Ch 5 Worksheet 3 Solutions

P5.53 Using $m = 12.0 \times 10^{-3}$ kg, $v_i = 260$ m/s, $v_f = 0$, $\Delta x = (x_f - x_i) = 0.230$ m, and $v_f^2 = v_i^2 + 2a(x_f - x_i)$, we find the acceleration of the bullet: $a = -1.47 \times 10^5$ m/s^2. Newton's second law then gives

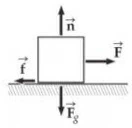
$$\sum F_x = ma_x$$

$$f_k = ma = -1.76 \times 10^5 \text{ N}$$

The (kinetic) friction force is $\boxed{1.76 \times 10^5 \text{ N in the negative } x \text{ direction}}$.

P5.55 For equilibrium: $f = F$ and $n = F_g$. Also, $f = \mu n$, i.e.,

$$\mu = \frac{f}{n} = \frac{F}{F_g}$$



ANS. FIG. P5.55

In parts (a) and (b), we replace F with the magnitude of the applied force and μ with the appropriate coefficient of friction.

(a) The coefficient of static friction is found from

$$\mu_s = \frac{F}{F_g} = \frac{75.0 \text{ N}}{(25.0 \text{ kg})(9.80 \text{ m/s}^2)} = \boxed{0.306}$$

(b) The coefficient of kinetic friction is found from

$$\mu_k = \frac{F}{F_g} = \frac{60.0 \text{ N}}{(25.0 \text{ kg})(9.80 \text{ m/s}^2)} = \boxed{0.245}$$

P5.59 Applying Newton's second law:

$$\sum F_x = ma_x:$$

$$f_s = ma$$

$$\mu_s mg = ma \quad \rightarrow \quad a = \mu_s g$$

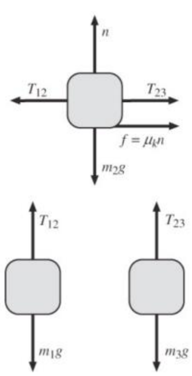
We find the time interval $\Delta t = t$ to accelerate from rest through $\Delta x = 3.00$ m using $x_f = x_i + v_{xi}t + \frac{1}{2}a_x t^2$:

$$\Delta x = \frac{1}{2}a_x(\Delta t)^2 \rightarrow \Delta t = \sqrt{\frac{2\Delta x}{a_x}} = \sqrt{\frac{2\Delta x}{\mu_s g}}$$

(a) For $\mu_s = 0.500$, $\Delta t = \boxed{1.11 \text{ s}}$

(b) For $\mu_s = 0.800$, $\Delta t = \boxed{0.875 \text{ s}}$

P5.64 (a) The free-body diagrams for each object appear on the right.



ANS. FIG. P5.64(a)

(b) Let a represent the positive magnitude of the acceleration $-a\hat{\mathbf{j}}$ of m_1, of the acceleration $-a\hat{\mathbf{i}}$ of m_2, and of the acceleration $+a\hat{\mathbf{j}}$ of m_3. Call T_{12} the tension in the left cord and T_{23} the tension in the cord on the right.

For m_1, $\sum F_y = ma_y$:

$$+T_{12} - m_1 g = -m_1 a$$

For m_2, $\sum F_x = ma_x$:

$$-T_{12} + \mu_k n + T_{23} = -m_2 a$$

and $\sum F_y = ma_y$, giving $n - m_2 g = 0$.

For m_3, $\sum F_y = ma_y$, giving $T_{23} - m_3 g = +m_3 a$.

We have three simultaneous equations:

$$-T_{12} + 39.2 \text{ N} = (4.00 \text{ kg})a$$
$$+T_{12} - 0.350(9.80 \text{ N}) - T_{23} = (1.00 \text{ kg})a$$
$$+T_{23} - 19.6 \text{ N} = (2.00 \text{ kg})a$$

Add them up (this cancels out the tensions):

$$+39.2 \text{ N} - 3.43 \text{ N} - 19.6 \text{ N} = (7.00 \text{ kg})a$$

$$a = \boxed{2.31 \text{ m/s}^2\text{, down for } m_1\text{, left for } m_2\text{, and up for } m_3}$$

(c) Now $-T_{12} + 39.2 \text{ N} = (4.00 \text{ kg})(2.31 \text{ m/s}^2)$

$$\boxed{T_{12} = 30.0 \text{ N}}$$

and $T_{23} - 19.6 \text{ N} = (2.00 \text{ kg})(2.31 \text{ m/s}^2)$

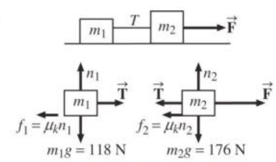
$$\boxed{T_{23} = 24.2 \text{ N}}$$

(d) If the tabletop were smooth, friction disappears ($\mu_k = 0$), and so the acceleration would become larger. For a larger acceleration, according to the equations above, the tensions change:

$$T_{12} = m_1 g - m_1 a \rightarrow \boxed{T_{12} \text{ decreases}}$$

$$T_{23} = m_3 g + m_3 a \rightarrow \boxed{T_{23} \text{ increases}}$$

P5.65 Because the cord has constant length, both blocks move the same number of centimeters in each second and so move with the same acceleration. To find just this acceleration, we could model the 30-kg system as a particle under a net force. That method would not help to finding the tension, so we treat the two blocks as separate accelerating particles.



ANS. FIG. P5.65

(a) ANS. FIG. P5.65 shows the free-body diagrams for the two blocks. The tension force exerted by block 1 on block 2 is the same size as the tension force exerted by object 2 on object 1. The tension in a light string is a constant along its length, and tells how strongly the string pulls on objects at both ends.

(b) We use the free-body diagrams to apply Newton's second law.

For m_1: $\sum F_x = T - f_1 = m_1 a$ or $T = m_1 a + f_1$ **[1]**

And also $\sum F_y = n_1 - m_1 g = 0$ or $n_1 = m_1 g$

Also, the definition of the coefficient of friction gives

$$f_1 = \mu n_1 = (0.100)(12.0 \text{ kg})(9.80 \text{ m/s}^2) = 11.8 \text{ N}$$

For m_2: $\sum F_x = F - T - f_2 = ma$ **[2]**

Also from the y component, $n_2 - m_2 g = 0$ or $n_2 = m_2 g$

And again $f_2 = \mu n_2 = (0.100)(18.0 \text{ kg})(9.80 \text{ m/s}^2) = 17.6$ N

Substituting T from equation [1] into [2], we get

$$F - m_1 a - f_1 - f_2 = m_2 a \quad \text{or} \quad F - f_1 - f_2 = m_2 a + m_1 a$$

Solving for a,

$$a = \frac{F - f_1 - f_2}{m_1 + m_2} = \frac{(68.0 \text{ N} - 11.8 \text{ N} - 17.6 \text{ N})}{(12.0 \text{ kg} + 18.0 \text{ kg})} = \boxed{1.29 \text{ m/s}^2}$$

(c) From equation [1],

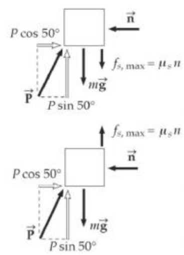
$$T = m_1 a + f_1 = (12.0 \text{ kg})(1.29 \text{ m/s}^2) + 11.8 \text{ N} = \boxed{27.2 \text{ N}}$$

P5.66 (a) To find the maximum possible value of P, imagine impending upward motion as case 1. Setting $\sum F_x = 0$:

$$P\cos 50.0° - n = 0$$

with $f_{s,\,\max} = \mu_s n$:

$$f_{s,\,\max} = \mu_s P\cos 50.0°$$
$$= 0.250(0.643)P = 0.161P$$



ANS. FIG. P5.66

Setting $\sum F_y = 0$:

$$P\sin 50.0° - 0.161P - (3.00\text{ kg})(9.80\text{ m/s}^2) = 0$$

$$P_{\max} = \boxed{48.6\text{ N}}$$

To find the minimum possible value of P, consider impending downward motion. As in case 1,

$$f_{s,\,\max} = 0.161P$$

Setting $\sum F_y = 0$:

$$P\sin 50.0° + 0.161P - (3.00\text{ kg})(9.80\text{ m/s}^2) = 0$$

$$P_{\min} = \boxed{31.7\text{ N}}$$

(b) $\boxed{\text{If } P > 48.6\text{ N, the block slides up the wall. If } P < 31.7\text{ N, the block slides down the wall.}}$

(c) We repeat the calculation as in part (a) with the new angle.

Consider impending upward motion as case 1. Setting

$$\sum F_x = 0: \quad P\cos 13° - n = 0$$
$$f_{s,\,\max} = \mu_s n: \quad f_{s,\,\max} = \mu_s P\cos 13°$$
$$= 0.250(0.974)P = 0.244P$$

Setting

$$\sum F_y = 0: \quad P\sin 13° - 0.244P - (3.00\text{ kg})(9.80\text{ m/s}^2) = 0$$
$$P_{\max} = -1\,580\text{ N}$$

The push cannot really be negative. However large or small it is, it cannot produce upward motion. To find the minimum possible value of P, consider impending downward motion. As in case 1,

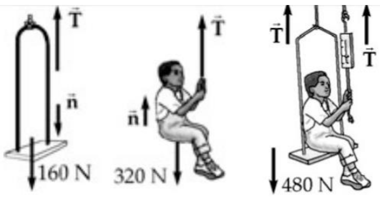
$$f_{s,\,\max} = 0.244P$$

Setting

$$\sum F_y = 0: \quad P\sin 13° + 0.244P - (3.00\text{ kg})(9.80\text{ m/s}^2) = 0$$
$$P_{\min} = \boxed{62.7\text{ N}}$$

$\boxed{P \geq 62.7\text{ N. The block cannot slide up the wall. If } P < 62.7\text{ N, the block slides down the wall.}}$

P5.81



ANS. FIG. P5.81(a)

(b) First consider Nick and the chair together as the system. Note that **two** ropes support the system, and $T = 250$ N in each rope.

Applying $\sum F = ma$, $\quad 2T - (160\text{ N} + 320\text{ N}) = ma$

where $\quad m = \dfrac{480\text{ N}}{9.80\text{ m/s}^2} = 49.0\text{ kg}$

Solving for a gives $\quad a = \dfrac{(500 - 480)\text{ N}}{49.0\text{ kg}} = \boxed{0.408\text{ m/s}^2}$

(c) On Nick, we apply

$\sum F = ma$: $\quad n + T - 320\text{ N} = ma$

where $\quad m = \dfrac{320\text{ N}}{9.80\text{ m/s}^2} = 32.7\text{ kg}$

The normal force is the one remaining unknown:

$$n = ma + 320\text{ N} - T$$

Substituting, $\quad n = (32.7\text{ kg})(0.408\text{ m/s}^2) + 320\text{ N} - 250\text{ N}$

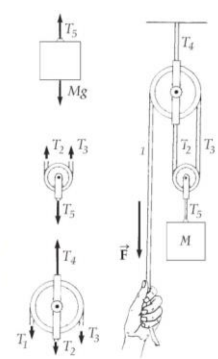
gives $\quad n = \boxed{83.3\text{ N}}$

P5.85 (a) See ANS. FIG. P5.85 showing the forces. All forces are in the vertical direction. The lifting can be done at constant speed, with zero acceleration and total force zero on each object.

(b) For M, $\quad \sum F = 0 = T_5 - Mg$

so $\quad T_5 = Mg$

Assume frictionless pulleys. The tension is constant throughout a light, continuous rope. Therefore, $T_1 = T_2 = T_3$.



ANS. FIG. 5.85

For the bottom pulley,

$$\sum F = 0 = T_2 + T_3 - T_5$$

so $2T_2 = T_5$. Then $\boxed{T_1 = T_2 = T_3 = \dfrac{Mg}{2}}$, $\boxed{T_4 = \dfrac{3Mg}{2}}$, and $\boxed{T_5 = Mg}$.

(c) Since $F = T_1$, we have $\boxed{F = \dfrac{Mg}{2}}$.