Chapter 4

Newton's Laws

Practice Problems

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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

Involved in the problem	Known	Implied	Unknown
m $\vec{F}_g$ $\vec{g}_{Earth}$	$m = 2.3$ kg	$\vec{g}_{Earth} = 9.81\ \frac{m}{s^2}$	$\vec{F}_g$

Strategy	Calculations
The acceleration due to gravity is known for the surface of Earth.	
Use the equation for weight.	$\vec{F}_{g\,Earth} = m\vec{g}_{Earth}$
Substitute the variables and solve.	$\vec{F}_{g\,Earth} = (2.3\text{kg})(9.81\frac{m}{s^2})[\text{down}]$
	$\vec{F}_{g\,Earth} = 22.56\ \text{kg}\frac{m}{s^2}[\text{down}]$
$1\ \text{kg}\frac{m}{s^2}$ is equivalent to 1 N.	$\vec{F}_{g\,Earth} = 22.56\ \text{N}[\text{down}]$
Convert to the appropriate number of significant digits.	$\vec{F}_{g\,Earth} = 22.6\ \text{N}[\text{down}]$

The 2.3 kg mass would weigh 22.6 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

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

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.	$\vec{F}_{g\,\text{North Pole}} = (66.722\ \text{kg})(9.8322\ \frac{\text{m}}{\text{s}^2})[\text{down}]$
$1\ \text{kg}\cdot\frac{\text{m}}{\text{s}^2}$ 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

Involved in the problem		Known	Implied	Unknown
m	$\vec{F}_{g\,Earth}$	m	$\vec{g}_{Earth} = 9.81\ \frac{m}{s^2}$	$\vec{F}_{g\,Earth}$
$\vec{F}_{g\,Moon}$	$\vec{g}_{Moon}$		$\vec{g}_{Moon} = 1.64\ \frac{m}{s^2}$	$\vec{F}_{g\,Moon}$
$\vec{g}_{Earth}$				

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.

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

Convert to the appropriate number of significant digits.

Calculations

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

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

(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

Involved in the problem		Known	Implied	Unknown
m	$\vec{F}_g$	$m = 1.00$ kg		$\vec{g}_a$
$\vec{g}_a$		$\vec{F}_g = 3.25 \times 10^{-2}$ 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 m/s^2.

Validate

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

Practice Problems

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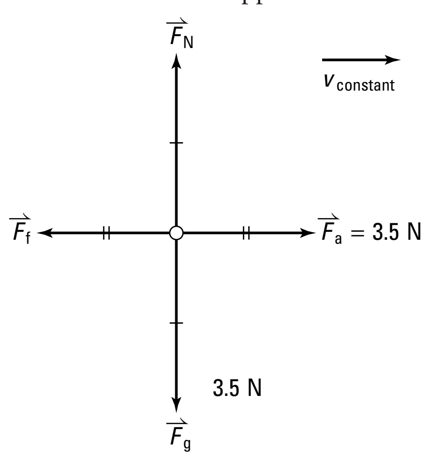
5. Frame the Problem

- 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, μ_s or μ_k?

Variables and Constants

Involved in the problem	Known	Implied	Unknown
m $\vec{F}_g$ μ_k	$m = 0.6$ kg	$\vec{g} = 9.81 \frac{m}{s^2}$	$\vec{F}_f$ $\vec{F}_g$
$\vec{F}_a$ $\vec{F}_f$	$\vec{F}_a = 3.50$N		μ_k $\vec{F}_N$
$\vec{g}$ $\vec{F}_N$			

Strategy

Convert grams to kilograms.

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

Substitute in the variables and solve.

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

Convert to the appropriate number of significant digits.

Apply the equation for a frictional force.

Calculations

(a) 600 g = 0.6 kg

$\vec{F}_N = \vec{F}_g$

$\vec{F}_N = m\vec{g}$

$\vec{F}_N = 0.6 \text{ kg}(9.81 \frac{N}{kg})$

$\vec{F}_N = 5.89$N

(b) $\vec{F}_f = 3.50$ N

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

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

$\mu_k = \frac{3.50 \text{ N}}{5.886 \text{ N}}$

$\mu_k = 0.595$

(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 μ_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

Involved in the problem	Known	Implied	Unknown
m $\vec{F}_g$ μ_s	$m = 125$ kg	$\vec{g} = 9.81 \frac{m}{s^2}$	$\vec{F}_f$ $\vec{F}_g$
$\vec{F}_a$ $\vec{F}_f$	$m = 62.5$ kg		$\vec{F}_a$ $\vec{F}_N$
$\vec{g}$ $\vec{F}_N$	$\mu_s = 0.430$		$\vec{F}_a$

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.

Apply the equation for a frictional force.

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.

Calculations

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

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

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

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

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

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

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

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

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

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

(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

Involved in the problem	Known	Implied	Unknown
m $\vec{F}_\text{g}$	$m = 2.00 \times 10^2\ \text{kg}$	$\vec{g} = 9.7647\frac{\text{m}}{\text{s}^2}$	$\vec{F}_\text{f}$ $\vec{F}_\text{g}$

$\vec{F}_f$ μ_s		$\mu_s = 0.10$	$\vec{F}_N$
$\vec{g}$ $\vec{F}_N$			

Strategy	Calculations
Use the equation for weight to find the weight and thus the normal force. Use the acceleration due to gravity on Mount Everest.	$\vec{F}_N = \vec{F}_g$ $\vec{F}_N = m\vec{g}_{Everest}$
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.	$\vec{F}_f = 1.95 \times 10^2\ N$

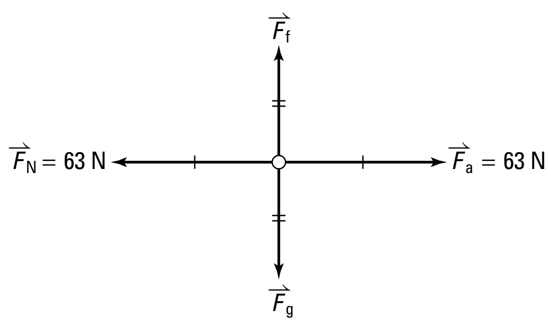
Only a 195 N force is needed to start this avalanche moving.

Validate

It appears that avalanches are easy to start. A force of 195 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

Involved in the problem	Known	Implied	Unknown
m $\vec{F}_g$	$m = 2.2$ kg	$\vec{g} = 9.81 \frac{m}{s^2}$	$\vec{F}_f$ $\vec{F}_g$
$\vec{F}_f$ μ_s			μ_s $\vec{F}_N$
$\vec{g}$ $\vec{F}_N$			

Strategy	Calculations
Use the equation for weight to find the weight and thus the normal force.	$\vec{F}_N = 63\ \text{N}$ $\vec{F}_g = m\vec{g}$
Substitute in the variables and solve. Use $1\ \frac{\text{N}}{\text{kg}} = 1\ \frac{\text{m}}{\text{s}^2}$	$\vec{F}_g = 2.2\ \text{kg}(9.81\frac{\text{N}}{\text{kg}})$ $\vec{F}_g = 21.582\ \text{N}$
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.	$\vec{F}_f = \mu_s\vec{F}_N$ $\vec{F}_f = \vec{F}_g$ $\mu_s\vec{F}_N = \vec{F}_g$ $\mu_s = \frac{\vec{F}_g}{\vec{F}_N}$
Convert to the appropriate number of significant digits.	$\mu_s = \frac{21.582\ \text{N}}{63\ \text{N}} = 0.34$

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.

Practice Problems

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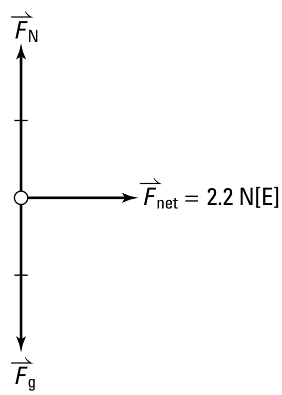
9. **Frame the Problem**
   - Draw a free body diagram of the problem.
   - The downward force of gravity is balanced by the upward normal force. Therefore, there is no net force in the vertical direction. These forces do not affect the acceleration of the object.
   - The net force is the only horizontal force on the object.
   - The net force determines the acceleration of the object according to Newton's second law of motion.



Identify the Goal
The acceleration of the object

Variables and Constants

Involved in the problem		Known	Implied	Unknown
m	$\vec{F}_{net}$	$m = 4.0\ \text{kg}$		$\vec{a}$
$\vec{a}$		$\vec{F}_{net}$		

Strategy

Since the net force is known, use Newton's second law in terms of acceleration.

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

Calculations

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

$\vec{a} = \frac{2.2\ N[E]}{4.0\ kg}$

$\vec{a} = 0.5\ \frac{m}{s^2} N[E]$

The acceleration of the object is $0.55\ m/s^2[E]$.

Validate

The object accelerated in the direction of the net force. The unit for acceleration is m/s^2 which is correct.

10. Frame the Problem

- Draw a free body diagram of the problem.
- The downward force of gravity is balanced by the upward normal force. Therefore, there is no net force in the vertical direction. These forces do not affect the acceleration of the object.
- The friction force is in the opposite direction of the applied force.
- The net force is the sum of the friction force and the applied force on the object.
- The net force determines the acceleration of the object according to Newton's second law of motion.

Identify the Goal

The acceleration of the object

Variables and Constants

Involved in the problem		Known	Implied	Unknown
m	$\vec{F}_{net}$	$m = 6.0$ kg		$\vec{a}$
$\vec{a}$	$\vec{F}_a$	$\vec{F}_a = 4.4$ N[E]		$\vec{F}_{net}$
$\vec{F}_f$		$\vec{F}_f = 1.2$ N[E]		

Strategy

Since the motion is all along one line, east and west, denote direction with signs only.

Let east be positive and west be negative.

Find the net force on the object by finding the vector sum of the applied force and the friction force acting on the object.

Calculations

$\vec{F}_{net} = \vec{F}_a + \vec{F}_f$

$\vec{F}_{net} = +4.4\ N - 1.2\ N$

$\vec{F}_{net} = +3.2\ N$

Apply Newton's second law in terms of acceleration and solve.

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

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

$\vec{a} = \frac{+3.2\ N}{6.0\ kg}$

$\vec{a} = +0.53\ \frac{m}{s^2}$

$\vec{a} = 0.53\ \frac{m}{s^2}[E]$

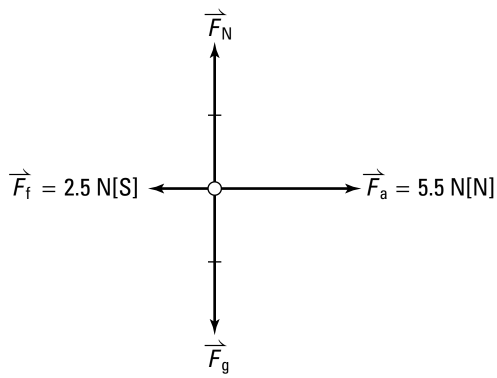
The acceleration of the object is $0.53 m/s^2[E]$.

Validate

The object accelerated in the direction of the net force. The unit for acceleration is m/s^2 which is correct.

11. Frame the Problem

- Draw a free body diagram of the problem.
- The downward force of gravity is balanced by the upward normal force. Therefore, there is no net force in the vertical direction. These forces do not affect the acceleration of the object.
- The friction force is in the opposite direction of the applied force.
- The net force is the sum of the friction force and the applied force on the object.
- The net force determines the acceleration of the object according to Newton's second law of motion.
- The equations of motion for uniform acceleration apply to the motion of the stone.



Identify the Goal

How far the object travelled

Variables and Constants

Involved in the problem		Known	Implied	Unknown
m	$\vec{F}_{net}$	$m = 15$ kg	$\vec{v}_i = 0.0\ \frac{m}{s}$	$\vec{a}$
$\vec{a}$	$\vec{F}_a$	$\vec{F}_a = 5.5$ N[N]		$\vec{F}_{net}$
$\vec{F}_f$	Δt	$\vec{F}_f = 2.5$ N[S]		$\Delta\vec{d}$
$\Delta\vec{d}$		$\Delta t = 4.0$ s		

Strategy

Since the motion is all along one line, north and south, denote direction with signs only.

Let north be positive and south be negative.

Find the net force on the object by finding the vector sum of the applied force and the friction force acting on the object.

Apply Newton's second law in terms of acceleration and solve.

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

Recall the equations of motion from Chapter 2. Use the equation that relates initial velocity, time, acceleration and displacement.

Calculations

$$\vec{F}_{net} = \vec{F}_a + \vec{F}_f$$

$$\vec{F}_{net} = +5.5\ \text{N} - 2.5\ \text{N}$$

$$\vec{F}_{net} = +3\ \text{N}$$

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

$$\vec{a} = \frac{+3\ \text{N}}{15\ \text{kg}}$$

$$\vec{a} = +0.2\ \frac{m}{s^2}$$

$$\vec{a} = 0.2\ \frac{m}{s^2}[N]$$

Substitute in the known values and solve for Δd.

The object travelled 1.6 m[N] after 4.0 s.

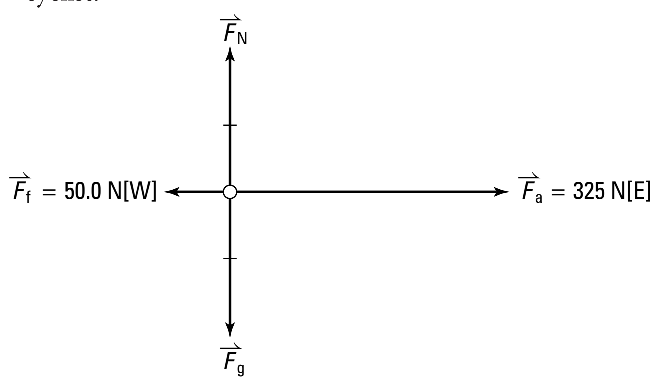
$$\Delta d = v_i\Delta t + \frac{1}{2}a\Delta t^2$$
$$\Delta d = 0.0\ \tfrac{\text{m}}{\text{s}} + \frac{1}{2}(0.2\ \tfrac{\text{m}}{\text{s}^2})(4.0\ \text{s})^2$$
$$\Delta d = (0.1)(16.0\ \text{m})$$
$$\Delta d = 1.6\ \text{m}$$
$$\Delta d = 1.6\ \text{m[N]}$$

Validate

The object accelerated in the direction of the net force, which was north, and travelled in that direction. The unit for displacement is m, which is correct.

12. Frame the Problem

- Draw a free body diagram of the problem.
- The downward force of gravity is balanced by the upward normal force. Therefore, there is no net force in the vertical direction. These forces do not affect the acceleration of the cyclist.
- The friction force is in the opposite direction of the cyclist's applied force.
- The net force is the sum of the friction force and the applied force on the cyclist.
- The net force determines the acceleration of the cyclist according to Newton's second law of motion.
- The equations of motion for uniform acceleration apply to the motion of the cyclist.



Identify the Goal

(a) The acceleration of the cyclist

(b) How far the student travelled

Variables and Constants

Involved in the problem		Known	Implied	Unknown
m_T	$\vec{F}_{net}$	$\vec{F}_a = 325$ N[E]	$\vec{v}_i = 3.0\ \frac{\text{m}}{\text{s}}$[E]	$\vec{a}$
$\vec{a}$	$\vec{F}_a$	$\vec{F}_f = 50$ N[W]	$m_T = 49$ kg	$\vec{F}_{net}$
$\vec{F}_f$	Δt	$\Delta t = 8.0$ s		$\Delta\vec{d}$
$\Delta\vec{d}$				

Strategy

Find the total mass of the cyclist and the bicycle.

Since the motion is all along one line, east and west, denote direction with signs only. Let east be positive and west be negative.

Calculations

(a) $m_T = 45\ \text{kg} + 4.0\ \text{kg}$

$m_T = 49.0\ \text{kg}$

Find the net force on the cyclist by finding the vector sum of the applied force and the friction force acting on the cyclist.

$$\vec{F}_{net} = \vec{F}_a + \vec{F}_f$$
$$\vec{F}_{net} = +325 \text{ N} - 50.0 \text{ N}$$
$$\vec{F}_{net} = +275 \text{ N}$$

Apply Newton's second law in terms of acceleration and solve.

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

$$\vec{a} = \frac{\vec{F}_{net}}{\text{m}}$$
$$\vec{a} = \frac{+275 \text{ N}}{49.0 \text{ kg}}$$
$$\vec{a} = +5.6 \frac{\text{m}}{\text{s}^2}$$
$$\vec{a} = +5.6 \frac{\text{m}}{\text{s}^2}[\text{N}]$$

Recall the equations of motion from Chapter 2. Use the equation that relates initial velocity, time, acceleration and displacement.

Substitute in the known values and solve for Δd.

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

$$\Delta d = 3.0 \frac{\text{m}}{\text{s}}(8.0 \text{ s}) + \frac{1}{2}(+5.6 \frac{\text{m}}{\text{s}^2})(8.0 \text{ s})^2$$
$$\Delta d = +24 \text{ m} + (2.8)(64.0 \text{ m})$$
$$\Delta d = +24 \text{ m} + 179.2 \text{ m}$$
$$\Delta d = +203.2 \text{ m}$$
$$\Delta d = 203 \text{ m}[\text{E}]$$

(a) The acceleration of the cyclist is 5.6 m/s^2[E].

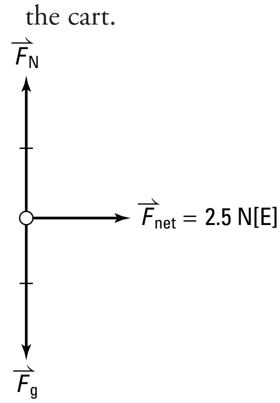
(b) The cyclist travelled 203 m[E] after 8.0 s.

Validate

The object accelerated in the direction of the net force, which was north, and travelled in that direction. The units for acceleration and displacement should be m/s^2 and m, respectively, and they are, which is correct.

13. Frame the Problem

- Draw a free body diagram of the problem.
- The downward force of gravity is balanced by the upward normal force. Therefore, there is no net force in the vertical direction. These forces do not affect the acceleration of the wheeled cart.
- Since frictional forces are ignored the net force on the wheeled cart is from the stretched elastic band only.
- The mass of the cart is related to the net force on the cart and to the acceleration of the cart.



Identify the Goal

The mass of the cart

Variables and Constants

Involved in the problem		Known	Implied	Unknown
m	$\vec{F}_{net}$	$\vec{F}_a = 2.5$ N[E]	$\vec{F}_{net}$	m
$\vec{a}$	$\vec{F}_a$	$\vec{a} = 1.5\ \frac{m}{s^2}$[E]		

Strategy

Find the net force on the wheeled cart.

Apply Newton's second law in terms of mass and solve.

Since $1\ \frac{N}{kg} = 1\ \frac{m}{s^2}$ it follows that $1\ N = 1\ kg \cdot \frac{m}{s^2}$ and the unit for mass is kg.

The mass of the cart is 1.7 kg.

Calculations

$\vec{F}_{net} = \vec{F}_a$

$\vec{F}_{net} = 2.5$ N[E]

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

$m = \frac{2.5\ N[E]}{1.5\ \frac{m}{s^2}[E]}$

$m = 1.67$ kg

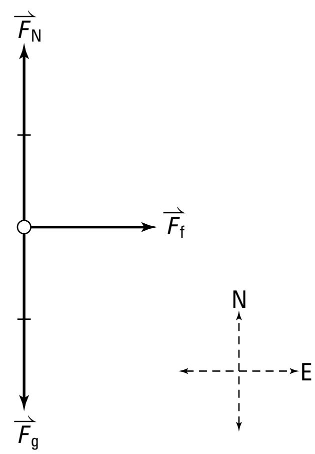
$m = 1.7$ kg

Validate

The unit for mass of the wheeled cart is kg, which is correct.

14. Frame the Problem

- Draw a free body diagram of the problem.
- The downward force of gravity is balanced by the upward normal force. Therefore, there is no net force in the vertical direction. These forces do not affect the acceleration of the car.
- The friction force is the only force acting on the car that will slow it down, so this is the net force.
- The mass of the car is related to the net force on the car and to the acceleration of the car.
- Use the equations of motion from Chapter 2 to solve for the acceleration.



Identify the Goal

The coefficient of friction between the road and the car tires.

Variables and Constants

Involved in the problem			Known	Implied	Unknown	
m	$\vec{F}_{net}$	Δd	$m = 1.2 \times 10^3$ kg	$\vec{g} = 9.8\ \frac{m}{s^2}$	$\vec{F}_{net}$	$\vec{F}_f$
$\vec{a}$	$\vec{F}_f$	$\vec{F}_g$	$\vec{v}_i = 45$ km/h		$\vec{a}$	$\vec{F}_N$

$\vec{g}$ $\vec{F}_N$ $\Delta d = 35$ m $\vec{F}_g$

$\vec{v}_i$ $\vec{v}_f$ $\vec{v}_f = 0$ km/h

Strategy

Convert km/h to m/s.

To find the friction force acting on the car the acceleration must be known so that a relationship between the net force and the friction force can be obtained.

Use the equation of motion that relates initial and final velocity acceleration and displacement.

Find the net force on the car, knowing its mass and acceleration using Newton's second law.

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

Since $1\ \frac{\text{N}}{\text{kg}} = 1\ \frac{\text{m}}{\text{s}^2}$ it follows that $1\ \text{N} = 1\ \text{kg}\frac{\text{m}}{\text{s}^2}$ and the unit for mass is kg.

Apply the equation for a frictional force.

Calculations

$$45\ \frac{\text{km}}{\text{h}} \times \frac{1\ \text{h}}{3600\ \text{s}} \times \frac{1000\ \text{m}}{1\ \text{km}} = 12.5\ \frac{\text{m}}{\text{s}}$$

$$a = \frac{v_f^2 - v_i^2}{2d}$$

$$a = \frac{(0\ \frac{\text{m}}{\text{s}})^2 - (12.5\ \frac{\text{m}}{\text{s}})^2}{2d}$$

$$a = \frac{-156.25\ (\frac{\text{m}}{\text{s}})^2}{2(35\ \text{m})}$$

$$a = \frac{-156.25\ (\frac{\text{m}}{\text{s}})^2}{70\ \text{m}}$$

$$a = -2.23\ \frac{\text{m}}{\text{s}^2}$$

$$\vec{F}_{net} = m\vec{a} = (1.2 \times 10^3\ \text{kg})(2.23\ \frac{\text{m}}{\text{s}^2})$$

$$\vec{F}_{net} = 2678\ \text{N}$$

$$\vec{F}_f = \mu_k F_N$$

$$\vec{F}_N = m\vec{g} = (1.2 \times 10^3\ \text{kg})(2.23\ \frac{\text{N}}{\text{kg}})$$

$$= 11772\ \text{N}$$

$$\vec{F}_{net} = \vec{F}_f$$

$$\vec{F}_{net} = \mu_k F_N$$

$$2678.6\ \text{N} = \mu_k 11772\ \text{N}$$

$$\mu_k = \frac{2678.6\ \text{N}}{11772\ \text{N}} = 0.23$$

The coefficient of friction between the slippery road and the car tires is 0.23.

Validate

The coefficient of kinetic friction is low and it should be since the surface is a slippery road.

Practice Problems

Student Textbook page 172

15. Frame the Problem

- Draw a free body diagram representing the forces acting on the swimmer. The net force is the sum of the forces acting on the swimmer.
- Use both a scale diagram and a mathematical solution to determine the net force acting on the swimmer.

Identify the Goal

Find the resultant force acting on the swimmer using a scale diagram and a mathematical solution

Variables and Constants

Involved in the problem		Known	Implied	Unknown
$\vec{F}_1$	$\vec{F}_2$	$\vec{F}_1 = 35.0$ N[N]		$\vec{F}_{resultant}$
$\theta_{resultant}$	$\vec{F}_{resultant}$	$\vec{F}_2 = 20$ N[E]		$\theta_{resultant}$

Strategies

Scale Vector Diagram Method

Draw a scale vector diagram, adding the vectors "tip to tail."

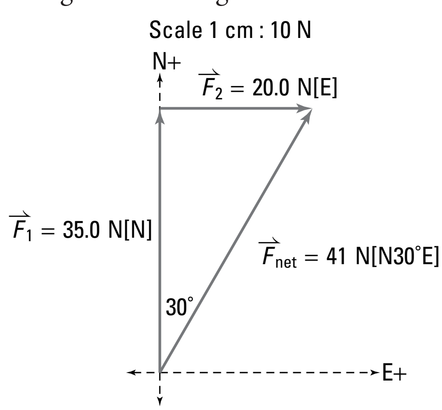
Measure the length of the resultant vector.

Use a scale factor to determine the magnitude of the force.

Use a protractor to measure the angle.

$$|\vec{F}_{net}| = 4.1 \text{ cm}$$
$$|\vec{F}_{net}| = (4.1 \text{ cm})\left(\frac{10 \text{ N}}{\text{cm}}\right)$$
$$|\vec{F}_{net}| = 41 \text{ N}$$
$$\theta = [\text{N}30^\circ\text{E}]$$

Using the scale diagram method the net force is 41 N[N30°E].



Components Method

Draw each vector with its tail at the origin at an *x*-*y*-coordinate system where +*y* coincides with north and +*x* coincides with east. Find the angle with the nearest *x*-axis.

North coincides with the *y*-axis so the angle is 90°. East coincides with the *x*-axis so the angle is 0°.

Find the *x*-component of each force vector.

$$\vec{F}_{1x} = |\vec{F}_1| \cos 90^\circ = (35 \text{ N})(0.0) = 0.0 \text{ N}$$
$$\vec{F}_{2x} = |\vec{F}_2| \cos 0^\circ = (20 \text{ N})(1.0) = 20.0 \text{ N}$$

Find the *y*-component of each force vector.

$$\vec{F}_{1y} = |\vec{F}_1| \sin 90^\circ = (35 \text{ N})(1.0) = 35.0 \text{ N}$$
$$\vec{F}_{2y} = |\vec{F}_2| \sin 0^\circ = (20 \text{ N})(1.0) = 0.0 \text{ N}$$

Make a table in which to list the *x*-and *y*-components. Add them to find the components of the resultant vector.

Vector	*x*-component	*y*-component
$\vec{F}_1$	0.0 N	35.0 N
$\vec{F}_2$	20.0 N	0.0 N
$\vec{F}_{net}$	20.0 N	35.0 N

Use the Pythagorean Theorem to find the magnitude of the net force. Use trigonometry to find the angle θ. The angle will be in the first quadrant.

$$|\vec{F}_{net}|^2 = (F_{x\,net})^2 + (F_{y\,net})^2$$
$$|\vec{F}_{net}|^2 = (20\text{ N})^2 + (35.0\text{ N})^2$$
$$|\vec{F}_{net}|^2 = 400\text{ N}^2 + 1225\text{ N}^2$$
$$|\vec{F}_{net}|^2 = 1625\text{ N}^2$$
$$|\vec{F}_{net}| = 40.31\text{ N}$$
$$|\vec{F}_{net}| = 40\text{ N}$$
$$\tan\theta = \frac{35.0\text{ N}}{20\text{ N}}$$
$$\tan\theta = 1.75$$
$$\theta = \tan^{-1} 1.75$$
$$\theta = 60^\circ$$

The net force acting on the swimmer is 40[N60°N] or 40[N30°E].

Validate

The magnitude and direction of the resultant force vectors are correct. Using the scale diagram and the component method gives nearly the same result. The magnitude of the net force is 41 N for the scale diagram and 40 N for the component method. The directions are both [N30°E].

16. Frame the Problem

- Connect the forces acting on each object on a scale vector diagram. The resultant represents the sum of the forces acting on each object.

Identify the Goal

Find the resultant force acting on each object pictured

Variables and Constants

Involved in the problem	Known	Implied	Unknown
$\vec{F}_1$ $\vec{F}_2$		$\vec{F}_1$ $\vec{F}_2$	$\vec{F}_{resultant}$
$\vec{F}_3$ $\vec{F}_4$ $\vec{F}_{resultant}$		$\vec{F}_3$ $\vec{F}_4$	$\theta_{resultant}$

Strategy and Calculations

Draw a scale vector diagram, adding the vectors "tip to tail".

Measure the length of the resultant vector.

Use a scale factor to determine the magnitude of the force.

Use a protractor to measure the angle.

(a) $|\vec{F}_{net}| = 0.86\text{cm}$

$$|\vec{F}_{net}| = (0.86\text{ cm})\left(\frac{50\text{ N}}{\text{cm}}\right)$$
$$|\vec{F}_{net}| = 43\text{ N}$$
$$\theta = [\text{E}]$$

The resultant force is 43 N[E].

(b) $\left|\vec{F}_{net}\right| = 0.148 \text{ cm}$

$\left|\vec{F}_{net}\right| = (0.148 \text{ cm})\left(\frac{50 \text{ N}}{\text{cm}}\right)$

$\left|\vec{F}_{net}\right| = 7.4 \text{ N}$

$\theta = [\text{N}]$

The resultant force is 7.4 N[N].

(c) $\left|\vec{F}_{net}\right| = 0.3 \text{ cm}$

$\left|\vec{F}_{net}\right| = (0.3 \text{ cm})\left(\frac{50 \text{ N}}{\text{cm}}\right)$

$\left|\vec{F}_{net}\right| = 15 \text{ N}$

$\theta = [\text{E}]$

The resultant force is 1 N[E].

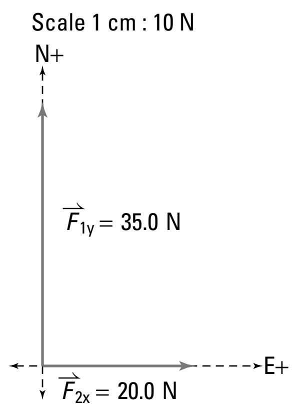
(d) $\left|\vec{F}_{net}\right| = 0.3 \text{ cm}$

$\left|\vec{F}_{net}\right| = (0.3 \text{ cm})\left(\frac{50 \text{ N}}{\text{cm}}\right)$

$\left|\vec{F}_{net}\right| = 15 \text{ N}$

$\theta = [\text{W28°S}]$

The resultant force is 15 N[W28°S].

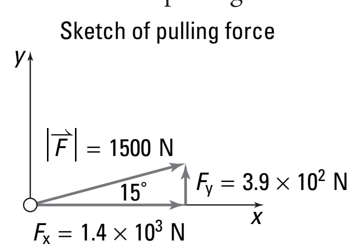


Validate

The magnitude and direction of the resultant force vectors are reasonable.

17. Frame the Problem

- Sketch the pulling force vector.
- Resolve the pulling force vector into its *x*- and *y*-components.



Identify the Goal

(a) Find the component of the pulling force in the direction of travel (*x*-component).

(c) Find the component of the pulling force perpendicular to the direction of travel (*y*-component).

Variables and Constants

Involved in the problem		Known	Implied	Unknown
F_x	F_y	$\vec{F} = 1500$ N[N]		F_x
θ	$\vec{F}$	θ		F_y

Strategy and Calculations

Find the *x*-component and *y*-component of the force vector.

$F_x = |\vec{F}| \cos 15° = (1500 \text{ N})(0.9659) = 1448.9 \text{ N}$

$F_x = 1.4 \times 10^3 \text{ N}$

$F_y = |\vec{F}| \cos 15° = (1500 \text{ N})(0.2588) = 388.2 \text{ N}$

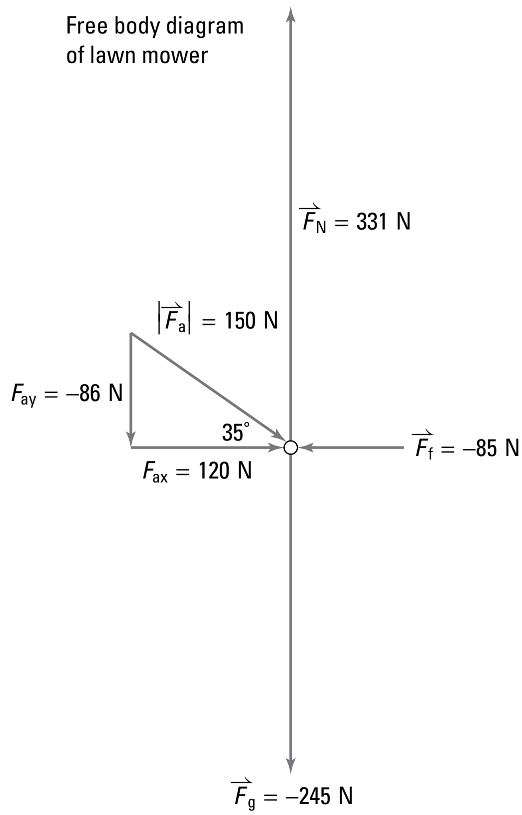
$F_y = 3.9 \times 10^2 \text{ N}$

Validate

The magnitude and direction of the resultant force vectors are reasonable.

18. Frame the Problem

- Draw a free body diagram of the lawn mower showing all the forces acting on it.
- Resolve the applied force into its vertical and horizontal components.
- The student pushing down on the lawn mower will increase the normal force, so that the force of gravity on the lawn mower may be smaller than the normal force.
- Newton's second law applies to this problem.



Identify the Goal

(a) Find the vertical and horizontal components of the applied force

(b) Calculate the normal force supporting the lawn mower while it is being pushed

(c) Calculate the net force propelling the mower if a frictional force of 85 N exists

(d) Calculate the horizontal acceleration of the lawn mower

Variables and Constants

Involved in the problem		Known	Implied	Unknown	
F_{ax}	F_{ay}	$\vec{F}_a = 150$ N	$\vec{g} = 9.81\ \frac{m}{s^2}$	F_{ax}	$\vec{a}$
θ	$\vec{F}_a$	$\theta = 35°$		F_{ay}	
$\vec{F}_N$	$\vec{F}_g$	$m = 25$ kg		$\vec{F}_g$	$\vec{F}_N$
$\vec{F}_{net}$	$\vec{a}$				
$\vec{g}$					

Strategy and Calculations

Find the vertical and horizontal components of the applied force.

Assume the lawn mower is moving to the right, which is positive and let "up" be positive.

$F_{ax} = |\vec{F}_a| \cos 35° = (150\ \text{N})(0.8192) = 122.88\ \text{N}$
$F_{ax} = 120\ \text{N}$
$F_{ay} = |\vec{F}_a| \sin 35° = (150\ \text{N})(0.5736) = 86.03\ \text{N}$
$F_{ay} = -86\ \text{N}$

The horizontal component of the applied force is 120 N to the right.

The vertical component of the applied force is 86 N down.

Calculate the normal force supporting the lawn mower. It is equal to all the downward forces acting on it, but opposite in sign.

$\vec{F}_g = m\vec{g} = 25\ \text{kg} \times (-9.81\ \frac{\text{N}}{\text{kg}})$

$\vec{F}_g = -245.25\ \text{N}$

$\vec{F}_N = \vec{F}_g + F_{ay} = 245.25\ \text{N} + 86\ \text{N}$

$\vec{F}_N = 331.25\ \text{N}$

$\vec{F}_N = 3.3 \times 10^2\ \text{N}$

Calculate the net force on the lawn mower if a 85 N friction force exists.

The sum of the vertical forces is zero, and the acceleration is in the direction of the sum of the horizontal forces only.

$\vec{F}_{net} = \vec{F}_x + \vec{F}_f$
$\vec{F}_{net} = 1.22.88\ \text{N} - 85\ \text{N} = 37.88\ \text{N}$
$\vec{F}_{net} = 38\ \text{N}$

The net force on the lawn mower is 38 N to the right along the horizontal.

Calculate the horizontal acceleration of the lawn mower.

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

$\vec{a} = \frac{38\ \text{N}}{25\ \text{kg}} = 1.52\ \frac{m}{s^2}$

$\vec{a} = 1.5\ \frac{m}{s^2}$

The lawn mower's horizontal acceleration is 1.5 m/s^2 to the right.

Validate

The magnitude and units of the component forces, normal force, net force and acceleration seem reasonable.

Problems For Understanding

22. (a) $\vec{F}_N = \vec{F}_g$

$\vec{F}_N = m\vec{g}$

$\vec{F}_N = 450 \text{ kg} \times 9.81 \ \frac{\text{m}}{\text{s}^2}$

$\vec{F}_N = 4414.5 \ \frac{\text{kg·m}}{\text{s}^2}$

$\vec{F}_N = 4414.5 \text{ N}$

$\therefore \vec{F}_N = 4.4 \times 10^3 \text{ N}$

(b) $\vec{F}_f = \mu_s \vec{F}_N$

$\vec{F}_f = 0.35(4.4 \times 10^3 \text{ N})$

$\vec{F}_f = 1.54 \times 10^3 \text{ N}$

$\vec{F}_f = 1.5 \times 10^3 \text{ N}$

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

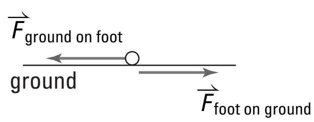
$\mu_k = \frac{\vec{F}_f}{\vec{F}_N}$

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

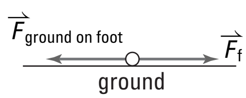
$\therefore \mu_k = 0.25$

23. Refer to the free body diagrams below.

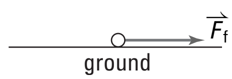
(a)



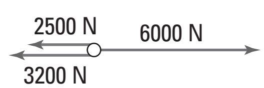
(b)



(c)



24. (a)



$\vec{F}_{net} = -3200 \text{ N} - 2500 \text{ N} + 6000 \text{ N}$

$\vec{F}_{net} = +300 \text{ N}$

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

$\vec{a} = \frac{+300 \text{ N}}{400 \text{ kg}}$

$\vec{a} = +0.75 \ \frac{\text{m}}{\text{s}^2}$

25. (a) $300\ \text{g} \times \frac{1\ \text{kg}}{1000\ \text{g}} = 0.3\ \text{kg}$

$$\vec{a} = \frac{\vec{F}_f}{m}$$

$$\vec{a} = \frac{0.45\ \text{N[left]}}{0.3\ \text{kg}} = 1.5\ \frac{\text{m}}{\text{s}^2}\text{[left]}$$

$$\vec{a} = \frac{v_f - v_i}{\Delta t}$$

$$\Delta t = \frac{v_f - v_i}{a}$$

$$\Delta t = \frac{0 - 6.0\ \frac{\text{m}}{\text{s}}\text{[right]}}{1.5\ \frac{\text{m}}{\text{s}}\text{[left]}}$$

$$\Delta t = \frac{6.0\ \frac{\text{m}}{\text{s}}\text{[left]}}{1.5\ \frac{\text{m}}{\text{s}^2}\text{[left]}}$$

$$\therefore \Delta t = 4\ \text{s}$$

26. (a) $21\frac{\text{km}}{\text{h}} \times \frac{1\ \text{h}}{3600\ \text{s}} \times \frac{1000\ \text{m}}{1\ \text{km}} = 5.83\frac{\text{m}}{\text{s}}$

$$\Delta d = \left(\frac{v_1 + v_2}{2}\right)\Delta t$$

$$15\ \text{m} = \left(\frac{5.83\frac{\text{m}}{\text{s}} + 0\frac{\text{m}}{\text{s}}}{2}\right)\Delta t$$

$$15\ \text{m} = \left(2.915\ \frac{\text{m}}{\text{s}}\right)\Delta t$$

$$\Delta t = \frac{15\ \text{m}}{2.915\ \frac{\text{m}}{\text{s}}} = 5.15\ \text{s}$$

$$a = \frac{v_f{}^2 - v_i{}^2}{2d}$$

$$a = \frac{0 - (5.83\ \frac{\text{m}}{\text{s}})^2}{2(15\ \text{m})}$$

$$a = \frac{-33.99\ \frac{\text{m}^2}{\text{s}^2}}{30\ \text{m}}$$

$$a = -1.13\ \frac{\text{m}}{\text{s}^2}$$

$$\therefore a = -1.1\ \frac{\text{m}}{\text{s}^2}$$

(b) $\vec{F}_N = \vec{F}_g$

$$\vec{F}_N = m\vec{g}$$

$$\vec{F}_N = 73\ \text{kg} \times 9.81\ \frac{\text{N}}{\text{kg}} = 716.13\ \text{N}$$

$$\vec{F}_f = m\vec{a} = 73\ \text{kg}\ (-1.13\ \frac{\text{m}}{\text{s}^2})$$

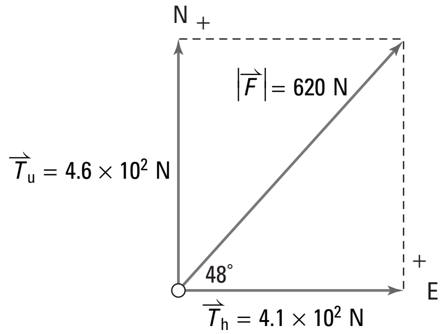
$$\vec{F}_f = -82.49\ \text{N}$$

$$\mu_k = \frac{\vec{F}_f}{\vec{F}_N} = \frac{82.49\ \text{N}}{716.13\ \text{N}}$$

$$\mu_k = 0.115$$

$$\therefore \mu_k = 0.12$$

27. Refer to the diagram and calculations below:



$\vec{T}_h = \left|\vec{F}\right| \cos\theta$

$\vec{T}_h = |620 \text{ N}| \cos 48°$

$\vec{T}_h = (620 \text{ N})(0.6691)$

$\vec{T}_h = 414.9 \text{ N}$

$\therefore \vec{T}_h = 4.1 \times 10^2 \text{ N}$

$\vec{T}_v = \left|\vec{F}\right| \sin\theta$

$\vec{T}_v = |620 \text{ N}| \sin 48°$

$\vec{T}_v = (620 \text{ N})(0.7431)$

$\vec{T}_v = 461.7 \text{ N}$

$\therefore \vec{T}_v = 4.6 \times 10^2 \text{ N}$

28. The acceleration is due to the net force in the *x* direction. The sum of the forces cancels in the *y* direction, so only forces in the *x* direction need be calculated.

$\vec{F}_g = 15 \text{ kg} \times -9.81 \ \frac{\text{m}}{\text{s}^2}$

$\vec{F}_g = -147.15 \text{ N}$

$\vec{F}_x = \left|\vec{F}\right| \cos\theta$

$\vec{F}_x = |45 \text{ N}| \cos 40°$

$\vec{F}_x = (45 \text{ N})(0.7660)$

$\vec{F}_x = 34.47 \text{ N}$

$\vec{F}_f = -28 \text{ N}$

$\vec{F}_{net} = F_x - F_f$

$\vec{F}_{net} = 34.47 \text{ N} - 28 \text{ N}$

$\vec{F}_{net} = 6.47 \text{ N}$

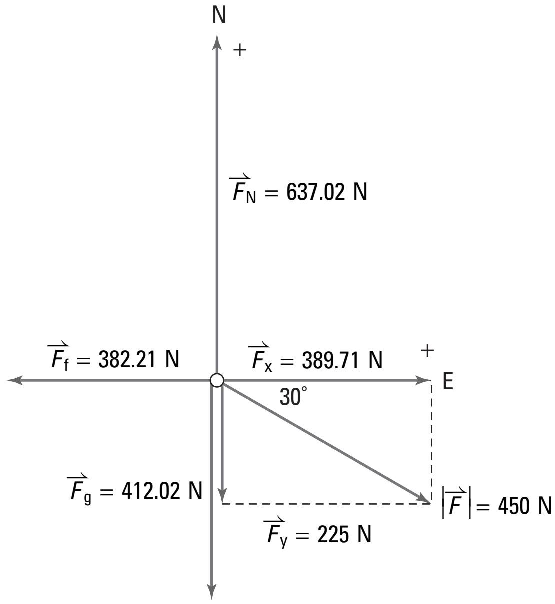
$\vec{a} = \frac{\vec{F}_{net}}{m}$

$\vec{a} = \frac{6.47 \text{ N}}{15 \text{ kg}}$

$\vec{a} = 0.43 \ \frac{\text{m}}{\text{s}^2}$

$\therefore \vec{a} = 0.4 \ \frac{\text{m}}{\text{s}^2}$

29. (a) Add the sum of all the vertical forces to obtain the normal force.



$$\vec{F}_g = 42\ \text{kg} \times -9.81\,\frac{\text{m}}{\text{s}^2}$$
$$\vec{F}_g = -412.02\ \text{N}$$

$$\vec{F}_y = |\vec{F}|\sin\theta$$
$$\vec{F}_y = |450\ \text{N}|\sin 30^\circ$$
$$\vec{F}_y = 450\ \text{N}\ (0.5)$$
$$\vec{F}_y = -225\ \text{N}$$

$$\vec{F}_N = \vec{F}_g + \vec{F}_y$$
$$\vec{F}_N = 412.02\ \text{N} + 225\ \text{N}$$
$$\vec{F}_N = 637.02\ \text{N}$$

$$\vec{F}_f = \mu_k \vec{F}_N$$
$$\vec{F}_f = (0.60)(637.02\ \text{N})$$
$$\vec{F}_f = -382.21\ \text{N}$$
$$\therefore \vec{F}_f = -3.80 \times 10^2\ \text{N}$$

(b) The acceleration of the grocery cart is in the horizontal direction. Find the sum of all the forces in the *x* direction. (The sum of the forces in the *y* direction is zero.)

$$\vec{F}_x = |\vec{F}|\cos\theta$$
$$\vec{F}_x = |450\ \text{N}|\cos 30^\circ$$
$$\vec{F}_x = (450\ \text{N})(0.8660)$$
$$\vec{F}_x = 389.71\ \text{N}$$

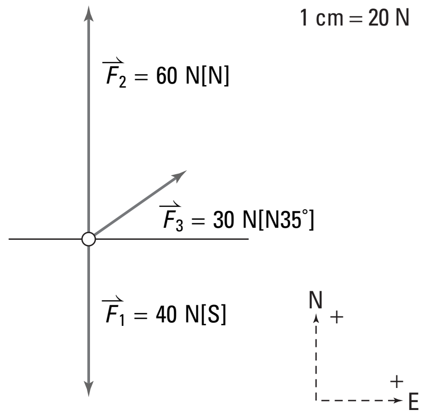
$$\vec{F}_{net} = \vec{F}_f + \vec{F}_x$$
$$\vec{F}_{net} = -382.21\ \text{N} + 389.71\ \text{N}$$
$$\vec{F}_{net} = 7.5\ \text{N}$$

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

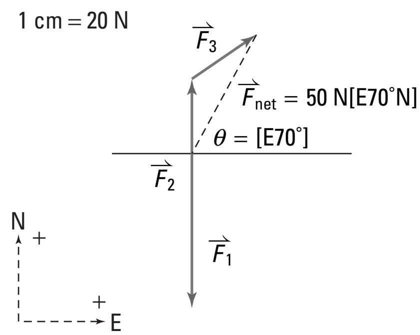
$$\vec{a} = \frac{7.5\ \text{N}}{42\ \text{kg}}$$

$$\vec{a} = 0.179\ \frac{\text{m}}{\text{s}^2}$$

$$\therefore \vec{a} = 0.18\ \frac{\text{m}}{\text{s}^2}$$



30. Refer to the scale diagram below:



$$\vec{F}_1 = 40\ \text{N[S]}$$

$$\vec{F}_2 = 60\ \text{N[N]}$$

$$\vec{F}_3 = 30\ \text{N[N35°E]}$$

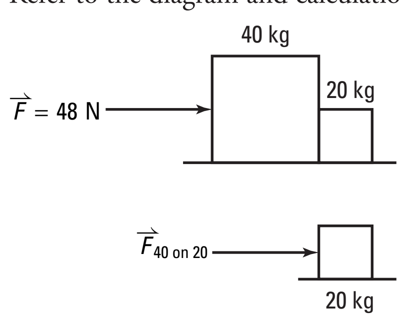
$$|\vec{F}_{net}| = (2.5\ \text{cm})(20\frac{\text{N}}{\text{cm}})$$

$$|\vec{F}_{net}| = 50\ \text{N}$$

$$\theta = [\text{E70°N}]$$

$$\vec{F}_{net} = 50\ \text{N[E70°N]}$$

31. (a) Refer to the diagram and calculations below:



$m_T = 40\text{ kg} + 20\text{ kg} = 60\text{ kg}$

$\vec{a} = \frac{\vec{F}_{net}}{m_T} = \frac{48\text{ N}}{60\text{ kg}} = 0.8\ \frac{\text{m}}{\text{s}^2}[\rightarrow]$

b) $\vec{F}_{40\text{ on }20} = m\vec{a}$

$= (20\text{ kg})\left(0.8\ \frac{\text{m}}{\text{s}^2}\right)[\rightarrow]$

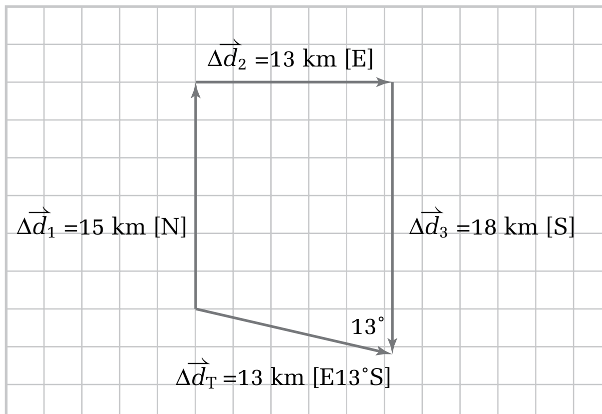
$\therefore \vec{F}_{40\text{ on }20} = 16\text{ N}[\rightarrow]$

Problems for Understanding

Student Textbook pages 189-191

33. Refer to the vector diagram and calculations below.

Scale 1 cm : 5 km



$\Delta\vec{d}_1 = 15\text{ km[N]}$

$\Delta\vec{d}_2 = 13\text{ km[E]}$

$\Delta\vec{d}_3 = 18\text{ km[S]}$

$\Delta\vec{d}_T = \Delta\vec{d}_1 + \vec{d}_2 + \Delta\vec{d}_3$

Vector	*x*-component (km)	*y*-component (km)
$\Delta\vec{d}_1$	0.0	+15
$\Delta\vec{d}_2$	+13	0.0
$\Delta\vec{d}_3$	0.0	−18
$\Delta\vec{d}_T$	+13	−3

$|\Delta d_T|^2 = (\Delta d_{T\ x})^2 + (\Delta d_{T\ y})^2$

$|\Delta d_T|^2 = (13\text{ km})^2 + (-3\text{ km})^2$

$|\Delta d_T|^2 = 169\text{ km}^2 + 9\text{ km}^2$

$|\Delta d_T|^2 = 178\text{ km}^2$

$|\Delta d_T| = 13.34\text{ km} = 13\text{ km}$

$\tan\theta = \frac{-3\text{ km}}{13\text{ km}}$

$\tan\theta = -0.2308$

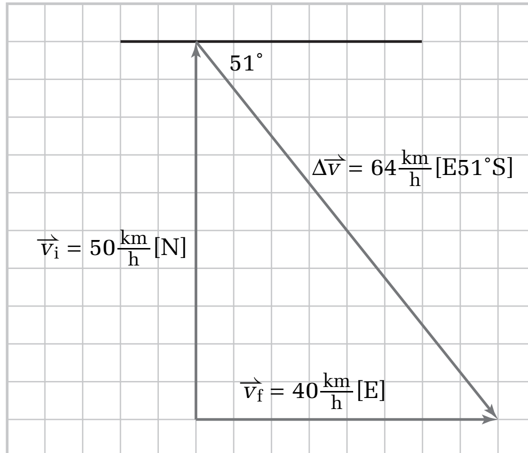
$\theta = \tan^{-1}(-0.2308)$

$\theta = -13°$

The truck's displacement is 13 km[E13°S].

34. Refer to the vector diagram and calculations below.

Scale 1 cm : 20 km



$\vec{v}_i = 50 \ \frac{km}{h}$ [N]

$\vec{v}_f = 40 \ \frac{km}{h}$ [E]

$\Delta\vec{v} = \vec{v}_f - \vec{v}_i$

Vector	***x*-component (km/h)**	***y*-component (km/h)**
$-\vec{v}_i$	0.0	−50
$\vec{v}_f$	40	0.0
$\Delta\vec{v}$	40	−50

$$\left|\Delta\vec{v}\right|^2 = (\Delta\vec{v}_x)^2 + (\Delta\vec{v}_y)^2$$

$$\left|\Delta\vec{v}\right|^2 = \left(40 \ \frac{km}{h}\right)^2 + \left(-50 \ \frac{km}{h}\right)^2$$

$$\left|\Delta\vec{v}\right|^2 = 1600 \ \frac{km}{h^2}^2 + 2500 \ \frac{km^2}{h^2}$$

$$\left|\Delta\vec{v}\right|^2 = 4100 \ \frac{km^2}{h^2}$$

$$\left|\Delta\vec{v}\right| = 64.03 \ \frac{km}{h} = 64 \ \frac{km}{h}$$

$$\tan\theta = \frac{-50 \ \frac{m}{s}}{40 \ \frac{m}{s}}$$

$$\tan\theta = -1.25$$

$$\theta = \tan^{-1}(-1.25)$$

$$\theta = -51.34° = -51°$$

The car’s change in velocity is 64 km/h[E51°S].

35. (a) 30 min or 0.50 h

(b) At 10:30 P.M., the tourist is 165 km[N] of Toronto, and at 11:00 P.M., the tourist is 110 km[N] of Toronto.

$\Delta\vec{d} = \vec{d}_2 - \vec{d}_1$

$\Delta\vec{d} = 110$ km[N] − 165 km[N]

$\Delta\vec{d} = -55$ km[N]

$\Delta\vec{d} = 55$ km[S]

Her displacement is 55 km[S].

(c) Her velocity is equal to displacement divided by the time interval.

$\vec{v} = \frac{\Delta\vec{d}}{\Delta t} = \frac{55\ \text{km[S]}}{0.5\ \text{h}}$

$\vec{v} = 110\ \frac{\text{km}}{\text{h}}\text{[S]}$

The tourist's velocity is 110 km/h[S].

36. (i) B: The car's position is the same.

(ii) C: The slope of the curve is increasing.

(iii) A: The slope is constant.

(iv) D: The slope of the curve is decreasing.

37. (a) The girl travels 400 m in 3 min.

$8.0\ \frac{\text{km}}{\text{h}} \times \frac{1\ \text{h}}{60\ \text{min}} \times \frac{1\ \text{min}}{60\ \text{s}} \times \frac{1000\ \text{m}}{1\ \text{km}} = 2.22\ \frac{\text{m}}{\text{s}}$

$12.0\ \frac{\text{km}}{\text{h}} \times \frac{1\ \text{h}}{60\ \text{min}} \times \frac{1\ \text{min}}{60\ \text{s}} \times \frac{1000\ \text{m}}{1\ \text{km}} = 3.33\ \frac{\text{m}}{\text{s}}$

$3\ \text{min} \times \frac{60\ \text{s}}{1\ \text{min}} = 180\ \text{s}$

$\Delta\vec{d}_{\text{girl}} = \vec{v}_{\text{girl}} \times \Delta t$

$\Delta\vec{d}_{\text{girl}} = 2.22\ \frac{\text{m}}{\text{s}} \times 180\ \text{s}$

$\Delta\vec{d}_{\text{girl}} = 400\ \text{m}$

$\Delta\vec{d}_{\text{girl}} + 400\ \text{m} = \Delta\vec{d}_{\text{mom}}$

$(\vec{v}_{\text{girl}} \times \Delta t) + 400\ \text{m} = (\vec{v}_{\text{mom}} \times \Delta t)$

$2.22\ \frac{\text{m}}{\text{s}} \times \Delta t + 400\ \text{m} = 3.33 \times \frac{\text{m}}{\text{s}}\Delta t$

$400\ \text{m} = 3.33\ \frac{\text{m}}{\text{s}} \times \Delta t - 2.22\ \frac{\text{m}}{\text{s}} \times \Delta t$

$400\ \text{m} = 1.11\ \frac{\text{m}}{\text{s}} \times \Delta t$

$\Delta t = \frac{400\ \text{m}}{1.11\ \frac{\text{m}}{\text{s}}}$

$\Delta t = 360.4\ \text{s}$

$\Delta t = 360\ \text{s}$

(b) As seen in the above equations, the mother catches the girl when they have travelled the same distance. The mother has to make up 400 m. It takes 360 s or 6 min for the mother to catch the girl.

(c) The mother catches the girl 1200 m from home as shown below.

$\Delta\vec{d}_{\text{mom}} = \vec{v}_{\text{mom}} \times \Delta t$

$\Delta\vec{d}_{\text{mom}} = 3.33\ \frac{\text{m}}{\text{s}} \times 360\ \text{s} = 1200\ \text{m}$

38. The car accelerates at $2.5\ \text{m/s}^2\text{[N]}$. Refer to the calculations below.

$\vec{a} = \frac{\Delta\vec{v}}{\Delta t} = \frac{\vec{v}_{\text{f}} - \vec{v}_{\text{i}}}{\Delta t}$

$\vec{a} = \frac{\vec{v}_{\text{f}} - \vec{v}_{\text{i}}}{\Delta t} = \frac{33\ \frac{\text{m}}{\text{s}} - 28\ \frac{\text{m}}{\text{s}}}{2.0\ \text{s}}$

$\vec{a} = \frac{5\ \frac{\text{m}}{\text{s}}}{2.0\ \text{s}} = +2.5\ \frac{\text{m}}{\text{s}^2} = 2.5\ \frac{\text{m}}{\text{s}^2}\text{[N]}$

39. The car travels 50 m or 5.0×10^1 m. Refer to the calculations below.

$$v_f^{\,2} = v_i^{\,2} + 2a\Delta d$$
$$\left(28\ \frac{\text{m}}{\text{s}}\right)^2 = \left(22\ \frac{\text{m}}{\text{s}}\right)^2 + 2 \times \left(3.0\ \frac{\text{m}}{\text{s}^2}\right) \times \Delta d$$
$$784\ \frac{\text{m}^2}{\text{s}^2} = 484\ \frac{\text{m}^2}{\text{s}^2} + 6\ \frac{\text{m}}{\text{s}^2} \times \Delta d$$
$$784\ \frac{\text{m}^2}{\text{s}^2} - 484\ \frac{\text{m}^2}{\text{s}^2} = 6\ \frac{\text{m}}{\text{s}^2} \times \Delta d$$
$$300\ \frac{\text{m}^2}{\text{s}^2} = 6\ \frac{\text{m}^2}{\text{s}^2} \times \Delta d$$
$$\Delta d = \frac{300\ \frac{\text{m}^2}{\text{s}^2}}{6\ \frac{\text{m}}{\text{s}^2}} = 50\ \text{m}$$

40. $v_f^{\,2} = v_i^{\,2} + 2a\Delta d$

$$v_f^{\,2} = \left(6.0\ \frac{\text{m}}{\text{s}}\right)^2 + 2 \times \left(4.0\ \frac{\text{m}}{\text{s}^2}\right) \times 216\ \text{m}$$
$$v_f^{\,2} = 36.0\ \frac{\text{m}^2}{\text{s}^2} + 1728\ \frac{\text{m}^2}{\text{s}^2}$$
$$v_f^{\,2} = 1764\ \frac{\text{m}^2}{\text{s}^2}$$
$$v_f = \sqrt{1764\ \frac{\text{m}^2}{\text{s}^2}}$$
$$v_f = 42\ \frac{\text{m}}{\text{s}}$$
$$\Delta t = \frac{v_f - v_i}{a}$$
$$\Delta t = \frac{42\ \frac{\text{m}}{\text{s}} - 6.0\ \frac{\text{m}}{\text{s}}}{4.0\ \frac{\text{m}}{\text{s}^2}}$$
$$\Delta t = \frac{36\ \frac{\text{m}}{\text{s}}}{4.0\ \frac{\text{m}}{\text{s}^2}}$$
$$\Delta t = 9.0\ \text{s}$$

It takes the race car 9.0 s to travel 216 m.

41. The sprinter achieves a time of 18.1 s for the race, as shown below.

First part of race

$$\Delta d_1 = \left(\frac{v_i + v_f}{2}\right)\Delta t_1$$
$$\Delta d_1 = \left(\frac{0 + 5.80\ \frac{\text{m}}{\text{s}}}{2}\right)(1.75\ \text{s})$$
$$\Delta d_1 = 5.075\ \text{m}$$

Second part of race

$$\Delta d_2 = 100\ \text{m} - 5.075\ \text{m} = 94.925\ \text{m}$$
$$\Delta t_2 = \frac{\Delta d_2}{v} = \frac{94.925\ \text{m}}{5.80\frac{\text{m}}{\text{s}}} = 16.37\ \text{s}$$
$$\Delta t_{total} = 1.75\ \text{s} + 16.37\ \text{s}$$
$$\Delta t_{total} = 18.12\ \text{s} = 18.1\ \text{s}$$

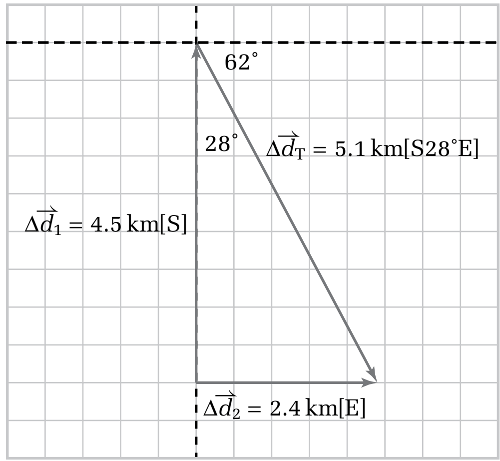
42. **(i)** (a)

(ii) (c)

(iii) (e)

43. Refer to the vector diagram and calculations below.

Scale 1 cm : 1 m



$30 \text{ min} \times \frac{60 \text{ s}}{1 \text{ min}} = 1800 \text{ s}$

$20 \text{ min} \times \frac{60 \text{ s}}{1 \text{ min}} = 1200 \text{ s}$

$\Delta\vec{d}_1 = \vec{v}_1\Delta t$

$\Delta\vec{d}_1 = 2.5 \frac{\text{m}}{\text{s}}[\text{S}](1800 \text{ s}) = 4500 \text{ m[S]}$

$\Delta\vec{d}_1 = 4.5 \text{ m[S]}$

$\Delta\vec{d}_2 = \vec{v}_2\Delta t$

$\Delta\vec{d}_2 = 2.0 \frac{\text{m}}{\text{s}}[\text{E}](1200 \text{ s}) = 2400 \text{ m[E]}$

$\Delta\vec{d}_2 = 2.4 \text{ m[E]}$

$\Delta\vec{d}_T = \Delta\vec{d}_1 + \Delta\vec{d}_2$

Vector	*x*-component (km)	*y*-component (km)
$\Delta\vec{d}_1$	0.0	–4.5
$\Delta\vec{d}_2$	+2.4	0.0
$\Delta\vec{d}_T$	+2.4	–4.5

$|\Delta d_T|^2 = (\Delta d_{T\ x})^2 + (\Delta d_{T\ y})^2$

$|\Delta d_T|^2 = (2.4 \text{ km})^2 + (-4.5 \text{ km})^2$

$|\Delta d_T|^2 = 5.76 \text{ km}^2 + 20.25 \text{ km}^2$

$|\Delta d_T|^2 = 26.01 \text{ km}^2$

$|\Delta d_T| = 5.1 \text{ km}$

$\tan\theta = \frac{-4.5 \text{ km}}{2.4 \text{ km}}$

$\tan\theta = -1.875$

$\theta = \tan^{-1}(-1.875)$

$\theta = -61.93° = -62°$

(a) The displacement of the kayak is 5.1 km[S28°E] or 5.1 km[E62°S].

(b) The average velocity is the displacement divided by the total time.

$\Delta t_T = 1800 \text{ s} + 1200 \text{ s} = 3000 \text{ s}$

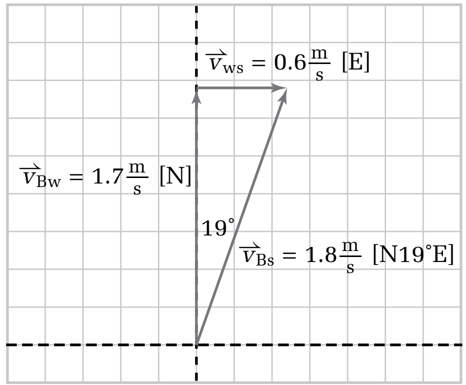
$\vec{v}_{ave} = \frac{5100 \text{ m[S28°E]}}{3000 \text{ s}}$

$\vec{v}_{ave} = 1.7 \frac{\text{m}}{\text{s}}[\text{S28°E}]$

The average velocity for the trip is 1.7 m/s[S28°E].

44. Refer to the vector diagram and the calculations below.

Scale 1 cm : 0.5 m/s



$$\vec{v}_{ws} = \frac{12 \text{ m[E]}}{20 \text{ s}} = 0.6 \ \frac{m}{s}[E]$$

$$\vec{v}_{Bw} = 1.7 \ \frac{m}{s}[N]$$

$$\vec{v}_{Bs} = \vec{v}_{Bw} + \vec{v}_{ws}$$

$$|\vec{v}_{Bs}|^2 = |\vec{v}_{Bw}|^2 + |\vec{v}_{ws}|^2$$

$$|\vec{v}_{Bs}|^2 = \left(1.7 \ \frac{m}{s}\right)^2 + \left(0.6 \ \frac{m}{s}\right)^2$$

$$|\vec{v}_{Bs}|^2 = 2.89 \ \frac{m^2}{s^2} + 0.36 \ \frac{m^2}{s^2}$$

$$|\vec{v}_{Bs}|^2 = 3.25 \ \frac{m^2}{s^2}$$

$$|\vec{v}_{Bs}| = 1.8 \ \frac{m}{s}$$

$$\tan \theta = \frac{0.6 \ \frac{m}{s}}{1.7 \ \frac{m}{s}}$$

$$\tan \theta = 0.3529$$

$$\theta = \tan^{-1}(0.3529)$$

$$\theta = 19.4° = 19°$$

Ben's velocity relative to the shore is 1.8 m/s[N19°E]. The time it takes to cross the river depends only on Ben's swimming velocity and is independent of the motion of the river.

$$\Delta t = \frac{|\Delta \vec{d}_R|}{|\vec{v}_{Bw}|}$$

$$\Delta t = \frac{1500 \text{ m}}{1.7 \ \frac{m}{s}}$$

$$\Delta t = 882.4 \text{ s}$$

$$\Delta t = 8.8 \times 10^2 \text{ s}$$

It will take 8.8×10^2 s for Ben to cross the river.

The downstream landing position depends only on the river current, and the time it took to cross the river, namely 882.4 s.

$$\Delta \vec{d}_S = \vec{v}_{ws} \Delta t$$

$$\Delta \vec{d}_S = 0.6 \ \frac{m}{s}[E](882.4 \text{ s})$$

$$\Delta \vec{d}_S = 529.4 \text{ m} = 5.3 \times 10^2 \text{ m[E]}$$

Ben will land 5.3×10^2 m downstream.

45. (a) Let p = passenger, t = train, w = walker, and g = ground.

$\vec{v}_{pg} = \vec{v}_{pt} + \vec{v}_{tg}$

$\vec{v}_{pg} = 1.8\ \frac{m}{s}[S] + 9.2\ \frac{m}{s}[N]$

$\vec{v}_{pg} = 7.4\ \frac{m}{s}[N]$

The velocity of the passenger relative to a person standing on the sidewalk (ground) is 7.4 m/s[N].

(b) From (a), the velocity of the passenger relative to the ground is always 7.4 m/s[N], and is used in the following equation.

$\vec{v}_{pg} = \vec{v}_{pw} + \vec{v}_{wg}$

$\vec{v}_{pw} = \vec{v}_{pg} - \vec{v}_{wg}$

$\vec{v}_{pw} = 7.4\ \frac{m}{s}[N] - 2.1\ \frac{m}{s}[S]$

$\vec{v}_{pw} = 7.4\ \frac{m}{s}[N] + 2.1\ \frac{m}{s}[N]$

$\vec{v}_{pw} = 9.5\ \frac{m}{s}[N]$

The velocity of the passenger relative to a person walking 2.1 m/s south is 9.5 m/s[N].

(c) The same formula is used.

$\vec{v}_{pg} = \vec{v}_{pw} + \vec{v}_{wg}$

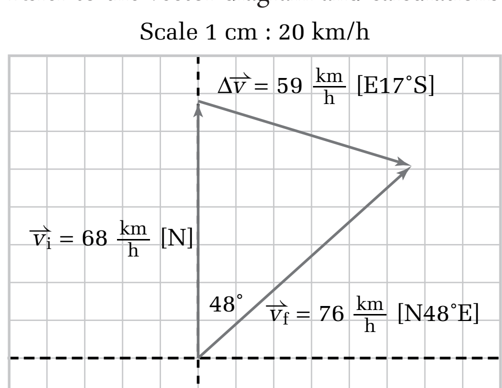
$\vec{v}_{pw} = \vec{v}_{pg} - \vec{v}_{wg}$

$\vec{v}_{pw} = 7.4\ \frac{m}{s}[N] - 2.1\ \frac{m}{s}[N]$

$\vec{v}_{pw} = 5.3\ \frac{m}{s}[N]$

The velocity of the passenger relative to a person walking 2.1 m/s south is 5.3 m/s[N].

46. Refer to the vector diagram and calculations below.



$\Delta\vec{v} = \vec{v}_f - v_i$

$-\vec{v}_i = 68\ \frac{km}{h}[N]$

$\vec{v}_f = 76\ \frac{km}{h}[N48°E]$

$\theta_f = 90° - 48° = 42°$

$v_{f\ x} = |\vec{v}_f| \cos\theta_f$

$v_{f\ x} = 76\ \frac{km}{h}(\cos 42°)$

$v_{f\ x} = 76\ \frac{km}{h} \times (0.7431)$

$v_{f\ x} = 56.48\ \frac{km}{h} = 57\ \frac{km}{h}$

$v_{f\,y} = \left|\vec{v_f}\right| \sin \theta_f$

$v_{f\,y} = 76\ \frac{km}{h}(\sin 42^\circ)$

$v_{f\,y} = 76\ \frac{km}{h} \times (0.6691)$

$v_{f\,y} = 50.85\ \frac{km}{h} = 51\ \frac{km}{h}$

Vector	*x*-component (km/h)	*y*-component (km/h)
$\vec{v_i}$	0.0	−68
$\vec{v_f}$	+56.48	+50.85
$\Delta\vec{v}$	+56.48	−17.15

$\left|\Delta\vec{v}\right|^2 = (\Delta\vec{v_x})^2 + (\Delta\vec{v_y})^2$

$\left|\Delta\vec{v}\right|^2 = \left(56.48\ \frac{km}{h}\right)^2 + \left(-17.15\ \frac{km}{h}\right)^2$

$\left|\Delta\vec{v}\right|^2 = 3189.99\ \frac{km^2}{h^2} + 294.12\ \frac{km^2}{h^2}$

$\left|\Delta\vec{v}\right|^2 = 3484.11\ \frac{km^2}{h^2}$

$\left|\Delta\vec{v}\right| = 59.02\ \frac{km}{h} = 59\ \frac{km}{h}$

$\tan\theta = \frac{-17.15\ \frac{km}{h}}{56.48\ \frac{km}{h}}$

$\tan\theta = -0.3036$

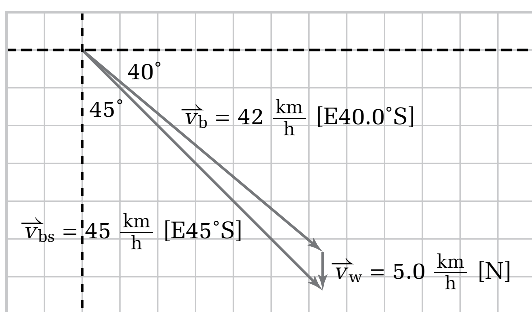
$\theta = \tan^{-1}(-0.3036)$

$\theta = -16.88^\circ = -17^\circ$

The skier's change in velocity is 59 km/h[E17°S]

47. Refer to the vector diagram and calculations below.

Scale 1 cm : 10 km/h



$\vec{v_b} = 42\ \frac{km}{h}$[E40.0°S]

$\vec{v_w} = 5.0\ \frac{km}{h}$[N]

$\theta_b = 40^\circ$

$v_{b\,x} = \left|\vec{v_b}\right| \cos\theta_b$

$v_{b\,x} = 42\ \frac{km}{h}(\cos 40^\circ)$

$v_{b\,x} = 42\ \frac{km}{h} \times (0.7660)$

$v_{b\,x} = 32.17\ \frac{km}{h} = 32.2\ \frac{km}{h}$

$$v_{b\,y} = \left|\vec{v}_b\right| \sin\theta_b$$
$$v_{b\,y} = 42\ \frac{km}{h}(\sin 40°)$$
$$v_{b\,y} = 42\frac{km}{h} \times (0.6428)$$
$$v_{b\,y} = 27.0\ \frac{km}{h} = 27\ \frac{km}{h}$$

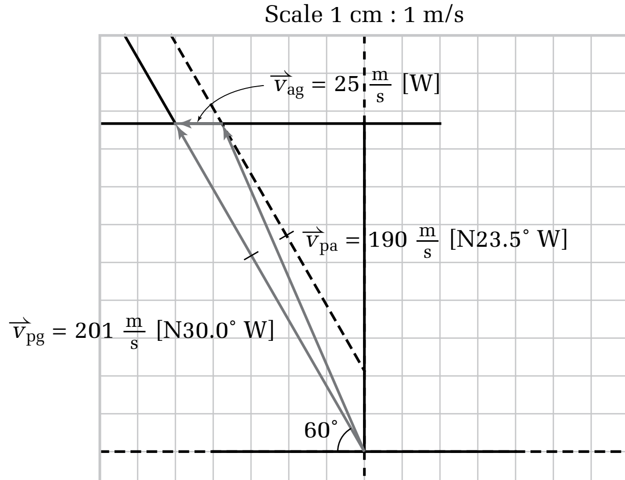
Vector	*x*-component (km/h)	*y*-component (km/h)
$\vec{v}_b$	+32.17	−27.0
$\vec{v}_w$	0.0	−5.0
$\vec{v}_{bs}$	+32.17	−32.0

$$\left|\Delta\vec{v}_{bs}\right|^2 = (\Delta\vec{v}_{bs\ x})^2 + (\Delta\vec{v}_{bs\ y})^2$$
$$\left|\Delta\vec{v}_{bs}\right|^2 = \left(32.17\ \frac{km}{h}\right)^2 + \left(-32\ \frac{km}{h}\right)^2$$
$$\left|\Delta\vec{v}_{bs}\right|^2 = 1034.91\ \frac{km^2}{h^2} + 1024\ \frac{km^2}{h^2}$$
$$\left|\Delta\vec{v}_{bs}\right|^2 = 2058.91\ \frac{km^2}{h^2}$$
$$\left|\Delta\vec{v}_{bs}\right| = 45.37\ \frac{km}{h} = 45\ \frac{km}{h}$$
$$\tan\theta = \frac{-32\ \frac{km}{h}}{32.17\ \frac{km}{h}}$$
$$\tan\theta = -0.9947$$
$$\theta = \tan^{-1}(-0.9947)$$
$$\theta = -44.85° = -45°$$

The velocity of the sailboat relative to the shore is 45 km/h[E45°S].

48. The solution is obtained by a scale vector diagram. Refer to the diagram below. The direction of the plane relative to the ground is known, but its magnitude is unknown. The magnitude of the plane's airspeed is known, but its direction is unknown. To solve the problem, draw a 25.0 m/s[W] wind vector dotted line parallel to the [N30.0°W] direction line. Then, draw the plane's airspeed vector so that it intersects the wind vector dotted line where it has a magnitude of 190 m/s. At this point, connect the tail of the wind vector to the tip of the airspeed vector, and join the plane's groundspeed vector to the tip of the wind vector to complete the diagram. From the scale diagram, the heading of the plane is [N23.5°W] and the velocity of the plane relative to the ground is 20 m/s[N30.0°W].

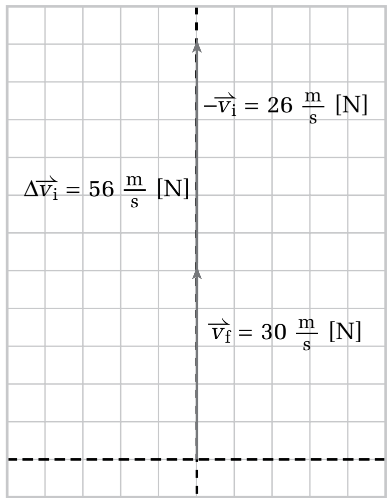
Scale 1 cm : 1 m/s



The plane should fly on a heading of [N23.5°W]. Its velocity relative to the ground will be 201 m/s[N30.0°W].

49. Refer to the vector diagram and calculations below.

Scale 1 cm : 10 m/s



$\vec{a} = \frac{\Delta\vec{v}}{\Delta t}$

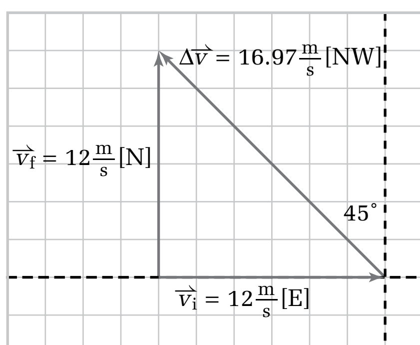
$\vec{a} = \frac{56\ \frac{m}{s}[N]}{3.0 \times 10^{-3}\ s}$

$\vec{a} = 1.9 \times 10^{4}\ \frac{m}{s^2}[N]$

The acceleration of the ball is 1.9×10^4 m/s^2[N].

50. Refer to the vector diagram and calculations below.

Scale 1 cm : 4 m/s



$\vec{v}_i = 12\ \frac{m}{s}$[E]

$\vec{v}_f = 12\ \frac{m}{s}$[N]

$\Delta\vec{v} = \vec{v}_f - \vec{v}_i$

Vector	***x*-component (m/s)**	***y*-component (m/s)**
$-\vec{v}_i$	−12	0.0
$\vec{v}_f$	0.0	+12
$\Delta\vec{v}$	−12	+12

$$\left|\Delta\vec{v}\right|^2 = (\Delta\vec{v}_x)^2 + (\Delta\vec{v}_y)^2$$

$$\left|\Delta\vec{v}\right|^2 = \left(-12\ \frac{m}{s}\right)^2 + \left(12\ \frac{m}{s}\right)^2$$

$$\left|\Delta\vec{v}\right|^2 = 144\ \frac{m^2}{s^2} + 144\ \frac{m^2}{s^2}$$

$$\left|\Delta\vec{v}\right|^2 = 288\ \frac{m^2}{s^2}$$

$$\left|\Delta\vec{v}\right| = 16.97\frac{m}{s}$$

$$\tan\theta = \frac{12\ \frac{m}{s}}{-12\ \frac{m}{s}}$$

$$\tan\theta = -1$$

$$\theta = \tan^{-1}(-1)$$

$$\theta = -45°$$

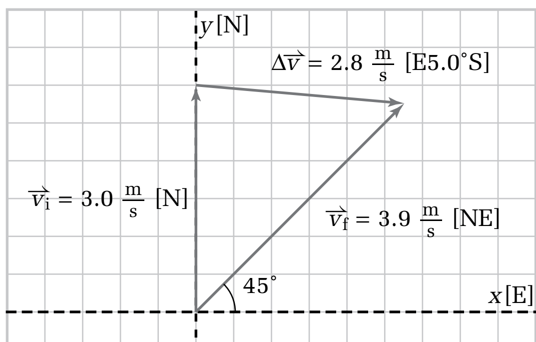
$$\vec{a} = \frac{\Delta v}{\Delta t} = \frac{16.97\ \frac{m}{s}[NW]}{2.5\ s} = 6.79\ \frac{m}{s^2}[NW]$$

$$\therefore \vec{a} = 6.8\ \frac{m}{s^2}[NW]$$

The acceleration of the cyclist is 6.8 m/s^2[NW]

51. Refer to the vector diagram and calculations below.

Scale 1 cm : 1 m/s



$$\vec{v}_f - \vec{v}_i = \Delta\vec{v}$$

$$\vec{v}_f = \Delta\vec{v} + \vec{v}_i$$

$$\vec{v}_i = 3.0\ \frac{m}{s}[N]$$

$$\Delta\vec{v} = \vec{a}\Delta t$$

$$\Delta\vec{v} = 1.4\ \frac{m}{s^2}[E5.0°S](2.0\ s)$$

$$\Delta\vec{v} = 2.8\ \frac{m}{s}[E5.0°S]$$

$$\Delta v_x = \left|\Delta\vec{v}\right| \cos\theta_{\Delta v}$$

$$\Delta v_x = 2.8\ \frac{m}{s}(\cos 5.0°)$$

$$\Delta v_x = 2.8\ \frac{m}{s} \times (0.9962)$$

$$\Delta v_x = 2.79\ \frac{m}{s}$$

$$\Delta v_y = -\left|\Delta\vec{v}\right| \sin\theta_{\Delta v}$$

$$\Delta v_y = -2.8\ \frac{m}{s}(\sin 5.0°)$$

$$\Delta v_y = -2.8\ \frac{m}{s}(0.0872)$$

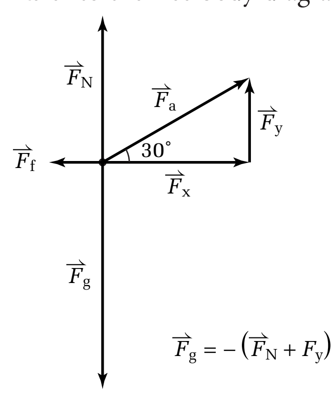
$$\Delta v_y = -0.244\ \frac{m}{s}$$

Vector	*x*-component (m/s)	*y*-component (m/s)
$\vec{v}_i$	0.0	+3.0
$\Delta\vec{v}$	+2.79	−0.244
$\vec{v}_f$	+2.79	+2.76

$$|\vec{v}_f|^2 = (\vec{v}_{f\ x})^2 + (\vec{v}_{f\ y})^2$$
$$|\vec{v}_f|^2 = \left(2.79\ \frac{m}{s}\right)^2 + \left(2.76\ \frac{m}{s}\right)^2$$
$$|\vec{v}_f|^2 = 7.78\ \frac{m^2}{s^2} + 7.62\ \frac{m}{s^2}$$
$$|\vec{v}_f|^2 = 15.40\ \frac{m^2}{s^2}$$
$$|\vec{v}_f| = 3.92\ \frac{m}{s} = 3.9\ \frac{m}{s}$$
$$\tan\theta_f = \frac{2.76\ \frac{m}{s}}{2.79\ \frac{m}{s}}$$
$$\tan\theta_f = 0.9892$$
$$\theta_f = \tan^{-1}(0.9892)$$
$$\theta_f = 44.69^\circ = 45^\circ$$

The new velocity of the player is 3.9 m/s[NE].

52. (a) Refer to the free body diagram.

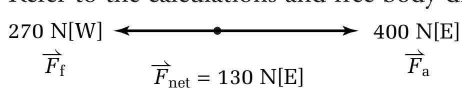


(b) The toboggan will accelerate in the horizontal direction.

(c) The toboggan will move at a constant velocity in the horizontal direction.

(d) It would slow down and stop.

53. Refer to the calculations and free body diagram below.



$$\vec{F}_g = m\vec{g}$$
$$\vec{F}_g = 32.0\ \text{kg} \times \left(-9.81\ \frac{N}{kg}\right)$$
$$\vec{F}_g = -313.92\ \text{N}$$
$$\vec{F}_N = -\vec{F}_g$$
$$\vec{F}_N = 313.92\ \text{N}$$
$$\vec{F}_f = -\mu\vec{F}_N$$
$$\vec{F}_f = -0.87 \times (313.92\ \text{N})$$
$$\vec{F}_f = -273.11\ \text{N} = -2.7 \times 10^2\ \text{N}$$

(a) The force of friction is 2.7×10^2 N[W]

$\vec{F}_{net} = \vec{F}_f + \vec{F}_a$

$\vec{F}_{net} = 270$ N[W] + 400 N[E]

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

$\vec{a} = \frac{\vec{F}_{net}}{m} = \frac{130 \text{ N[E]}}{32.0 \text{ kg}}$

$\vec{a} = 4.0 \frac{\text{m}}{\text{s}^2}$[E]

(b) The acceleration of the cart is 4.0 m/s^2[E].

$\Delta\vec{d} = \vec{v}_i \Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$

$\Delta\vec{d} = 0 + \frac{1}{2}(4.0 \frac{\text{m}}{\text{s}^2}\text{[E]})(5.0 \text{ s})^2$

$\Delta\vec{d} = 2.0 \frac{\text{m}}{\text{s}^2}\text{[E]}(25.0 \text{ s}^2)$

$\Delta\vec{d} = 50 \text{ m[E]} = 5.0 \times 10^1 \text{ m[E]}$

(c) The cart moves 5.0×10^1 m[E] in 5.0 s

54. Refer to the calculations below.

$\Delta\vec{d} = \vec{v}_i \Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$

$15 \text{ m[N]} = 0 + \frac{1}{2}\vec{a} \times (10 \text{ s})^2$

$15 \text{ m[N]} = \frac{1}{2}\vec{a} \times 100 \text{ s}^2$

$15 \text{ m[N]} = \vec{a} \times 50 \text{ s}^2$

$\vec{a} = \frac{15 \text{ m[N]}}{50 \text{ s}^2}$

$\vec{a} = 0.30 \frac{\text{m}}{\text{s}^2}$[N]

(a) The acceleration of the wagon is 0.30 m/s^2[N].

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

$\vec{F}_{net} = 27 \text{ kg} \times 0.3 \frac{\text{m}}{\text{s}^2}$[N]

$\vec{F}_{net} = 8.1$ N[N]

(b) The net force acting on the wagon is 8.1 N[N].

$\vec{F}_{net} = \vec{F}_x + \vec{F}_f$

$\vec{F}_x = \vec{F}_{net} - \vec{F}_f$

$\vec{F}_x = 8.1 \text{ N} - (-3.1 \text{ N})$

$F_x = 8.1 \text{ N} + 3.1 \text{ N} = 11.2 \text{ N}$

$\cos 25° = \frac{|\vec{F}_x|}{|\vec{F}_a|}$

$|\vec{F}_a| = \frac{|\vec{F}_x|}{\cos 25°} = \frac{11.2 \text{ N}}{0.9063}$

$|\vec{F}_a| = 12.36 \text{ N}$

$\vec{F}_a = 12$ N[at an angle of 25°]

55. $\vec{F}_1 = 20$ N[W]

$F_{1\,x} = -20$ N

$F_{1\,y} = 0.0$ N

$\vec{F}_2 = 15\text{ N[N]}$

$F_{2\ x} = 0.0\text{ N}$

$F_{2\ y} = 15\text{ N}$

$\vec{F}_3 = 40\text{ N[E30°S]}$

$$F_{3\ x} = \left|\vec{F}_3\right| \cos\theta_3$$
$$F_{3\ x} = 40\text{ N}(\cos 30°)$$
$$F_{3\ x} = 40\text{ N} \times (0.8660)$$
$$F_{3\ x} = 34.64\text{ N} = 34.6\text{ N}$$

$$F_{3\ y} = \left|\vec{F}_3\right| \sin\theta_3$$
$$F_{3\ y} = -40\text{ N}(\sin 30°)$$
$$F_{3\ y} = -40\text{ N} \times (0.5)$$
$$F_{3\ y} = -20\text{ N}$$

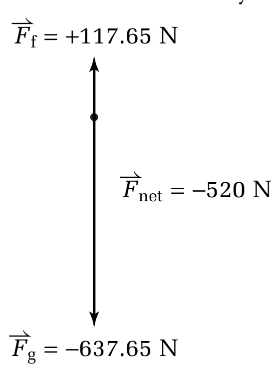
Vector	*x*-component (N)	*y*-component (N)
$\vec{F}_1$	−20	0.0
$\vec{F}_2$	0.0	+15
$\vec{F}_3$	+34.6	−20
$\vec{F}_{net}$	+14.6	−5

$$\left|\vec{F}_{net}\right|^2 = (\vec{F}_{net\ x})^2 + (\vec{F}_{net\ y})^2$$
$$\left|\vec{F}_{net}\right|^2 = \left(14.6\text{ N}\right)^2 + \left(-5\text{ N}\right)^2$$
$$\left|\vec{F}_{net}\right|^2 = 213.16\text{ N}^2 + 25\text{ N}^2$$
$$\left|\vec{F}_{net}\right|^2 = 238.16\text{ N}^2$$
$$\left|\vec{F}_{net}\right| = 15.43\text{ N} = 15\text{ N}$$

$$\tan\theta = \frac{-5\text{ N}}{14.6\text{ N}}$$
$$\tan\theta = 0.3425$$
$$\theta = \tan^{-1}(0.3271)$$
$$\theta = 18.91° = 19°$$

The net force on the toy is 15N[E19°S]

56. Refer to the free body diagram and calculations below.



$$\vec{F}_g = m\vec{g}$$
$$\vec{F}_g = 65\text{ kg} \times \left(-9.81\ \frac{\text{N}}{\text{kg}}\right)$$
$$\vec{F}_g = -637.65\text{ N}$$

$$\vec{F}_{net} = m\vec{a}$$
$$\vec{F}_{net} = 65\ \text{kg} \times (-8.0\ \tfrac{\text{m}}{\text{s}^2}) = -520\ \text{N}$$
$$\vec{F}_{net} = \vec{F}_f + \vec{F}_g$$
$$\vec{F}_f = \vec{F}_{net} - \vec{F}_g$$
$$\vec{F}_f = -520\ \text{N} - (-637.65\ \text{N})$$
$$\vec{F}_f = +117.65\ \text{N}$$
$$\vec{F}_f = 1.2 \times 10^2\ \text{N[up]}$$

The force of air resistance is 1.2×10^2 N[up].