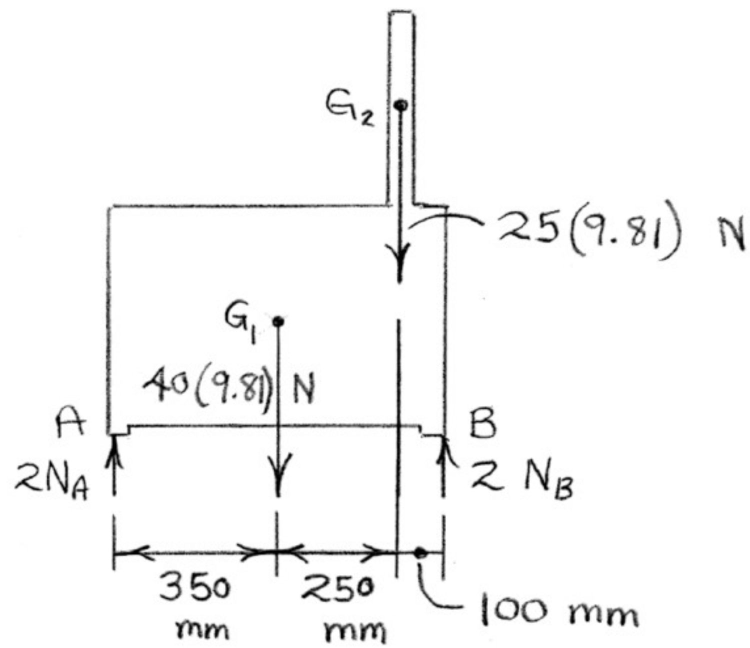
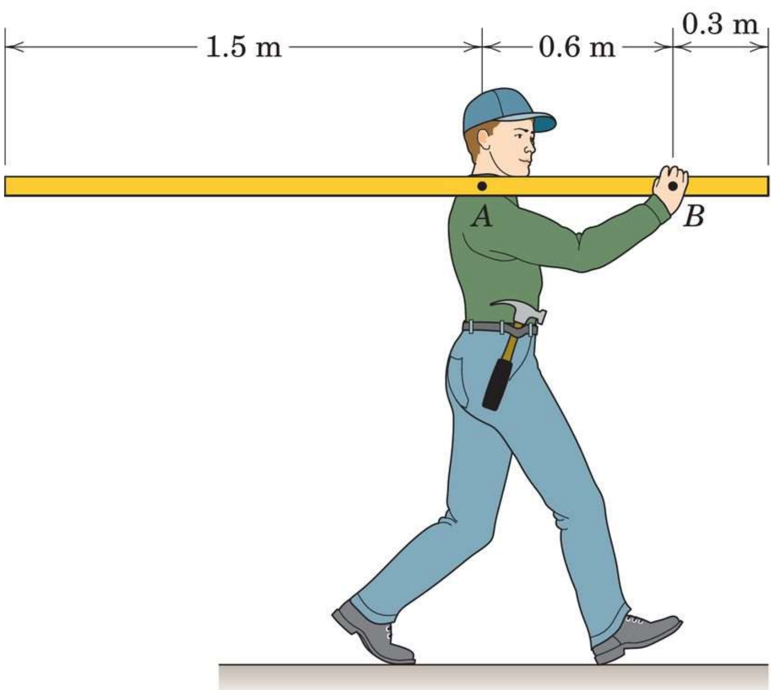
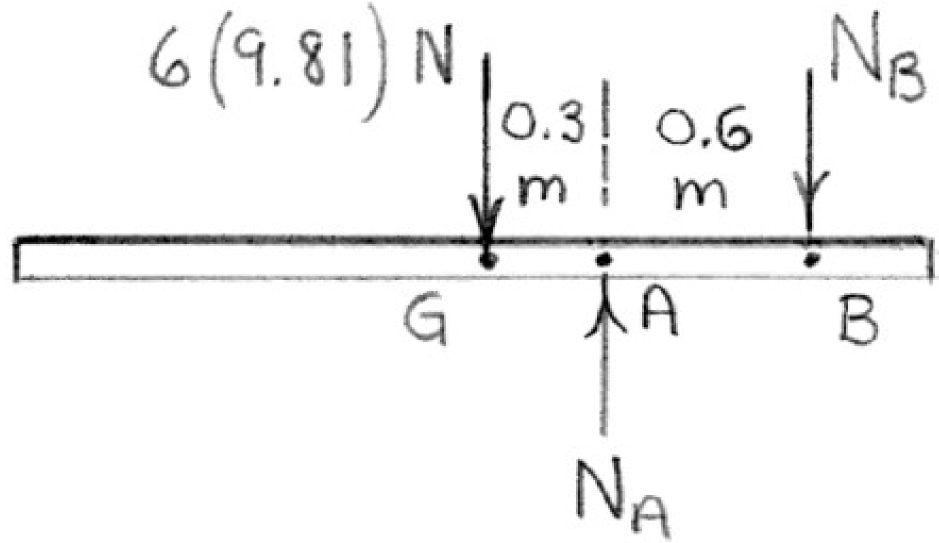
3/1) In the side view of a 25-kg flat-screen television resting on a 40-kg cabinet, the respective centers of mass are labeled G2 and G1. Assume symmetry into the paper and calculate the normal reaction force at each of the four casters (Wheel).





3/3) A carpenter carries a 6-kg uniform board as shown. What downward force does he feel on his shoulder at A?

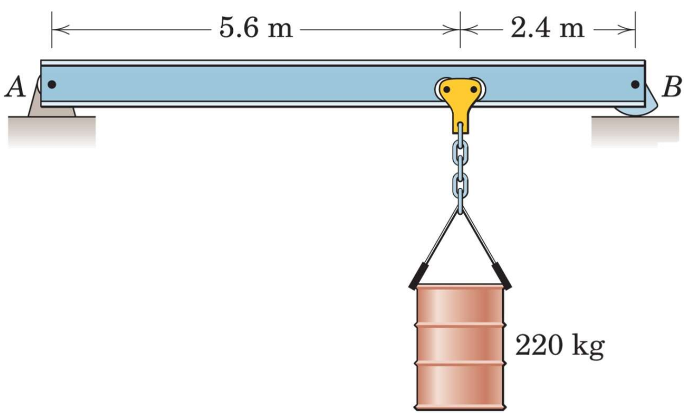


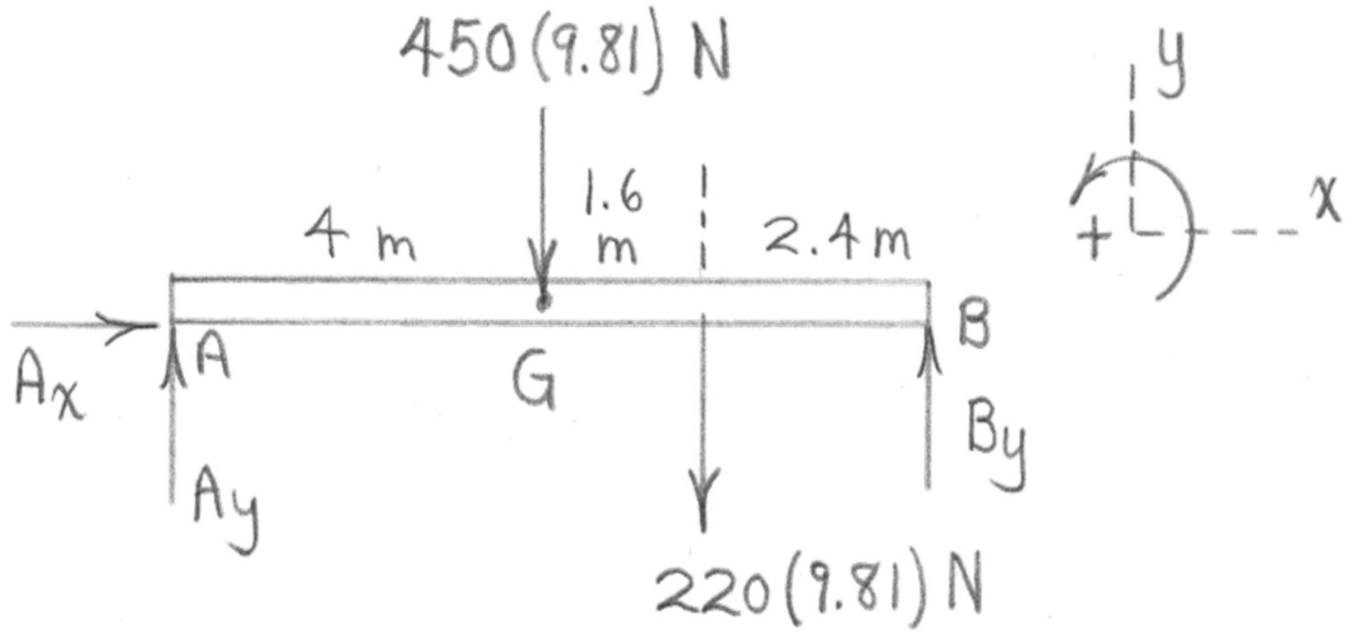


ENGINEERING MECHANICS

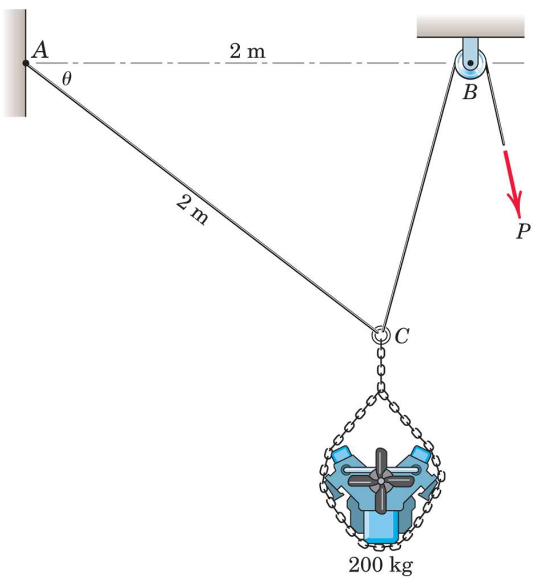
Equilibrium - Numerical

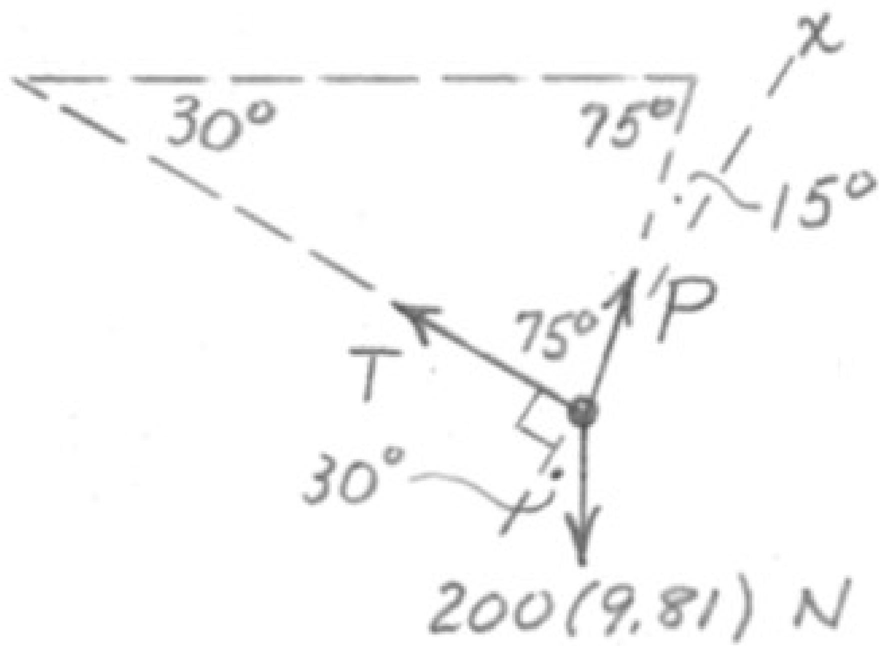
3/4) The 450-kg uniform I-beam supports the load shown. Determine the reactions at the supports.



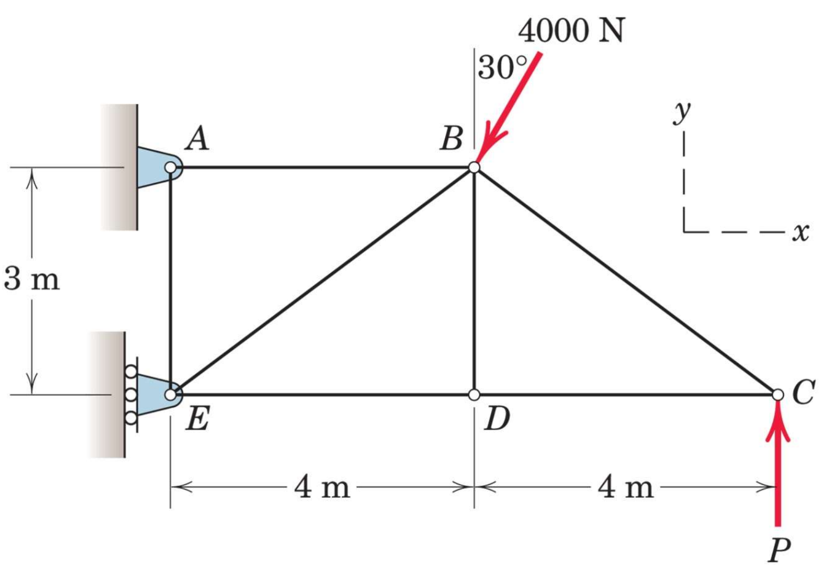


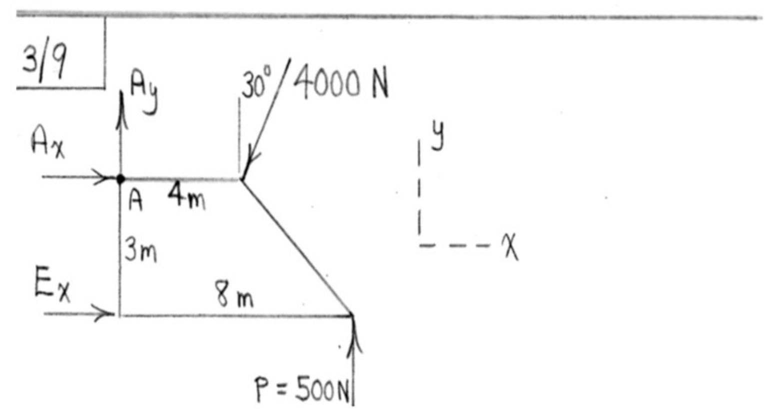
3/5) Determine the force P required to maintain the 200-kg engine in the position for which θ = 30°. The diameter of the pulley at B is negligible.





3/9) Determine the reactions at A and E if P = 500 N. What is the maximum value which P may have for static equilibrium? Neglect the weight of the structure compared with the applied loads.





$$\Sigma F_x = 0: \; A_x + E_x - 4000 \sin 30^\circ = 0$$

$$\Sigma F_y = 0: \; A_y - 4000 \cos 30^\circ + 500 = 0$$

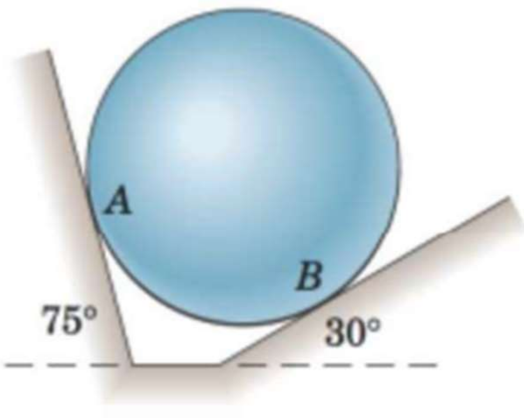
$$\Sigma M_A = 0: \; E_x(3) + 500(8) - 4000 \cos 30^\circ (4) = 0$$

$$\Rightarrow \; \underline{A_x = -1285 \text{ N}}, \quad \underline{A_y = 2960 \text{ N}}, \quad \underline{E_x = 3290 \text{ N}}$$

For maximum P: $E_x = 0$ and $\Sigma M_A = 0$:

$$P(8) - 4000 \cos 30^\circ (4) = 0, \quad \underline{P = 1732 \text{ N}}$$

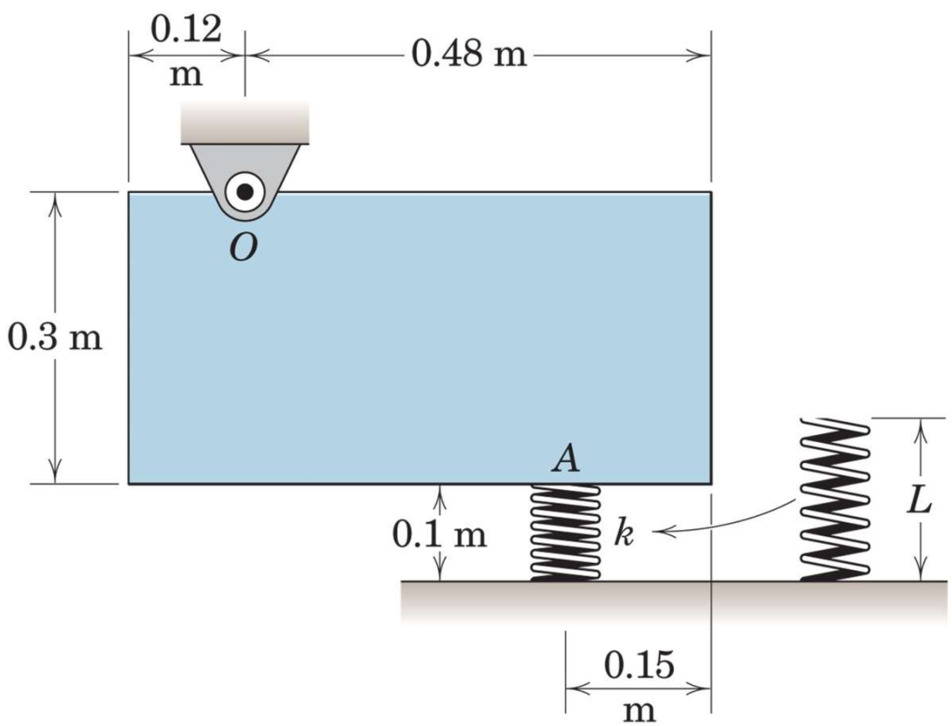
3/6) The 20-kg homogeneous smooth sphere rests on the two inclines as shown figure. Determine the contact force at A and B.

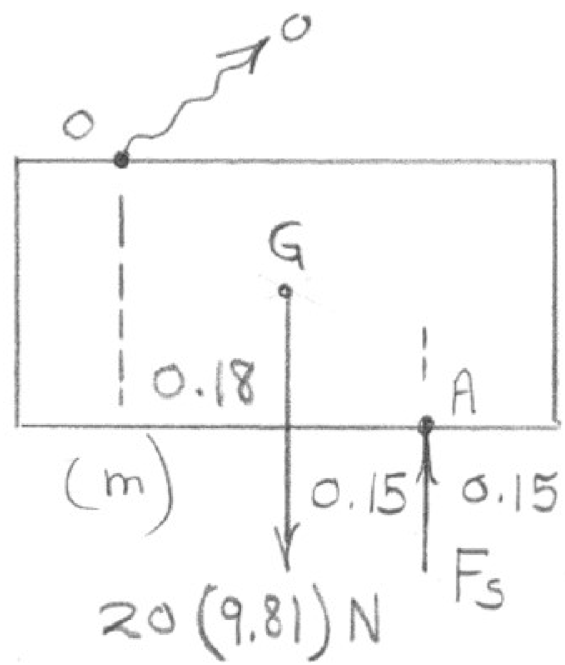


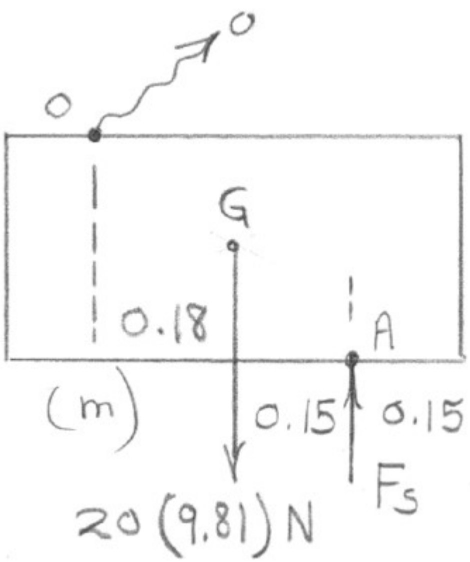
$$\begin{cases} \Sigma F_x = 0: & N_A \cos 15° - N_B \sin 30° = 0 \quad (1) \\ \Sigma F_y = 0 & N_A \sin 15° + N_B \cos 30° - 20(9.81) = 0 \quad (2) \end{cases}$$

Solution : $\begin{cases} N_A = 101.6 \text{ N} \\ N_B = 196.2 \text{ N} \end{cases}$

3/11) The 20-kg uniform rectangular plate is supported by an ideal pivot at 0 and a spring which must be compressed prior to being slipped into place at point A. If the modulus of the spring is k = 2 kN/m, what must be its undeformed length L?







$$\circlearrowleft + \sum M_O = 0 : \; -20(9.81)(0.18) + F_s(0.18 + 0.15) = 0$$

$$F_s = 107.0 \text{ N}$$

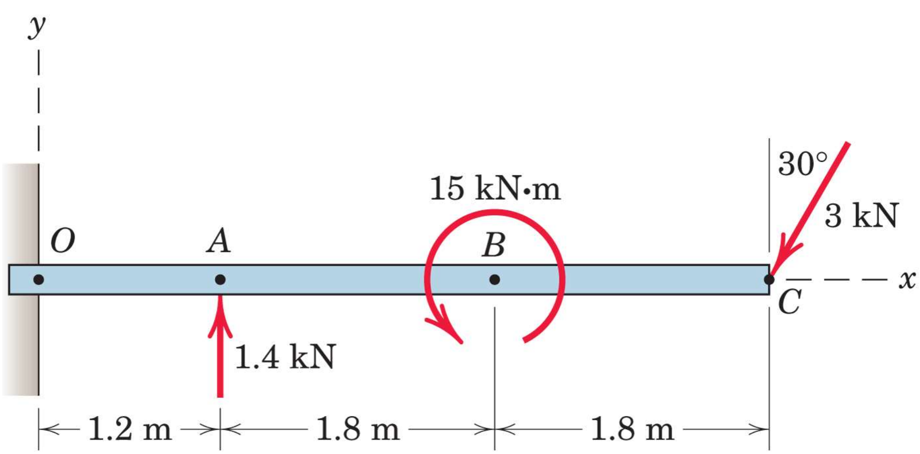
$$F_s = k\delta : \quad 107.0 = 2000\delta, \quad \delta = 0.0535 \text{ m}$$

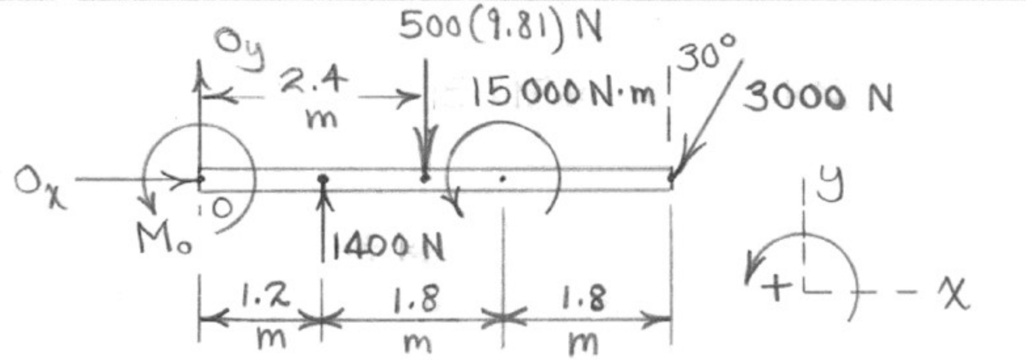
$$\text{or} \quad \delta = 53.5 \text{ mm}$$

$$L = 0.1 + \delta = 0.1 + 0.0535 = 0.1535 \text{ m}$$

$$\text{or} \quad \underline{153.5 \text{ mm}}$$

3/12) The 500-kg uniform beam is subjected to the three external loads shown. Compute the reactions at the support point 0. The x-y plane is vertical.





$\Sigma F_x = 0 : \quad O_x - 3000 \sin 30^\circ = 0 , \quad \underline{O_x = 1500 \text{ N}}$

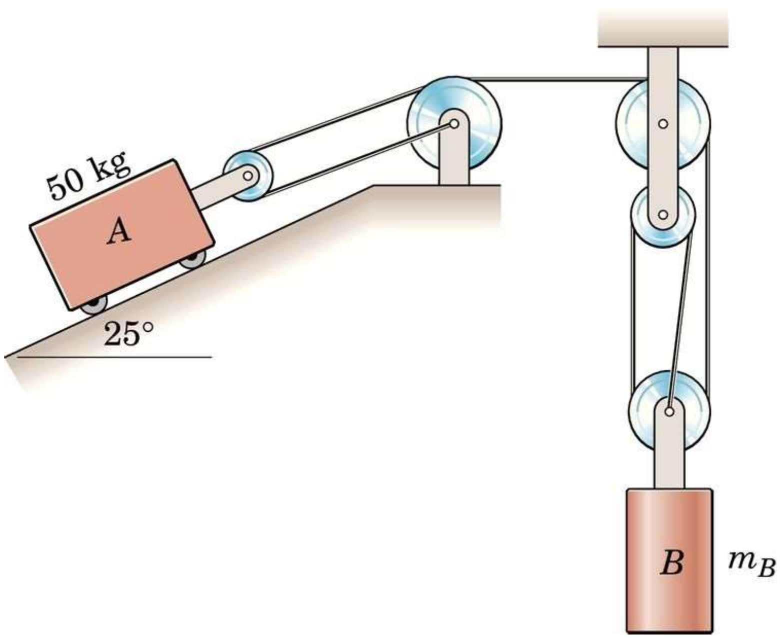
$\Sigma F_y = 0 : \quad O_y + 1400 - 500(9.81) - 3000 \cos 30^\circ = 0$

$\underline{O_y = 6100 \text{ N}}$

$\Sigma M_O = 0 : \quad M_O + 1400(1.2) - 500(9.81)(2.4) + 15000 - (3000 \cos 30^\circ)(4.8) = 0$

$M_O = 7560 \text{ N·m}$

3/15) What mass m_B will cause the system to be in equilibrium? Neglect all friction, and state any other assumptions.



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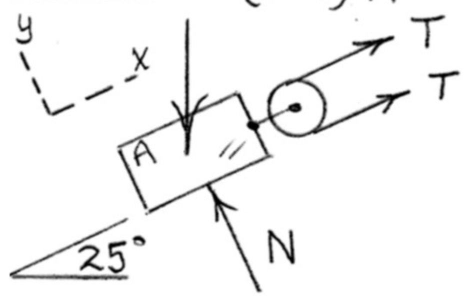
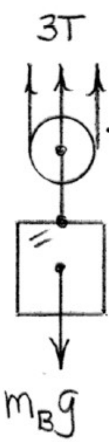


$$\Sigma F_x = 0: \quad 2T - 50(9.81)\sin 25^\circ = 0$$

$$T = 103.6 \text{ N}$$

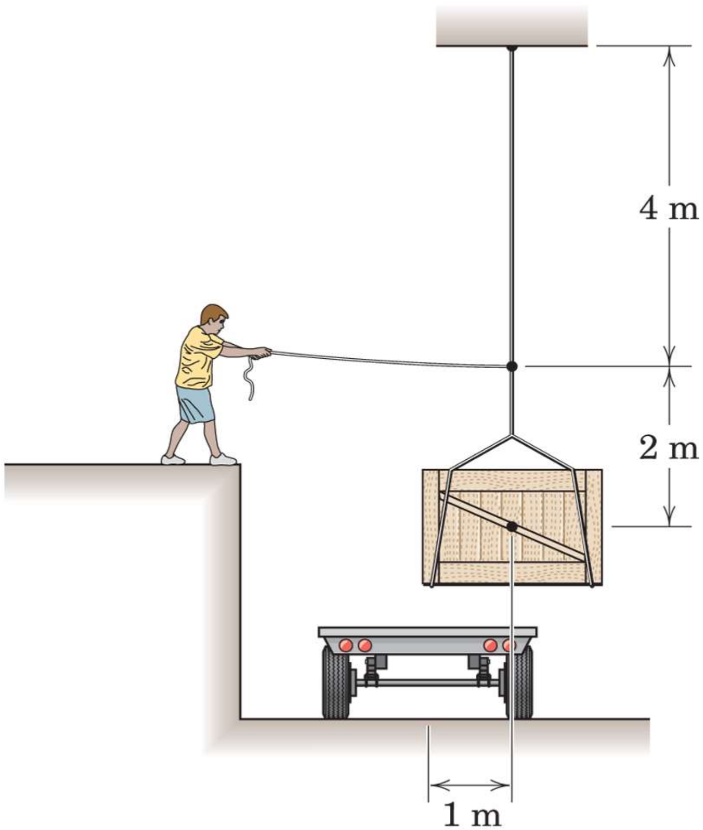


$$+\uparrow \Sigma F = 0: \quad 3(103.6) - m_B(9.81) = 0$$

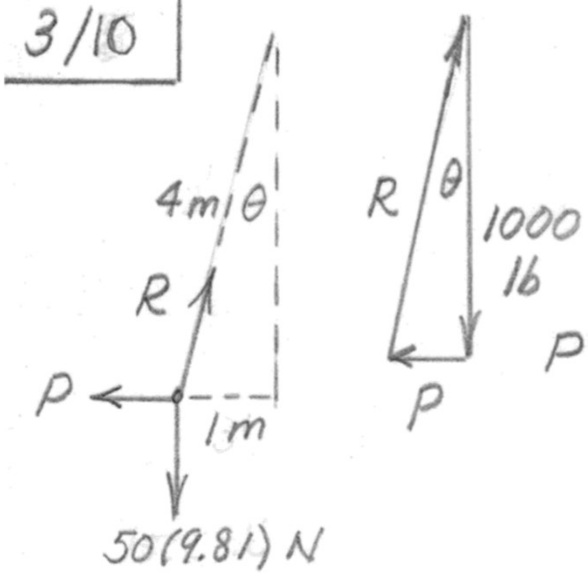
$$\underline{m_B = 31.7 \text{ kg}}$$

(Assume all cables to be vertical)

3/10) What horizontal force P must a worker exert on the rope to position the 50 kg crate directly over the trailer.



3/10



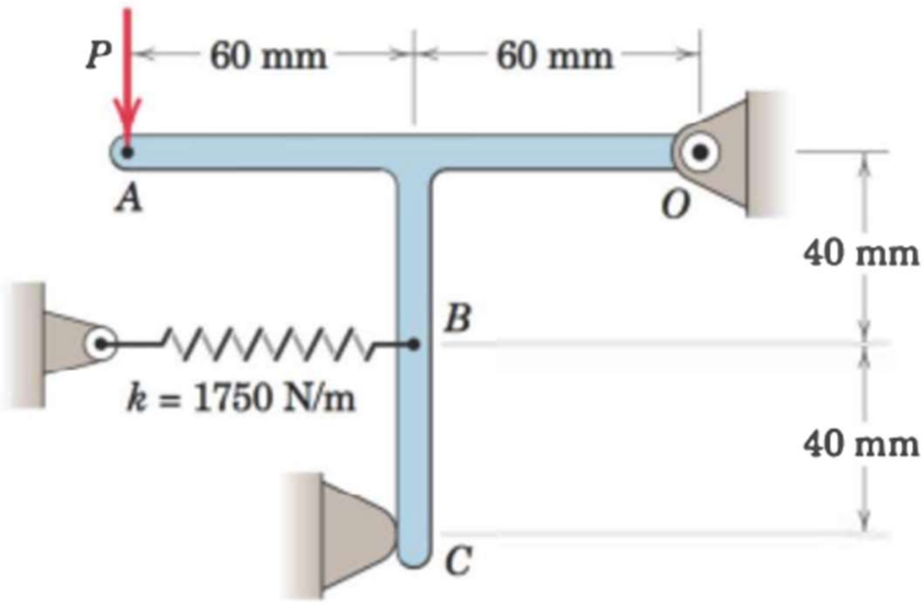
$P = 50(9.81)\tan\theta$

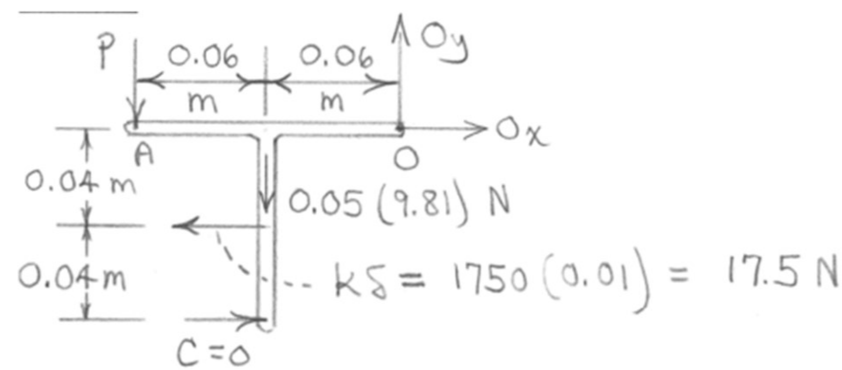
$\sin\theta = 1/4$

$\tan\theta = 1/\sqrt{4^2-1^2} = 0.258$

$P = 50(9.81)(0.258) = \underline{126.6\ N}$

3/19) When the 0.05 kg body is in the position shown, the linear spring is stretched 10 mm. Determine the force P required to break contact at C. Complete solution for (a) including the effect of the weight and (b) neglecting the weight.





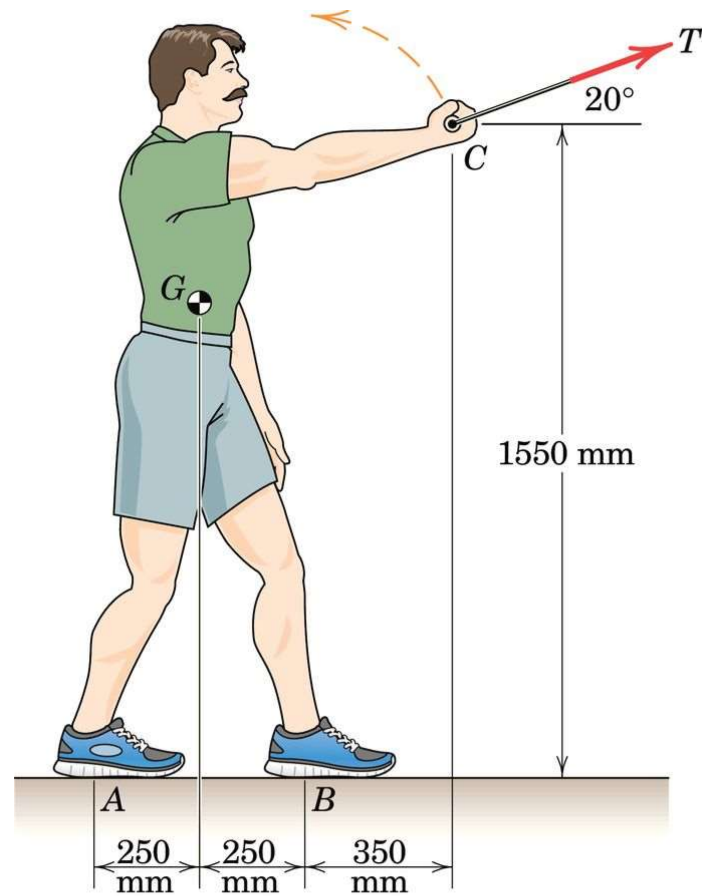
(a) $\circlearrowleft\!+ \sum M_O = 0: \; P(0.12) + 0.05(9.81)(0.06) - 17.5(0.04) = 0$

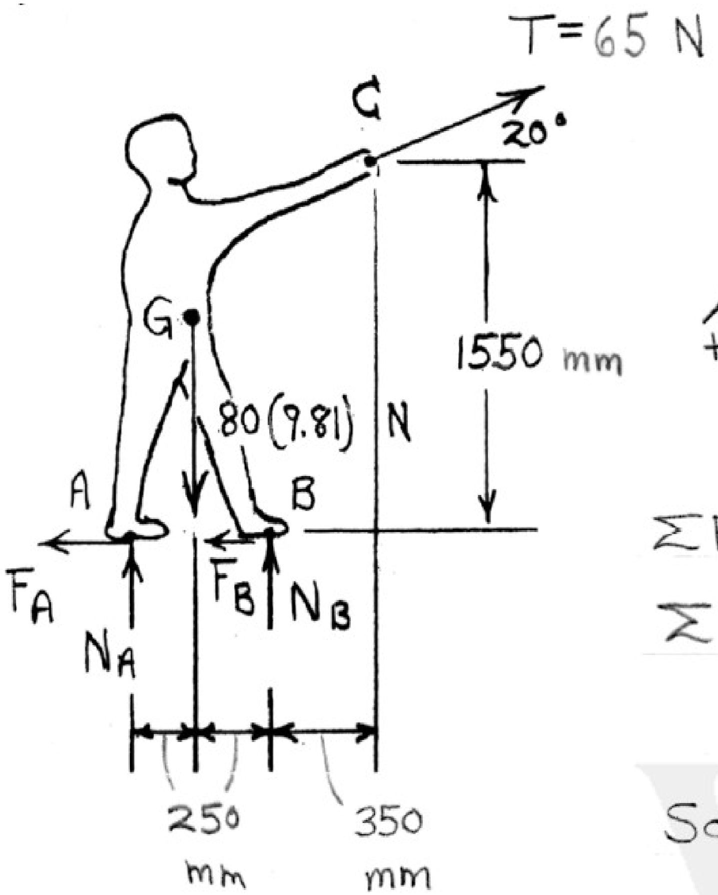
$\underline{P = 5.59 \text{ N}}$

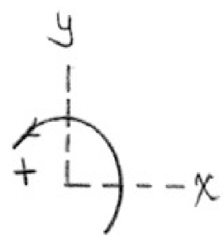
(b) $\circlearrowleft\!+ \sum M_O = 0: \; P(0.12) - 17.5(0.04) = 0$

$\underline{P = 5.83 \text{ N}}$

3/23) The 80-kg exerciser is beginning to execute some slow, steady bicep curls. As the tension T = 65 N is developed against an exercise machine (not shown), determine the normal reaction forces at the feet A and B. Friction is sufficient to prevent slipping, and the exerciser maintains the position shown with center of mass at G.





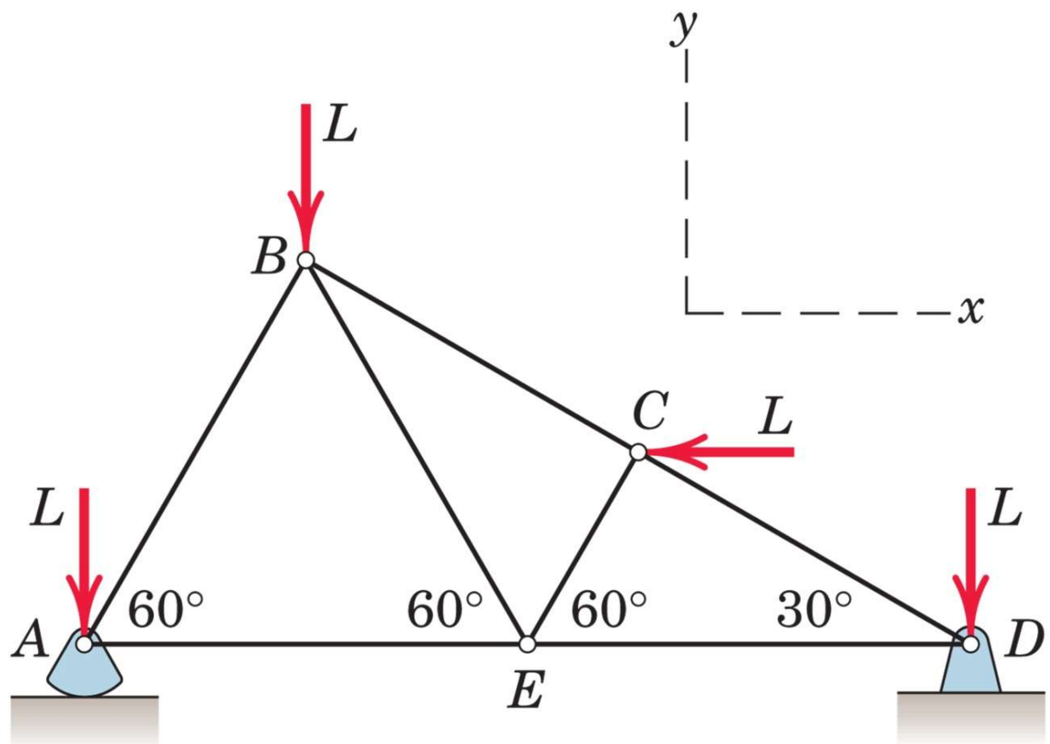


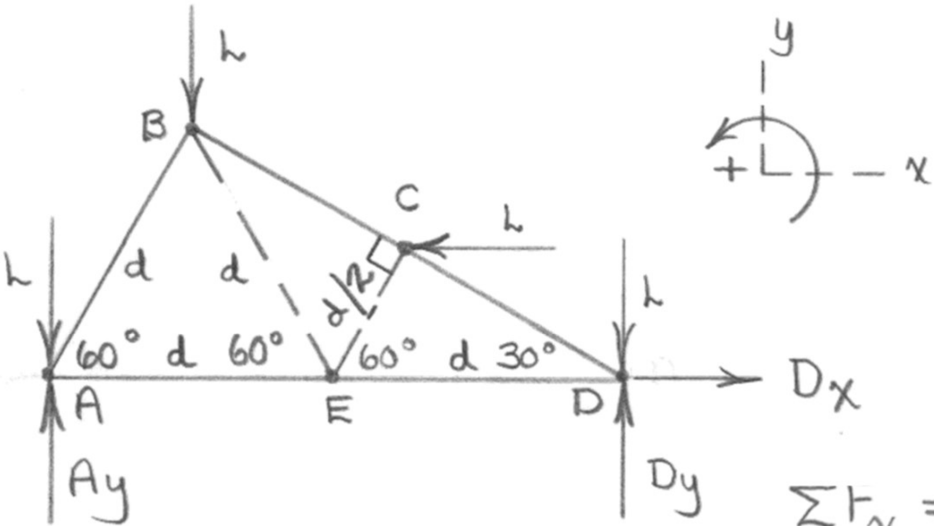
$$\Sigma F_y = 0: \quad N_A + N_B - 80(9.81) + 65 \sin 20^\circ = 0$$

$$\Sigma M_B = 0: \quad 80(9.81)(250) - N_A(500) - 65\left[1550 \cos 20^\circ - 350 \sin 20^\circ\right] = 0$$

Solution : $\begin{cases} N_A = 219 \text{ N} \\ N_B = 544 \text{ N} \end{cases}$

3/35) The asymmetric simple truss is loaded as shown. Determine the reactions at A and D. Neglect the weight of the structure compared with the applied loads. Is knowledge of the size of the structure necessary?





$$\sum F_x = 0: \quad D_x - L = 0, \qquad \underline{D_x = L}$$

$$\sum F_y = 0: \quad A_y + D_y - 3L = 0$$

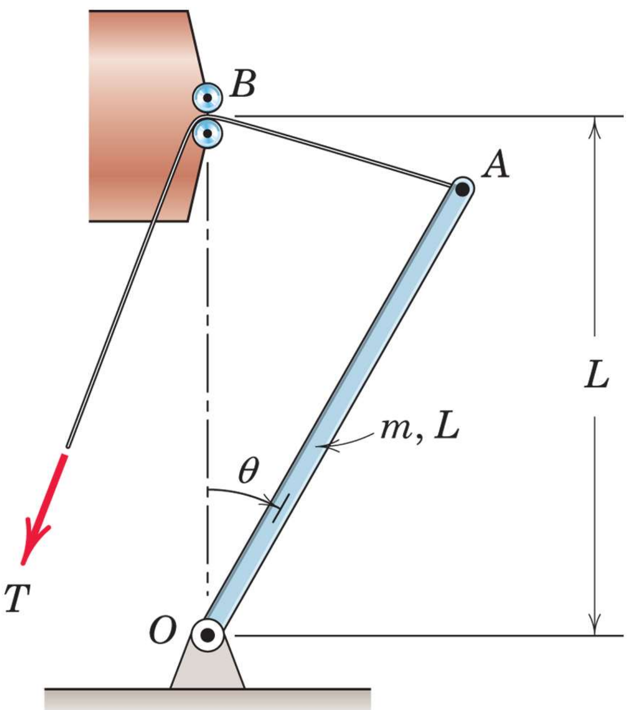
$$\sum M_A = 0: \quad D_y(2d) + L\left(\frac{d}{2}\frac{\sqrt{3}}{2}\right) - L\left(\frac{d}{2}\right) - L(2d) = 0$$

Solving the last 2 equations : $A_y = \frac{L}{4}\left(7 + \frac{\sqrt{3}}{2}\right)$

$$\underline{D_y = \frac{L}{4}\left(5 - \frac{\sqrt{3}}{2}\right)}$$

(or $A_y = 1.967L$, $D_y = 1.033L$)

3/39) Determine the force T required to hold the uniform bar of mass m and length L in an arbitrary angular position θ. State the value of T for θ = 40^0.



$$\circlearrowleft + \Sigma M_O = 0: \; T(L\cos\theta) - mg\left(\frac{L}{2}\sin\theta\right) = 0$$

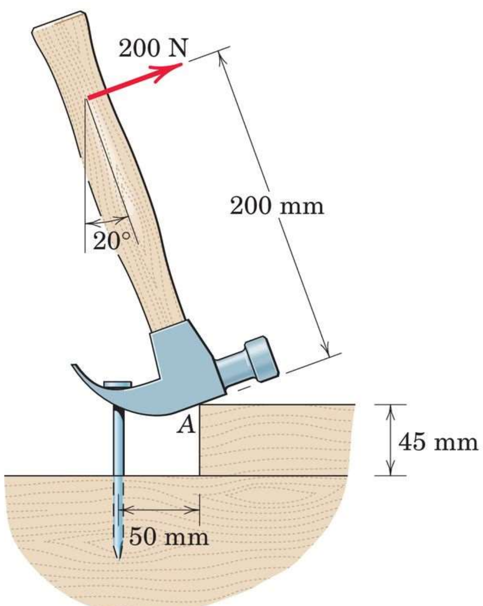
$$T = \frac{mg\sin\theta}{2\cos\frac{\theta}{2}}$$

$$T_{40^\circ} = 0.342\,mg$$

ENGINEERING MECHANICS

Equilibrium - Numerical

3/40) A block placed under the head of the claw hammer as shown greatly facilitates the extraction of the nail. If a 200-N pull on the handle is required to pull the nail, calculate the tension T in the nail and the magnitude A of the force exerted by the hammer head on the block. The contacting surfaces at A are sufficiently rough to prevent slipping.



$\sum M_A = 0 : 200(200) - 50T = 0, \quad \underline{T = 800\text{ N}}$

$\sum F_x = 0 : 200\cos 20° - A_x = 0$

$A_x = 187.9\text{ N}$

$\sum F_y = 0 : A_y + 200\sin 20° - 800 = 0$

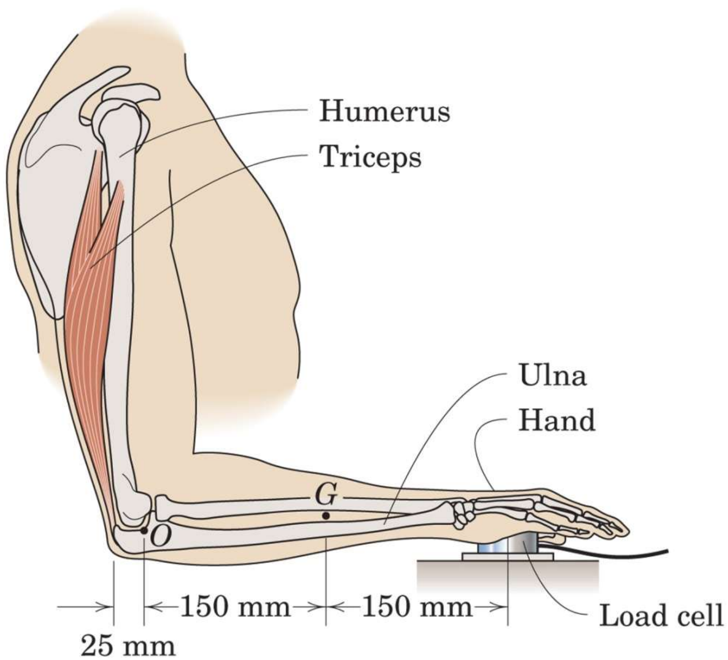
$A_y = 732\text{ N}$

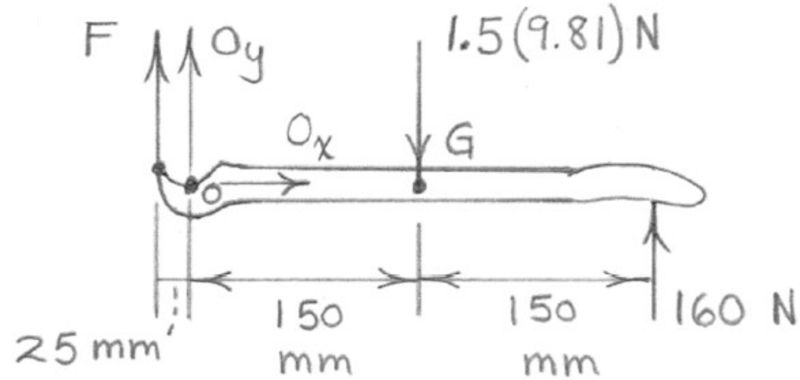
$A = \sqrt{A_x^2 + A_y^2} = \underline{755\text{ N}}$

ENGINEERING MECHANICS

Equilibrium - Numerical

3/43) In a procedure to evaluate the strength of the triceps muscle, a person pushes down on a load cell with the palm of his hand as indicated in the figure. If the load-cell reading is 160 N, determine the vertical tensile force F generated by the triceps muscle. The mass of the lower arm is 1.5 kg with mass center at G. State any assumptions.

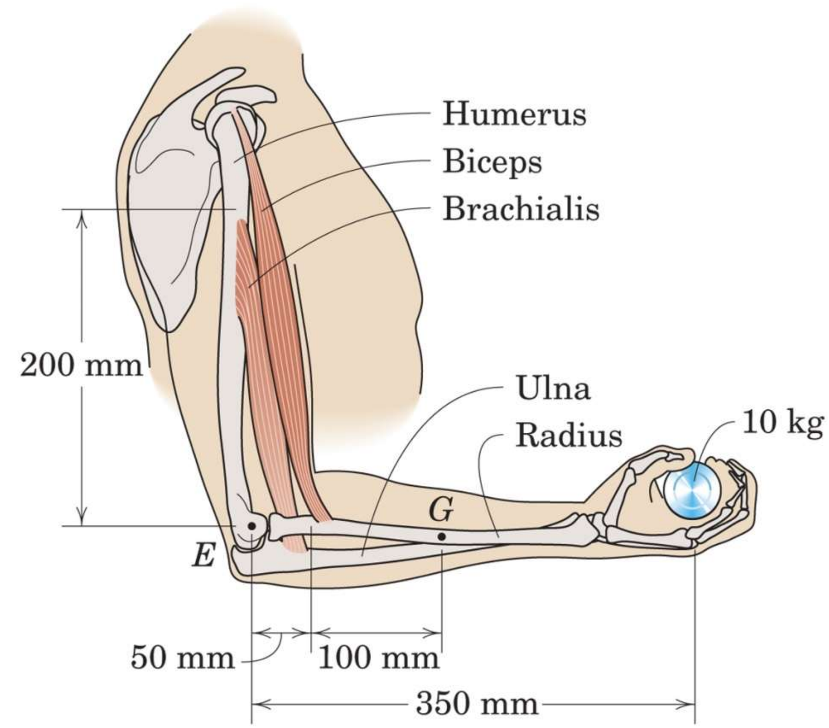




$$\circlearrowleft+ \ \Sigma M_O = 0: \ -F(25) - 1.5(9.81)(150) + 160(300) = 0$$

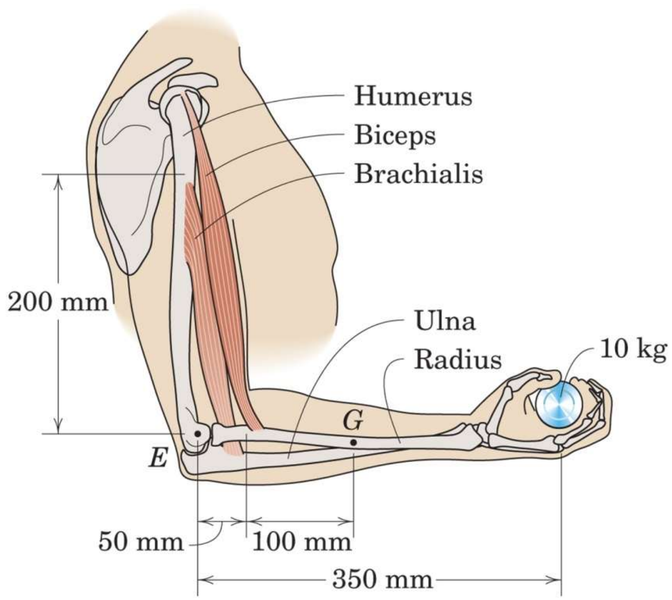
$$\underline{F = 1832 \text{ N}}$$

3/45) A person is performing slow arm curls with a 10-kg weight as indicated in the figure. The brachialis muscle group (consisting of the biceps and brachialis muscles) is the major factor in this exercise. Determine the magnitude F of the brachialis-musclegroup force and the magnitude E of the elbow joint reaction at point E for the forearm position shown in the figure. Take the dimensions shown to locate the effective points of application of the two muscle groups; these points are 200 mm directly above E and 50 mm directly to the right of E. Include the effect of the 1.5-kg forearm mass with mass center at point G. State any assumptions.

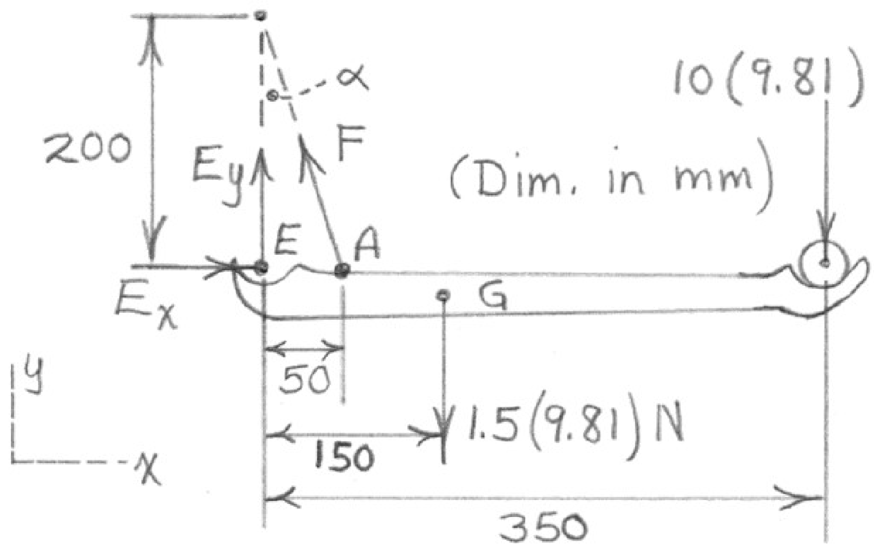


ENGINEERING MECHANICS

Equilibrium - Numerical

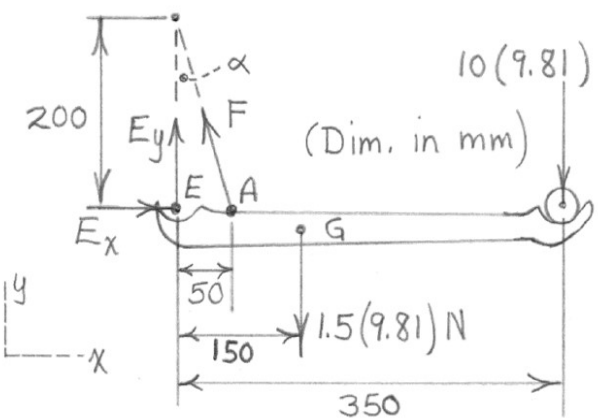


$$\alpha = \tan^{-1}\left(\frac{50}{200}\right) = 14.04^\circ$$



Assume that A & E are on a horizontal line.

$$\alpha = \tan^{-1}\left(\frac{50}{200}\right) = 14.04^\circ$$



Assume that A & E are on a horizontal line.

$$\Sigma F_x = 0: -753 \sin 14.04^\circ + E_x = 0$$

$$E_x = 182.7 \text{ N}$$

$$\Sigma F_y = 0: 753 \cos 14.04^\circ - (10+1.5)(9.81) + E_y = 0$$

$$E_y = -618 \text{ N}$$

$$E = \sqrt{E_x^2 + E_y^2} = \sqrt{182.7^2 + 618^2} = \underline{644 \text{ N}}$$

$$\circlearrowleft + \Sigma M_E = 0: F\cos 14.04^\circ(50) - 1.5(9.81)(150)$$

$$-10(9.81)(350) = 0, \quad \underline{F = 753 \text{ N}}$$

THANK YOU

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