Section 3.3: Newton's Second Law of Motion

Tutorial 1 Practice, page 133

1. Given: $\vec{F}_{net}$ = 126 N [S]; m = 70 kg

Required: $\vec{a}$

Analysis: $\vec{F}_{net} = m\vec{a}$. Choose north as positive. So, south is negative.

Solution:

$$\vec{F}_{net} = m\vec{a}$$
$$\vec{a} = \frac{\vec{F}_{net}}{m}$$
$$a = \frac{-126 \text{ N}}{70 \text{ kg}}$$
$$= -1.8 \text{ m/s}^2$$
$$\vec{a} = 1.8 \text{ m/s}^2 \text{ [S]}$$

Statement: The acceleration of the sprinter is 1.8 m/s^2 [S].

2. Given: $\vec{a}$ = 1.20 m/s^2 [forward]; $\vec{F}_{net}$ = 1560 N [forward]

Required: m

Analysis: $\vec{F}_{net} = m\vec{a}$. Choose forward as positive.

Solution:

$$\vec{F}_{net} = m\vec{a}$$
$$m = \frac{\vec{F}_{net}}{\vec{a}}$$
$$= \frac{+1560 \text{ N}}{+1.20 \text{ m/s}^2}$$
$$m = 1300 \text{ kg}$$

Statement: The mass of the car is 1300 kg.

3. Given: $\vec{v}_1$ = 6.0 m/s [E]; $\vec{v}_2$ = 14.0 m/s [E]; Δt = 6.0 s; m = 58 kg

Required: $\vec{F}_{net}$

Analysis: Choose east as positive. First calculate the acceleration using $\vec{a} = \frac{\vec{v}_2 - \vec{v}_1}{\Delta t}$. Then calculate the net force using $\vec{F}_{net} = m\vec{a}$.

Solution:

$$a = \frac{v_2 - v_1}{\Delta t}$$
$$= \frac{+14.0 \text{ m/s} - (+6.0 \text{ m/s})}{6.0 \text{ s}}$$
$$a = +1.33 \text{ m/s}^2 \text{ (one extra digit carried)}$$

Calculate the net force.

$$\vec{F}_{net} = m\vec{a}$$
$$F_{net} = (58 \text{ kg})(+1.33 \text{ m/s}^2)$$
$$= +77 \text{ N}$$
$$\vec{F}_{net} = 77 \text{ N [E]}$$

Statement: The net force acting on the cyclist and bicycle is 77 N [E].

4. (a) Given: m = 1420 kg; $\vec{v}_1$ = 64.8 km/h [W]; $\vec{v}_2$ = 0 m/s; $\Delta\vec{d}$ = 729 m [W]

Required: $\vec{F}_{net}$

Analysis: $\vec{F}_{net} = m\vec{a}$. Choose east as positive. First convert the value of v_1 to SI units. Then calculate the acceleration using $\vec{v}_2^{\,2} = \vec{v}_1^{\,2} + 2\vec{a}\Delta\vec{d}$.

Solution:

$$v_1 = -64.8 \text{ km/h}$$
$$= \left(-64.8 \frac{\cancel{\text{km}}}{\cancel{\text{h}}}\right)\left(\frac{1 \cancel{\text{h}}}{60 \cancel{\text{min}}}\right)\left(\frac{1 \cancel{\text{min}}}{60 \text{ s}}\right)\left(\frac{1000 \text{ m}}{1 \cancel{\text{km}}}\right)$$
$$v_1 = -18.0 \text{ m/s}$$

Since v_2 = 0 m/s,

$$0 = v_1^2 + 2a\Delta d$$
$$v_1^2 = -2a\Delta d$$
$$a = \frac{v_1^2}{-2\Delta d}$$
$$= \frac{(-18.0 \text{ m/s})^2}{-2(-729 \text{ m})}$$
$$a = +0.2222 \text{ m/s}^2 \text{ (one extra digit carried)}$$

Calculate the net force.

$$\vec{F}_{net} = m\vec{a}$$
$$F_{net} = (1420 \text{ kg})(+0.2222 \text{ m/s}^2)$$
$$F_{net} = +316 \text{ N}$$
$$\vec{F}_{net} = 316 \text{ N [E]}$$

Statement: The net force acting on the car is 316 N [E].

(b) The normal force and gravity will cancel when the car is on horizontal ground. When the car slows down, the net force acting on the car is the force of friction. Therefore, the force of friction is 316 N [E].

5. (a) Given: m = 8.0 kg; three forces of 24 N [left], 31 N [left], and 19 N [right]

Required: $\vec{F}_{net}$; $\vec{a}$

Analysis: Find $\vec{F}_{net}$ by adding all horizontal forces. Choose right as positive. So, left is negative. Calculate the acceleration using $\vec{F}_{net} = m\vec{a}$.

Solution:

$$F_{net} = -24\text{ N} + (-31\text{ N}) + 19\text{ N}$$
$$= -36\text{ N}$$
$$\vec{F}_{net} = 36\text{ N [left]}$$

Calculate the acceleration.

$$\vec{F}_{net} = m\vec{a}$$
$$\vec{a} = \frac{\vec{F}_{net}}{m}$$
$$a = \frac{-36\text{ N}}{8.0\text{ kg}}$$
$$= -4.5\text{ m/s}^2$$
$$\vec{a} = 4.5\text{ m/s}^2\text{ [left]}$$

Statement: The net force applied to the object is 36 N [left] and its acceleration is 4.5 m/s^2 [left].

(b) Given: m = 125 kg; three vertical forces of 1200 N [up], 1100 N [up], and 1300 N [down]; two horizontal forces of 600 N [right] and 600 N [left]

Required: $\vec{F}_{net}$; $\vec{a}$

Analysis: The left and right forces cancel each other. Find $\vec{F}_{net}$ by adding all vertical forces. Choose up as positive. So, down is negative. Calculate the acceleration using $\vec{F}_{net} = m\vec{a}$.

Solution:

$$F_{net} = +1200\text{ N} + 1100\text{ N} + (-1300\text{ N})$$
$$= +1000\text{ N}$$
$$\vec{F}_{net} = 1000\text{ N [up]}$$

Calculate the acceleration.

$$\vec{F}_{net} = m\vec{a}$$
$$\vec{a} = \frac{\vec{F}_{net}}{m}$$
$$a = \frac{+1000\text{ N}}{125\text{ kg}}$$
$$= +8\text{ m/s}^2$$
$$\vec{a} = 8\text{ m/s}^2\text{ [up]}$$

Statement: The net force applied to the object is 1000 N [up] and its acceleration is 8 m/s^2 [up].

6. Given: $\vec{F}_1$ = 310 N [forward]; $\vec{F}_2$ = 354 N [forward]; $\vec{F}_f$ = 40 N [backward]; m = 390 kg

Required: $\vec{a}$

Analysis: Find $\vec{F}_{net}$ by adding all forward and backward forces. Choose forward as positive. So, backward is negative. Calculate the acceleration using $\vec{F}_{net} = m\vec{a}$.

Solution:

$$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_f$$
$$F_{net} = +310\text{ N} + 354\text{ N} + (-40\text{ N})$$
$$= +624\text{ N}$$
$$\vec{F}_{net} = 624\text{ N [forward]}$$

Calculate the acceleration.

$$\vec{F}_{net} = m\vec{a}$$
$$\vec{a} = \frac{\vec{F}_{net}}{m}$$
$$a = \frac{+624\text{ N}}{390\text{ kg}}$$
$$= +1.6\text{ m/s}^2$$
$$\vec{a} = 1.6\text{ m/s}^2\text{ [forward]}$$

Statement: The acceleration of the bobsled is 1.6 m/s^2 [forward].

Tutorial 2 Practice, page 135

1. (a) Given: m_1 = 1.20 kg; m_2 = 0.60 kg; $\vec{F}_f = 0$ N

Required: $\vec{a}$

Analysis: Draw a FBD of each object.
For the cart, the normal force and gravity cancel each other.
So, $(F_{net})_{cart} = F_T = m_1 a$.

$m_1 a = F_T$ (Equation 1)

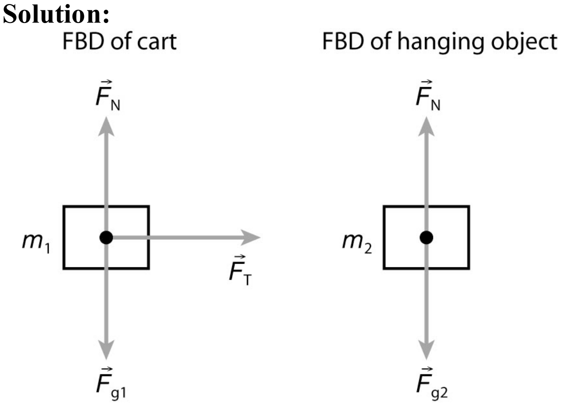
For the hanging object,

$(F_{net})_{object} = F_{g_2} - F_T = m_2 a$.

$m_2 a = m_2 g - F_T$ (Equation 2)

The cart will accelerate to the right. Choose right as positive. So, left is negative. Solve the two equations for a.

Solution:



Add the equations to solve for a.

$$m_1 a + m_2 a = F_T + m_2 g - F_T$$
$$m_1 a + m_2 a = m_2 g$$
$$(m_1 + m_2)a = m_2 g$$
$$(1.20 \text{ kg} + 0.60 \text{ kg})a = (0.60 \text{ kg})(9.8 \text{ m/s}^2)$$
$$a = 3.3 \text{ m/s}^2$$

The acceleration of the cart is 3.3 m/s^2 [right].

(b) Given: m_1 = 1.20 kg; m_2 = 0.60 kg; $\vec{F}_f$ = 0.50 N [left]

Required: $\vec{a}$

Analysis: Draw a FBD of each object.

For the cart, the normal force and gravity cancel each other.

So, $(F_{net})_{cart} = F_T - F_N = m_1 a$.

$m_1 a = F_T - F_N$ (Equation 1)

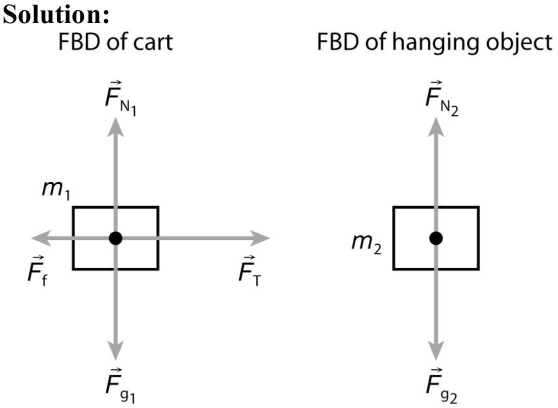
For the hanging object,

$(F_{net})_{object} = F_{g_2} - F_T = m_2 a$.

$m_2 a = m_2 g - F_T$ (Equation 2)

The cart will accelerate to the right. Choose right as positive. So, left is negative. Solve the two equations for a.

Solution:



Add the equations to solve for a.

$$m_1 a + m_2 a = F_T - F_N + m_2 g - F_T$$
$$m_1 a + m_2 a = m_2 g - F_N$$
$$(m_1 + m_2)a = m_2 g - F_N$$
$$(1.20 \text{ kg} + 0.60 \text{ kg})a = (0.60 \text{ kg})(9.8 \text{ m/s}^2) - 0.50 \text{ N}$$
$$a = 3.0 \text{ m/s}^2$$

The acceleration of the cart is 3.0 m/s^2 [right].

2. (a) Given: m_1 = 2.0 kg; m_2 = 0.40 kg; $\vec{F}_f$ = 0 N

Required: $\vec{a}$

Analysis: Draw a FBD of each object.

For the cart, the normal force and gravity cancel each other.

So, $(F_{net})_{cart} = F_T = m_1 a$.

$m_1 a = F_T$ (Equation 1)

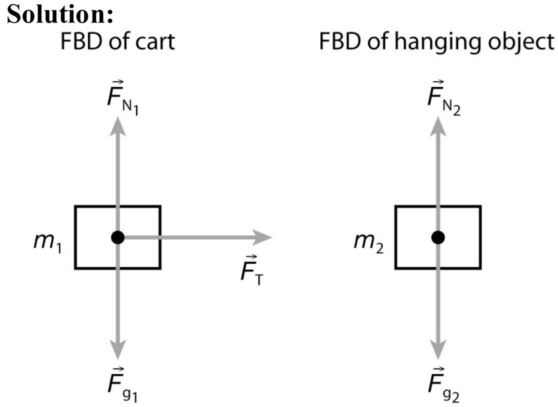
For the hanging object,

$(F_{net})_{object} = F_{g_2} - F_T = m_2 a$.

$m_2 a = m_2 g - F_T$ (Equation 2)

The cart will accelerate to the right. Choose right as positive. So, left is negative. Solve the two equations for a.

Solution:



Add the equations to solve for a.

$$m_1 a + m_2 a = F_T + m_2 g - F_T$$
$$m_1 a + m_2 a = m_2 g$$
$$(m_1 + m_2)a = m_2 g$$
$$(2.0 \text{ kg} + 0.40 \text{ kg})a = (0.40 \text{ kg})(9.8 \text{ m/s}^2)$$
$$a = 1.6 \text{ m/s}^2$$

The acceleration of the cart is 1.6 m/s^2 [right].

(b) If the mass of the object on top of the cart increases, the acceleration of the cart decreases. Using the equation for the acceleration of the cart, $a = \dfrac{m_2 g}{(m_1 + m_2)}$, the value a decreases when the value m_1 increases.

(c) If an object is taken from the top of the cart and tied to the hanging object, the acceleration of the cart increases. Using the equation for the acceleration of the cart, $a = \dfrac{m_2 g}{(m_1 + m_2)}$, the value a increases when the value m_1 decreases and the value m_2 increases.

Section 3.3 Questions, page 136

1. (a) Given: m = 72 kg; $\vec{a}$ = 1.6 m/s^2 [forward]

Required: $\vec{F}_{net}$

Analysis: $\vec{F}_{net} = m\vec{a}$. Choose forward as positive.

Solution:

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

$F_{net} = (72 \text{ kg})(+1.6 \text{ m/s}^2)$

$= +120 \text{ N}$

$\vec{F}_{net} = 120 \text{ N [forward]}$

Statement: The net force on the rugby player is 120 N [forward].

(b) Given: m = 2.3 kg; $\vec{a}$ = 12 m/s^2 [up]

Required: $\vec{F}_{net}$

Analysis: $\vec{F}_{net} = m\vec{a}$. Choose up as positive.

Solution:

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

$F_{net} = (2.3 \text{ kg})(+12 \text{ m/s}^2)$

$= +28 \text{ N}$

$\vec{F}_{net} = 28 \text{ N [up]}$

Statement: The net force on the model rocket is 28 N [up].

2. (a) Given: $\vec{F}_{net}$ = 2.4 × 10^4 N [E]; m = 5.0 kg

Required: $\vec{a}$

Analysis: $\vec{F}_{net} = m\vec{a}$. Choose east as positive. So, west is negative.

Solution:

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

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

$a = \frac{+2.4 \times 10^4 \text{ N}}{5.0 \text{ kg}}$

$= +4800 \text{ m/s}^2$

$\vec{a} = 4800 \text{ m/s}^2 \text{ [E]}$

Statement: The acceleration of the shell is 4800 m/s^2 [E].

(b) Given: m = 160 g; $\vec{F}_{net}$ = 24 N [forward]

Required: $\vec{a}$

Analysis: $\vec{F}_{net} = m\vec{a}$; First convert the value m to SI units. Choose forward as positive.

Solution:

m = 160 = 0.16 kg

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

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

$a = \frac{+24 \text{ N}}{0.16 \text{ kg}}$

$= +150 \text{ m/s}^2$

$\vec{a} = 150 \text{ m/s}^2 \text{ [forward]}$

Statement: The acceleration of the hockey puck is 150 m/s^2 [forward].

3. (a) Given: $\vec{a}$ = 1.2 m/s^2 [backward]; $\vec{F}_{net}$ = 1400 N [backward]

Required: m

Analysis: $\vec{F}_{net} = m\vec{a}$. Choose forward as positive.

Solution:

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

$m = \frac{F_{net}}{a}$

$= \frac{-1400 \text{ N}}{-1.2 \text{ m/s}^2}$

$m = 1200 \text{ kg}$

Statement: The mass of the car is 1200 kg.

(b) Given: $\vec{F}_{net}$ = 33 N [forward]; $\vec{a}$ = 6.0 m/s^2 [forward]

Required: m

Analysis: $\vec{F}_{net} = m\vec{a}$. Choose forward as positive.

Solution:

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

$m = \frac{F_{net}}{a}$

$= \frac{+33 \text{ N}}{+6.0 \text{ m/s}^2}$

$m = 5.5 \text{ kg}$

Statement: The mass of the shot put is 5.5 kg.

4. Given: m = 54 kg; $\vec{v}_1$ = 0 m/s; $\vec{v}_2$ = 12 m/s [downhill]; Δt = 5.0 s

Required: $\vec{F}_{net}$

Analysis: $\vec{F}_{net} = m\vec{a}$; First calculate the acceleration using $\vec{a} = \frac{\vec{v}_2 - \vec{v}_1}{\Delta t}$. Choose uphill as positive. So, downhill is negative.

Solution:

Since v_1 = 0 m/s,

$a = \frac{v_2}{\Delta t}$

$= \frac{-12 \text{ m/s}}{5.0 \text{ s}}$

$= -2.4 \text{ m/s}^2$

$\vec{a} = 2.4 \text{ m/s}^2 \text{ [downhill]}$

Calculate the net force.

$\vec{F}_{\text{net}} = m\vec{a}$

$F_{\text{net}} = (54 \text{ kg})(-2.4 \text{ m/s}^2)$

$= -130 \text{ N}$

$\vec{F}_{\text{net}} = 130 \text{ N [downhill]}$

Statement: The net force acting on the skier is 130 N [downhill].

5. Given: $\vec{v}_1 = 0$ m/s; $\vec{F}_{\text{net}} = 1.2$ N [forward]; $\Delta\vec{d} = 6.6$ m [forward]; $\vec{v}_2 = 3.2$ m/s [forward]

Required: m

Analysis: $\vec{F}_{\text{net}} = m\vec{a}$; $\vec{v}_2^{\,2} = \vec{v}_1^{\,2} + 2\vec{a}\Delta\vec{d}$. Choose forward as positive. First calculate the acceleration using $\vec{v}_2^{\,2} = \vec{v}_1^{\,2} + 2\vec{a}\Delta\vec{d}$.

Solution:

Since $v_1 = 0$ m/s,

$v_2^{\,2} = 2a\Delta d$

$a = \dfrac{v_2^{\,2}}{2\Delta d}$

$= \dfrac{(+3.2 \text{ m/s})^2}{2(+6.6 \text{ m})}$

$a = +0.776 \text{ m/s}^2$ (one extra digit carried)

Calculate the mass.

$\vec{F}_{\text{net}} = m\vec{a}$

$m = \dfrac{F_{\text{net}}}{a}$

$= \dfrac{+1.2 \text{ N}}{+0.776 \text{ m/s}^2}$

$m = 1.5 \text{ kg}$

Statement: The mass of the cart is 1.5 kg.

6. (a) Given: $m = 58$ kg; $\vec{F}_{\text{a}} = 720$ N [up]

Required: m

Analysis: Add all the vertical forces. Use $\vec{F}_{\text{net}} = \vec{F}_{\text{a}} + \vec{F}_{\text{g}}$. Choose up as positive.

Solution:

$\vec{F}_{\text{net}} = \vec{F}_{\text{a}} + \vec{F}_{\text{g}}$

$\vec{F}_{\text{net}} = \vec{F}_{\text{a}} + m\vec{g}$

$F_{\text{net}} = +720 \text{ N} + (58 \text{ kg})(-9.8 \text{ m/s}^2)$

$= +150 \text{ N}$

$\vec{F}_{\text{net}} = 150 \text{ N [up]}$

Statement: The net force acting on the person is 150 N [up].

(b) Given: $m = 58$ kg; $\vec{F}_{\text{net}} = 150$ N [up]

Required: $\vec{a}$

Analysis: $\vec{F}_{\text{net}} = m\vec{a}$. Choose up as positive.

Solution:

$\vec{F}_{\text{net}} = m\vec{a}$

$\vec{a} = \dfrac{\vec{F}_{\text{net}}}{m}$

$a = \dfrac{+150 \text{ N}}{58 \text{ kg}}$

$= +2.6 \text{ m/s}^2$

$\vec{a} = 2.6 \text{ m/s}^2 \text{ [up]}$

Statement: The acceleration of the person is 2.6 m/s^2 [up].

7. Given: $F_{\text{net}} = 36$ N [forward]; $a_1 = 6.0$ m/s^2 [forward]; $a_{1+2} = 2.0$ m/s^2 [forward]

Required: a_2

Analysis: $\vec{F}_{\text{net}} = m\vec{a}$. Choose forward as positive.

Solution:

For mass m_1,

$\vec{F}_{\text{net}} = m_1\vec{a}_1$

$m_1 = \dfrac{F_{\text{net}}}{a_1}$

$= \dfrac{36 \text{ N}}{6.0 \text{ m/s}^2}$

$m_1 = 6.0 \text{ kg}$

For masses m_1 and m_2 together,

$F_{\text{net}} = (m_1 + m_2)a_{1+2}$

$m_1 + m_2 = \dfrac{F_{\text{net}}}{a_{1+2}}$

$m_2 = \dfrac{F_{\text{net}}}{a_{1+2}} - m_1$

$= \dfrac{36 \text{ N}}{2.0 \text{ m/s}^2} - 6.0 \text{ kg}$

$m_2 = 12 \text{ kg}$

For mass m_2,

$\vec{F}_{\text{net}} = m_2\vec{a}_2$

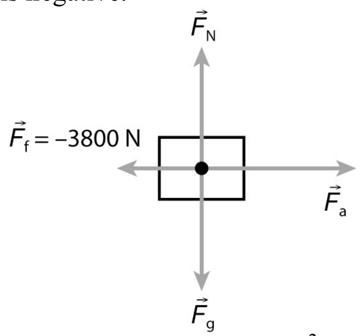
$\vec{a}_2 = \dfrac{\vec{F}_{\text{net}}}{m_2}$

$a_2 = \dfrac{36 \text{ N}}{12 \text{ kg}}$

$a_2 = 3.0 \text{ m/s}^2$

Statement: Mass m_2 will experience an acceleration of 3.0 m/s^2.

8. (a) Choose up and east as positive. So, down and west is negative.



(b) Given: m = 1300 kg; $\vec{a}$ = 1.6 m/s^2 [E]; $\vec{F}_f$ = 3800 N [W]

Required: $\vec{F}_a$

Analysis: The normal force and gravity cancel each other since the car is on horizontal ground. To find $\vec{F}_a$, add all the horizontal forces. Use $\vec{F}_{net} = m\vec{a}$ and $\vec{F}_{net} = \vec{F}_a + \vec{F}_f$.

Solution:

$$\vec{F}_{net} = \vec{F}_a + \vec{F}_f$$
$$\vec{F}_a = \vec{F}_{net} - \vec{F}_f$$
$$F_a = ma - F_f$$
$$= (1300 \text{ kg})(+1.6 \text{ m/s}^2) - (-3800 \text{ N})$$
$$= +5900 \text{ N}$$
$$\vec{F}_a = 5900 \text{ N [E]}$$

Statement: The applied force acting on the car is 5900 N [E].

9. Assume that no friction acts on the chain on top of the table.
m_1 = mass of chain on top of table
m_2 = mass of chain hanging over the edge
The tension, F_T, in the chain is the same for both m_1 and m_2.

(a) For the chain on top of the table, the normal force and gravity cancel each other.

$F_{net} = F_T = m_1a$ (Equation 1)

For the hanging chain,

$F_{net} = F_g - F_T = m_2a$ (Equation 2)

Add the equations.

$$m_1a + m_2a = F_T + m_2g - F_T$$
$$(m_1 + m_2)a = m_2g$$

The chain will accelerate to the right down the table. The force of gravity acting on the hanging chain, m_2g, causes the acceleration.

(b) Solve the equations for a.

$$(m_1 + m_2)a = m_2g$$
$$a = \frac{m_2g}{m_1 + m_2}$$

From the equation, when the value m_2 increases, the value $(m_1 + m_2)$ stays the same, and the value a increases. As more chain moves over the edge of the table, the acceleration of the chain increases.

10. (a) Given: m = 80 kg; three horizontal forces of 170 N [left], 170 N [left], and 150 N [right]

Required: a

Analysis: The normal force and gravity cancel each other since the crate is on the floor. Find $\vec{F}_{net}$ by adding all horizontal forces. Choose right as positive. So, left is negative. Calculate the acceleration using $\vec{F}_{net} = m\vec{a}$.

Solution:

$$F_{net} = -170 \text{ N} + (-170 \text{ N}) + 150 \text{ N}$$
$$= -190 \text{ N}$$
$$\vec{F}_{net} = 190 \text{ N [left]}$$

Calculate the acceleration.

$$\vec{F}_{net} = m\vec{a}$$
$$\vec{a} = \frac{\vec{F}_{net}}{m}$$
$$a = \frac{-190 \text{ N}}{80 \text{ kg}}$$
$$= -2.4 \text{ m/s}^2$$
$$\vec{a} = 2.4 \text{ m/s}^2 \text{ [left]}$$

Statement: The acceleration of the crate is 2.4 m/s^2 [left].

(b) If a fourth student jumps on top of the crate, the mass, m, of the crate increases but the net force $\vec{F}_{net}$ on the crate is the same. Using $\vec{F}_{net} = m\vec{a}$, as the value m increases, the value a decreases. So, the magnitude of the acceleration of the crate decreases.

11. Given: m = 30 kg; $\vec{v}_i$ = 0 m/s; Δd = 22 m; m_{max} = 12 kg

Required: Δt

Analysis: Use the equation $F_T = m_sg$ to find the maximum tension of the string when it holds up a 12 kg mass. Assume no friction on the ice. The normal force and gravity cancel each other since the object is on the ice. The net force acting on the pulled object is the tension in the string.
Use $F_T = ma$ to calculate the acceleration and use

$\Delta d = v_i \Delta t + \frac{1}{2} a \Delta t^2$ to calculate the minimum possible time.

Solution:

$F_T = m_s g$

$= (12 \text{ kg})(9.8 \text{ m/s})$

$F_T = 117.6 \text{ N}$

Calculate the acceleration.

$F_T = ma$

$a = \frac{F_T}{m}$

$= \frac{117.6 \text{ N}}{30 \text{ kg}}$

$a = 3.92 \text{ m/s}^2$

Calculate the minimum possible time.

Since $v_i = 0$ m/s,

$\Delta d = v_i \Delta t + \frac{1}{2} a \Delta t^2$

$\Delta d = \frac{1}{2} a \Delta t^2$

$\Delta t^2 = \frac{2\Delta d}{a}$

$\Delta t = \sqrt{\frac{2\Delta d}{a}}$

$= \sqrt{\frac{2(22 \cancel{\text{m}})}{3.92 \cancel{\text{m}}/\text{s}^2}}$

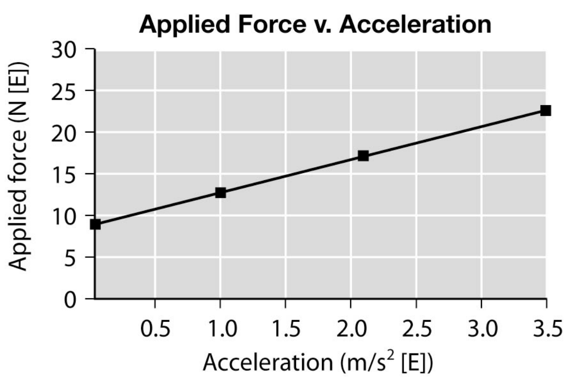
$\Delta t = 3.4 \text{ s}$

Statement: The minimum possible time to complete the task is 3.4 s.

12. (a)

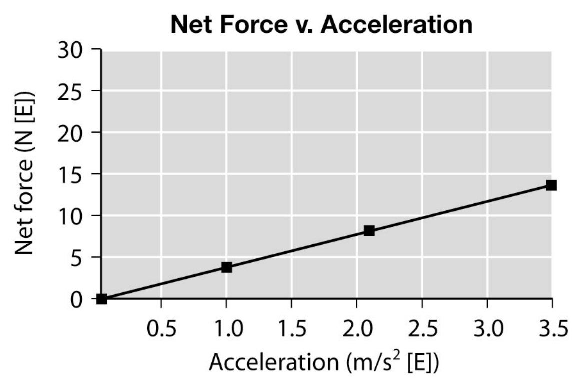
Mass (kg)	Friction (N) [W]	Applied force (N) [E]	Net force (N) [E]	Acceleration (m/s^2) [E]
4.0	9.0	9.0	**0.0**	**0.0**
4.0	9.0	13.0	**4.0**	**1.0**
4.0	9.0	**17.4**	8.4	**2.1**
4.0	9.0	**23.0**	**14.0**	3.5

(b)



The *y*-intercept represents the friction. When the applied force equals the friction, the net force on the object is zero and its acceleration will also be zero.

(c)



$\text{slope} = \frac{\text{rise}}{\text{run}}$

$= \frac{1.4 \text{ N [E]}}{3.5 \text{ m/s}^2 \text{ [E]}}$

$\text{slope} = 4.0 \text{ kg}$

For the same graph, $\text{slope} = \frac{F_{net}}{a} = m$. So, the slope represents the mass of the object, which is 4.0 kg.