Physics 100A – Summer 2016  
Chapter 6

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

3. **Picture the Problem**: A baseball player slides in a straight line and comes to rest due to the frictional force.

   **Strategy**: Find the acceleration of the player using Newton’s Second Law, and insert the result into equation 2-12 to find the slide distance. Let the initial velocity $v_0$ point in the positive direction.

   **Solution**: 1. Find the acceleration of the player using Newton’s Second Law:
   
   $$ \sum F_x = f_k = ma$$
   
   $$a = \frac{f_k}{m} = -\frac{\mu_k mg}{m} = -\mu_k g$$

   2. Use equation 2-12 to find the slide distance:
   
   $$\Delta x = \frac{v_f^2 - v_0^2}{2a} = \frac{0 - v_0^2}{-2\mu_k g} = \frac{(4.0 \text{ m/s})^2}{2(0.46)(9.81 \text{ m/s}^2)} = 1.8 \text{ m}$$

   **Insight**: If the player were running faster, say, 8.0 m/s, a $\mu_k$ of 0.46 would result in a slide distance of 7.1 m, a quarter of the 27 m between the bases! He might very well overshoot the base and be tagged out.

12. **Picture the Problem**: The crate slides down the incline when the angle is $26^\circ$. A free-body diagram of the situation is depicted at right.

   **Strategy**: Choose the $x$-axis to be parallel to the ramp, pointing uphill, and the $y$ axis to point perpendicular to the ramp. Write Newton’s Second Law in the $y$ direction to find the normal force $N$. Then write Newton’s Second Law in the $x$ direction with $a_x = 0$ (the box just begins to slide) to find the coefficient of static friction $\mu_s$.

   **Solution**: 1. (a) Write Newton’s Second Law in the $y$ direction:
   
   $$\sum F_y = N - mg \cos \theta = 0$$
   
   $$N = mg \cos \theta$$
2. Write Newton’s Second Law in the $x$ direction, setting $a_x = 0$ (the box just begins to slide) and solving for $\mu_s$:

\[ \sum F_x = \mu_s N - mg \sin \theta = ma_x = 0 \]

\[ \mu_s (mg \cos \theta) - mg \sin \theta = 0 \]

\[ \mu_s = \tan \theta = \tan 26^\circ = 0.49 \]

3. (b) Since $\theta$ only depends upon $\mu_s$, changing the mass will not change $\theta$ and the angle remains $26^\circ$.

**Insight:** Increasing the mass does increase the normal force and hence the friction force, but the component of the crate’s weight that pulls it down the ramp is also increased. The two effects cancel and $\theta$ depends upon $\mu_s$ only.

25. **Picture the Problem:** The spring force is increased until the backpack begins to slide in the negative $x$ direction.

**Strategy:** There are two forces acting on the backpack, the spring force to the left and the friction force to the right. The magnitudes of these two forces must be equal for the backpack to remain at rest. Use Newton’s Second Law in the horizontal direction to relate the magnitudes of the forces and Hooke’s law (equation 6-4) to find the spring force and hence the friction force. Newton’s Second Law in the vertical direction can then be used to find the normal force, which together with the friction force can be used to find the coefficient of static friction.

**Solution:**

1. Write Newton’s Second Law in the horizontal direction:

\[ \sum F_x = f_x - F = ma_x = 0 \]

2. Use Hooke’s law to find the spring force and the friction force. Note that the spring stretches in the negative $x$ direction.

\[ f_x = F = -kx \]

3. Write Newton’s Second Law in the vertical direction:

\[ \sum F_y = N - mg = 0 \Rightarrow N = mg \]

4. Use equation 6-3 to find the coefficient $\mu_s$:

\[ \mu_s = \frac{f_{x,\text{max}}}{N} = \frac{-k x}{mg} = \frac{-150 \text{ N/m}(0.0250 \text{ m})}{52.0 \text{ N}} = 0.07 \]
Insight: Doubling the mass of the backpack will double the friction force and therefore double the required stretch distance of the spring if the coefficient of static friction remains the same.

31. Picture the Problem: The free-body diagram for the contact point between the two strings is depicted at right.

Strategy: The horizontal components of the string tensions must be equal because the picture is not accelerating. The same is true of the vertical components of the forces. Use Newton’s Second Law in the horizontal direction to find the tension in string 2, and in the vertical direction to find the weight of the picture.

Solution: 1. (a) The tension in string 2 is less than the tension in string 1, because it provides mostly a sideways component of force that is balanced by the horizontal component of string 1. That means string 1 must support most of the weight of the picture plus balance string 2’s horizontal component, giving it a larger tension than string 2.

2. (b) Write Newton’s Second Law in the horizontal direction in order to find the tension in string 2:

\[ T_2 = \frac{T_1 \cos \theta_1}{\cos \theta_2} \]

\[ T_2 = \frac{(1.7 \text{ N}) \cos 65^\circ}{\cos 32^\circ} = 0.85 \text{ N} \]

3. (c) Write Newton’s Second Law in the vertical direction in order to find the picture’s weight:

\[ W = (1.7 \text{ N}) \sin 65^\circ + (0.85 \text{ N}) \sin 32^\circ = 2.0 \text{ N} \]

Insight: As the angle of string 1 approaches 90° and the angle of string 2 approaches 0°, the tension in string 2 drops to zero and the entire 2.0 N weight of the picture is supported by string 1.

37. Picture the Problem: The forces exerted on the left and right blocks are depicted at right.

Strategy: Because the pulley is ideal, the tension in the string is equal to the weight of the hanging block. This can be verified by Newton’s Second Law in the vertical direction for the hanging block:

\[ \sum F_y = T - mg = 0 \]

Write Newton’s Second Law along the direction parallel to the incline for the 6.7 kg block.
and substitute $T = mg$ into the resulting equation to find $m$.

**Solution:** 1. Write Newton’s Second Law along the direction parallel to the incline:

$$\sum F_x = T - Mg \sin \theta = 0$$

2. Substitute $T = mg$ into the resulting equation to find $m$.

$$T = mg = Mg \sin \theta$$

$$m = M \sin \theta = (6.7 \text{ kg}) \sin 42^\circ = 4.5 \text{ kg}$$

**Insight:** A larger $m$ is required if the angle $\theta$ is increased. If it is increased all the way to $\theta = 90^\circ$, the large mass will be hanging straight down and the mass $m$ required to maintain equilibrium would be 6.7 kg.

44. **Picture the Problem:** The physical apparatus is shown at right.

**Strategy:** Write Newton’s Second Law for each of the three blocks and add the equations to eliminate the unknowns $T_1$ and $T_2$. Solve the resulting equation for the acceleration $a$. Let $x$ be positive in the direction of each mass’s motion.

**Solution:** 1. Write Newton’s Second Law for each of the three blocks and add the equations:

$$\sum F_x^{\text{blk.1}} = T_1 = ma$$

$$\sum F_x^{\text{blk.2}} = -T_1 + T_2 = ma$$

$$\sum F_x^{\text{blk.3}} = -T_2 + mg = ma$$

$$mg = (m_1 + m_2 + m_3)a$$

2. Solve the resulting equation for $a$:

$$a = \left( \frac{m_2}{m_1 + m_2 + m_3} \right) g = \frac{3.0 \text{ kg}}{6.0 \text{ kg}} \left( 9.81 \text{ m/s}^2 \right) = 4.9 \text{ m/s}^2$$

**Insight:** Note that the blocks move as if they were a single block of mass 6.0 kg under the influence of a force equal to $m_1 g = 29$ N.

56. **Picture the Problem:** The test tube travels along a circular path at constant speed.

**Strategy:** Solve equation 6-15 for the speed required to attain the desired acceleration.
Solution: Solve equation 6-15 for \( v = \sqrt{r a_y} = \sqrt{r (52,000 \text{ g})} = \sqrt{(0.075 \text{ m})(52,000)(9.81 \text{ m/s}^2)} \) the speed:

\[
200 \text{ m/s} = 0.20 \text{ km/s}
\]

Insight: This speed corresponds to 25,000 revolutions per minute for the centrifuge, or 415 revolutions per second.

62. Picture the Problem: The car follows a circular path at constant speed as it passes over the bump.

Strategy: The centripetal acceleration is downward, toward the center of the circle, as the car passes over the bump. Write Newton’s Second Law in the vertical direction and solve for the normal force \( N \), which is also the apparent weight of the passenger.

Solution: 1. Write Newton’s Second Law for the passenger and solve for \( N \):

\[
\sum F_y = N - mg = -ma_y = -m v^2 / r \\
N = m \left( g - \frac{v^2}{r} \right)
\]

2. Insert numerical values:

\[
N = (67 \text{ kg}) \left[ 9.81 \text{ m/s}^2 - \frac{(12 \text{ m/s})^2}{35 \text{ m}} \right] = 380 \text{ N} = 0.38 \text{ kN}
\]

Insight: This apparent weight is 42% less than the normal 0.66-kN weight of the passenger.