Section 2.3: Applying Newton's Laws of Motion
Tutorial 1 Practice, page 79

1. Given: $\overrightarrow{F}_{\text{gB}} = 2.8\text{ N}$; $\overrightarrow{F}_{\text{gA}} = 6.5\text{ N}$; $\overrightarrow{F}_{\text{f}} = 1.4\text{ N}$

(a) Required: F_1

Analysis: $\Sigma\vec{F} = 0\text{ N}$

Solution: The FBD for block B is shown below.

Equation for block B:

$$\begin{aligned} \Sigma\vec{F} &= 0\text{ N} \\ \vec{F}_1 - \vec{F}_{\text{gB}} &= 0\text{ N} \\ \vec{F}_1 &= \vec{F}_{\text{gB}} \\ \vec{F}_1 &= 2.8\text{ N} \end{aligned}$$

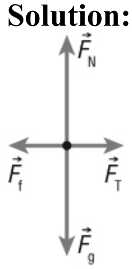
Statement: The tension in the vertical rope is 2.8 N.

(b) Given: $\vec{F}_{\text{gA}} = 6.5\text{ N}$; $\vec{F}_{\text{f}} = 1.4\text{ N}$

Required: $\vec{F}_2$; $\vec{F}_{\text{N}}$

Analysis: $\Sigma\vec{F} = 0\text{ N}$

Solution: The FBD for block A is shown below.



Equations for block A:

$$\begin{aligned} \Sigma\vec{F}_x &= 0\text{ N} \\ \vec{F}_2 - \vec{F}_{\text{f}} &= 0\text{ N} \\ \vec{F}_2 &= \vec{F}_{\text{f}} \\ \vec{F}_2 &= 1.4\text{ N} \end{aligned}$$

$$\begin{aligned} \Sigma\vec{F} &= 0\text{ N} \\ \vec{F}_{\text{N}} - \vec{F}_{\text{gA}} &= 0\text{ N} \\ \vec{F}_{\text{N}} &= \vec{F}_{\text{gA}} \\ \vec{F}_{\text{N}} &= 6.5\text{ N} \end{aligned}$$

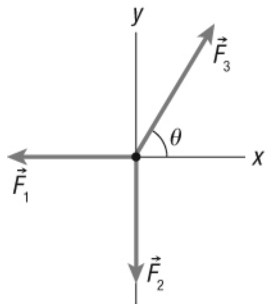
Statement: The tension in the horizontal rope is 1.4 N. The normal force acting on block A is 6.5 N.

(c) Given: $\vec{F}_2 = 1.4\text{ N}$

Required: $\vec{F}_3$

Analysis: $\Sigma\vec{F} = 0\text{ N}$

Solution: The FBD for point P is shown below.



Equations for point P.

For the *x*-components of the force:

$$\begin{aligned} \Sigma\vec{F}_x &= 0\text{ N} \\ \vec{F}_{3x} - \vec{F}_2 &= 0\text{ N} \\ \vec{F}_{3x} &= \vec{F}_2 \\ \vec{F}_{3x} &= 1.4\text{ N} \end{aligned}$$

For the *y*-components of the force:

$$\begin{aligned} \Sigma\vec{F} &= 0\text{ N} \\ \vec{F}_{3y} - \vec{F}_1 &= 0\text{ N} \\ \vec{F}_{3y} &= \vec{F}_1 \\ \vec{F}_{3y} &= 2.8\text{ N} \end{aligned}$$

Construct the vector $\vec{F}_3$ from its components:

$$\begin{aligned} \left|\vec{F}_3\right| &= \sqrt{(\vec{F}_{3x})^2 + (\vec{F}_{3y})^2} \\ &= \sqrt{(1.4\text{ N})^2 + (2.8\text{ N})^2} \\ \left|\vec{F}_3\right| &= 3.1\text{ N} \end{aligned}$$

$$\begin{aligned} \theta &= \tan^{-1}\left(\frac{\vec{F}_{3y}}{\vec{F}_{3x}}\right) \\ &= \tan^{-1}\left(\frac{2.8\ \cancel{\text{N}}}{1.4\ \cancel{\text{N}}}\right) \\ \theta &= 63^\circ \end{aligned}$$

Statement: The tension in the third rope is 3.1 N [right 63° up].

2. Given: $m = 62\text{ kg}$; $\vec{F}_\text{T} = 7.1\times10^2\text{ N [right 32° up]}$

Required: $\vec{F}_\text{W}$

Analysis: $\Sigma\vec{F} = 0\text{ N}$

Balance the *x*-components of the forces:

$$\begin{aligned}\Sigma\vec{F}_x &= 0\text{ N}\\ \vec{F}_{\text{W}x} + \vec{F}_\text{T}\cos\theta &= 0\text{ N}\\ \vec{F}_{\text{W}x} &= -\vec{F}_\text{T}\cos\theta\\ &= -(710\text{ N})\cos 32°\\ \vec{F}_{\text{W}x} &= -602.1\text{ N (two extra digits carried)}\end{aligned}$$

Balance the *y*-components of the forces:

$$\begin{aligned}\Sigma\vec{F}_y &= 0\text{ N}\\ \vec{F}_{\text{W}y} + \vec{F}_{\text{T}y} - \vec{F}_\text{g} &= 0\text{ N}\\ \vec{F}_{\text{W}y} &= -\vec{F}_\text{T}\sin\theta + mg\\ \vec{F}_{\text{W}y} &= -(710\text{ N})\sin 32° + (62\text{ kg})(9.8\text{m/s}^2)\\ &= -376.2\text{ N} + 607.6\text{ N}\\ \vec{F}_{\text{W}y} &= 231.4\text{ N (two extra digits carried)}\end{aligned}$$

Construct the vector $\vec{F}_\text{W}$ from its components:

$$\begin{aligned}\left|\vec{F}_\text{W}\right| &= \sqrt{(\vec{F}_{\text{W}x})^2 + (\vec{F}_{\text{W}y})^2}\\ &= \sqrt{(602.1\text{ N})^2 + (231.4\text{ N})^2}\text{ (two extra digits carried)}\\ \left|\vec{F}_\text{W}\right| &= 6.5\times10^2\text{ N}\end{aligned}$$

$$\begin{aligned}\theta &= \tan^{-1}\left(\frac{F_{\text{W}y}}{F_{\text{W}x}}\right)\\ &= \tan^{-1}\left(\frac{231.4\text{ N}}{602.1\text{ N}}\right)\\ \theta &= 21°\end{aligned}$$

Statement: The force exerted by the wall on the climber's feet is 6.5×10^2 N [left 21° up].

3. Given: $\vec{F}_1 = 60.0 \text{ N [E } 30.0° \text{ S]}$; $\vec{F}_2 = 50.0 \text{ N [E } 60.0° \text{ N]}$; $\Sigma\vec{F} = 0 \text{ N}$

Required: $\vec{F}_3$

Analysis: $\Sigma\vec{F} = 0 \text{ N}$; $\vec{F}_1 + \vec{F}_2 + \vec{F}_3 = 0 \text{ N}$. Choose east and north as positive.

Solution: For the *x*-components of the force:

$$\vec{F}_{1x} + \vec{F}_{2x} + \vec{F}_{3x} = 0\text{N}$$

$$\begin{aligned} \vec{F}_{3x} &= -(60.0 \text{ N})\cos 30.0° - (50.0 \text{ N})\cos 60.0° \\ &= -51.96 \text{ N} - 25.0 \text{ N} \\ \vec{F}_{3x} &= -76.96 \text{ N (two extra digits carried)} \end{aligned}$$

For the *y*-components of the force:

$$\vec{F}_{1y} + \vec{F}_{2y} + \vec{F}_{3y} = 0 \text{ N}$$

$$\begin{aligned} \vec{F}_{3y} &= -(-60.0 \text{ N})\sin 30.0° - (50.0 \text{ N})\sin 60.0° \\ &= 30.0 \text{ N} - 43.30 \text{ N} \\ \vec{F}_{3y} &= -13.30 \text{ N (two extra digits carried)} \end{aligned}$$

Construct the vector $\vec{F}_3$ from its components:

$$\begin{aligned} \left|\vec{F}_3\right| &= \sqrt{(\vec{F}_{3x})^2 + (\vec{F}_{3y})^2} \\ &= \sqrt{(76.96 \text{ N})^2 + (13.30 \text{ N})^2} \\ \left|\vec{F}_3\right| &= 78 \text{ N} \end{aligned}$$

$$\begin{aligned} \theta_3 &= \tan^{-1}\left(\frac{\vec{F}_{3y}}{\vec{F}_{3x}}\right) \\ &= \tan^{-1}\left(\frac{13.30 \cancel{\text{N}}}{76.96 \cancel{\text{N}}}\right) \\ \theta_3 &= 9.8° \end{aligned}$$

Statement: The magnitude of the force is 78 N, at an angle [W 9.8° S].

Tutorial 2 Practice, pages 81–82

1. (a) Solutions may vary. Sample solution:

Given: $m_1 = 1.2 \text{ kg}$; $m_2 = 1.8 \text{ kg}$; $\vec{a} = 1.2 \text{ m/s}^2 \text{ [up]}$

Required: $\vec{F}_1$; $\vec{F}_2$

Analysis: $\Sigma\vec{F} = m\vec{a}$

Solution: Equation for top block (mass m_1):

$$\Sigma\vec{F} = m_1\vec{a}$$
$$\vec{F}_1 - \vec{F}_2 - m_1 g = m_1\vec{a}$$
$$\vec{F}_1 = \vec{F}_2 + m_1 g + m_1\vec{a}$$
$$\vec{F}_1 = \vec{F}_2 + m_1(g + \vec{a}) \text{ (Equation 1)}$$

Equation for bottom block (mass m_2):

$$\Sigma\vec{F} = m_2\vec{a}$$
$$\vec{F}_2 - m_2 g = m_2\vec{a}$$
$$\vec{F}_2 = m_2 g + m_2\vec{a}$$
$$= m_2(g + \vec{a}) \text{ (Equation 2)}$$
$$= (1.8 \text{ kg})(9.8 \text{ m/s}^2 + 1.2 \text{ m/s}^2)$$
$$\vec{F}_2 = 20 \text{ N}$$

To calculate $\vec{F}_1$, substitute Equation 2 into Equation 1:

$$\vec{F}_1 = \vec{F}_2 + m_1(g + \vec{a})$$
$$\vec{F}_1 = m_2(g + \vec{a}) + m_1(g + \vec{a})$$
$$= (m_2 + m_1)(g + \vec{a}) \text{ (Equation 3)}$$
$$= (3.0 \text{ kg})(11.0 \text{ m/s}^2)$$
$$\vec{F}_1 = 33 \text{ N}$$

Statement: The tension in the top string is 33 N, and the tension in the bottom string is 20 N.

(b) Given: $m_1 = 1.2$ kg; $m_2 = 1.8$ kg; maximum string tension is 38 N

Required: maximum $\vec{a}$ that will not break the string

Analysis: $(m_2 + m_1)(g + a) \le 38$ N

Solution: $(m_2 + m_1)(g + \vec{a}) \le 38$ N

$$g + \vec{a} \le \frac{38 \text{ N}}{m_2 + m_1}$$
$$\vec{a} \le \frac{38 \text{ N}}{3.0 \text{ kg}} - g$$
$$\vec{a} \le 12.67 \text{ m/s}^2 - 9.8 \text{ m/s}^2$$
$$\vec{a} \le 2.9 \text{ m/s}^2$$

Statement: The maximum acceleration of the elevator that will not break the strings is 2.9 m/s^2 [up].

2. (a) Given: $m = 63$ kg; $\vec{F}_{\text{f}} = 0$ N; $\theta = 14°$ [above the horizontal]

Required: $\vec{F}_{\text{N}}$

Analysis: $\Sigma\vec{F}_y = 0$ N

Solution:

$$\begin{aligned}\Sigma\vec{F}_y &= 0 \text{ N}\\ \vec{F}_{\text{N}} - \vec{F}_{\text{g}y} &= 0 \text{ N}\\ \vec{F}_{\text{N}} &= mg\cos\theta\\ &= (63 \text{ kg})(9.8 \text{ m/s}^2)\cos 14°\\ \vec{F}_{\text{N}} &= 6.0\times10^2 \text{ N}\end{aligned}$$

Statement: The magnitude of the normal force on the skier is 6.0×10^2 N.

(b) Given: θ=14° [above the horizontal]; g = 9.8 m/s^2

Required: $a = |\vec{a}|$

Analysis: $\Sigma\vec{F}_x = m\vec{a}$. Choose +$x$-direction as the direction of acceleration, parallel to the hillside.

Solution:

$$\begin{aligned}\Sigma\vec{F}_x &= m\vec{a}\\ \vec{F}_{\text{g}x} &= m\vec{a}\\ \vec{a} &= \frac{\vec{F}_{\text{g}x}}{m}\\ &= \frac{\cancel{m}g\sin\theta}{\cancel{m}}\\ &= (9.8 \text{ m/s}^2)\sin 14°\\ \vec{a} &= 2.4 \text{ m/s}^2\end{aligned}$$

Statement: The magnitude of the skier's acceleration is 2.4 m/s^2.

3. Given: $\vec{a} = 1.9$ m/s^2 [down hill]; $\vec{F}_{\text{f}} = 0$ N

Required: θ

Analysis: $\vec{a} = g\sin\theta$

Solution:

$$\begin{aligned}\vec{a} &= g\sin\theta\\ \theta &= \sin^{-1}\left(\frac{\vec{a}}{g}\right)\\ &= \sin^{-1}\left(\frac{1.9 \ \cancel{\text{m/s}^2}}{9.8 \ \cancel{\text{m/s}^2}}\right)\\ \theta &= 11°\end{aligned}$$

Statement: The angle between the hill and the horizontal is 11°.

4. (a) Given: $\vec{F}_a = 82$ N [right 17° up]; $\vec{F}_N = 213$ N ; $\vec{a} = 0.15$ m/s^2 [right]

Required: m

Analysis: $\Sigma\vec{F}_y = 0$ N . Choose right and up as positive.

Solution: For the y-components of the forces:

$$\Sigma\vec{F}_y = 0 \text{ N}$$

$$\vec{F}_N + \vec{F}_a \sin\theta - mg = 0 \text{ N}$$

$$m = \frac{\vec{F}_N + \vec{F}_a \sin\theta}{g}$$

$$= \frac{213 \text{ N} + (82 \text{ N})\sin 17°}{9.8 \text{ m/s}^2}$$

$$m = 24.18 \text{ kg (two extra digits carried)}$$

Statement: The mass of the desk is 24 kg.

(b) Given: $\vec{F}_a = 82$ N [right 17° up]; $\vec{F}_N = 213$ N ; $\vec{a} = 0.15$ m/s^2 [right]

Required: $\vec{F}_f$

Analysis: $\Sigma\vec{F}_x = m\vec{a}$

Solution:

$$\Sigma\vec{F}_x = m\vec{a}$$

$$\vec{F}_{ax} - \vec{F}_f = m\vec{a}$$

$$\vec{F}_f = \vec{F}_{ax} - m\vec{a}$$

$$= (82 \text{ N})\cos 17° - (24.18 \text{ kg})(0.15 \text{ m/s}^2)$$

$$\vec{F}_f = 75 \text{ N}$$

Statement: The magnitude of the friction force on the desk is 75 N.

5. (a) Given: $m_1 = 9.1$ kg; $m_2 = 12$ kg; $m_3 = 8.7$ kg; $\vec{F}_3 = 29$ N [right 23° up]

Required: $\vec{a}$

Analysis: $\Sigma F_x = ma$. Choose right and up as positive.

Solution: For the x-components of the force:

$$\Sigma\vec{F}_x = m_T\vec{a}$$

$$\vec{F}_{3x} = m_T\vec{a}$$

$$\vec{a} = \frac{\vec{F}_3 \cos\theta}{m_T}$$

$$= \frac{(29 \text{ N})\cos 23°}{29.8 \text{ kg}}$$

$$\vec{a} = 0.8958 \text{ m/s}^2 \text{ (two extra digits carried)}$$

Statement: The carts accelerate at 0.90 m/s^2 to the right.

(b) Given: $m_3 = 8.7 \text{ kg}$; $\vec{a} = 0.8958 \text{ m/s}^2$

Required: $\vec{F}_1$

Analysis: $\Sigma\vec{F}_x = m\vec{a}$

Solution: For the *x*-components of the force:

$$\begin{aligned}\Sigma\vec{F}_x &= m_3\vec{a} \\ \vec{F}_1 &= m_3\vec{a} \\ &= (8.7 \text{ kg})(0.8958 \text{ m/s}^2) \\ &= 7.793 \text{ N (two extra digits carried)} \\ \vec{F}_1 &= 7.8 \text{ N}\end{aligned}$$

Statement: The tension in the cord between m_3 and m_2 is 7.8 N.

(c) Given: $\vec{a} = 0.90 \text{ m/s}^2$; $\vec{F}_1 = 7.793 \text{ N}$

Required: $\vec{F}_2$

Analysis: $\Sigma\vec{F}_x = m\vec{a}$

Solution: Using the *x*-components of the force:

$$\begin{aligned}\Sigma\vec{F}_x &= m_2\vec{a} \\ -\vec{F}_1 + \vec{F}_2 &= m_2\vec{a} \\ \vec{F}_2 &= \vec{F}_1 + (12 \text{ kg})(0.8958 \text{ m/s}^2) \\ &= 7.793 \text{ N} + 10.75 \text{ N} \\ \vec{F}_2 &= 19 \text{ N}\end{aligned}$$

Statement: The tension in the cord between m_2 and m_1 is 19 N.

6. (a) Given: $m_\text{A} = 4.2 \text{ kg}$; $m_\text{B} = 1.8 \text{ kg}$; $\theta = 32°$

Required: $\vec{a}$

Analysis: $\Sigma\vec{F} = m\vec{a}$

Solution: Equation for block A:

$$\begin{aligned}\Sigma\vec{F}_y &= m_\text{A}\vec{a}_y \\ \vec{F}_\text{gA} - \vec{F}_\text{T} &= m_\text{A}\vec{a} \\ m_\text{A}g - \vec{F}_\text{T} &= m_\text{A}\vec{a} \quad \text{(Equation 1)}\end{aligned}$$

Equation for block B:

$$\begin{aligned}\Sigma\vec{F}_x &= m_\text{B}\vec{a}_x \\ \vec{F}_\text{T} + \vec{F}_{\text{gB}x} &= m_\text{B}\vec{a} \\ \vec{F}_\text{T} - m_\text{B}g\sin\theta &= m_\text{A}\vec{a} \quad \text{(Equation 2)}\end{aligned}$$

Solve for acceleration by adding equations (1) and (2):

$$(m_A g - \vec{F}_T) + (\vec{F}_T - m_B g \sin\theta) = m_A \vec{a} + m_B \vec{a}$$

$$(m_A - m_B \sin\theta) g = (m_A + m_B)\vec{a}$$

$$\begin{aligned} \vec{a} &= \frac{(m_A - m_B \sin\theta) g}{m_A + m_B} \\ &= \frac{(4.2 \text{ kg} - (1.8 \text{ kg}) \sin 32°)(9.8 \text{ m/s}^2)}{4.2 \text{ kg} + 1.8 \text{ kg}} \\ &= 5.302 \text{ m/s}^2 \text{ (two extra digits carried)} \\ \vec{a} &= 5.3 \text{ m/s}^2 \end{aligned}$$

Statement: The blocks accelerate at 5.3 m/s^2.

(b) Given: $m_A = 4.2$ kg; $m_B = 1.8$ kg; $\theta = 32°$; $\vec{a} = 5.302 \text{ m/s}^2$

Required: tension in the string, F_T

Analysis: We can substitute the value of acceleration into either of the equations from part (a) to solve for F_T. We will use Equation (1) because it is a bit simpler.

Solution: $m_A g - \vec{F}_T = m_A \vec{a}$

$$\begin{aligned} \vec{F}_T &= m_A g + m_A \vec{a} \\ &= m_A (g + \vec{a}) \\ &= (4.2 \text{ kg})(9.8 \text{ m/s}^2 + 5.302 \text{ m/s}^2) \\ \vec{F}_T &= 19 \text{ N} \end{aligned}$$

Statement: The tension in the string is 19 N.

Section 2.3 Questions, page 83

1. Given: $\vec{F}_1 = 30$ N [E 30° N]; $\vec{F}_2 = 40$ N [E 50° S]

Required: $\Sigma\vec{F}$

Analysis: $\left|\Sigma\vec{F}\right| = \sqrt{(\Sigma\vec{F}_x)^2 + (\Sigma\vec{F}_y)^2}$; $\theta = \tan^{-1}\left(\frac{\Sigma\vec{F}_y}{\Sigma\vec{F}_x}\right)$. Choose east and north as positive.

Solution: For the *x*-components of the force:

$$\begin{aligned} \Sigma\vec{F}_x &= \vec{F}_{1x} + \vec{F}_{2x} \\ &= (30 \text{ N})\cos 30° + (40 \text{ N})\cos 50° \\ &= 25.98 \text{ N} + 25.71 \text{ N} \\ \Sigma\vec{F}_x &= 51.69 \text{ N (two extra digits carried)} \end{aligned}$$

For the y-components of the force:

$$\Sigma\vec{F}_y = \vec{F}_{1y} + \vec{F}_{2y}$$
$$= (30\text{ N})\sin 30° + (-40\text{ N})\sin 50°$$
$$= 15\text{ N} - 30.64\text{ N}$$
$$\Sigma\vec{F}_y = -15.64\text{ N (two extra digits carried)}$$

Construct $\Sigma\vec{F}$:

$$\left|\Sigma\vec{F}\right| = \sqrt{(\Sigma\vec{F}_x)^2 + (\Sigma\vec{F}_y)^2}$$
$$= \sqrt{(51.69\text{ N})^2 + (15.64\text{ N})^2}$$
$$= 54.00\text{ N}$$
$$\left|\Sigma\vec{F}\right| = 54\text{ N}$$

$$\theta = \tan^{-1}\left(\frac{\Sigma\vec{F}_y}{\Sigma\vec{F}_x}\right)$$
$$= \tan^{-1}\left(\frac{15.64\ \cancel{\text{N}}}{51.69\ \cancel{\text{N}}}\right)$$
$$\theta = 17°$$

Statement: The total force exerted by the ropes on the skater is 54 N [E 17° S].

2. Given: $m = 45\text{ kg}$

Required: $\vec{F}_{\text{T1}}$; $\vec{F}_{\text{T2}}$; $\vec{F}_{\text{T3}}$

Analysis: $\Sigma\vec{F} = 0\text{ N}$

Solution: For the forces on the mass,

$$\vec{F}_{\text{T2}} - mg = 0\text{ N}$$
$$\vec{F}_{\text{T2}} = mg$$

For the y-components of the force:

$$\vec{F}_{\text{T2}y} + \vec{F}_{\text{T3}y} = 0\text{ N}$$
$$-\vec{F}_{\text{T2}} + \vec{F}_{\text{T3}}\sin\theta = 0\text{ N}$$
$$\vec{F}_{\text{T3}} = \frac{\vec{F}_{\text{T2}}}{\sin\theta}$$
$$\vec{F}_{\text{T3}} = \frac{mg}{\sin\theta}$$

For the x-components of the force:

$$\vec{F}_{\text{T1}x} + \vec{F}_{\text{T3}x} = 0 \text{ N}$$
$$-\vec{F}_{\text{T1}} + \vec{F}_{\text{T3}} \cos\theta = 0 \text{ N}$$
$$\vec{F}_{\text{T1}} = \vec{F}_{\text{T3}} \cos\theta$$
$$= \left(\frac{mg}{\sin\theta}\right)\cos\theta$$
$$\vec{F}_{\text{T1}} = \frac{mg}{\tan\theta}$$

Calculate the tensions in the three cables.

$$\vec{F}_{\text{T1}} = \frac{mg}{\tan\theta}$$
$$= \frac{45 \text{ kg } (9.8 \text{ m/s}^2)}{\tan 60.0°}$$
$$\vec{F}_{\text{T1}} = 250 \text{ N}$$

$$\vec{F}_{\text{T2}} = mg$$
$$= 45 \text{ kg } (9.8 \text{ m/s}^2)$$
$$\vec{F}_{\text{T2}} = 440 \text{ N}$$

$$\vec{F}_{\text{T3}} = \frac{mg}{\sin\theta}$$
$$= \frac{45 \text{ kg } (9.8 \text{ m/s}^2)}{\sin 60.0°}$$
$$\vec{F}_{\text{T3}} = 510 \text{ N}$$

Statement: $\vec{F}_{\text{T1}}$ is 250 N, $\vec{F}_{\text{T2}}$ is 440 N, and $\vec{F}_{\text{T3}}$ is 510 N.

3. **Given:** $m = 2.5 \text{ kg}$; $\vec{F}_{\text{air}} = 12 \text{ N [right]}$; $\Sigma\vec{F} = 0 \text{ N}$

Required: θ

Analysis: $\Sigma\vec{F} = 0 \text{ N}$; $\left|\vec{F}_{\text{T}}\right| = \sqrt{(\vec{F}_{\text{T}x})^2 + (\vec{F}_{\text{T}y})^2}$; $\theta = \tan^{-1}\left(\frac{\vec{F}_{\text{T}y}}{\vec{F}_{\text{T}x}}\right)$. Choose right and up as positive.

Solution: For the x-components of the force:

$$\Sigma\vec{F}_x = 0 \text{ N}$$
$$\vec{F}_{\text{T}x} + \vec{F}_{\text{air}} = 0 \text{ N}$$
$$\vec{F}_{\text{T}x} = -\vec{F}_{\text{air}}$$
$$\vec{F}_{\text{T}x} = -12 \text{ N}$$

For the *y*-components of the force:

$$\Sigma\vec{F}_y = 0 \text{ N}$$
$$\vec{F}_{\text{T}y} - mg = 0 \text{ N}$$
$$\vec{F}_{\text{T}y} = mg$$
$$= (2.5 \text{ kg})(9.8 \text{ m/s}^2)$$
$$\vec{F}_{\text{T}x} = 24.5 \text{ N (one extra digit carried)}$$

Construct $\vec{F}_\text{T}$ from its components:

$$\left|\vec{F}_\text{T}\right| = \sqrt{(\vec{F}_{\text{T}x})^2 + (\vec{F}_{\text{T}y})^2}$$
$$= \sqrt{(12 \text{ N})^2 + (24.5 \text{ N})^2}$$
$$\left|\vec{F}_\text{T}\right| = 27 \text{ N}$$

$$\theta = \tan^{-1}\left(\frac{\vec{F}_{\text{T}y}}{\vec{F}_{\text{T}x}}\right)$$
$$= \tan^{-1}\left(\frac{24.5 \not{\text{N}}}{12 \not{\text{N}}}\right)$$
$$\theta = 64°$$

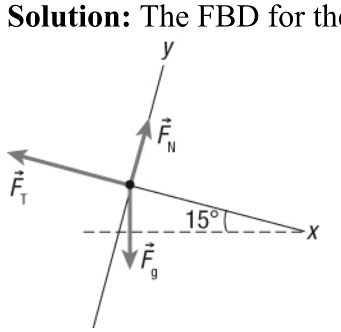
Statement: The tension is the rope is 27 N. The rope makes an angle of 64° with the horizontal.

4. (a) Given: $\theta = 15°$; $m = 1.41 \times 10^3$ kg; $\Sigma\vec{F} = 0$ N

Required: FBD showing the forces on the car

Analysis: Choose [down the hill] as the positive *x*-direction and [up perpendicular to hill] as the positive *y*-direction.

Solution: The FBD for the car is shown below.



(b) Given: $\Sigma\vec{F} = 0$ N
Required: equations for the conditions for static equilibrium along horizontal and vertical directions
Analysis: $\Sigma\vec{F}_x = 0$ N; $\Sigma\vec{F}_y = 0$ N
Solution: For the *x*-components of the force (horizontal):

$$\Sigma\vec{F}_x = 0 \text{ N}$$
$$\vec{F}_{gx} - \vec{F}_\text{T} = 0 \text{ N}$$
$$mg\sin\theta - \vec{F}_\text{T} = 0 \text{ N}$$

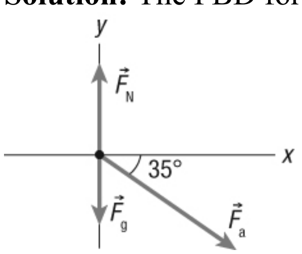
For the *y*-components of the force (vertical):

$$\Sigma\vec{F}_y = 0 \text{ N}$$
$$\vec{F}_\text{N} + \vec{F}_{gy} = 0 \text{ N}$$
$$\vec{F}_\text{N} - mg\cos\theta = 0 \text{ N}$$

(c) Given: $\theta = 15°$; $m = 1.41\times10^3$ kg; $\Sigma\vec{F} = 0$ N
Required: F_T
Analysis: $mg\sin\theta - \vec{F}_\text{T} = 0$ N
Solution: $mg\sin\theta - \vec{F}_\text{T} = 0$ N

$$\vec{F}_\text{T} = mg\sin\theta$$
$$= (1410 \text{ kg})(9.8 \text{ m/s}^2)\sin 15°$$
$$\vec{F}_\text{T} = 3.6\times10^3 \text{ N}$$

Statement: The tension in the cable is 3.6×10^3 N.
5. (a) Given: $\vec{F}_\text{a} = 42$ N [right 35° down]; $m = 18$ kg; $\Delta d = 5.0$ m
Required: FBD for the mower
Analysis: Choose forward and up as positive
Solution: The FBD for the lawn mower is shown below.



(b) Given: $\vec{F}_\text{a} = 42$ N [right 35° down]; $m = 18$ kg; $\Delta d = 5.0$ m
Required: a
Analysis: $\Sigma\vec{F}_x = m\vec{a}$

Solution: $\Sigma \vec{F}_x = m\vec{a}$

$$\vec{F}_{ax} = m\vec{a}$$

$$\vec{a} = \frac{\vec{F}_{ax}}{m}$$

$$= \frac{(42\text{ N})\cos 35°}{18\text{ kg}}$$

$$= 1.911\text{ m/s}^2 \text{(two extra digits carried)}$$

$$\vec{a} = 1.9\text{ m/s}^2$$

Statement: The acceleration of the mower is 1.9 m/s^2 [forward].

(c) Given: $\vec{F}_a = 42$ N [right 35° down]; $m = 18$ kg

Required: $\vec{F}_N$

Analysis: Use the FBD to identify the forces with vertical components. Use $\Sigma \vec{F}_y = 0$ N to solve for the normal force.

Solution: $\Sigma \vec{F}_y = 0\text{ N}$

$$\vec{F}_N + \vec{F}_{ay} - mg = 0\text{ N}$$

$$\vec{F}_N = mg - \vec{F}_{ay}$$

$$= (18\text{ kg})(9.8\text{ m/s}^2) - (-42\text{ N})\sin 35°$$

$$= 176.4\text{ N} + 24.09\text{ N}$$

$$\vec{F}_N = 200\text{ N}$$

Statement: The normal force is 2.0×10^2 N [up].

(d) Given: $\Delta d = 5.0$ m; $\vec{a} = 1.911$ m/s^2

Required: $\vec{v}_f$

Analysis: $v_f^2 = v_i^2 + 2\vec{a}\Delta d$

Solution: $v_f^2 = v_i^2 + 2\vec{a}\Delta d$

$$v_f^2 = 2(1.911\text{ m/s}^2)(5.0\text{ m})$$

$$v_f = 4.4\text{ m/s}$$

Statement: The velocity of the mower when it reaches the lawn is 4.4 m/s [forward].

6. (a) Given: $m = 1.3$ kg; $\theta = 25°$; $\Sigma \vec{F} = 0$ N

Required: $\vec{F}_a$

Analysis: $\Sigma \vec{F}_x = 0$ N

Solution: $\Sigma\vec{F}_x = 0\text{ N}$

$$\vec{F}_\text{a} - mg\sin\theta = 0\text{ N}$$

$$\vec{F}_\text{a} = mg\sin\theta$$

$$= (1.3\text{ kg})(9.8\text{ m/s}^2)\sin 25°$$

$$\vec{F}_\text{a} = 5.4\text{ N}$$

Statement: A force of 5.4 N is required to pull the cart up the ramp at a constant velocity.

(b) Given: $m = 1.3\text{ kg}$; $\theta = 25°$; $\vec{a} = 2.2\text{ m/s}^2$ [up the ramp]

Required: $\vec{F}_\text{a}$

Analysis: $\Sigma\vec{F}_x = m\vec{a}_x$

Solution: $\Sigma\vec{F}_x = m\vec{a}$

$$\vec{F}_\text{a} - mg\sin\theta = m\vec{a}$$

$$\vec{F}_\text{a} = m\vec{a} + mg\sin\theta$$

$$= (1.3\text{ kg})(2.2\text{ m/s}^2) + (1.3\text{ kg})(9.8\text{ m/s}^2)\sin 25°$$

$$= 2.86\text{ N} + 5.384\text{ N}$$

$$\vec{F}_\text{a} = 8.2\text{ N}$$

Statement: A force of 8.2 N is required to pull the cart up the ramp at an acceleration of 2.2 m/s.