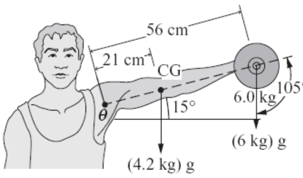
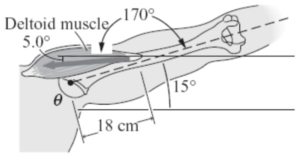
28. The magnitude of the (external) torque on the arm is $\tau_0 = [(4.2\text{ kg})(0.21\text{ m}) + (6\text{ kg})(0.56\text{ m})](9.8\text{ m/s}^2)\sin 105° = 40.2\text{ N}\cdot\text{m}$. The direction is clockwise (into the page) about the shoulder joint. **(b)** The deltoid muscle exerts a counterclockwise torque of magnitude $Fr\sin\theta = F(0.18\text{ m})\sin 170°$, which, under equilibrium conditions, equals the magnitude of the torque in part **(a)**. Thus, $F = 40.2\text{ N}\cdot\text{m}/(0.18\text{ m})\sin 170° = 1.28\text{ kN}$, underscoring the comment at the end of Example 12.3. The skeleto-muscular structure of the human extremities evolved for speed and range of motion, not mechanical advantage.

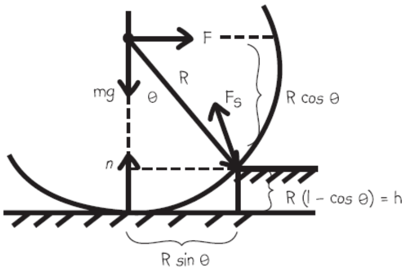


(a)

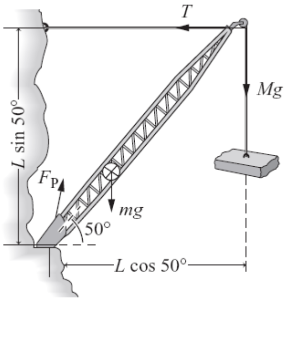


(b)

30. We assume that a horizontal push on the cart results in a horizontal force exerted on the wheels by the axle, as shown. (We also suppose both wheels share the forces equally, so they can be treated together.) Also shown are the weight of the cart and the normal force of the ground, both acting through the center of the wheels, and the force of the step, F_s. If we consider the sum of the torques (positive CCW) about the step, the latter does not contribute, and the wheels (and cart) will remain stationary as long as $(\sum\tau)_{\text{step}} = MgR\sin\theta - nR\sin\theta - FR\cos\theta = 0$. When $n = 0$, however, the wheels begin to lose contact with the ground and go over the step. This occurs when $F = Mg\tan\theta$. From the geometry of the situation, $R(1-\cos\theta) = h$, the height of the step, so $\theta = \cos^{-1}(1 - h/R) = \cos^{-1}(1 - 8/30)$. Then $F = (55\times 9.8\text{ N})\tan(\cos^{-1}(11/15)) = 500\text{ N}$ is the minimum force.



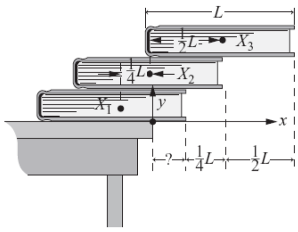
40. As in Problem 37, the equilibrium condition for torques about the pivot does not contain the unknown pivot force, and thus allows the tension to be directly determined without use of the force equations. Thus, $TL\sin 50° = MgL\cos 50° + mg\frac{1}{3}L\cos 50°$, or $T = (M + \frac{1}{3}m)g\cot 50° = (2500 + \frac{1}{3}\times 830)(9.8\text{ N})\cot 50° = 22.8\text{ kN}$.



56. In equilibrium, the farthest right the center of mass of the combination of three books can lie is directly above the edge of the table. (This is unstable equilibrium, since the slightest disturbance to the right would cause the books to fall.) The center of mass of each book is at its center, so if we take the origin at the edge with positive to the right, this condition becomes

$$0 = x_{cm} = \frac{1}{3\text{m}}\left[mx_1 + m\left(x_1 + \frac{1}{4}L\right) + m\left(x_1 + \frac{1}{4}L + \frac{1}{2}L\right)\right]$$

where x_1 is the horizontal position of the center of the bottom book, and the centers of the other books are displaced as given. Therefore, $3x_1 + L = 0$, or $x_1 = -\frac{1}{3}L$. If the center of the bottom book is $\frac{1}{3}L$ to the left of the edge, then only $\frac{1}{2}L - \frac{1}{3}L = \frac{1}{6}L$ can overhang on the right. (An argument based on torques is equivalent, since at the farthest right position, the normal contact force on the books acts essentially just at the table's edge.)

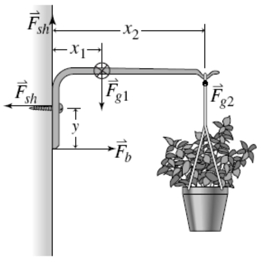


60. **Interpret** We use equilibrium methods to find the horizontal component of force on a bracket mounting screw. The bracket is in equilibrium, so the sum of forces and the sum of torques is both zero. Since the sum of forces is zero, we may use any point as the pivot for calculating the torques. We would expect that the horizontal force is much larger than the weight of the plant, since the plant has more leverage than the bracket.

Develop We start by drawing a diagram showing the forces and their approximate locations, as shown in the figure. The mass of the plant is $m_p = 4.2$ kg, the mass of the bracket is $m_b = 0.85$ kg, the distance $y = 7.2$ cm, the distance $x_1 = 9$ cm, and the distance $x_2 = 28$ cm.

Since we know nothing about the force $\vec{F}_b$ acting on the bottom corner of the bracket, we will use that point as our pivot point. The sum of torques around this point must be zero; use this to find F_{sh}.

Evaluate $\sum\tau = 0 = F_{g1}x_1 + F_{g2}x_2 - F_{sh}y \rightarrow F_{sh} = \frac{(F_{g1}x_1 + F_{g2}x_2)}{y} = \frac{(m_1x_1 + m_2x_2)g}{y} = 170$ N.



Assess The force is much larger than the weight of the plant, as we expected.