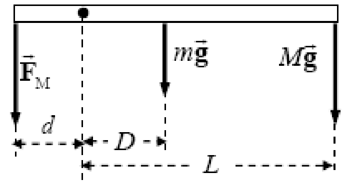
2. Calculate the torques about the elbow joint (the dot in the free body diagram). The arm is in equilibrium. Counterclockwise torques are positive.

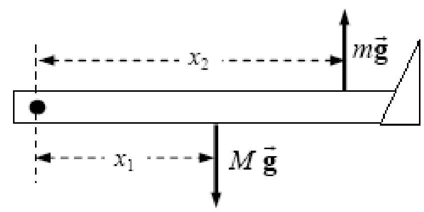


$$\sum \tau = F_M d - mgD - MgL = 0$$

$$F_M = \frac{mD + ML}{d} g$$

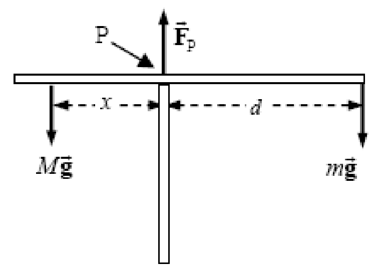
$$= \frac{(2.3\,\text{kg})(0.12\,\text{m}) + (7.3\,\text{kg})(0.300\,\text{m})}{0.025\,\text{m}}(9.80\,\text{m/s}^2) = \boxed{970\,\text{N}}$$

3. Because the mass m is stationary, the tension in the rope pulling up on the sling must be mg, and so the force of the sling on the leg must be mg, upward. Calculate torques about the hip joint, with counterclockwise torque taken as positive. See the free-body diagram for the leg. Note that the forces on the leg exerted by the hip joint are not drawn, because they do not exert a torque about the hip joint.



$$\sum \tau = mgx_2 - Mgx_1 = 0 \quad \rightarrow \quad m = M\frac{x_1}{x_2} = (15.0\,\text{kg})\frac{(35.0\,\text{cm})}{(78.0\,\text{cm})} = \boxed{6.73\,\text{kg}}$$

4. (*a*) See the free-body diagram. Calculate torques about the pivot point P labeled in the diagram. The upward force at the pivot will not have any torque. The total torque is zero since the crane is in equilibrium.



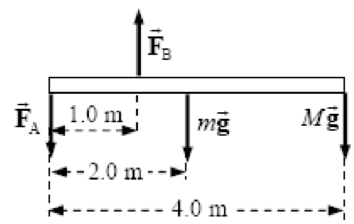
$$\sum \tau = Mgx - mgd = 0 \quad \rightarrow$$

$$x = \frac{md}{M} = \frac{(2800\,\text{kg})(7.7\,\text{m})}{(9500\,\text{kg})} = \boxed{2.3\,\text{m}}$$

(*b*) Again we sum torques about the pivot point. Mass m is the unknown in this case, and the counterweight is at its maximum distance from the pivot.

$$\sum \tau = Mgx_{\text{max}} - m_{\text{max}}gd = 0 \quad \rightarrow \quad m_{\text{max}} = \frac{Mx_{\text{max}}}{d} = \frac{(9500\,\text{kg})(3.4\,\text{m})}{(7.7\,\text{kg})} = \boxed{4200\,\text{kg}}$$

5. (*a*) Let $m = 0$. Calculate the net torque about the left end of the diving board, with counterclockwise torques positive. Since the board is in equilibrium, the net torque is zero.



$$\sum \tau = F_B(1.0\text{ m}) - Mg(4.0\text{ m}) = 0 \quad \rightarrow$$

$$F_B = 4Mg = 4(52\text{ kg})(9.80\text{ m/s}^2) = 2038\text{ N} \approx \boxed{2.0\times10^3\text{ N, up}}$$

Use Newton's second law in the vertical direction to find F_A.

$$\sum F_y = F_B - Mg - F_A = 0 \quad \rightarrow$$

$$F_A = F_B - Mg = 4Mg - Mg = 3Mg = 3(52\text{ kg})(9.80\text{ m/s}^2) = 1529\text{ N} \approx \boxed{1500\text{ N, down}}$$

(*b*) Repeat the basic process, but with $m = 28$ kg. The weight of the board will add more clockwise torque.

$$\sum \tau = F_B(1.0\text{ m}) - mg(2.0\text{ m}) - Mg(4.0\text{ m}) = 0 \quad \rightarrow$$

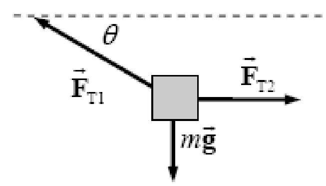
$$F_B = 4Mg + 2mg = [4(52\text{ kg}) + 2(28\text{ kg})](9.80\text{ m/s}^2) = 2587\text{ N} \approx \boxed{2600\text{ N, up}}$$

$$\sum F_y = F_B - Mg - mg - F_A \quad \rightarrow$$

$$F_A = F_B - Mg - mg = 4Mg + 2mg - Mg - mg = 3Mg + mg$$

$$= [3(52\text{ kg}) + 28\text{ kg}](9.80\text{ m/s}^2) = 1803\text{ N} \approx \boxed{1800\text{ N, down}}$$

11. Using the free-body diagram, write Newton's second law for both the horizontal and vertical directions, with net forces of zero.



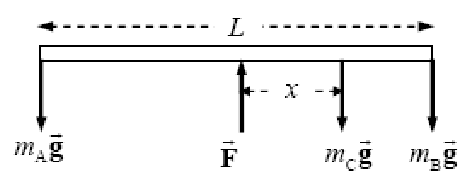
$$\sum F_x = F_{T2} - F_{T1}\cos\theta = 0 \quad \rightarrow \quad F_{T2} = F_{T1}\cos\theta$$

$$\sum F_y = F_{T1}\sin\theta - mg = 0 \quad \rightarrow \quad F_{T1} = \frac{mg}{\sin\theta}$$

$$F_{T2} = F_{T1}\cos\theta = \frac{mg}{\sin\theta}\cos\theta = \frac{mg}{\tan\theta} = \frac{(190\text{ kg})(9.80\text{ m/s}^2)}{\tan 33^\circ} = 2867\text{N} \approx \boxed{2900\text{ N}}$$

$$F_{T1} = \frac{mg}{\sin\theta} = \frac{(190\text{ kg})(9.80\text{ m/s}^2)}{\sin 33^\circ} = 3418\text{ N} \approx \boxed{3400\text{ N}}$$

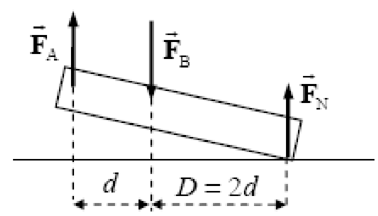
18. From the free-body diagram, the conditions of equilibrium are used to find the location of the girl (mass m_C). The 45-kg boy is represented by m_A, and the 35-kg girl by m_B. Calculate torques about the center of the see-saw, and take counterclockwise torques to be positive. The upward force of the fulcrum on the see-saw $(\vec{F})$ causes no torque about the center.



$$\sum \tau = m_A g\left(\tfrac{1}{2}L\right) - m_C g x - m_B g\left(\tfrac{1}{2}L\right) = 0$$

$$x = \frac{(m_A - m_B)}{m_C}\left(\tfrac{1}{2}L\right) = \frac{(45\text{ kg} - 35\text{ kg})}{25\text{ kg}}\tfrac{1}{2}(3.2\text{ m}) = \boxed{0.64\text{ m}}$$

19. There will be a normal force upwards at the ball of the foot, equal to the person's weight $(F_N = mg)$. Calculate torques about a point on the floor directly below the leg bone (and so in line with the leg bone force, $\vec{F}_B$). Since the foot is in equilibrium, the sum of the torques will be zero. Take counterclockwise torques as positive.



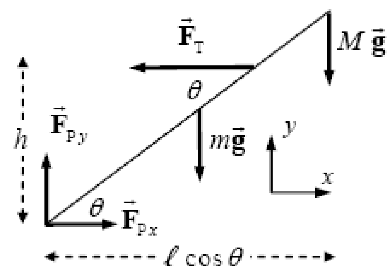
$$\sum \tau = F_N(2d) - F_A d = 0 \rightarrow$$

$$F_A = 2F_N = 2mg = 2(72\text{ kg})(9.80\text{ m/s}^2) = \boxed{1400\text{ N}}$$

The net force in the *y* direction must be zero. Use that to find F_B.

$$\sum F_y = F_N + F_A - F_B = 0 \rightarrow F_B = F_N + F_A = 2mg + mg = 3mg = \boxed{2100\text{ N}}$$

21. (*a*) The pole is in equilibrium, and so the net torque on it must be zero. From the free-body diagram, calculate the net torque about the lower end of the pole, with counterclockwise torques as positive. Use that calculation to find the tension in the cable. The length of the pole is ℓ.



$$\sum \tau = F_T h - mg(\ell/2)\cos\theta - Mg\ell\cos\theta = 0$$

$$F_T = \frac{(m/2 + M)g\ell\cos\theta}{h}$$

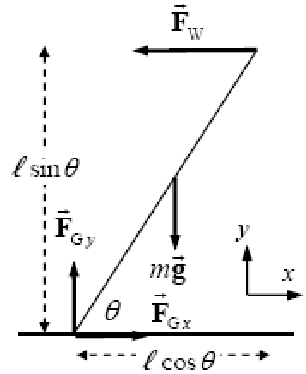
$$= \frac{(6.0\text{ kg} + 21.5\text{ kg})(9.80\text{ m/s}^2)(7.20\text{ m})\cos 37^\circ}{3.80\text{ m}} = 407.8\text{ N} \approx \boxed{410\text{ N}}$$

(*b*) The net force on the pole is also zero since it is in equilibrium. Write Newton's second law in both the *x* and *y* directions to solve for the forces at the pivot.

$$\sum F_x = F_{Px} - F_T = 0 \rightarrow F_{Px} = F_T = \boxed{410\text{ N}}$$

$$\sum F_y = F_{Py} - mg - Mg = 0 \rightarrow F_{Py} = (m + M)g = (33.5\text{ kg})(9.80\text{ m/s}^2) = \boxed{328\text{ N}}$$

32. Write the conditions of equilibrium for the ladder, with torques taken about the bottom of the ladder, and counterclockwise torques as positive.



$$\sum \tau = F_W \ell \sin\theta - mg\left(\tfrac{1}{2}\ell\cos\theta\right) = 0 \quad \rightarrow \quad F_W = \tfrac{1}{2}\frac{mg}{\tan\theta}$$

$$\sum F_x = F_{Gx} - F_W = 0 \quad \rightarrow \quad F_{Gx} = F_W = \tfrac{1}{2}\frac{mg}{\tan\theta}$$

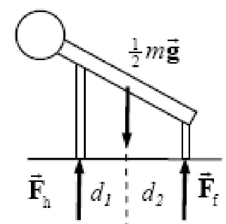
$$\sum F_y = F_{Gy} - mg = 0 \quad \rightarrow \quad F_{Gy} = mg$$

For the ladder to not slip, the force at the ground F_{Gx} must be less than or equal to the maximum force of static friction.

$$F_{Gx} \le \mu F_N = \mu F_{Gy} \quad \rightarrow \quad \tfrac{1}{2}\frac{mg}{\tan\theta} \le \mu mg \quad \rightarrow \quad \frac{1}{2\mu} \le \tan\theta \quad \rightarrow \quad \theta \ge \tan^{-1}\left(\frac{1}{2\mu}\right)$$

Thus the minimum angle is $\boxed{\theta_{min} = \tan^{-1}\left(\frac{1}{2\mu}\right)}$.

72. (*a*) The man is in equilibrium, so the net force and the net torque on him must be zero. We use half of his weight, and then consider the force just on one hand and one foot, considering him to be symmetric. Take torques about the point where the foot touches the ground, with counterclockwise as positive.



$$\sum \tau = \tfrac{1}{2}mgd_2 - F_h\left(d_1 + d_2\right) = 0$$

$$F_h = \frac{mgd_2}{2\left(d_1+d_2\right)} = \frac{(68\,\text{kg})(9.80\,\text{m/s}^2)(0.95\,\text{m})}{2(1.37\,\text{m})} = 231\,\text{N} \approx \boxed{230\,\text{N}}$$

(*b*) Use Newton's second law for vertical forces to find the force on the feet.

$$\sum F_y = 2F_h + 2F_f - mg = 0$$

$$F_f = \tfrac{1}{2}mg - F_h = \tfrac{1}{2}(68\,\text{kg})(9.80\,\text{m/s}^2) - 231\,\text{N} = 103\,\text{N} \approx \boxed{100\,\text{N}}$$

The value of 100 N has 2 significant figures.