Physics 100A – Summer 2016
Chapter 11

Solutions are provided only for problems from your textbook. The other problems already have so much guidance and notes that you should be able to understand where you have gone wrong.

Problems

4. **Picture the Problem**: The arm extends out either horizontally and the weight of the crab trap is exerted straight downward on the hand.

   Strategy: The torque equals the moment arm times the force according to equation 11-3. In this case the moment arm is the horizontal distance between the shoulder and the hand, and the force is the downward weight of the crab trap.

   Solution: Multiply the moment arm by the weight: $\tau = r_{\perp} mg = (0.70\text{ m})(3.6\text{ kg})(9.81\text{ m/s}^2) = \boxed{25\text{ N}\cdot}$

   Insight: If the man bent his elbow and brought his hand up next to his shoulder, the torque on the shoulder would be zero but the force on his hand would remain 35 N or 7.9 lb.

11. **Picture the Problem**: The ceiling fan rotates about its axis, decreasing its angular speed at a constant rate.

    Strategy: Determine the angular acceleration using equation 10-6 and then use equation 11-4 to find the moment of inertia of the fan.

    Solution: Solve equation 11-4 for *I*: $I = \dfrac{\tau}{\alpha} = \dfrac{\tau}{\Delta\omega/\Delta t} = \dfrac{\tau\,\Delta t}{\Delta\omega} = \dfrac{(-0.120\text{ N}\cdot\text{m})(22.5\text{ s})}{(0 - 2.75\text{ rad/s})} = \boxed{0.982\text{ kg}}$

    Insight: Friction converts the fan's initial kinetic energy of $\frac{1}{2}I\omega_0^2 = 3.10\text{ J}$ into heat. Rotational work will be examined in more detail in section 11-8.

19. **Picture the Problem**: The fish exerts a torque on the fishing reel and it rotates with constant angular acceleration.

    Strategy: Use Table 10-1 to determine the moment of inertia of the fishing reel assuming it is a uniform cylinder ($\frac{1}{2}MR^2$). Find the torque the fish exerts on the reel by using equation 11-1. Then apply Newton's Second Law for rotation (equation 11-4) to find the angular acceleration and equations 10-2 and 10-10 to find the amount of line pulled from the reel.

    Solution: 1. (a) Use Table 10-1 to find *I*: $I = \frac{1}{2}MR^2 = \frac{1}{2}(0.99\text{ kg})(0.055\text{ m})^2 = \underline{\underline{0.0015\text{ kg}\cdot\text{m}^2}}$

2. Apply equation 11-1 directly to find τ:

$\tau = rF = (0.055\text{ m})(2.2\text{ N}) = \underline{\underline{0.121\text{ N}\cdot\text{m}}}$

3. Solve equation 11-14 for α:

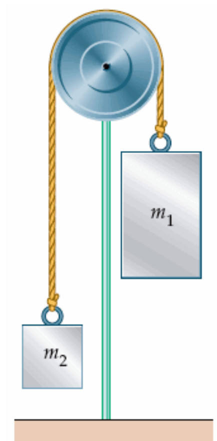
$\alpha = \dfrac{\tau}{I} = \dfrac{0.121\text{ N}\cdot\text{m}}{0.0015\text{ kg}\cdot\text{m}^2} = \boxed{81\text{ rad/s}^2}$

4. (b) Apply equations 10-2 and 10-10:

$s = r\theta = r\left(\tfrac{1}{2}\alpha t^2\right) = (0.055\text{ m})\tfrac{1}{2}\left(81\text{ rad/s}^2\right)(0.25\text{ s})^2$
$= \boxed{0.14\text{ m}}$

Insight: This must be a small fish because it is not pulling very hard; 2.2 N is about 0.49 lb or 7.9 ounces of force. Or maybe the fish is tired?

22. Picture the Problem: The two masses hang on either side of a pulley.



Strategy: Use Newton's Second Law for rotation (equation 11-4) to find the frictional torque τ_{fr} that would make the angular acceleration of the system equal to zero. In each case the torque exerted on the pulley by the hanging masses is the weight of the mass times the radius of the pulley. Let $m_1 = 0.635$ kg and $m_2 = 0.321$ kg. The torque due to m_1 is clockwise and therefore taken to be in the negative direction.

Solution: Write Newton's Second Law for rotation and solve for τ_{fr}:

$\sum \vec{\boldsymbol{\tau}} = -r(m_1 g) + r(m_2 g) + \tau_{\text{fr}} = 0$

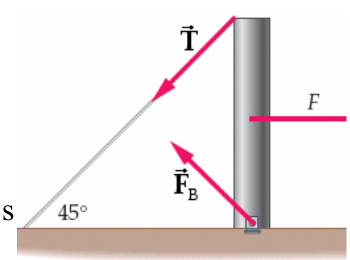
$\tau_{\text{fr}} = r\,g\,(m_1 - m_2)$

$= (0.0940\text{ m})\left(9.81\text{ m/s}^2\right)(0.635 - 0.321\text{ k}$

$\tau_{\text{fr}} = \boxed{0.290\text{ N}\cdot\text{m}}$

Insight: This frictional torque represents a static friction force. If a little bit of mass were added to m_1, the system would begin accelerating clockwise and the frictional torque would be reduced to its kinetic value.

36. Picture the Problem: The horizontal force F is applied to the rod as shown in the figure at right.



Strategy: Let L = the rod length and write Newton's Second Law for torques (let the bolt be the pivot point) in order to determine the wire tension T. Then write Newton's Second Law in the horizontal and vertical directions to determine the components of the bolt force $\vec{\mathbf{F}}_{\text{b}}$.

Solution: 1. (a) Set $\sum \tau = 0$ and solve for T:

$$\sum \tau = L\left(T\cos 45°\right) - \left(\tfrac{1}{2}L\right)F =$$

$$T = \frac{F}{2\cos 45°} = \boxed{\frac{F}{\sqrt{2}}}$$

2. (b) Set $\sum F_x = 0$ and solve for $F_{b,x}$:

$$\sum F_x = F + F_{b,x} - T\cos 45° = 0$$

$$F_{b,x} = T\cos 45° - F = \left(\frac{F}{2\cos 45°}\right)\cos 45° - F = \boxed{-\tfrac{1}{2}F}$$

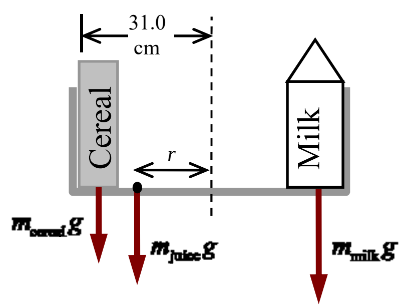
3. (c) Set $\sum F_y = 0$ and solve for $F_{b,y}$:

$$\sum F_y = F_{b,y} - T\sin 45° = 0$$

$$F_{b,y} = \left(\frac{F}{2\cos 45°}\right)\sin 45° = \boxed{\tfrac{1}{2}F}$$

Insight: The bolt force has a magnitude of $F/\sqrt{2}$ and points 45° above the horizontal and to the left.

41. Picture the Problem: The box of cereal is at the left end of the basket and the milk carton is at the right end.



Strategy: Place the origin at the center of the $L = 0.620\text{ m}$ basket. Write Newton's Second Law for torque with the pivot axis at the center of the basket. Set the net torque equal to zero and solve for the distance *r* of the orange juice from the center of the basket. The orange juice will be placed on the cereal side of the basket because the cereal has less mass and exerts less torque than does the milk.

Solution: Set $\sum \tau = 0$ and solve for *r*:

$$\sum \tau = +(\frac{1}{2}L)m_{cereal}g + rm_{juice}g - (\frac{1}{2}L)m_{milk}g = 0$$

$$r = \frac{(L/2)(m_{milk} - m_{cereal})}{m_{milk}} = \frac{(1/2)(0.620)(1.81 - 0.722)}{1.80} = 0.187m = 18.7cm$$

Insight: Another way to solve this question is ensure that the center of mass of the basket is at its geometric center, in a manner similar to problem 46 in Chapter 9. However, the balancing of the torques is actually a bit simpler in this case.

50. Picture the Problem: You pull straight downward on a rope that passes over a disk-shaped pulley and then supports a weight on the other side. The force of your pull rotates the pulley and accelerates the mass upward.

Strategy: In the previous problem, we wrote Newton's Second Law for the hanging mass and Newton's Second Law for torque about the axis of the pulley, and solved the two expressions for the tension T_2 at the other end of the rope. We found that $T_1 = 25\text{ N}$ and $T_2 = 16\text{ N}$. Use Newton's Second Law for the hanging mass to find the linear acceleration.

Solution: Set $\sum \vec{\mathbf{F}} = m\vec{\mathbf{a}}$ for the hanging mass and solve for *a*:

$$\sum F_y = T_2 - Mg = Ma$$

$$a = \frac{T_2}{M} - g = \frac{16 \text{ N}}{0.67 \text{ kg}} - 9.81 \text{ m/s}^2 = \boxed{14 \text{ m/}}$$

Insight: If you reduce your force and pull on the rope with a force equal to the weight of the hanging mass, 6.6 N, the acceleration would be zero and both tensions would be 6.6 N; and the system would move at constant speed.

54. Picture the Problem: The disk-shaped record rotates about its axis with a constant angular speed.

Strategy: Use equation 11-11 and the moment of inertia of a uniform disk rotating about its axis, $I = \frac{1}{2}MR^2$, to find the angular momentum of the record.

Solution: Apply equation 11-11 directly:

$$L = I\omega$$

$$= \left(\tfrac{1}{2}MR^2\right)\omega = \tfrac{1}{2}(0.015 \text{ kg})(0.15 \text{ m})^2\left(33\tfrac{1}{3}\ \frac{\text{rev}}{\text{min}}\right)\left(\frac{2\pi \text{ rad}}{\text{rev}}\right)($$

$$L = \boxed{5.9\times10^{-4}\ \text{kg}\cdot\text{m}^2/\text{s}}$$

Insight: The angular momentum of a compact disk rotating at 300 rev/min is about 7.5×10^{-4} kg·m^2/s. The compact disk (m = 13 g, r = 6.0 cm) is smaller than a record, but it spins faster, so the angular momenta are similar.

65. Picture the Problem: The skater pulls his arms in, decreasing his moment of inertia and increasing his angular speed.

Strategy: The angular momentum of the skater remains the same throughout the spin because there is assumed to be no torque of any kind acting on his body. Use the conservation of angular momentum (equation 11-15) together with equation 11-11, to find the ratio I_f/I_i.

Solution: Set $L_i = L_f$ and solve for I_f/I_i: $I_i\omega_i = I_f\omega_f \Rightarrow \dfrac{I_f}{I_i} = \dfrac{\omega_i}{\omega_f} = \dfrac{3.17 \text{ rad/s}}{5.46 \text{ rad/s}} = \boxed{0.581}$

Insight: By rearranging his mass, especially by bringing his arms and legs in close to his axis of rotation, the skater has reduced his moment of inertia by an impressive 42% and increased his angular speed by 72%.

80. Picture the Problem: The torque acting through an angular displacement does work on the ice cream crank.

Strategy: Use equation 11-17 to find the work done by the torque acting through the given angular displacement. One complete turn corresponds to an angular displacement of 2π radians.

Solution: Apply equation 11-17 directly: $W = \tau\,\Delta\theta = (3.95 \text{ N}\cdot\text{m})(2\pi \text{ rad}) = \boxed{24.8 \text{ J}}$

Insight: The work done on the ice cream crank is dissipated as heat via friction in the viscous ice cream mixture.