## Chapter 4

# Introducing Forces

## Practice Problem Solutions

**Student Textbook page 137**

**1. Frame the Problem**
- The object is on the surface of Earth.
- Its weight is the force of gravity acting on it.
- Weight is related to mass through the acceleration due to gravity.
- The acceleration due to gravity on Earth is given in Table 4.4.

**Identify the Goal**
Weight or the force of gravity, $F_g$, acting on a mass on Earth

**Variables and Constants**

| Known | Implied | Unknown |
|---|---|---|
| $m = 2.3$ kg | $\vec{g}_{\text{Earth}} = 9.81\ \frac{\text{m}}{\text{s}^2}$ | $\vec{F}_g$ |

| Strategy | Calculations |
|---|---|
| The acceleration due to gravity is known for the surface of Earth. | |
| Use the equation for weight. | $\vec{F}_{\text{g Earth}} = m\vec{g}_{\text{Earth}}$ |
| Substitute the variables and solve. | $\vec{F}_{\text{g Earth}} = (2.3\text{kg})(9.81\frac{\text{m}}{\text{s}^2})[\text{down}]$ |
| | $\vec{F}_{\text{g Earth}} = 22.56\ \text{kg}\frac{\text{m}}{\text{s}^2}[\text{down}]$ |
| $1\ \text{kg}\frac{\text{m}}{\text{s}^2}$ is equivalent to 1 N. | $\vec{F}_{\text{g Earth}} = 22.56\ \text{N}[\text{down}]$ |
| Convert to the appropriate number of significant digits. | $\vec{F}_{\text{g Earth}} \cong 23\ \text{N}[\text{down}]$ |

The 2.3 kg mass would weigh 23 N[down] on the surface of Earth.

**Validate**
Weight is a force and, therefore, should have units of newtons (N).

**2. Frame the Problem**
- Weight is defined as the force of gravity acting on a mass.
- If you know the weight and the acceleration due to gravity, you can find the mass.
- Weight is related to mass through the acceleration due to gravity.
- The acceleration due to gravity on the equator, the North Pole and the International Space Station is given in Table 4.3.
- Would it be possible to weigh yourself on the International Space Station?

**Identify the Goal**
**(a)** Your mass, $m$, on Earth near the equator
**(b)** Weight or the force of gravity, $F_g$, acting on you near the North Pole

**(c)** i. Weight or the force of gravity, $F_g$, acting on you on the International Space Station.

ii. Would this value be possible to verify your weight on the International Space Station experimentally?

### Variables and Constants

| Known | Implied | Unknown |
|---|---|---|
| $\vec{F}_{g\,\text{Equator}}$ | $\vec{g}_{\text{Equator}} = 9.7805\,\frac{\text{m}}{\text{s}^2}$ | $m$ |
| | $\vec{g}_{\text{North Pole}} = 9.8322\,\frac{\text{m}}{\text{s}^2}$ | $\vec{F}_{g\,\text{North Pole}}$ |
| | $\vec{g}_{\text{I.S.S.}} = 9.0795\,\frac{\text{m}}{\text{s}^2}$ | $\vec{F}_{g\,\text{I.S.S.}}$ |

| Strategy | Calculations |
|---|---|
| **(a)** The acceleration due to gravity is known for the surface of Earth near the equator. | |
| Use the equation for mass. | $\vec{F}_{g\ \text{Equator}} = 652.58\text{N}$ |
| Substitute in the variables and solve. | $\vec{F}_{g\ \text{Equator}} = 9.7805\ \frac{\text{m}}{\text{s}^2}$ |
| Convert to the appropriate number of significant digits. | $m = \frac{\vec{F}_{g\ \text{Equator}}}{\vec{g}_{\ \text{Equator}}} = \frac{652.58\text{N}}{9.7805\ \frac{\text{m}}{\text{s}^2}} = 66.72\text{ kg}$ |
| **(b)** and **(c)** The acceleration due to gravity is known for the surface of Earth near the North Pole or the International Space Station | |
| Use the equation for weight. | $\vec{F}_{g\,\text{North Pole}} = m\vec{g}_{\text{North Pole}}$ |
| Substitute in the variables and solve. | $\vec{F}_{g\,\text{North Pole}} = (66.722\text{ kg})(9.8322\ \frac{\text{m}}{\text{s}^2})[\text{down}]$ |
| 1 kg$\cdot\frac{\text{m}}{\text{s}^2}$ is equivalent to 1 N. | $\vec{F}_{g\,\text{North Pole}} = 656.03\text{ kg}\frac{\text{m}}{\text{s}^2}[\text{down}]$ |
| Convert to the appropriate number of significant digits. | $\vec{F}_{g\,\text{North Pole}} = 656.03\text{ N}[\text{down}]$ |
| | $\vec{F}_{g\,\text{I.S.S.}} = m\vec{g}_{\text{I.S.S.}}$ |
| | $\vec{F}_{g\,\text{I.S.S.}} = (66.722\text{ kg})(9.0795\ \frac{\text{m}}{\text{s}^2})[\text{down}]$ |
| | $\vec{F}_{g\,\text{I.S.S.}} = 605.81\text{ kg}\cdot\frac{\text{m}}{\text{s}^2}[\text{down}]$ |
| | $\vec{F}_{g\,\text{I.S.S.}} = 605.81\text{ N}[\text{down}]$ |

**(a)** Your mass on Earth would be 66.722 kg.

**(b)** Your weight on the North Pole would be 656.03 N.

**(c)** i. Your weight on the International Space Station would be 605.81 N
ii. A spring scale would be required to measure weight experimentally, but a spring scale and the space station would be both accelerating toward Earth at the same rate. Contact could not be made with a spring scale to weigh the station.

### Validate

**(a)** Mass should have units of kg.

**(b)** Weight is a force and, therefore, should have units of newtons (N).

**(c)** Your weight should be less on the International Space Station than on the North Pole due to its smaller acceleration due to gravity and it is smaller.

**3. Frame the Problem**

- Weight is defined as the force of gravity acting on a mass.
- If you know the weight and the acceleration due to gravity, you can find the mass.
- Weight is related to mass through the acceleration due to gravity.
- The acceleration due to gravity on Earth and on the Moon is given in Table 4.4.

**Identify the Goal**

**(a)** Weight or the force of gravity, $F_g$, acting on the LRV on Earth

**(b)** Weight or the force of gravity, $F_g$, acting on the LRV on the Moon

**Variables and Constants**

| Known | Implied | Unknown |
|---|---|---|
| $m = 209$ kg | $\vec{g}_{\text{Earth}} = 9.81\ \frac{\text{m}}{\text{s}^2}$ | $\vec{F}_{\text{g Earth}}$ |
| | $\vec{g}_{\text{Moon}} = 1.64\ \frac{\text{m}}{\text{s}^2}$ | $\vec{F}_{\text{g Moon}}$ |

**Strategy**

The acceleration due to gravity is known for the surface of Earth and the Moon.

Use the equation for weight.

Substitute in the variables and solve.

1 kg$\frac{\text{m}}{\text{s}^2}$ is equivalent to 1 N.

Convert to the appropriate number of significant digits.

**Calculations**

**(a)**
$$\vec{F}_{\text{g Earth}} = m\vec{g}_{\text{Earth}}$$
$$\vec{F}_{\text{g Earth}} = (209\ \text{kg})(9.81\ \tfrac{\text{m}}{\text{s}^2})[\text{down}]$$
$$\vec{F}_{\text{g Earth}} = 2050.29\ \text{kg}\tfrac{\text{m}}{\text{s}^2}[\text{down}]$$
$$\vec{F}_{\text{g Earth}} = 2050\ \text{N}[\text{down}]$$
$$\vec{F}_{\text{g Earth}} = 2.05 \times 10^3\ \text{N}[\text{down}]$$

**(b)**
$$\vec{F}_{\text{g Moon}} = m\vec{g}_{\text{Moon}}$$
$$\vec{F}_{\text{g Moon}} = (209\ \text{kg})(1.64\ \tfrac{\text{m}}{\text{s}^2})[\text{down}]$$
$$\vec{F}_{\text{g Moon}} = 342.76\ \text{kg}\cdot\tfrac{\text{m}}{\text{s}^2}[\text{down}]$$
$$\vec{F}_{\text{g Moon}} = 343\ \text{N}[\text{down}]$$
$$\vec{F}_{\text{g Moon}} = 3.43 \times 10^2\ \text{N}[\text{down}]$$

**(a)** The 209 kg mass LRV would weigh 2050 N[down] on the surface of Earth.

**(b)** The 209 kg mass LRV would weigh 343 N[down] on the surface of the Moon.

**Validate**

Weight is a force and, therefore, should have units of newtons (N). The LRV should weigh more on Earth than on the Moon since the acceleration due to gravity is more on Earth than on the Moon.

**4. Frame the Problem**

- The acceleration due to gravity is defined as the force of gravity acting on a 1.00 kg mass.
- If you know the weight and the mass, you can find the acceleration due to gravity.
- The acceleration due to gravity is related to the weight and the mass.

**Identify the Goal**

**(a)** The acceleration due to gravity of a 1.00 kg mass on the surface of the asteroid

**Variables and Constants**

| Known | Implied | Unknown |
|---|---|---|
| $m = 1.00$ kg | | $\vec{g}_a$ |
| $\vec{F}_g = 3.25 \times 10^{-2}$ N | | |

| Strategy | Calculations |
|---|---|
| The mass and the force of gravity acting on the 1.00 kg mass on the asteroid is known. | |
| Use the equation for the acceleration due to gravity. | $\vec{g}_a = \frac{F_g}{m}$ |
| Substitute in the variables and solve. | $\vec{g}_a = \frac{3.25 \times 10^{-2}\ \text{N}}{1.00\ \text{kg}}$ |
| Use $1\ \frac{\text{N}}{\text{kg}} = 1\ \frac{\text{m}}{\text{s}^2}$. | $\vec{g}_a = 3.25 \times 10^{-2}\ \frac{\text{m}}{\text{s}^2}$ |
| Convert to the appropriate number of significant digits. | |
| The acceleration due to gravity on the surface of the asteroid is $0.0325\ \text{m/s}^2$. | |

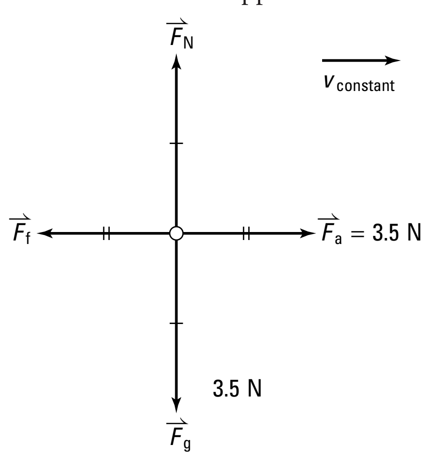
**Validate**

The acceleration due to gravity should have the units $\text{m/s}^2$, and it should be small because the asteroid has a small mass.

## Practice Problem Solutions

**Student Textbook page 144**

5. **Frame the Problem**
   - Sketch the problem.
   - The equation relating frictional force to the coefficient of friction and the normal force applies to this problem.
   - The static coefficient applies when you start to move an object from rest. The kinetic coefficient applies while the object is moving.




**Identify the Goal**

**(a)** The normal force supporting the textbook

**(b)** The force of friction and the coefficient of friction between the book and the bench

**(c)** Which coefficient of friction applies, $\mu_s$ or $\mu_k$?

**Variables and Constants**

| Known | Implied | Unknown | |
|---|---|---|---|
| $m = 0.6$ kg | $\vec{g} = 9.81\frac{\text{m}}{\text{s}^2}$ | $\vec{F}_\text{f}$ | $\vec{F}_\text{g}$ |
| $\vec{F}_a = 3.50\text{N}$ | | $\mu_\text{k}$ | $\vec{F}_\text{N}$ |

| Strategy | Calculations |
|---|---|
| Convert grams to kilograms. | |
| Use the equation for weight to find the weight and thus the normal force. | **(a)** 600 g = 0.6 kg |
| | $\vec{F}_\text{N} = \vec{F}_\text{g}$ |
| Substitute in the variables and solve. | $\vec{F}_\text{N} = m\vec{g}$ |
| Use $1\ \frac{\text{N}}{\text{kg}} = 1\ \frac{\text{m}}{\text{s}^2}$. | $\vec{F}_\text{N} = 0.6\ \text{kg}(9.81\frac{\text{N}}{\text{kg}})$ |
| Convert to the appropriate number of significant digits. | $\vec{F}_\text{N} = 5.89\text{N}$ |
| Apply the equation for a frictional force. | **(b)** $\vec{F}_\text{f} = 3.50$ N |
| | $\vec{F}_\text{f} = \mu_\text{k}\vec{F}_\text{N}$ |
| | $\mu_\text{k} = \frac{\vec{F}_\text{f}}{\vec{F}_\text{N}}$ |
| | $\mu_\text{k} = \frac{3.50\ \text{N}}{5.886\ \text{N}}$ |
| | $\mu_\text{k} = 0.595$ |

**(a)** The normal force is 5.89 N.

**(b)** The friction force is 3.50 N and the coefficient of friction is 0.595.

**(c)** This is $\mu_\text{k}$ since the book is moving.

**Validate**

The value of the coefficient of friction is reasonable for the lab bench and book surfaces.

**6. Frame the Problem**

- Sketch the problem.
- The equation relating frictional force to the coefficient of friction and the normal force applies to this problem.
- The static coefficient applies when you start to move an object from rest, and the kinetic coefficient applies while the object is moving.
- An applied force that is the value of the static friction force is the minimum force required to start an object moving.

**Identify the Goal**

**(a)** The normal force supporting the crate

**(b)** The minimum force to start the crate moving if the coefficient of static friction between the crate and the floor is 0.430

**(c)** The minimum force to start the crate moving if half the mass is removed

**Variables and Constants**

| Known | Implied | Unknown | |
|---|---|---|---|
| $m = 125$ kg | $\vec{g} = 9.81\frac{\text{m}}{\text{s}^2}$ | $\vec{F}_\text{f}$ | $\vec{F}_\text{g}$ |
| $m = 62.5$ kg | | $\vec{F}_\text{a}$ | $\vec{F}_\text{N}$ |
| $\mu_\text{s} = 0.430$ | | $\vec{F}_\text{a}$ | |

**Strategy**
Use the equation for weight to find the weight and thus the normal force.

Substitute the variables and solve.

Use $1\ \frac{\text{N}}{\text{kg}} = 1\ \frac{\text{m}}{\text{s}^2}$.

Convert to the appropriate number of significant digits.

**Calculations**

**(a)** $\vec{F}_\text{N} = \vec{F}_\text{g}$

$\vec{F}_\text{N} = m\vec{g}$

$\vec{F}_\text{N} = 125\ \text{kg}(9.81\frac{\text{N}}{\text{kg}})$

$\vec{F}_\text{N} = 1226.25\ \text{N}$

$\vec{F}_\text{N} = 1.23 \times 10^3\ \text{N}$

Apply the equation for a frictional force.

**(b)** $\vec{F}_\text{f} = \mu_\text{s}\vec{F}_\text{N}$

The applied force must just equal the static frictional force to start the crate moving. Find the applied force required to start the crate moving with half the mass removed.

$\vec{F}_\text{f} = 0.430(1226.25\ \text{N})$

$\vec{F}_\text{f} = 527\ \text{N}$

$\vec{F}_\text{a} = \vec{F}_\text{f}$

$\vec{F}_\text{a} = 527\ \text{N}$

**(c)** $\vec{F}_\text{N} = \vec{F}_\text{g}$

$\vec{F}_\text{N} = m\vec{g}$

$\vec{F}_\text{N} = 62.5\ \text{kg}(9.81\frac{\text{N}}{\text{kg}})$

$\vec{F}_\text{N} = 613.13\ \text{N}$

$\vec{F}_\text{f} = \mu_\text{s}\vec{F}_\text{N}$

$\vec{F}_\text{f} = 0.430(613.13\ \text{N})$

$\vec{F}_\text{f} = 264\ \text{N}$

$\vec{F}_\text{a} = \vec{F}_\text{f}$

$\vec{F}_\text{a} = 264\ \text{N}$

**(a)** The normal force is 1230 N.

**(b)** The minimum force required is 527 N

**(c)** With half the mass the minimum force required is 264 N.

**Validate**
It is reasonable that the crate needs half the force to start it moving if half the mass is removed.

**7. Frame the Problem**

- The equation relating frictional force to the coefficient of friction and the normal force applies to this problem.
- The static coefficient of friction applies when you start to move an object from rest.
- The static coefficient of friction for ice on ice is given on Table 4.5
- The acceleration due to gravity at the top of Mount Everest is given in Table 4.4.

**Identify the Goal**
The force of static friction between two layers of horizontal ice on the top of Mount Everest

**Variables and Constants**

| Known | Implied | Unknown | |
|---|---|---|---|
| $m = 2.00 \times 10^2\ \text{kg}$ | $\vec{g} = 9.7647\frac{\text{m}}{\text{s}^2}$ | $\vec{F}_\text{f}$ | $\vec{F}_\text{g}$ |
| | $\mu_\text{s} = 0.10$ | $\vec{F}_\text{N}$ | |

**Strategy**
Use the equation for weight to find the weight and thus the normal force. Use the acceleration due to gravity on Mount Everest.

**Calculations**
$\vec{F}_N = \vec{F}_g$
$\vec{F}_N = m\vec{g}_{Everest}$

Substitute in the variables and solve. Use $1\ \frac{N}{kg} = 1\ \frac{m}{s^2}$.

$\vec{F}_N = 2.00 \times 10^2\ kg(9.7647\frac{N}{kg})$
$\vec{F}_N = 1952.94\ N$

Apply the equation for a frictional force.

$\vec{F}_f = \mu_s\vec{F}_N$

Use the static coefficient for ice.

$\vec{F}_f = 0.10(1952.94)\ N$
$\vec{F}_f = 195.29\ N$

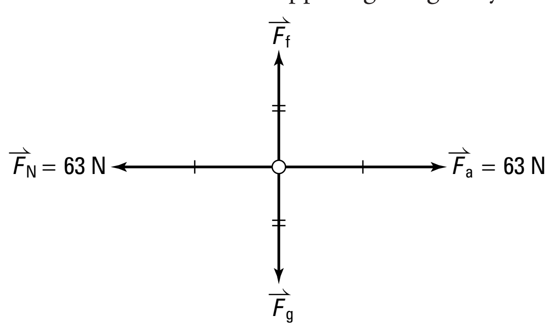
Convert to the appropriate number of significant digits.

$\vec{F}_f \cong 2.0 \times 10^2\ N$

Only a $2.0 \times 10^2$ N force is needed to start this avalanche moving.

**Validate**
It appears that avalanches are easy to start. A force of $2.0 \times 10^2$ N seems very small to get a 200 kg layer of ice moving, but it is correct.

**8. Frame the Problem**
- Sketch the problem.
- The equation relating frictional force to the coefficient of friction and the normal force applies to this problem.
- The static coefficient of friction applies when you start to move an object from rest.
- In this case the hand pushing against the wall is producing the normal force, and the force of friction is opposing the gravity force keeping the book from falling.




**Identify the Goal**
The coefficient of static friction between the book and the wall

**Variables and Constants**

| Known | Implied | Unknown |
|---|---|---|
| $m = 2.2$ kg | $\vec{g} = 9.81\frac{m}{s^2}$ | $\vec{F}_f$ $\vec{F}_g$ |
| | $\mu_s$ | $\vec{F}_N$ |

**Strategy**
Use the equation for weight to find the weight and thus the normal force.

**Calculations**
$\vec{F}_N = 63\ N$
$\vec{F}_g = m\vec{g}$

Substitute in the variables and solve. Use $1\ \frac{N}{kg} = 1\ \frac{m}{s^2}$

$\vec{F}_g = 2.2\ kg(9.81\frac{N}{kg})$
$\vec{F}_g = 21.582\ N$

Apply the equation for a frictional force. The force of the hand pushing against the wall is producing the normal force and the friction force is opposing gravity.

Convert to the appropriate number of significant digits.

$$\vec{F}_f = \mu_s \vec{F}_N$$
$$\vec{F}_f = \vec{F}_g$$
$$\mu_s \vec{F}_N = \vec{F}_g$$
$$\mu_s = \frac{\vec{F}_g}{\vec{F}_N}$$
$$\mu_s = \frac{21.582 \text{ N}}{63 \text{ N}} = 0.34$$

The coefficient of friction between the book and the wall is 0.34.

**Validate**

The value of the coefficient between the book and the wall seems reasonable.

## Chapter 4 Review

## Answers to Problems For Understanding

**Student Textbook page 151**

**26.** The mass of the sack of potatoes is 11.2 kg.

$$\vec{F}_g = m\vec{g}$$
$$m = \frac{\vec{F}_g}{\vec{g}}$$
$$m = \frac{1.10 \times 10^2 \text{N}}{9.81 \frac{\text{m}}{\text{s}^2}}$$
$$m = 11.2 \text{ kg}$$

**27.** You would weigh 90.4 N on the Moon and 205 N on Mars.
Find the mass:

$$\vec{F}_g = m\vec{g}$$
$$m = \frac{\vec{F}_g}{\vec{g}} = \frac{541 \text{ N}}{9.81 \frac{\text{m}}{\text{s}^2}} = 55.147 \text{ kg}$$
$$\vec{F}_{g_{\text{Moon}}} = m\vec{g}_{\text{Moon}}$$
$$\vec{F}_{g_{\text{Moon}}} = (55.147 \text{ kg})(1.64 \tfrac{\text{m}}{\text{s}^2})$$
$$\vec{F}_{g_{\text{Moon}}} = 90.4 \text{ N}$$
$$\vec{F}_{g_{\text{Mars}}} = m\vec{g}_{\text{Mars}}$$
$$\vec{F}_{g_{\text{Mars}}} = (55.147 \text{ kg})(3.72 \tfrac{\text{m}}{\text{s}^2})$$
$$\vec{F}_{g_{\text{Mars}}} = 205.15 \text{ N}$$
$$\vec{F}_{g_{\text{Mars}}} \cong 205 \text{ N}$$

**28.** It would weigh $1.20\times10^2$ N on Jupiter.

$$\vec{F}_{g_{\text{Jupiter}}} = m\vec{g}_{\text{Jupiter}}$$
$$\vec{F}_{g_{\text{Jupiter}}} = (4.6 \text{ kg})(25.9 \tfrac{\text{m}}{\text{s}^2})$$
$$\vec{F}_{g_{\text{Jupiter}}} = 119.14 \text{ N}$$
$$\vec{F}_{g_{\text{Jupiter}}} \cong 1.2\times10^2 \text{ N}$$

**29.** The percent error in the scale when used on Mars would be 260%.
First, consider that an object of mass 1.0 kg would exert a force of 9.81 N on the spring on Earth:

$$\vec{F}_g = m\vec{g} = (1.0 \text{ kg})(9.81 \tfrac{\text{m}}{\text{s}^2}) = 9.81 \text{ N}$$

Exerting the same force on the spring on Mars would indicate a mass of 2.63 kg:

$$\vec{F}_g = m\vec{g}_{\text{Mars}}$$
$$m = \frac{\vec{F}_g}{\vec{g}_{\text{Mars}}}$$
$$m = \frac{9.81 \text{ N}}{3.72 \frac{\text{m}}{\text{s}^2}}$$
$$m = 2.63 \text{ kg}$$

Then, the percent error is:

$$\frac{m_{\text{Mars}} - m_{\text{Earth}}}{m_{\text{Earth}}}\times100 = \frac{2.63 \text{ kg} - 1.0 \text{ kg}}{1.0 \text{ kg}}\times100 = 260\%$$

**30.** The coefficient of friction between the chair and the floor is 0.87.

$$\vec{F}_f = \mu_k\vec{F}_N$$
$$\mu_k = \frac{\vec{F}_f}{\vec{F}_N} = \frac{\vec{F}_f}{m\vec{g}}$$
$$\mu_k = \frac{401 \text{ N}}{(47 \text{ kg})(9.81 \text{ m/s}^2)}$$
$$\mu_k = 0.8697$$
$$\mu_k \cong 0.87$$

**31.** The mass of the wooden crate is 196 kg.

$$\vec{F}_f = \mu_k\vec{F}_N = \mu_k m\vec{g}$$
$$m = \frac{\vec{F}_f}{\mu_k\vec{g}}$$
$$m = \frac{385 \text{ N}}{(0.20)(9.81 \text{ m/s}^2)}$$
$$m = 196.2 \text{ kg}$$
$$m \cong 2.0\times10^2 \text{ kg}$$

**32.** To prevent the block from sliding down, you must exert a force of 49 N.
See the free body diagram for Practice Problem #8. For the book not to slip, the applied horizontal force is balanced by the normal force, both of which are unknown. And, as seen in the free body diagram, the force of friction is balanced by the force of gravity.

$$\vec{F}_{\mathrm{f}} = \vec{F}_{\mathrm{g}}$$

$$\mu_{\mathrm{s}}\vec{F}_{\mathrm{N}} = \vec{F}_{\mathrm{g}} = m\vec{g}$$

$$\vec{F}_{\mathrm{N}} = \frac{m\vec{g}}{\mu_{\mathrm{s}}}$$

$$\vec{F}_{\mathrm{N}} = \frac{(3.0 \text{ kg})(9.81 \text{ m/s}^2)}{0.60}$$

$$\vec{F}_{\mathrm{N}} = 49.05 \text{ N}$$

$$\vec{F}_{\mathrm{N}} \cong 49 \text{ N}$$

**33.** The required force would be reduced by 37% to $2.9 \times 10^2$ N.
Use the given information to find the mass of the crate:

$$\vec{F}_{\mathrm{f}} = \mu_{\mathrm{kdry}}\vec{F}_{\mathrm{N}} = \mu_{\mathrm{kdry}}m\vec{g}$$

$$m = \frac{\vec{F}_{\mathrm{f}}}{\mu_{\mathrm{kdry}}\vec{g}}$$

$$m = \frac{457 \text{ N}}{(0.80)(9.81 \text{ m/s}^2)}$$

$$m = 58.23 \text{ kg}$$

After spraying the cement with water, the new required force will be:

$$\vec{F}_{\mathrm{fnew}} = \mu_{\mathrm{kwet}}\vec{F}_{\mathrm{N}} = \mu_{\mathrm{kwet}}m\vec{g}$$

$$\vec{F}_{\mathrm{fnew}} = (0.50)(58.23 \text{ kg})(9.81 \text{ m/s}^2)$$

$$\vec{F}_{\mathrm{fnew}} = 285.6 \text{ N}$$

$$\vec{F}_{\mathrm{fnew}} \cong 2.9 \times 10^2 \text{ N}$$

This is a reduction of $\dfrac{457 \text{ N} - 286 \text{ N}}{457 \text{ N}} \times 100 = 37.4\%$.

**34. (a)**
$$\overrightarrow{F}_{\mathrm{N}} = \overrightarrow{F}_{\mathrm{g}}$$
$$\overrightarrow{F}_{\mathrm{N}} = m\overrightarrow{g}$$
$$\overrightarrow{F}_{\mathrm{N}} = 450 \text{ kg} \times 9.81 \ \tfrac{\text{m}}{\text{s}^2}$$
$$\overrightarrow{F}_{\mathrm{N}} = 4414.5 \ \tfrac{\text{kg}\cdot\text{m}}{\text{s}^2}$$
$$\overrightarrow{F}_{\mathrm{N}} = 4414.5 \text{ N}$$
$$\therefore \overrightarrow{F}_{\mathrm{N}} = 4.4 \times 10^3 \text{ N}$$

**(b)**
$$\overrightarrow{F}_{\mathrm{f}} = \mu_{\mathrm{s}}\overrightarrow{F}_{\mathrm{N}}$$
$$\overrightarrow{F}_{\mathrm{f}} = 0.35(4.4 \times 10^3 \text{ N})$$
$$\overrightarrow{F}_{\mathrm{f}} = 1.54 \times 10^3 \text{ N}$$
$$\overrightarrow{F}_{\mathrm{f}} = 1.5 \times 10^3 \text{ N}$$

**(c)** $\vec{F}_a = \vec{F}_f = 1.1 \times 10^3$ N

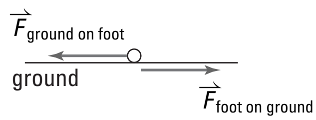
$\mu_k = \frac{\vec{F}_f}{\vec{F}_N}$

$\mu_k = \frac{1.1 \times 10^3 \text{ N}}{4.4 \times 10^3 \text{ N}} = 0.25$

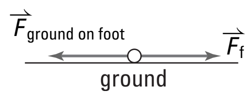
$\therefore \mu_k = 0.25$

**35.** Refer to the free body diagrams below.

**(a)**




**(b)**




**(c)**