# Work, Power, and Efficiency 

## Practice Problem Solutions

## Student Textbook page 221

## 1. (i) Frame the Problem

- Paul Anderson is doing work against gravity as he lifts the students.
- His applied force causes the students to move upward at a constant velocity.
- Since the force and the displacement are in the same direction, positive work is done.


## Identify the Goal

The amount of work done when lifting the students

## Variables and Constants

Known

## Unknown

$F_{\|}=1.1 \times 10^{4} \mathrm{~N}$
W
$\Delta d=0.52 \mathrm{~m}$

## Strategy

Use the formula for work when lifting.
Substitute the variables into the formula.
Multiply.
An $\mathrm{N} \cdot \mathrm{m}$ is equivalent to a J , therefore,

Calculations
$W=F_{\|} \Delta d$
$W=\left(1.1 \times 10^{4} \mathrm{~N}\right)(0.52 \mathrm{~m})$
$W=5720 \mathrm{~N} \cdot \mathrm{~m}$
$W=5720 \mathrm{~J}$

He did $5.7 \times 10^{3} \mathrm{~J}$ of work to lift the students.

## Validate

He did positive work on the students as he lifted them. The unit for work is the joule.

## (ii) Frame the Problem

- The child's weight is given. This is the force needed to lift him.
- When you lift the child, you do work on him.

Identify the Goal
The height the child must be lifted for you to do 5720 J of work

## Variables and Constants

| Known | Unknown |
| :--- | :--- |
| $W=5720 \mathrm{~J}$ | $\Delta d$ |
| $F_{\\|}=135 \mathrm{~N}$ |  |

Strategy
Use the formula for work done when lifting.
Rearrange to solve for $\Delta d$.
Substitute the variables into the formula.
Divide.
A $\frac{\mathrm{J}}{\mathrm{N}}$ is equivalent to an m .

## Calculations

$W=F_{\|} \Delta d$
$\Delta d=\frac{W}{F_{1}}$
$\Delta d=\frac{5720 \mathrm{~J}}{135 \mathrm{~N}}$
$\Delta d=42 \frac{\mathrm{~J}}{\mathrm{~N}}$
$\Delta d=42 \mathrm{~m}$

You would have to lift the student 42 m up to do the same work as Paul Anderson did.

## Validate

The height lifted is equal to the work done divided by the force required. The unit for height is the m .

## 2. Frame the Problem

- The force of gravity does work on the boulder to make it fall.
- The mass can be used along with the acceleration due to gravity to determine the force of gravity on the boulder.


## Identify the Goal

The distance the boulder fell
Variables and Constants

| Known | Implied | Unknown |
| :--- | :--- | :--- |
| $m=75 \mathrm{~kg}$ | $g=9.81 \frac{\mathrm{~m}}{\mathrm{~s}^{2}}$ | $\Delta d$ |
| $W=6.0 \times 10^{4} \mathrm{~J}$ |  | $F_{g}$ |

## Strategy

## Calculations

Find the force of gravity on the boulder by using
the formula.

$$
\begin{aligned}
& F_{\mathrm{g}}=m g \\
& F_{\mathrm{g}}=(75 \mathrm{~kg})\left(9.81 \frac{\mathrm{~m}}{\mathrm{~s}^{2}}\right) \\
& F_{\mathrm{g}}=735.75 \mathrm{~N} \\
& \Delta d=\frac{W}{F_{11}} \\
& \Delta d=\frac{6.0 \times 10^{4} \mathrm{~J}}{735.75} \mathrm{~N} \\
& \Delta d=8 \frac{\mathrm{~J}}{\mathrm{~N}} \\
& \Delta d=82 \mathrm{~m}
\end{aligned}
$$

Substitute in the variables.
Multiply.
Use the formula for work to find the distance.
Substitute in the variables.
Divide.
A $\frac{\mathrm{J}}{\mathrm{N}}$ is equivalent to an m .
The boulder fell a distance of 82 m .

## Validate

The force of gravity does work on the boulder, causing it to fall. The unit for distance is the $m$.

## 3. Frame the Problem

- The student does work on the cart by exerting a force on it over a distance.
- The applied force causes the cart to accelerate since there is no friction acting on it.


## Identify the Goal

The acceleration of the cart

## Variables and Constants

Known

## Unknown

$$
\begin{array}{ll}
m=0.100 \mathrm{~kg} & a \\
\Delta d=0.100 \mathrm{~m} & F_{\|} \\
W=0.0230 \mathrm{~J} &
\end{array}
$$

## Strategy

## Calculations

Use the formula for work to find the force applied. $\quad F_{\|}=\frac{W}{\Delta d}$
Substitute in the variables.
Divide.
A $\frac{\mathrm{J}}{\mathrm{m}}$ is equivalent to an N .
$F_{\|}=\frac{0.0230 \mathrm{~J}}{0.100 \mathrm{~m}}$
$F_{\|}=0.230 \frac{\mathrm{~J}}{\mathrm{~m}}$
$F_{\|}=0.230 \mathrm{~N}$
Use Newton's second law to find acceleration.
$a=\frac{F}{m}$
Substitute in the variables.
Divide.
An $\frac{\mathrm{N}}{\mathrm{kg}}$ is equivalent to an $\frac{\mathrm{m}}{\mathrm{s}^{2}}$.

$$
a=\frac{0.230 \mathrm{~N}}{0.100 \mathrm{~kg}}
$$

$$
a=2.30 \frac{\mathrm{~N}}{\mathrm{~kg}}
$$

The cart's acceleration is $2.30 \mathrm{~m} / \mathrm{s}^{2}$.

## Validate

The work done on the cart and its displacement were used to find the force applied. Force has units of N . The force and mass were used to find the acceleration, which has units of $\mathrm{m} / \mathrm{s}^{2}$. Since there was no friction acting, the net force was equal to the applied force.

## Practice Problem Solutions

## Student Textbook page 225

## 4. Frame the Problem

- The mover exerts a force on the box to move it some distance along the hallway.


## Identify the Goal

The length of the hallway

## Variables and Constants

| Known | Unknown |
| :--- | :--- |
| $F_{\\|}=3.00 \times 10^{2} \mathrm{~N}$ | $\Delta d$ |
| $W=1.90 \times 10^{3} \mathrm{~J}$ |  |

## Strategy

## Calculations

Use the formula for work to find the displacement.
Substitute in the variables.

$$
\Delta d=\frac{1.90 \times 10^{3} \mathrm{~J}}{30.0 \times 10^{2} \mathrm{~N}}
$$

Divide.
$\Delta d=6.33 \frac{\mathrm{~J}}{\mathrm{~N}}$
A $\frac{\mathrm{J}}{\mathrm{N}}$ is equivalent to an m .
$\Delta d=6.33 \mathrm{~m}$

The box moved 6.33 m , so this is the length of the hallway.

## Validate

The force and the displacement were in the same direction; thus, the force did work on the box to make it move. The length of the hallway has the same units as the displacement, which is $m$.

## 5. Frame the Problem

- Work is done on the piano as the force makes it move across the floor.
- The maximum amount of work is done if the force is horizontal, because this is in the same direction as the piano's displacement.


## Identify the Goal

The average horizontal force
Variables and Constants

Known
$\Delta d=12.0 \mathrm{~m}$
$W=2.70 \times 10^{3} \mathrm{~J}$

Unknown
$F_{\|}$

## Strategy

Use the formula for work to find the force.
Substitute in the variables.
Divide.
A $\frac{\mathrm{J}}{\mathrm{m}}$ is equivalent to an N .

## Calculations

$F_{\|}=\frac{W}{\Delta d}$
$F_{\|}=\frac{2.70 \times 10^{3} \mathrm{~J}}{12.0 \mathrm{~m}}$
$F_{\| \|}=225 \frac{\mathrm{~J}}{\mathrm{~m}}$
$F_{\| \mid}=225 \mathrm{~N}$

The average horizontal force needed on the piano is 225 N .

## Validate

The force and the displacement were in the same direction; thus, the force did work on the piano.

## 6. Frame the Problem

- The crane does work on the beam to lift it.
- The force required by the crane to lift the beam is equal to the force of gravity on the beam because it is lifted at a constant velocity.


## Identify the Goal

The vertical distance the beam is lifted

## Variables and Constants

| Known | Implied | Unknown <br> $m=487 \mathrm{~kg}$ |
| :--- | :--- | :--- |
|   <br> $W=5.20 \times 10^{4} \mathrm{~J}$ $g=9.81 \frac{\mathrm{~m}}{\mathrm{~s}^{2}}$ | $F_{\mathrm{g}}$ |  |

## Strategy

Find the force of gravity on the beam by using the formula.
Substitute in the variables.

## Calculations

$F_{\mathrm{g}}=m g$

Multiply.
Use the formula for work to find the distance.
Substitute in the variables.
Divide.
A $\frac{\mathrm{J}}{\mathrm{N}}$ is equivalent to an m .
The boulder fell a distance of 10.9 m .
Validate
The force of the crane does work on the beam, causing it to rise. The unit for distance is the m .

## 7. (a) and (b)

Frame the Problem

- The teacher's hand exerts a force straight upward on the briefcase.
- The briefcase is moving horizontally.
- The directions of the force and the displacement are perpendicular.


## Identify the Goal

The work done by the teacher's hand on the briefcase

## Strategy

Since the force and displacement are perpendicular, the work done by the force is zero.

## Validate

This situation satisfies Case 3 in the textbook.

## 8. Frame the Problem

- The force is exerted horizontally on the bowling ball.
- The bowling ball moves horizontally.
- The force does positive work on the bowling ball.


## Identify the Goal

The work done by the force on the ball
Variables and Constants

| Known | Unknown |
| :--- | :--- |
| $F_{\\| \mid}=2.00 \times 10^{2} \mathrm{~N}$ | $W$ |
| $\Delta d=1.50 \mathrm{~m}$ |  |

## Strategy

Use the formula for work.
Substitute in the variables.
Multiply.
An $\mathrm{N} \cdot \mathrm{m}$ is equivalent to a J .

## Calculations

$W=F_{\|} \Delta d$
$W=\left(2.00 \times 10^{2} \mathrm{~N}\right)(1.50 \mathrm{~m})$
$W=3.00 \times 10^{2} \mathrm{~N} \cdot \mathrm{~m}$
$W=3.00 \times 10^{2} \mathrm{~J}$

The force did $3.00 \times 10^{2} \mathrm{~J}$ of work on the bowling ball.

## Validate

The force and the displacement were both in the same direction; thus, the force did positive work on the ball. The unit for work is the joule.

## 9. Frame the Problem

- Voyager is moving in deep space, where no forces are acting on it.


## Identify the Goal

The amount of work done on Voyager

## Strategy

No force is needed to act on Voyager to keep it moving, since there is no friction or gravity to impede its motion. Since there is no force, there is no work being done on it.

## Validate

The force on Voyager is zero; thus, the work done is also zero. This satisfies Case 2 in the textbook.

## 10. Frame the Problem

- The students exert a force on the stump.
- The stump does not move.


## Identify the Goal

The work done on the stump by the students

## Strategy

Since the stump did not move, the students did not do work on it.
Validate
This satisfies Case 1 in the textbook.

## Practice Problem Solutions

## Student Textbook page 229

## 11. Frame the Problem

- The area under the force-versus-position graphs gives the amount of work done.
- The area of a rectangle or triangle can be found using simple formulas.


## Identify the Goal

The work done by the force.

## Variables and Constants

Known Unknown

Area

## GRAPH A

## Strategy

Find the area of the rectangle using the formula for area.
Substitute in the variables.
Multiply.
An $\mathrm{N} \cdot \mathrm{m}$ is equivalent to a J .
The work done is equal to the area
The work done is $1.8 \times 10^{2} \mathrm{~J}$.

## GRAPH B

## Strategy

Find the area of the triangles using the formula for area.
Substitute in the variables.

Multiply, then add.
An $\mathrm{N} \cdot \mathrm{m}$ is equivalent to a J .
The work done is equal to the area

## Calculations

Area $=\frac{1}{2}$ base $\times$ height
$A=\frac{1}{2}(15.0 \mathrm{~m})(2.0 \mathrm{~N})$ $+\frac{1}{2}(25.0 \mathrm{~m})(4.0 \mathrm{~N})$
$A=65 \mathrm{~N} \cdot \mathrm{~m}$
$A=65 \mathrm{~J}$
$W=65 \mathrm{~J}$

## Calculations

Area $=$ length $\times$ width
$A=(15 \mathrm{~N})(12 \mathrm{~m})$
$A=1.8 \times 10^{2} \mathrm{~N} \cdot \mathrm{~m}$
$A=1.8 \times 10^{2} \mathrm{~J}$
$W=1.8 \times 10^{2} \mathrm{~J}$
$\mathrm{N} \cdot \mathrm{m}$

The work done is 65 J .

## GRAPH C

## Strategy

Find the area of the triangles using the formula for area.
Substitute in the variables.

Multiply, then add.
An $\mathrm{N} \cdot \mathrm{m}$ is equivalent to a J .
The work done is equal to the area
The work done is 0 J .

## GRAPH D

## Strategy

Find the approximate area of the triangle using the formula for area.
Substitute in the variables.
Multiply.
An $\mathrm{N} \cdot \mathrm{m}$ is equivalent to a J .
The work done is equal to the area

## Calculations

Area $=\frac{1}{2}$ base $\times$ height
$A=\frac{1}{2}(2.0 \mathrm{~m})(5.0 \mathrm{~N})$ $+\frac{1}{2}(2.0 \mathrm{~m})(-5.0 \mathrm{~N})$
$A=0 \mathrm{~N} \cdot \mathrm{~m}$
$A=0 \mathrm{~J}$
$W=0 \mathrm{~J}$

## Calculations

Area $=\frac{1}{2}$ base $\times$ height
$A=\frac{1}{2}(15.0 \mathrm{~m})(30 \mathrm{~N})$
$A=225 \mathrm{~N} \cdot \mathrm{~m}$
$A=225 \mathrm{~J}$
$W=225 \mathrm{~J}$

The work done is approximately 225 J . (Note: the painstaking process of dividing the area into numerous rectangles and triangles gives a slightly larger answer of 230 J .)

Validate
Work equal force times displacement, which is equal to the area of the graph in each case. The unit for work is the J.
12.
force vs. displacement


## 13. Frame the Problem

- The amount of force required will increase as the elastic band is stretched.


## Strategy

Answers will vary depending on the elastic band used and the students' ability to estimate the amount of force. However, the force versus displacement graphs should all resemble the one below.
force vs. displacement


## Practice Problem Solutions

Student Textbook page 235

## 14. Frame the Problem

- The applied force does positive work on the statue as it lifts it.
- The applied force does negative work on the statue as it lowers it back down.

PART A

## Identify the Goal

The work done by the applied force.
Variables and Constants

## Known

$\Delta d=2.33 \mathrm{~m}$
$m=180 \mathrm{~kg}$

## Strategy

Find the force of gravity on the statue by using the formula
Substitute in the variables
Multiply
Use the formula for work.
Substitute in the variables.
Multiply.
An $\mathrm{N} \cdot \mathrm{m}$ is equivalent to a J .

Unknown
F
W

## Calculations

$F_{\mathrm{g}}=m g$
$F_{\mathrm{g}}=(180 \mathrm{~kg})\left(9.81 \frac{\mathrm{~N}}{\mathrm{~kg}}\right)$
$F_{\mathrm{g}}=1765.8 \mathrm{~N}$
$W=F \Delta d$
$W=(1765.8 \mathrm{~N})(2.33 \mathrm{~m})$
$W=4.11 \times 10^{3} \mathrm{~N} \cdot \mathrm{~m}$
$W=4.11 \times 10^{3} \mathrm{~J}$

The applied force did $4.11 \times 10^{3} \mathrm{~J}$ of work to lift the statue.

## Validate

The force and the displacement were in the same direction, so the force did positive work on the statue. The unit for work is the J.

## PART B

Identify the Goal
The work done by the applied force.
Variables and Constants

| Known | Implied | Unknown |
| :--- | :--- | :--- |
| $\Delta d=-2.33 \mathrm{~m}$ | $g=9.81 \frac{\mathrm{~N}}{\mathrm{~kg}}$ | $F$ |
| $m=180 \mathrm{~kg}$ |  | $W$ |

## Strategy

Find the force of gravity on the statue
by using the formula
Substitute in the variables
Multiply
Use the formula for work.
Substitute in the variables.
Multiply.
An $\mathrm{N} \cdot \mathrm{m}$ is equivalent to a J .

## Calculations

$F_{\mathrm{g}}=m g$
$F_{\mathrm{g}}=(180 \mathrm{~kg})\left(9.81 \frac{\mathrm{~N}}{\mathrm{~kg}}\right)$
$F_{\mathrm{g}}=1765.8 \mathrm{~N}$
$W=F \Delta d$
$W=(1765.8 \mathrm{~N})(-2.33 \mathrm{~m})$
$W=-4.11 \times 10^{3} \mathrm{~N} \cdot \mathrm{~m}$
$W=-4.11 \times 10^{3} \mathrm{~J}$

The applied force did $-4.11 \times 10^{3} \mathrm{~J}$ of work to lower the statue.

## Validate

The force and the displacement were in the opposite direction, so the force did negative work on the statue. The unit for work is the J.

## 15. Frame the Problem

- As the mechanic raises the hood he does positive work on the hood since the applied force and displacement are in the same direction.
- As the mechanic lowers the hood he does negative work on the hood since the applied force and the displacement are in opposite directions.


## Identify the Goal

The work done by the mechanic.

## PART A

Variables and Constants

Known
$F=45 \mathrm{~N}$
$\Delta d=2.80 \mathrm{~m}$

## Strategy

Use the formula for work.
Substitute the variables.
Multiply.
An $\mathrm{N} \cdot \mathrm{m}$ is equivalent to a J .

## Unknown

W

The mechanic did 126 J of work on the hood to lift it.
Validate
The applied force and the displacement are in the same directions. The work done is positive. The unit for work is the J.

PART B
Variables and Constants
Known
Unknown
$F=45 \mathrm{~N}$
W
$\Delta d=-2.80 \mathrm{~m}$

Strategy
Use the formula for work.
Substitute the variables.
Multiply.
An $\mathrm{N} \cdot \mathrm{m}$ is equivalent to a J .

Calculations
$W=F \Delta d$
$W=(45 \mathrm{~N})(-2.80 \mathrm{~m})$
$W=-126 \mathrm{~N} \cdot \mathrm{~m}$
$W=-126 \mathrm{~J}$

The mechanic did -126 J of work on the hood to lower it.

## Validate

The applied force and the displacement are in opposite directions. The work done is negative. The unit for work is the J .

## 16. Frame the Problem

- The applied force and the displacement are not parallel to each other, so only part of the force does work in the direction of motion.


## Identify the Goal

The work done by the father on the baby carriage.
Variables and Constants
Known Unknown
$F=172.0 \mathrm{~N} \quad W$
$\Theta=47^{\circ}$
$\Delta d=16.0 \mathrm{~m}$

Strategy
Use the formula for work.
Substitute in the variables.
Multiply.
An $\mathrm{N} \cdot \mathrm{m}$ is equivalent to a J .

## Calculations

$W=F \Delta d \cos \Theta$
$W=(172.0 \mathrm{~N})(16.0 \mathrm{~m})\left(\cos 47^{\circ}\right)$
$W=1.88 \times 10^{3} \mathrm{~N} \cdot \mathrm{~m}$
$W=1.88 \times 10^{3} \mathrm{~J}$

The father did $1.88 \times 10^{3} \mathrm{~J}$ of work on the baby carriage.

## Validate

The force and the displacement were not parallel, so only a component of the force did the work. The unit for work is the J.

## 17. Frame the Problem

- The applied force and the displacement are not parallel to each other, so only part of the force does work in the direction of motion.


## Identify the Goal

The magnitude of the force.

## Variables and Constants

Known
$W=2690 \mathrm{~J}$
$\Theta=32^{\circ}$
$\Delta d=23.0 \mathrm{~m}$

## Strategy

Use the formula for work to find the force.
Substitute in the variables.
Multiply and divide.
A $\frac{\mathrm{J}}{\mathrm{m}}$ is equivalent to an N .

Unknown
F

The force required has a magnitude of 138 N .

## Validate

The force was not parallel to the displacement, so only part of it was doing work to move the shopping cart. The unit for force is the N .

## 18. Frame the Problem

The applied force and the displacement are not parallel, so only a component of the force is doing work to move the wheelbarrow.

## Identify the Goal

The angle between the direction of the force and the horizontal.

## Variables and Constants

Known
$F=124 \mathrm{~N}$
$W=7314 \mathrm{~J}$
$\Delta d=77.0 \mathrm{~m}$

## Strategy

Use the formula for work to find the angle.
Substitute in the variables.
Multiply and divide.
Take the inverse cosine.

Unknown
$\Theta$

The angle between the force and the horizontal is $40.0^{\circ}$.

## Validate

The force and displacement are not parallel to each other, so only a component of the force is doing the work.

## Practice Problem Solutions

## Student Textbook page 238

## 19. Frame the Problem

- The tennis ball is moving so it has kinetic energy.
- The speed needs to be expressed in the appropriate units, the $\frac{\mathrm{m}}{\mathrm{s}}$.


## Identify the Goal

The kinetic energy of the tennis ball.

Variables and Constants

Known

$$
m=0.100 \mathrm{~kg}
$$

$$
V=145 \frac{\mathrm{~km}}{\mathrm{~h}}
$$

Unknown $E_{\mathrm{k}}$

Strategy
Convert the speed from $\mathrm{km} / \mathrm{h}$ to $\mathrm{m} / \mathrm{s}$.

Use the formula for kinetic energy.
Substitute the variables into the formula.
Multiply.
A $\mathrm{kg} \cdot \frac{\mathrm{m}^{2}}{\mathrm{~s}^{2}}$ is equivalent to a J .
The tennis ball has 81.1 J of kinetic energy.
Validate
The moving tennis ball has kinetic energy. The unit for kinetic energy is the J.

## 20. Frame the Problem

The moving bowling ball has kinetic energy.

## Identify the Goal

The mass of the bowling ball.
Variables and Constants
Known
$v=0.95 \frac{\mathrm{~m}}{\mathrm{~s}}$
$E_{\mathrm{k}}=4.5 \mathrm{~J}$

## Strategy

Use the formula for kinetic energy to
find the mass.
Substitute the variables in to the formula.
Multiply and divide.
A $\frac{\mathrm{J}}{\left(\frac{m^{2}}{s^{2}}\right)}$ is equivalent to a kg .
The mass of the bowling ball is $1.0 \times 10^{1} \mathrm{~kg}$.

## Validate

The mass has units of kg .

## 21. Frame the Problem

The moving skier has kinetic energy.

## Identify the Goal

The kinetic energy of the skier at the bottom of the hill.

## Variables and Constants

## Known

$m=69.0 \mathrm{~kg}$

## Unknown

$E_{\mathrm{k}}$
$v=7.25 \frac{\mathrm{~m}}{\mathrm{~s}}$

## Strategy

Use the kinetic energy formula.
Substitute in the variables.
Multiply.
A $\mathrm{kg} \cdot \frac{\mathrm{m}^{2}}{\mathrm{~s}^{2}}$ is equivalent to a J .
The skier's kinetic energy is $1.81 \times 10^{3} \mathrm{~J}$.
Validate
The moving skier has kinetic energy. The unit for kinetic energy is the J.

## Practice Problem Solutions

## Student Textbook pages 245-246

## 22. Frame the Problem

- The rock is assumed to be initially at rest, and thus has no initial kinetic energy.
- The force does work on the rock.
- The force applied to the rock will make it accelerate since there is no frictional force.
- The work-kinetic energy theorem applies.


## Identify the Goal

The final velocity of the rock.

## Variables and Constants

| Known | Implied | Unknown |
| :--- | :--- | :--- |
| $m=6.30 \mathrm{~kg}$ | $v_{1}=0 \frac{\mathrm{~m}}{\mathrm{~s}}$ | $v_{2}$ |
| $F=30.0 \mathrm{~N}$ | $E_{\mathrm{k}_{1}}=0 \mathrm{~J}$ | $E_{\mathrm{k}_{2}}$ |
| $\Delta d=13.9 \mathrm{~m}$ |  |  |

## Strategy

Find the work done on the rock using the formula for work.
Substitute in the variables.
Multiply.
An $\mathrm{N} \cdot \mathrm{m}$ is equivalent to a J .
Use the work-kinetic energy.
$E_{\mathrm{k}_{1}}$ is zero, so work done equals $E_{\mathrm{k}_{2}}$.

## Calculations

$W=F \Delta d$
$W=(30.0 \mathrm{~N})(13.9 \mathrm{~m})$
$W=417 \mathrm{~N} \cdot \mathrm{~m}$
$W=417 \mathrm{~J}$
$W=E_{\mathrm{k}_{2}}-E_{\mathrm{k}_{1}}$
$E_{\mathrm{k}_{2}}=417 \mathrm{~J}$
Rearrange to solve for final velocity.
Substitute in the variables.
Multiply and divide.
$v_{2}=\sqrt{\frac{2 E_{\mathrm{k}_{2}}}{m}}$
$v_{2}=\sqrt{\frac{2(417 \mathrm{~J})}{6.30 \mathrm{~kg}}}$

A $\left(\sqrt{\frac{\mathrm{J}}{\mathrm{kg}}}\right)$ is equivalent to a $\mathrm{m} / \mathrm{s}$

The rock's final velocity is $11.5 \mathrm{~m} / \mathrm{s}$.
Validate
The force did work on the rock to make it accelerate because frictional forces were absent. The unit for velocity is the $\mathrm{m} / \mathrm{s}$.

## 23. Frame the Problem

- The moving electron will have kinetic energy.


## Identify the Goal

The speed of the electron.
Variables and Constants

Known
$m=9.1 \times 10^{-31} \mathrm{~kg}$
$E_{\mathrm{k}}=7.6 \times 10^{-18} \mathrm{~kg}$

Unknown
$v$

## Strategy

Use the formula for kinetic energy to find the speed.
Substitute in the variables.
Multiply and divide.
A $\left(\sqrt{\frac{\mathrm{J}}{\mathrm{kg}}}\right)$ is equivalent to a $\mathrm{m} / \mathrm{s}$

Calculations
$v=\sqrt{\frac{2 E_{\mathrm{k}}}{m}}$
$v=\sqrt{\frac{2\left(7.6 \times 10^{-18} \mathrm{~J}\right)}{9.1 \times 10^{-31} \mathrm{~kg}}}$
$v=4.1 \times 10^{6}\left(\frac{\mathrm{~J}}{\mathrm{~kg}}\right)$
$v=4.1 \times 10^{6} \frac{\mathrm{~m}}{\mathrm{~s}}$

The electron travels at a speed of $4.1 \times 10^{6} \mathrm{~m} / \mathrm{s}$.
Validate
The moving electron has kinetic energy, The unit for speed is the $\frac{\mathrm{m}}{\mathrm{s}}$.

## 24. Frame the Problem

- The cart starts from rest, so the initial kinetic energy is 0 J .
- There is no friction acting, so the work-kinetic energy theorem applies.


## PART I

Identify the Goal
The kinetic energy of the cart when traveling at a speed of $1.2 \mathrm{~m} / \mathrm{s}$.

## Variables and Constants

| Known | Unknown |
| :--- | :--- |
| $m=0.500 \mathrm{~kg}$ | $E_{\mathrm{k}_{2}}$ |
| $v=1.2 \frac{\mathrm{~m}}{\mathrm{~s}}$ |  |

## Strategy

Use the formula for kinetic energy.
Substitute in the variables.
Multiply.
A $\mathrm{kg} \cdot \frac{\mathrm{m}^{2}}{\mathrm{~s}^{2}}$ is equivalent to a J .

## Calculations

$E_{\mathrm{k}_{2}}=\frac{1}{2} m v^{2}$
$E_{\mathrm{k}_{2}}=\frac{1}{2}(0.500 \mathrm{~kg})\left(1.2 \frac{\mathrm{~m}}{\mathrm{~s}}\right)^{2}$
$E_{\mathrm{k}_{2}}=0.36 \mathrm{~kg} \cdot \frac{\mathrm{~m}^{2}}{\mathrm{~s}^{2}}$
$E_{\mathrm{k}_{2}}=0.36 \mathrm{~J}$

The cart's kinetic energy is 0.36 J when it is travelling with a velocity of $1.2 \mathrm{~m} / \mathrm{s}$.
Validate
The cart has kinetic energy when it is moving. The unit for kinetic energy is the J.

## PART II

Identify the Goal
The force exerted on the cart.

Variables and Constants

## Known

$\Delta d=0.1 \mathrm{~m}$

Unknown
W
$E_{\mathrm{k}}$
F

## Strategy

Use the work-kinetic energy theorem.
$E_{\mathrm{k}_{1}}$ is zero.
Substitute in the value for $E_{\mathrm{k}_{2}}$.
Use the formula for work to find the force.
Substitute in the values.
Divide.
A $\frac{\mathrm{J}}{\mathrm{m}}$ is equivalent to an N .

> Calculations
> $W=\Delta E_{\mathrm{k}}$
> $W=E_{\mathrm{k}_{2}}$
> $W=0.36 \mathrm{~J}$
> $F=\frac{W}{\Delta d}$
> $F=\frac{0.36 \mathrm{~J}}{0.10 \mathrm{~m}}$
> $F=3.6 \frac{\mathrm{~J}}{\mathrm{~m}}$
> $F=3.6 \mathrm{~N}$

The force exerted on the cart is 3.6 N .

## Validate

The force exerted on the cart caused it to accelerate.

## 25. Frame the Problem

- The moving car has kinetic energy.
- The kinetic energy equation applies.


## Identify the Goal

The mass of the toy car.
Variables and Constants

| Known |  |
| :--- | :--- |
| $v=2.10 \frac{\mathrm{~m}}{\mathrm{~s}}$ | Unknown |
| $E_{\mathrm{k}}=14.0 \mathrm{~J}$ | $m$ |

## Strategy

Use the formula for kinetic energy to find the mass.
Substitute in the variables.
Multiply and divide.
A $\frac{\mathrm{J}}{\frac{\mathrm{m}^{2}}{\mathrm{~s}^{2}}}$ is equivalent to a kg .

## Calculations

$m=\frac{2 E_{\mathrm{k}}}{v^{2}}$
$m=\frac{2(14.0 \mathrm{~J})}{\left(2.10 \frac{\mathrm{~m}}{\mathrm{~s}}\right)^{2}}$
$m=6.35 \frac{\mathrm{~J}}{\left(\frac{m^{2}}{s^{2}}\right)}$
$m=6.35 \mathrm{~kg}$
The mass of the car is 6.35 kg .
Validate
The car has kinetic energy when it is moving. The unit for mass is the kg .

## 26. Frame the Problem

- The car has kinetic energy when it is moving.
- The brakes do negative work on the car to stop it.
- The amount of work done by the brakes is equal to the change in the car's kinetic energy.
- The work-kinetic energy theorem applies.


## PART I

Identify the Goal
The average force of friction stopping the car.

## Variables and Constants

## Known

$m=1250 \mathrm{~kg}$
$v_{1}=25 \frac{\mathrm{~km}}{\mathrm{~h}}=6.9 \frac{\mathrm{~m}}{\mathrm{~s}}$
$v_{2}=0 \frac{\mathrm{~m}}{\mathrm{~s}}$
$\Delta d=10 \mathrm{~m}$

## Strategy

Use the formula for change in kinetic energy.
Use the formula for kinetic energy.
Substitute in the variables.
Multiply.
A $\mathrm{kg} \cdot \frac{\mathrm{m}^{2}}{\mathrm{~s}^{2}}$ is equivalent to a J .
Use the work-kinetic energy theorem to find the work done.
Use the formula for work to find the force.
Substitute in the variables.
Divide.
A $\frac{\mathrm{J}}{\mathrm{m}}$ is equivalent to an N .
The average frictional force w
Validate
The force of friction did negative work on the car to stop it. The force has a negative value because it is directed backwards on the car. The unit for force is the N .

PART II
Identify the Goal
The distance traveled by the car to stop.

## Variables and Constants

| Known | Unknown |
| :--- | :--- |
| $m=1250 \mathrm{~kg}$ | $\Delta d$ |
| $v_{1}=50 \frac{\mathrm{~km}}{\mathrm{~h}}=13.9 \frac{\mathrm{~m}}{\mathrm{~s}}$ |  |
| $v_{2}=0 \frac{\mathrm{~m}}{\mathrm{~s}}$ |  |
| $F=-3014.08 \mathrm{~N}$ |  |

## Strategy

Use the formula for change in kinetic energy.
Use the formula for kinetic energy.
Substitute in the variables.
Multiply.
A $\mathrm{kg} \cdot \frac{\mathrm{m}^{2}}{\mathrm{~s}^{2}}$ is equivalent to a J .
Use the work-kinetic energy theorem to find the work done.
Use the formula for work to find the distance.
Substitute in the variables.

## Calculations

$\Delta E_{\mathrm{k}}=E_{\mathrm{k}_{2}}-E_{\mathrm{k}_{1}}$
$\Delta E_{\mathrm{k}}=0-\frac{1}{2} m v_{1}^{2}$
$\Delta E_{\mathrm{k}}=-\frac{1}{2}(1250 \mathrm{~kg})\left(13.9 \frac{\mathrm{~m}}{\mathrm{~s}}\right)^{2}$
$\Delta E_{\mathrm{k}}=-120756.25 \mathrm{~kg} \cdot \frac{\mathrm{~m}^{2}}{\mathrm{~s}^{2}}$
$\Delta E_{\mathrm{k}}=-120756.25 \mathrm{~J}$
$W=\Delta E_{\mathrm{k}}=-120756.25 \mathrm{~J}$
$\Delta d=\frac{W}{F}$
$\Delta d=\frac{-120756.25 \mathrm{~J}}{-3014.08 \mathrm{~N}}$

Divide.

$$
\Delta d=40 \frac{\mathrm{~J}}{\mathrm{~N}}
$$

A $\frac{\mathrm{J}}{\mathrm{N}}$ is equivalent to an m .
$\Delta d=40 \mathrm{~m}$
The distance required for the car to stop is 40 m .

## Validate

The force of friction did negative work on the car to stop it. The force has a negative value because it is directed backwards on the car. The unit for distance is the m .

PART III
Identify the Goal
The distance traveled by the car to stop.
Variables and Constants

Known

## Unknown

$m=1250 \mathrm{~kg}$
$\Delta d$
$v_{1}=100 \frac{\mathrm{~km}}{\mathrm{~h}}=27.8 \frac{\mathrm{~m}}{\mathrm{~s}}$
$v_{2}=0 \frac{\mathrm{~m}}{\mathrm{~s}}$
$F=-3014.08 \mathrm{~N}$

## Strategy

Use the formula for change in kinetic energy.
Use the formula for kinetic energy.
Substitute in the variables.
Multiply.
A $\mathrm{kg} \cdot \frac{\mathrm{m}^{2}}{\mathrm{~s}^{2}}$ is equivalent to a J .
Use the work-kinetic energy theorem to find the work done.
Use the formula for work to find the distance.
Substitute in the variables.
Divide.
A $\frac{\mathrm{J}}{\mathrm{N}}$ is equivalent to an m .
The distance required for the car to stop is 161 m .
Validate
The force of friction did negative work on the car to stop it. The force has a negative value because it is directed backwards on the car. The unit for distance is the m .

## PART IV

stopping distance vs. speed


Based on the parabolic shape of the graph, one can conclude that the stopping distance depends on the square of the initial speed.

## Practice Problem Solutions

## Student Textbook page 250

## 27. Frame the Problem

- When the picture is lifted it will gain gravitational potential energy.
- The reference level is the ground.


## Identify the Goal

The gravitational potential energy of the picture when hung on the wall

## Variables and Constants

| Known | Implied | Unknown |
| :--- | :--- | :--- |
| $\Delta h=2.0 \mathrm{~m}$ | $g=9.81 \frac{\mathrm{~N}}{\mathrm{~kg}}$ | $E_{\mathrm{g}}$ |
| $m=4.45 \mathrm{~kg}$ |  |  |

## Strategy

## Calculations

Use the formula for gravitational potential
$E_{\mathrm{g}}=m g \Delta h$ energy.
Substitute in the variables.
$E_{\mathrm{g}}=(4.45 \mathrm{~kg})\left(9.81 \frac{\mathrm{~N}}{\mathrm{~kg}}\right)(2.0 \mathrm{~m})$
Multiply.
$E_{\mathrm{g}}=87 \mathrm{~N} \cdot \mathrm{~m}$
An $\mathrm{N} \cdot \mathrm{m}$ is equivalent to a J .
$E_{\mathrm{g}}=87 \mathrm{~J}$
The gravitational potential energy of the picture is 87 J when hung on the wall.
Validate
The picture gains gravitational potential energy when it is lifted. The unit for gravitational potential energy is the J .

## 28. Frame the Problem

- The cubic metre of water in the reservoir has gravitational potential energy relative to the water in front of the dam.
- The mass of the cubic metre of water can be found using the density.
- The formula for gravitational potential energy applies.


## Identify the Goal

The gravitational potential energy of the cubic metre of water in the reservoir.

## Variables and Constants

| Known | Implied | Unknown |
| :--- | :--- | :--- |
| $\Delta h=250 \mathrm{~m}$ | $g=9.81 \frac{\mathrm{~N}}{\mathrm{~kg}}$ | $m$ |
| density $=1.00 \mathrm{~kg} / \mathrm{L}$ | $E_{\mathrm{g}}$ |  |
| $V=1 \mathrm{~m}^{3}=1000 \mathrm{~L}$ |  |  |

## Strategy

Use the density formula to find the mass of one cubic metre of water.
Substitute in the variables.
Multiply.
Use the formula for gravitational potential energy.
Substitute in the variables.
Multiply.
An $\mathrm{N} \cdot \mathrm{m}$ is equivalent to a J .

## Calculations

$m=d V$
$m=\left(1.00 \frac{\mathrm{~kg}}{\mathrm{~L}}\right)(1000 \mathrm{~L})$
$m=1000 \mathrm{~kg}$
$E_{\mathrm{g}}=m g \Delta h$
$E_{\mathrm{g}}=(1000 \mathrm{~kg})\left(9.81 \frac{\mathrm{~N}}{\mathrm{~kg}}\right)(250 \mathrm{~m})$
$E_{\mathrm{g}}=2.5 \times 10^{6} \mathrm{~N} \cdot \mathrm{~m}$
$E_{\mathrm{g}}=2.5 \times 10^{6} \mathrm{~J}$

Each cubic metre of water in the reservoir has $2.5 \times 10^{6} \mathrm{~J}$ of gravitational potential energy relative to the water in front of the dam.

## Validate

The water in the reservoir is above the water in front of the dam, so it has gravitational potential energy. The unit for gravitational potential energy is the J .

## 29. Frame the Problem

- The baseball has gravitational potential energy when it is lifted up.
- The formula for gravitational potential energy applies.


## Identify the Goal

The height to which the baseball must be raised
Variables and Constants

| Known | Implied | Unknown |
| :--- | :--- | :--- |
| $m=0.300 \mathrm{~kg}$ | $g=9.81 \frac{\mathrm{~N}}{\mathrm{~kg}}$ | $\Delta h$ |
| $E_{\mathrm{g}}=12.0 \mathrm{~J}$ |  |  |

Strategy
Use the formula for gravitational potential energy to find the height.
Substitute in the variables.
Multiply and divide.
$A \frac{\mathrm{~J}}{\mathrm{~N}}$ is equivalent to an m .

Calculations
$\Delta h=\frac{E_{g}}{\mathrm{mg}}$
$\Delta h=\frac{12.0 \mathrm{~J}}{(0.300 \mathrm{~kg})\left(9.81 \frac{\mathrm{~N}}{\mathrm{~kg}}\right)}$
$\Delta h=4.08 \frac{\mathrm{~J}}{\mathrm{~N}}$
$\Delta h=4.08 \mathrm{~m}$

The baseball must be raised to a height of 4.08 m .
Validate
The baseball has gravitational potential energy when it is raised. The unit for the height is the m .

## Practice Problem Solutions

## Student Textbook page 254

## 30. Frame the Problem

- Work must be done on the books in order to lift them above the ground.
- The formula for work done when lifting applies.


## Identify the Goal

The height through which the books must be lifted.

## Variables and Constants

| Known | Implied | Unknown |
| :--- | :--- | :--- |
| $m=2.20 \mathrm{~kg}$ | $g=9.81 \frac{\mathrm{~N}}{\mathrm{~kg}}$ | $\Delta h$ |
| $W=12.0 \mathrm{~J}$ |  |  |

## Strategy

Use the formula for work done when lifting to find the height.
Substitute in the variables.

## Calculations

$\Delta h=\frac{W}{m g}$

Multiply and divide.
$\Delta h=\frac{25.0 \mathrm{~J}}{(2.20 \mathrm{~kg})\left(9.81 \frac{\mathrm{~N}}{\mathrm{Kg}}\right)}$
A $\frac{\mathrm{J}}{\mathrm{N}}$ is equivalent to an m .
$\Delta h=1.16 \frac{\mathrm{~J}}{\mathrm{~N}}$

The books must be lifted through a height of 1.16 m .

## Validate

Work was done on the books to lift them above the ground. The unit for height is the m .

## 31. Frame the Problem

- As the child cycles up the hill she does work to lift herself up the hill.
- This work is transformed into gravitational potential energy.
- At the bottom of the hill the child's gravitational potential energy is 0 J .


## PART A

Identify the Goal
The change in the child's gravitational potential energy.
Variables and Constants

| Known | Implied | Unknown |
| :--- | :--- | :--- |
| $m=46.0 \mathrm{~kg}$ | $g=9.81 \frac{\mathrm{~N}}{\mathrm{~kg}}$ | $E_{\mathrm{g}_{2}}$ |
| $\Delta h=5.25 \mathrm{~m}$ | $E_{\mathrm{g} 1}=0 \mathrm{~J}$ | $\Delta E_{\mathrm{g}}$ |

## Strategy

Use the formula to find gravitational potential energy at the top.
Substitute in the variables.

## Calculations

$E_{\mathrm{g}}=m g \Delta h$

Multiply.
An $\mathrm{N} \cdot \mathrm{m}$ is equivalent to a J .
Use the formula for change in the gravitational potential energy.
Substitute in the variables.
$E_{\mathrm{g}}=(46.0 \mathrm{~kg})\left(9.81 \frac{\mathrm{~N}}{\mathrm{~kg}}\right)(5.25 \mathrm{~m})$
$E_{\mathrm{g}}=2.37 \times 10^{3} \mathrm{~N} \cdot \mathrm{~m}$
$E_{\mathrm{g}}=2.37 \times 10^{3} \mathrm{~J}$
$\Delta E_{\mathrm{g}}=E_{\mathrm{g}_{2}}-E_{\mathrm{g}_{1}}$
$\Delta E_{\mathrm{g}}=2.37 \times 10^{3} \mathrm{~J}-0 \mathrm{~J}$

Simplify.

$$
\Delta E_{\mathrm{g}}=2.37 \times 10^{3} \mathrm{~J}
$$

The change in the child's gravitational potential energy is $2.37 \times 10^{3} \mathrm{~J}$.

## Validate

The child gained gravitational potential energy as she cycled up the hill, thus her change in gravitational potential energy is positive in value. The unit for gravitational potential energy is the J.

## PART B

## Identify the Goal

The amount of work done against gravity.

## Validate

The amount of work done against gravity to lift the child up the hill is equal to the change in her gravitational potential energy. Thus $W=\Delta E_{\mathrm{g}}=2.37 \times 10^{3} \mathrm{~J}$.

## 32. Frame the Problem

- The pendulum gains gravitational potential energy as it is raised.


## Identify the Goal

The gravitational potential energy of the pendulum.

## Variables and Constants

| Known | Implied | Unknown |
| :--- | :--- | :--- |
| $m=2.50 \mathrm{~kg}$ | $g=9.81 \frac{\mathrm{~N}}{\mathrm{~kg}}$ | $E_{g}$ |
| $\Delta h=0.652 \mathrm{~m}$ |  |  |

## Strategy

## Calculations

Use the formula for gravitational potential

$$
E_{\mathrm{g}}=m g \Delta h
$$

energy.
Substitute in the variables.

$$
E_{\mathrm{g}}=(2.50 \mathrm{~kg})\left(9.81 \frac{\mathrm{~N}}{\mathrm{~kg}}\right)(0.652 \mathrm{~m})
$$

Multiply.
An $\mathrm{N} \cdot \mathrm{m}$ is equivalent to a J .
$E_{\mathrm{g}}=16.0 \mathrm{~N} \cdot \mathrm{~m}$
$E_{\mathrm{g}}=16.0 \mathrm{~J}$

The gravitational potential energy of the pendulum is 16.0 J .

## Validate

The pendulum gains gravitational potential energy as it is raised. The unit for gravitational potential energy is the J.

## 33. Frame the Problem

- The train gains gravitational potential energy as it is raised.
- The gravitational potential energy of the train at its starting position is 0 J .
- The change in gravitational potential energy is the difference between the final and initial values for gravitational potential energy.


## Identify the Goal

The change in gravitational potential energy of the train.

## Variables and Constants

| Known | Implied | Unknown |
| :--- | :--- | :--- |
| $\Delta h=39.4 \mathrm{~m}$ | $g=9.81 \frac{\mathrm{~N}}{\mathrm{~kg}}$ | $E_{\mathrm{g}_{2}}$ |
| $m=3.90 \times 10^{3} \mathrm{~kg}$ | $E_{\mathrm{g} 1}=0 \mathrm{~J}$ | $\Delta E_{\mathrm{g}^{2}}$ |

## Strategy

Use the formula to find gravitational potential energy at the top.
Substitute in the variables.
Multiply.
An $\mathrm{N} \cdot \mathrm{m}$ is equivalent to a J .
Use the formula for change in the gravitational potential energy.
Substitute in the variables.
Simplify.

## Calculations

$E_{\mathrm{g}}=m g \Delta h$
$E_{\mathrm{g}}=\left(3.90 \times 10^{3} \mathrm{~kg}\right)\left(9.81 \frac{\mathrm{~N}}{\mathrm{~kg}}\right)(39.4 \mathrm{~m})$
$E_{\mathrm{g}}=1.51 \times 10^{6} \mathrm{~N} \cdot \mathrm{~m}$
$E_{\mathrm{g}}=1.51 \times 10^{6} \mathrm{~J}$
$\Delta E_{\mathrm{g}}=E_{\mathrm{g}_{2}}-E_{\mathrm{g}_{1}}$
$\Delta E_{\mathrm{g}}=1.51 \times 10^{6} \mathrm{~J}-0 \mathrm{~J}$
$\Delta E_{\mathrm{g}}=1.51 \times 10^{6} \mathrm{~J}$

The change in the train's gravitational potential energy is $1.51 \times 10^{6} \mathrm{~J}$.

## Validate

The train gains gravitational potential energy as it is raised, thus the change in gravitational potential energy is positive. The unit for gravitational potential energy is the J .

## 34. Frame the Problem

- The height for one floor can be found.
- The elevator gains gravitational potential energy as it rises.
- The gravitational potential energy must be measured from some reference point.


## PART A

Identify the Goal
The gravitational potential energy of the elevator when at the eighth floor, relative to the sixth floor.

Variables and Constants

| Known | Implied | Unknown |
| :--- | :--- | :--- |
| $m=1.35 \times 10^{3} \mathrm{~kg}$ | $g=9.81 \frac{\mathrm{~N}}{\mathrm{~kg}}$ | $\Delta h$ |
|  | $E_{\mathrm{g}}$ |  |

## Strategy

## Calculations

The height of one floor is 6.00 m .
Find the height in this case.
$\Delta h=\frac{30.0 \mathrm{~m}}{5 \text { floors }}$
$\Delta h=$ (\# floors)( 6.00 m )
Substitute in the variables.
$\Delta h=(2)(6.00 \mathrm{~m})$
Multiply.
$\Delta h=12.0 \mathrm{~m}$
$E_{\mathrm{g}}=m g \Delta h$
potential energy.
Substitute in the variables.
$E_{\mathrm{g}}=\left(1.35 \times 10^{3} \mathrm{~kg}\right)\left(9.81 \frac{\mathrm{~N}}{\mathrm{~kg}}\right)(12.0 \mathrm{~m})$
Multiply.
$E_{\mathrm{g}}=1.59 \times 10^{5} \mathrm{~N} \cdot \mathrm{~m}$
$E_{\mathrm{g}}=1.59 \times 10^{5} \mathrm{~J}$
An $\mathrm{N} \cdot \mathrm{m}$ is equivalent to a J

$$
E_{\mathrm{g}}=1.59 \times 10^{\mathrm{J}} \mathrm{~J}
$$

The gravitational potential energy of the elevator is $1.59 \times 10^{5} \mathrm{~J}$.
Validate
The elevator gains gravitational potential energy as it rises. The unit for gravitational potential energy is the J.

## PART B

Identify the Goal
The gravitational potential energy of the elevator when at the eleventh floor, relative to the eighth floor.

## Variables and Constants

| Known | Implied | Unknown |
| :--- | :--- | :--- |
| $m=1.35 \times 10^{3} \mathrm{~kg}$ |  |  |
|  | $g=9.81 \frac{\mathrm{~N}}{\mathrm{~kg}}$ | $\Delta h$ |
|  | $E_{\mathrm{g}}$ |  |

## Strategy

The height of one floor is 6.00 m .
Find the height in this case.
Substitute in the variables.
Multiply.
Use the formula for gravitational
potential energy.
Substitute in the variables.
Multiply.
An $\mathrm{N} \cdot \mathrm{m}$ is equivalent to a J

## Calculations

$\Delta h=\frac{30.0 \mathrm{~m}}{5 \text { floors }}$
$\Delta h=$ (\# floors)( 6.00 m )
$\Delta h=(3)(6.00 \mathrm{~m})$
$\Delta h=18.0 \mathrm{~m}$
$E_{\mathrm{g}}=m g \Delta h$
$E_{\mathrm{g}}=\left(1.35 \times 10^{3} \mathrm{~kg}\right)\left(9.81 \frac{\mathrm{~N}}{\mathrm{~kg}}\right)(18.0 \mathrm{~m})$
$E_{\mathrm{g}}=2.38 \times 10^{5} \mathrm{~N} \cdot \mathrm{~m}$
$E_{\mathrm{g}}=2.38 \times 10^{5} \mathrm{~J}$

The gravitational potential energy of the elevator is $2.38 \times 10^{5} \mathrm{~J}$.
Validate
The elevator gains gravitational potential energy as it rises. The unit for gravitational potential energy is the J .

## PART C

Identify the Goal
The gravitational potential energy of the elevator when at the eleventh floor, relative to the sixth floor.

Variables and Constants

| Known |  |
| :--- | :--- |
| $m=1.35 \times 10^{3} \mathrm{~kg} \quad$ | Implied <br> $g=9.81$ <br> Ng |

## Strategy

The height of one floor is 6.00 m .
Find the height in this case.
Substitute in the variables.
Multiply.
Use the formula for gravitational potential energy.
Substitute in the variables.
Multiply.
An $\mathrm{N} \cdot \mathrm{m}$ is equivalent to a J

$$
\begin{aligned}
& E_{\mathrm{g}}=\left(1.35 \times 10^{3} \mathrm{~kg}\right)\left(9.81 \frac{\mathrm{~N}}{\mathrm{~kg}}\right)(30.0 \mathrm{~m}) \\
& E_{\mathrm{g}}=3.97 \times 10^{5} \mathrm{~N} \cdot \mathrm{~m} \\
& E_{\mathrm{g}}=3.97 \times 10^{5} \mathrm{~J}
\end{aligned}
$$

## Calculations

$\Delta h=\frac{30.0 \mathrm{~m}}{5 \text { floors }}$
$\Delta h=$ (\# floors)(6.00 m)
$\Delta h=(5)(6.00 \mathrm{~m})$
$\Delta h=30.0 \mathrm{~m}$
$E_{\mathrm{g}}=m g \Delta h$


The gravitational potential energy of the elevator is $3.97 \times 10^{5} \mathrm{~J}$.

## Validate

The elevator gains gravitational potential energy as it rises. The unit for gravitational potential energy is the J.

## Practice Problem Solutions

## Student Textbook page 258

## 35. Conceptualize the Problem

- Hooke's law applies to this problem.
- Realize that when the scale shows the maximum displacement it means the spring is using the maximum amount of force.


## Identify the Goal

The spring constant, $k$, of the spring

## Identify the Variables

| Known | Unknown |
| :--- | :--- |
| $F_{\mathrm{a}}=50 \mathrm{~N}$ | $k$ |
| $x=9.5 \mathrm{~cm}$ |  |

## Develop a Strategy

Use Hooke's law (applied force form).
Calculations
Solve for the spring constant.
$F_{\mathrm{a}}=k x$
$k=\frac{F_{\mathrm{a}}}{x}$
$k=\frac{(50 \mathrm{~N})}{9.5 \mathrm{~cm} \times \frac{1 \mathrm{~m}}{100 \mathrm{~cm}}}$
$k=526 \frac{\mathrm{~N}}{\mathrm{~m}}$
$k \cong 5 \times 10^{2} \frac{\mathrm{~N}}{\mathrm{~m}}$
The spring constant is about $5 \times 10^{2} \frac{\mathrm{~N}}{\mathrm{~m}}$.
Validate the Solution
The units are $\frac{\mathrm{N}}{\mathrm{m}}$, appropriate for the spring constant.

## 36. Conceptualize the Problem

- A cord with a known spring constant is stretched by a known force.
- Hooke's law applies to this problem.
- By Newton's third law, the cord exerts a force that is equal in magnitude and opposite in direction to the applied force.


## Identify the Goal

(a) The distance, $x$, the cord stretches
(b) The restoring force, $F_{\mathrm{r}}$, exerted by the cord

## Identify the Variables

## Known

$k=1.10 \times 10^{3} \frac{\mathrm{~N}}{\mathrm{~m}}$
$F_{\mathrm{a}}=455 \mathrm{~N}$

## Develop a Strategy

Use Hooke's law (applied force form).
Solve for the displacement.

## Unknown <br> $x$ <br> $F_{\mathrm{r}}$

$$
\begin{aligned}
& \text { Calculations } \\
& F_{\mathrm{a}}=k x \\
& x=\frac{F_{\mathrm{a}}}{k} \\
& x=\frac{(455 \mathrm{~N})}{1.10 \times 10^{3} \frac{\mathrm{~N}}{\mathrm{~m}}} \\
& x=0.4136 \mathrm{~m} \\
& x \cong 0.414 \mathrm{~m}
\end{aligned}
$$

(a) The cord is stretched about 0.414 m .

Apply Newton's third law.

$$
\begin{aligned}
& F_{\mathrm{r}}=-F_{\mathrm{a}} \\
& F_{\mathrm{r}}=-455 \mathrm{~N}
\end{aligned}
$$

(b) The restoring force is -455 N .

## Validate the Solution

In part (a), the units work out to be metres, as required.
For a large spring constant it is reasonable to expect a small value for the
displacement when a force of less magnitude than the spring constant is applied.

## 37. Conceptualize the Problem

- A spring with a known spring constant is stretched a known (maximum) distance.
- Hookés law applies to this problem.
- The applied force that gives the maximum extension will be equivalent to the weight of the maximum mass that can be applied to the spring without damaging it.


## Identify the Goal

The largest mass, $m$, that can be placed on the spring without damaging it

## Identify the Variables

| Known | Implied | Unknown |
| :--- | :--- | :--- |
| $k=1.50 \frac{\mathrm{~N}}{\mathrm{~m}}$ | $g=9.81 \frac{\mathrm{~m}}{\mathrm{~s}^{2}}$ | m |
| $x=10.0 \mathrm{~cm}$ |  |  |

## Develop a Strategy

Use Hooke's law (applied force form).
Let the applied force, from Hooke's law, be equal to the weight of the maximum mass.

$$
\begin{aligned}
& \text { Calculations } \\
& F_{\mathrm{a}}=F_{\mathrm{g}} \\
& k x=m g \\
& m=\frac{k x}{g} \\
& m=\frac{(1.50 \mathrm{~N} / \mathrm{m})\left(10.0 \mathrm{~cm} \times \frac{1.00 \mathrm{~m}}{100 \mathrm{~cm}}\right)}{9.81 \frac{\mathrm{~m}}{\mathrm{~s}^{2}}} \\
& m=0.01529 \mathrm{~kg} \\
& m \cong 0.0153 \mathrm{~kg}
\end{aligned}
$$

The maximum mass is about 0.0153 kg .
Validate the Solution
The spring constant is small, so it is expected that the mass will be small too.

## Practice Problem Solutions

## Student Textbook page 261

## 38. Conceptualize the Problem

- The elastic potential energy of the spring increases as it is stretched.
- The definition of elastic potential energy applies to this problem.
- The gravitational potential energy can be defined as zero at the place where the spring is stretched and thus ignored.


## Identify the Goal

The potential energy, $E_{\mathrm{e}}$, of the stretched spring

## Identify the Variables

| Known | Implied | Unknown |
| :--- | :--- | :--- |
| $k=35 \frac{\mathrm{~N}}{\mathrm{~m}}$ |  | $E_{\mathrm{e}}$ |
| $x=24 \mathrm{~cm}$ |  |  |

## Develop a Strategy

Apply the equation for elastic potential energy.

## Calculations

$E_{\mathrm{e}}=\frac{1}{2} k x^{2}$
$E_{\mathrm{e}}=\frac{1}{2}\left(35 \frac{\mathrm{~N}}{\mathrm{~m}}\right)\left(24 \mathrm{~cm} \times \frac{1.00 \mathrm{~m}}{100 \mathrm{~cm}}\right)^{2}$
$E_{\mathrm{e}}=1.008 \mathrm{~N} \cdot \mathrm{~m}$
$E_{\mathrm{e}} \cong 1.0 \mathrm{~J}$

The potential energy of the spring is about 1.0 J .

## Validate the Solution

The units are in $\mathrm{N} \cdot \mathrm{m}$, or joules, as required.

## 39. Conceptualize the Problem

- The elastic potential energy of the elastic band increases as it is stretched.
- The definition of elastic potential energy applies to this problem.


## Identify the Goal

The distance, $x$, that the elastic band is stretched

## Identify the Variables

| Known | Implied | Unknown |
| :--- | :--- | :--- |
| $E_{\mathrm{e}}=2.2 \mathrm{~J}$ |  | $x$ |
| $k=48 \frac{\mathrm{~N}}{\mathrm{~m}}$ |  |  |

## Develop a Strategy

Apply the equation for elastic potential energy.
Solve for the distance.

The elastic band was stretched about 0.30 m .

Calculations
$E_{\mathrm{e}}=\frac{1}{2} k x^{2}$
$x^{2}=\frac{2 E_{\mathrm{e}}}{k}$
$x=\sqrt{\frac{2 E_{\mathrm{e}}}{k}}$
$x=\sqrt{\frac{2(2.2 \mathrm{~J})}{48 \frac{\mathrm{~N}}{\mathrm{~m}}}}$
$x=0.3028 \mathrm{~m}$
$x \cong 0.30 \mathrm{~m}$

Validate the Solution
The units are in metres ( $1 \mathrm{~J}=1 \mathrm{~N} \cdot \mathrm{~m}$ ) and distance of 0.30 m seems reasonable for typical elastic bands.

## 40. Conceptualize the Problem

- The elastic potential energy of the spring increases as it is compressed.
- Hooke's law and the definition of elastic potential energy applies to this problem.


## Identify the Goal

The distance, $x$, that the elastic band is stretched

Identify the Variables
Known Implie
$F=18 \mathrm{~N}$
$x=15 \mathrm{~cm}$

## Develop a Strategy

Apply Hooke's law.
Solve for the spring constant.

$$
\begin{aligned}
& \text { Implied } \\
& \qquad \begin{aligned}
& \begin{array}{l}
\text { Unknown } \\
F_{\mathrm{a}}
\end{array} \\
k=k x & \Delta E_{\mathrm{e}} \\
k & =\frac{F_{\mathrm{a}}}{x} \\
k & =\frac{18 \mathrm{~N}}{15 \mathrm{~cm} \times \frac{1.00 \mathrm{~m}}{100 \mathrm{~cm}}} \\
k & =120 \frac{\mathrm{~N}}{\mathrm{~m}}
\end{aligned}
\end{aligned}
$$

The spring constant is $120 \frac{\mathrm{~N}}{\mathrm{~m}}$.
Apply the equation for the elastic potential energy.

$$
\begin{aligned}
& E_{\mathrm{e}}=\frac{1}{2} k x^{2} \\
& E_{\mathrm{e}}=\frac{1}{2}(120 \mathrm{~N} / \mathrm{m})\left(15 \mathrm{~cm} \times \frac{1.00 \mathrm{~m}}{100 \mathrm{~cm}}\right)^{2} \\
& E_{\mathrm{e}}=1.35 \mathrm{~N} \cdot \mathrm{~m} \\
& E_{\mathrm{e}} \cong 1.4 \mathrm{~J}
\end{aligned}
$$

The elastic potential energy of the spring is about 1.4 J .

Validate the Solution
Substituting variables directly gives:
$E_{\mathrm{e}}=\frac{1}{2} k x^{2}=\frac{1}{2} \frac{F_{\mathrm{a}}}{x} x^{2}=\frac{1}{2} F_{\mathrm{a}} x=\frac{1}{2}(18 \mathrm{~N})(0.15 \mathrm{~m})=1.35 \mathrm{~N} \cdot \mathrm{~m}$, the same result.

## Practice Problem Solutions

## Student Textbook page 266

## 41. Frame the Problem

- The mover exerts a force on the box to move it, and thus does work on the box.
- Power is the rate at which work is done by the mover.


## Identify the Goal

The power generated by the mover

## Variables and Constants

Known

## Unknown

$m=25.5 \mathrm{~kg}$
$F=85 \mathrm{~N}$
$\Delta d=15 \mathrm{~m}$
$\Delta t=8.30 \mathrm{~s}$

## Strategy

Use the formula for work done.
Substitute in the variables.
Simplify.
$1 \mathrm{~N} \cdot \mathrm{~m}$ is equivalent to 1 J .
Use the formula for power.
Substitute in the variables.

## Calculations

$W=F \Delta d$
$W=(85 \mathrm{~N})(15 \mathrm{~m})$
$W=1275 \mathrm{~N} \cdot \mathrm{~m}$
$W=1275 \mathrm{~J}$
$P=\frac{W}{\Delta t}$
$P=\frac{1275 \mathrm{~J}}{8.30 \mathrm{~s}}$

Simplify.

$$
P=1.5 \times 10^{2} \frac{\mathrm{~J}}{\mathrm{~s}}
$$

$1 \frac{\mathrm{~J}}{\mathrm{~s}}$ is equivalent to 1 W .
$P=1.5 \times 10^{2} \mathrm{~W}$
The power generated by the mover is $1.5 \times 10^{2} \mathrm{~W}$.

## Validate

The mover did work on the box to move it. The unit for work is the joule. The unit for power is the watt.

## 42. Frame the Problem

- The chair lift does work on the skiers to lift them up the hill.
- Power is the rate at which work is done.
- Power can be expressed in units of watts or horsepower.


## Identify the Goal

The power of the chairlift
Variables and Constants

| Known | Implied | Unknown |
| :--- | :--- | :--- |
| $W=1.85 \times 10^{5} \mathrm{~J}$ | $1 \mathrm{hp}=746 \mathrm{~W}$ | $P$ |
| $\Delta t=12.0 \mathrm{~s}$ |  |  |

## Strategy

Use the power formula.
Substitute in the variables.
Simplify.
$1 \frac{\mathrm{~J}}{\mathrm{~s}}$ is equivalent to 1 W .
Convert the power to horsepower using the conversion factor.
Substitute in the variables.
Simplify.

Calculations
$P=\frac{W}{\Delta t}$
$P=\frac{1.85 \times 10^{5} \mathrm{~J}}{12.0 \mathrm{~s}}$
$P=1.54 \times 10^{4} \frac{\mathrm{~J}}{\mathrm{~s}}$
$P=1.54 \times 10^{4} \mathrm{~W}$
$1 \mathrm{hp}=746 \mathrm{~W}$
$P=\frac{1.54 \times 10^{4} \mathrm{~W}}{746 \frac{\mathrm{~W}}{\mathrm{hp}}}$
$P=20.7 \mathrm{hp}$

The power of the chairlift is $1.54 \times 10^{4} \mathrm{~W}$ or 20.7 hp .
Validate
The unit for power is the watt or horsepower.

## 43. Frame the Problem

- The student does work on herself to lift herself up the flight of stairs.
- Power is the rate at which she can do work.


## Identify the Goal

The amount of time required for the student to climb the stairs
Variables and Constants

| Known | Implied | Unknown |
| :--- | :--- | :--- |
| $m=75.0 \mathrm{~kg}$ | $g=9.81 \frac{\mathrm{~N}}{\mathrm{~kg}}$ | $\Delta t_{\text {(required) }}$ |

$\Delta h=5.75 \mathrm{~m}$
$P=200 \mathrm{~W}$
$\Delta t_{\text {(allowed) }}=20.0 \mathrm{~s}$

## Strategy

Use the formula for work done against gravity to find the work done by the girl to lift herself up the stairs.
Substitute in the variables.
Simplify.
$1 \mathrm{~N} \cdot \mathrm{~m}$ is equivalent to 1 J .
Use the formula for power to find the time required to climb the stairs.
Substitute in the variables.
Simplify.
$1 \frac{\mathrm{~J}}{\mathrm{~W}}$ is equivalent to 1 s .

## Calculations

$W=m g \Delta h$
$W=(75.0 \mathrm{~kg})\left(9.81 \frac{\mathrm{~N}}{\mathrm{~kg}}\right)(5.75 \mathrm{~m})$
$W=4230.56 \mathrm{~N} \cdot \mathrm{~m}$
$W=4230.56 \mathrm{~J}$
$\Delta t=\frac{W}{P}$
$\Delta t=\frac{4230.56 \mathrm{~J}}{200 \mathrm{~W}}$
$\Delta t=21.15 \frac{\mathrm{~J}}{\mathrm{~W}}$
$\Delta t=21.15 \mathrm{~s}$

The girl requires 21.15 s to climb up the stairs. This is more than the time required.

## Validate

The girl will be late for class by 1.15 s , since she only had 20.0 s until the bell rang, but she required 21.15 s to climb the stairs.

## Practice Problem Solutions

## Student Textbook pages 270-271

## 44. Frame the Problem

- The stereo transforms electric energy into sound energy.
- The efficiency formula applies here.


## Identify the Goal

(a) The efficiency of the stereo
(b) The transformation of the "lost" energy

Variables and Constants

| Known | Unknown |
| :--- | :--- |
| $E_{\text {in }}=265 \mathrm{~J}$ | Efficiency |
| $E_{\text {out }}=200 \mathrm{~J}$ |  |

## Strategy

Use the formula for efficiency.
Substitute in the variables.
Simplify.

Calculations
Efficiency $=\frac{E_{\text {out }}}{E_{\text {in }}} \times 100 \%$
Efficiency $=\frac{200 \mathrm{~J}}{265 \mathrm{~J}} \times 100 \%$
Efficiency $=75.5 \%$
(a) The stereo has an efficiency of $75.5 \%$.
(b) The "lost" energy has been transformed mainly into thermal energy (heat).

## Validate

The efficiency of the stereo was less than $100 \%$ since some energy was lost during the transformation process.

## 45. Frame the Problem

- The child has gravitational potential energy while at the top of the slide.
- The child has some kinetic energy while moving at the bottom of the slide, and zero gravitational potential energy at this point.
- The efficiency of the transformation process will be $100 \%$ only if all of the gravitational potential energy while at the top gets transformed into kinetic energy as the child reaches the bottom of the slide.
- The efficiency here will likely be less than $100 \%$ because there will be friction present.


## Identify the Goal

The efficiency of the transformation process
Variables and Constants

| Known | Implied | Unknown |
| :--- | :--- | :--- |
| $m=49.0 \mathrm{~kg}$ | $g=9.81 \frac{\mathrm{~N}}{\mathrm{~kg}}$ | $E_{\mathrm{g}}$ |
| $\Delta h=1.80 \mathrm{~m}$ |  | $E_{\mathrm{k}}$ |

$v=3.00 \mathrm{~m} / \mathrm{s} \quad$ Efficiency

## Strategy

## Calculations

Find the child's gravitational potential
$E_{g}=m g \Delta h$ energy while at the top of the slide by using the formula for gravitational potential energy.
Substitute in the variables.
Simplify.
A $\mathrm{N} \cdot \mathrm{m}$ is equivalent to a J .
Find the child's kinetic energy while at the bottom of the slide.

Substitute in the variables.
Simplify.
A $\mathrm{kg} \cdot \frac{\mathrm{m}^{2}}{\mathrm{~s}^{2}}$ is equivalent to a J .
Use the formula for efficiency, where the energy input is the gravitational potential energy and the energy out is the kinetic energy.

Substitute in the variables.
Simplify.
Efficiency $=\frac{220.5 \mathrm{~J}}{865.24 \mathrm{~J}} \times 100 \%$

The gravitational potential energy was transformed into kinetic energy with a $25.5 \%$ efficiency.

## Validate

The efficiency was much less than $100 \%$ here because friction was acting on the child as she was sliding. The unit for gravitational potential energy and kinetic energy is the joule.

## 46. Frame the Problem

- The machine transforms the energy input into useful work, but some energy will be "lost" during this process.
- The efficiency will be less than $100 \%$ because the energy in and the useful work are not equal.


## Identify the Goal

The efficiency of the machine

Variables and Constants

| Known | Unknown |
| :--- | :--- |
| $E_{\text {in }}=580 \mathrm{~J}$ | Efficiency |
| $E_{\text {out }}=110 \mathrm{~J}$ |  |

## Strategy

Use the formula for efficiency.
Substitute in the variables.
Simplify.

Calculations
Efficiency $=\frac{E_{\text {out }}}{E_{\text {in }}} \times 100 \%$
Efficiency $=\frac{110 \mathrm{~J}}{580 \mathrm{~J}} \times 100 \%$
Efficiency $=19.0 \%$

The machine has an efficiency of $19.0 \%$.

## Validate

The efficiency was less than $100 \%$.

## 47. Frame the Problem

- Both light bulbs transform electric energy into light and thermal energy.
- The fluorescent bulb requires less electric energy input to give the same amount of light energy out.
- The fluorescent bulb is more efficient.


## Identify the Goal

(a) The efficiency of each bulb
(b) Reason(s) why the fluorescent bulb is more efficient

Variables and Constants

| Known | Unknown |
| :--- | :--- |
| $E_{\text {inc }}=120 \mathrm{~J}$ | Efficiency |
| $E_{\text {f }}=60 \mathrm{~J}$ |  |
| $E_{\text {out }}=5 \mathrm{~J}$ |  |

## Strategy

Find the efficiency of the incandescent bulb by using the efficiency formula.
Substitute in the variables.
Simplify.
Find the efficiency of the fluorescent bulb by using the efficiency formula.

Substitute in the variables.
Simplify.

## Calculations

Efficiency $=\frac{E_{\text {out }}}{E_{\text {inc }}} \times 100 \%$
Efficiency $=\frac{5 \mathrm{~J}}{120 \mathrm{~J}} \times 100 \%$
Efficiency $=4 \%$
Efficiency $=\frac{E_{\text {out }}}{E_{\mathrm{f}}} \times 100 \%$
Efficiency $=\frac{5 \mathrm{~J}}{60 \mathrm{~J}} \times 100 \%$
Efficiency $=8 \%$
(a) The efficiency of the incandescent bulb is $4 \%$ while the efficiency of the fluorescent bulb is $8 \%$.
(b) The fluorescent bulb is more efficient than the incandescent bulb because it produces much less thermal energy. As is commonly known a fluorescent bulb is much cooler to the touch than an incandescent bulb.

## Validate

The fluorescent bulb required less energy input to give the same energy out as the incandescent bulb, thus its efficiency is greater.

## 48. Frame the Problem

- In the food inside the microwave, radiant energy is transformed into thermal energy.
- The formula for efficiency applies here.


## Identify the Goal

The efficiency of energy transformation inside the microwave
Variables and Constants

Known
$E_{\text {in }}=345 \mathrm{~J}$
$E_{\text {out }}=301 \mathrm{~J}$

Strategy
Find the efficiency by using the efficiency formula.
Substitute in the variables.
Simplify.

Unknown
Efficiency

The efficiency of energy transformation inside the microwave is $87.2 \%$.

## Validate

The efficiency is fairly large here because the energy out is only slightly less than the energy input.

## 49. Frame the Problem

- The force does work on the ball, giving it kinetic energy.
- As the ball moves through the atmosphere some of its kinetic energy is "lost" as it is transformed into thermal energy.
- The ratio of the actual kinetic energy of the ball to the amount of work that was done on it by the force gives the fraction of remaining energy of the ball.
Subtracting this amount from 100 gives the fraction of energy lost to the atmosphere.


## Identify the Goal

(a) The work done on the ball
(b) The kinetic energy of the ball just before it is caught
(c) The fraction of energy lost to the atmosphere

Variables and Constants

| Known | Unknown |
| :--- | :--- |
| $m=125 \mathrm{~g}$ | $W$ |
| $F=85.0 \mathrm{~N}$ | $E_{\mathrm{k}}$ |
| $\Delta d=78.0 \mathrm{~cm}$ | fraction of energy lost |
| $v=9.84 \mathrm{~m} / \mathrm{s}$ |  |

## Strategy

Use the formula for work done.
Substitute in the variables.
Convert the distance from cm to m by dividing by 100 .
Simplify.
$1 \mathrm{~N} \cdot \mathrm{~m}$ is equivalent to 1 J .

## Calculations

$W=F \Delta d$
$W=(85.0 \mathrm{~N})(78.0 \mathrm{~cm})$
$W=(85.0 \mathrm{~N})(0.780 \mathrm{~m})$
$W=66.3 \mathrm{~N} \cdot \mathrm{~m}$
$W=66.3 \mathrm{~J}$
(a) The force did 66.3 J of work on the ball.

## Strategy

Use the formula for kinetic energy.
Substitute in the variables.
Convert the mass from g to kg by dividing by 1000 .
Substitute in the variables.
$1 \mathrm{~kg} \cdot \frac{\mathrm{~m}^{2}}{\mathrm{~s}^{2}}$ is equivalent to 1 J .

Calculations
$E_{\mathrm{k}}=\frac{1}{2} m v^{2}$
$E_{\mathrm{k}}=\frac{1}{2}(125 \mathrm{~g})\left(9.84 \frac{\mathrm{~m}}{\mathrm{~s}}\right)^{2}$
$E_{\mathrm{k}}=\frac{1}{2}(0.125 \mathrm{~kg})\left(9.84 \frac{\mathrm{~m}}{\mathrm{~s}}\right)^{2}$
$E_{\mathrm{k}}=6.05 \mathrm{~kg} \cdot \frac{\mathrm{~m}^{2}}{\mathrm{~s}^{2}}$
$E_{\mathrm{k}}=6.05 \mathrm{~J}$
(b) The ball has 6.05 J of kinetic energy just before it is caught.

## Strategy

Find the fraction of energy remaining in the ball by comparing the ratio of kinetic energy to work done on the ball.
Substitute in the variables.
Simplify.
Convert to a percentage by multiplying by 100 .
Simplify.
Find the percentage of energy lost by subtracting the percentage of energy remaining from 100.
Substitute in the variables.
Simplify.

## Calculations

fraction of energy remaining $=\frac{E_{\mathrm{k}}}{W}$
fraction of energy remaining $=\frac{6.05 \mathrm{~J}}{66.3 \mathrm{~J}}$
fraction of energy remaining $=0.091$
percentage of energy remaining

$$
=0.091 \times 100 \%
$$

percentage of energy remaining $=9.1 \%$
percentage of energy lost $=100 \%$

- percentage of energy remaining
percentage of energy lost

$$
=100 \%-9.1 \%
$$

percentage of energy lost $=90.9 \%$
(c) The ball has lost $90.9 \%$ of its kinetic energy to the atmosphere as thermal energy.

## Validate

Work was done on the ball to give it kinetic energy. The ball lost some of its kinetic energy to the atmosphere as thermal energy due to the effects of friction. The unit for work and kinetic energy is the joule.

## 50. Frame the Problem

- The kinetic energy of rubbing the hands together gets partly transformed into thermal energy.
- The addition of thermal energy to the palms causes a temperature rise.
- Since not all of the kinetic energy gets transformed into thermal energy the efficiency is less than $100 \%$.
- The formula for efficiency applies to this transformation, where the energy input is the 450 J of kinetic energy required to rub the hands together, and the energy out is the 153 J of thermal energy added to the palms.


## Identify the Goal

The efficiency of energy transformation
Variables and Constants

## Known

$E_{\text {in }}=450 \mathrm{~J}$
$E_{\text {out }}=153 \mathrm{~J}$

Unknown
Efficiency

Strategy
Use the formula for efficiency.
Substitute in the variables.
Simplify.

Calculations
Efficiency $=\frac{E_{\text {out }}}{E_{\mathrm{in}}} \times 100 \%$
Efficiency $=\frac{{ }^{2} 53 \mathrm{~J}}{450 \mathrm{~J}} \times 100 \%$
Efficiency $=34 \%$

The kinetic energy is transformed into thermal energy with an efficiency of $34 \%$.

## Validate

Since only some of the kinetic energy is transformed into thermal energy the efficiency is less than $100 \%$.

## Chapter 6 Review

## Answers to Problems for Understanding

Student Textbook pages 275-277
15. (a) The forces on the car are

- the thrust pushes the car forward
- the drag is the total of all of the frictional forces pushing backward on the car
- the weight is the force of gravity downward on the car
- the normal force or reaction force from the ground pushing upward on the car
(b) The thrust does positive work on the car, since it is pointed in the same direction as the car's displacement, and the drag does negative work on the car since its direction is opposite to the direction of the car's displacement. The amount of work done by each of these forces is equal, since the car is travelling at a constant velocity. The weight and normal force do no work on the car, since they are perpendicular to the direction of the car's displacement.

16. $F_{\|}=\frac{W}{\Delta d}$

$$
=\frac{0.20 \mathrm{~J}}{4.50 \times 10^{-3} \mathrm{~m}}
$$

$$
=44 \mathrm{~N}
$$

17. $W=F_{\|} \Delta d$

$$
\begin{aligned}
& =(50.0 \mathrm{~N})(7.00 \mathrm{~m}) \\
& =3.5 \times 10^{2} \mathrm{~J}
\end{aligned}
$$

18. Total work done by the horse on the wagon is the sum of the work done in each part of the motion:

$$
\begin{aligned}
W_{1} & =F_{\|(2)} \Delta d_{1} \\
& =(525 \mathrm{~N})(18.3 \mathrm{~m}) \\
& =9607.5 \mathrm{~J} \\
W_{2} & =F_{\|(2)} \Delta d_{2} \\
& =(345 \mathrm{~N})(13.8 \mathrm{~m}) \\
& =4761 \mathrm{~J} \\
W_{\mathrm{T}} & =W_{1}+W_{2} \\
& =9607.5 \mathrm{~J}=4761 \mathrm{~J} \\
& =14368.5 \mathrm{~J} \\
& =1.44 \times 10^{4} \mathrm{~J}
\end{aligned}
$$

19. $W=F \Delta d \cos \theta$

$$
\begin{aligned}
& =(112.0 \mathrm{~N})(6.00 \mathrm{~m})\left(\cos 23^{\circ}\right) \\
& =6.2 \times 10^{2} \mathrm{~J}
\end{aligned}
$$

20. From Newton's second law, $F=m a$, and the equation for work, $W=F_{\|} \Delta d$ :

$$
\begin{aligned}
W & =F_{\|} \Delta d \\
& =(m a) \Delta d \\
& =(65.0 \mathrm{~kg})\left(0.561 \frac{\mathrm{~m}}{\mathrm{~s}^{2}}\right)(12.0 \mathrm{~m}) \\
& =438 \mathrm{~J}
\end{aligned}
$$

21. (i) From 0 to 5.0 m :

$$
\begin{aligned}
\text { Work } & =\text { area of graph } \\
& =\frac{1}{2} b h \\
& =\frac{1}{2}(5.0 \mathrm{~m})(40 \mathrm{~N}) \\
& =100 \mathrm{~J}
\end{aligned}
$$

Using the work-kinetic energy theorem:

$$
\begin{aligned}
W & =\Delta E_{\mathrm{k}} \\
W & =E_{\mathrm{k}_{2}}-E_{\mathrm{k}_{1}} \\
100 \mathrm{~J} & =E_{\mathrm{k}_{2}}-0 \mathrm{~J} \\
E_{\mathrm{k}_{2}} & =100 \mathrm{~J}
\end{aligned}
$$

Using the kinetic energy equation:

$$
\begin{aligned}
v & =\sqrt{\frac{2 \mathrm{k}_{\mathrm{k}}}{m}} \\
& =\sqrt{\frac{2(100 \mathrm{~J})}{1.25 \mathrm{~kg}}} \\
& =12.6 \frac{\mathrm{~m}}{\mathrm{~s}}
\end{aligned}
$$

(ii) From 0 to 15.0 m :

Work $=$ area of graph

$$
=575 \mathrm{~J}
$$

therefore, $E_{\mathrm{k}_{2}}=W=575 \mathrm{~J}$
and $v=\sqrt{\frac{2 E_{k_{2}}}{m}}$
$=\sqrt{\frac{2(575 \mathrm{~J})}{1.25 \mathrm{~kg}}}$
$=30.3 \frac{\mathrm{~m}}{\mathrm{~s}}$
(iii) From 0 to 25.0 m:

Work $=$ area of graph

$$
=725 \mathrm{~J}
$$

therefore $E_{\mathrm{k}_{2}}=W=725 \mathrm{~J}$
and $v=\sqrt{\frac{2 E_{\mathrm{k}}}{m}}$
$=\sqrt{\frac{2(725 \mathrm{~J})}{1.25 \mathrm{~kg}}}$
$=34.1 \frac{\mathrm{~m}}{\mathrm{~s}}$
22. Horizontally,

$$
\begin{aligned}
F \cos \theta & =m a \\
\cos \theta & =\frac{m a}{F} \\
\cos \theta & =\frac{(15 \mathrm{~kg})\left(1.27 \frac{\mathrm{~m}}{\mathrm{~s}^{2}}\right)}{65 \mathrm{~N}} \\
\theta & =73^{\circ}
\end{aligned}
$$

23. Using the kinetic energy equation for each player shows that the running back has more kinetic energy.

Running back:

$$
\begin{aligned}
E_{\mathrm{k}} & =\frac{1}{2} m v^{2} \\
& =\frac{1}{2}(55 \mathrm{~kg})\left(6.3 \frac{\mathrm{~m}}{\mathrm{~s}}\right)^{2} \\
& =1.1 \times 10^{3} \mathrm{~J}
\end{aligned}
$$

Linebacker:

$$
\begin{aligned}
E_{\mathrm{k}} & =\frac{1}{2} m v^{2} \\
& =\frac{1}{2}(95 \mathrm{~kg})\left(4.2 \frac{\mathrm{~m}}{\mathrm{~s}}\right)^{2} \\
& =8.4 \times 10^{2} \mathrm{~J}
\end{aligned}
$$

24. (a) $v_{2}=v_{1}+a t$

$$
\begin{aligned}
& =0 \frac{\mathrm{~m}}{\mathrm{~s}}+\left(0.21 \frac{\mathrm{~m}}{\mathrm{~s}^{2}}\right)(15 \mathrm{~s}) \\
& =3.15 \frac{\mathrm{~m}}{\mathrm{~s}} \\
E_{\mathrm{k}_{2}} & =\frac{1}{2} m v_{2}^{2} \\
& =\frac{1}{2}(68 \mathrm{~kg})\left(3.15 \frac{\mathrm{~m}}{\mathrm{~s}}\right)^{2} \\
& =337.365 \mathrm{~J} \\
& =3.4 \times 10^{2} \mathrm{~J}
\end{aligned}
$$

(b) The work done by friction to stop the skater $=-337.365 \mathrm{~J}$. Thus, using the work equation:

$$
\begin{aligned}
\Delta d & =\frac{W}{F} \\
& =\frac{-337.365 \mathrm{~J}}{-280 \mathrm{~N}} \\
& =1.2 \mathrm{~m}
\end{aligned}
$$

25. It is only the vertical displacement, not the horizontal displacement of the girl that has an effect on her gravitational potential energy.

$$
\begin{aligned}
m & =\frac{E g}{g \Delta h} \\
& =\frac{6800 \mathrm{~J}}{\left(9.81 \frac{\mathrm{~m}}{\mathrm{~s}^{2}}\right)(14.0 \mathrm{~m})} \\
& =49.5 \mathrm{~kg}
\end{aligned}
$$

26. (a) The average frictional force on the block is approximately $-3.5 \times 10^{-2} \mathrm{~N}$.

$$
\begin{array}{rlrl}
W & =E_{\mathrm{kf}}-E_{\mathrm{ki}} & W=F_{\mathrm{f}} \Delta d \\
W & =0-\frac{1}{2} m v_{\mathrm{i}}^{2} & F_{\mathrm{f}}=\frac{W}{\Delta d} \\
W & =-\frac{1}{2}(0.80 \mathrm{~kg})\left(0.25 \frac{\mathrm{~m}}{\mathrm{~s}}\right)^{2} & & F_{\mathrm{f}}=\frac{-2.5 \times 10^{-2} \mathrm{~J}}{0.72 \mathrm{~m}} \mathrm{~N} \\
W & =-2.5 \times 10^{-2} \mathrm{~J} & F_{\mathrm{f}} \cong-3.5 \times 10^{-2} \mathrm{~N}
\end{array}
$$

(b) Friction does $-2.5 \times 10^{-2} \mathrm{~J}$ of work on the block.

$$
\begin{aligned}
& W=F_{\mathrm{f}} \Delta d \\
& W=\left(-3.5 \times 10^{-2} \mathrm{~N}\right)(0.72 \mathrm{~m})=-2.5 \times 10^{-2} \mathrm{~J}
\end{aligned}
$$

(c) The block does $2.5 \times 10^{-2} \mathrm{~J}$ of work on the table.
27. (a) The gravitational force did approximately 16 J of work on the book.

$$
\begin{aligned}
W & =E_{\mathrm{gf}}-E_{\mathrm{gi}} \\
W & =0-m g \Delta h \\
W & =-(1.5 \mathrm{~kg})\left(9.81 \frac{\mathrm{~m}}{\mathrm{~s}^{2}}\right)(1.12 \mathrm{~m}) \\
W & \cong-16 \mathrm{~J}
\end{aligned}
$$

(b) The book lost approximately 16 J of gravitational potential energy.
28. (a) The applied force did $7.7 \times 10^{3} \mathrm{~J}$ of work on the cart.

$$
\begin{aligned}
& W=F_{\|} \Delta d \\
& W=(425 \mathrm{~N})(18 \mathrm{~m}) \\
& W \cong 7.7 \times 10^{3} \mathrm{~J}
\end{aligned}
$$

(b) The frictional force did $-9.5 \times 10^{2} \mathrm{~J}$ of work on the cart.

$$
\begin{aligned}
W & =F_{\|} \Delta d \\
W & =(-53 \mathrm{~N})(18 \mathrm{~m}) \\
W & \cong-9.5 \times 10^{2} \mathrm{~J}
\end{aligned}
$$

(c) When released, the cart had $6696 \mathrm{~J}(7650 \mathrm{~J}-954 \mathrm{~J}$ ) of kinetic energy. It was travelling at approximately $8.7 \mathrm{~m} / \mathrm{s}$ when it was released.

$$
\begin{aligned}
& E_{\mathrm{k}}=\frac{1}{2} m v^{2} \\
& v=\sqrt{\frac{2 E_{\mathrm{k}}}{m}} \\
& v=\sqrt{\frac{2(7650 \mathrm{~J}-954 \mathrm{~J})}{175 \mathrm{~kg}}} \\
& v \cong 8.7 \frac{\mathrm{~m}}{\mathrm{~s}}
\end{aligned}
$$

(d) The cart will travel approximately $1.3 \times 10^{2} \mathrm{~m}$ after it is released.

$$
\begin{aligned}
W & =F_{\|} \Delta d \\
\Delta d & =\frac{W}{F_{\|}} \\
\Delta d & =\frac{-6696 \mathrm{~J}}{-53 \mathrm{~N}} \\
\Delta d & \cong 1.3 \times 10^{2} \mathrm{~m}
\end{aligned}
$$

29. The man did $2.6 \times 10^{3} \mathrm{~J}$ of work on the crate. The problem asks only for the work done by the man. Therefore, friction is not a consideration.

$$
\begin{aligned}
W & =\left|\vec{F}_{\mathrm{a}}\right||\Delta \vec{d}| \cos \theta \\
W & =(225 \mathrm{~N})(12 \mathrm{~m}) \cos 15^{\circ} \\
W & \cong 2.6 \times 10^{3} \mathrm{~J}
\end{aligned}
$$

30. The spring constant is $4.6 \times 10^{2} \mathrm{~N} / \mathrm{m}$.

$$
\begin{aligned}
F & =k x \\
k & =\frac{F}{x} \\
k & =\frac{25 \mathrm{~N}}{0.055 \mathrm{~m}} \\
k & \cong 4.6 \times 10^{2} \frac{\mathrm{~N}}{\mathrm{~m}}
\end{aligned}
$$

31. (a) Change in the elastic potential energy of the spring: $3.8 \times 10^{-1} \mathrm{~J}$

$$
\begin{aligned}
& \Delta E_{\mathrm{e}}=\frac{1}{2} k x^{2} \\
& \Delta E_{\mathrm{e}}=\frac{1}{2}\left(120 \frac{\mathrm{~N}}{\mathrm{~m}}\right)(0.080 \mathrm{~m})^{2} \\
& \Delta E_{\mathrm{e}}=0.384 \mathrm{~J} \\
& \Delta E_{\mathrm{e}}=3.8 \times 10^{-1} \mathrm{~J}
\end{aligned}
$$

(b) Force required to compress spring: 9.6 N

$$
\begin{aligned}
& F=k x \\
& F=\left(120 \frac{\mathrm{~N}}{\mathrm{~m}}\right)(0.080 \mathrm{~m}) \\
& F=9.6 \mathrm{~N}
\end{aligned}
$$

32. The dart is travelling at $3.6 \mathrm{~m} / \mathrm{s}$ when it leaves the gun.

$$
\begin{aligned}
& E_{\mathrm{e}}=\frac{1}{2} k x^{2} \\
& E_{\mathrm{e}}=\frac{1}{2}\left(74 \frac{\mathrm{~N}}{\mathrm{~m}}\right)(0.065 \mathrm{~m})^{2} \\
& E_{\mathrm{e}}=0.1563 \mathrm{~J} \\
& E_{\mathrm{k}}=0.75(0.1563 \mathrm{~J}) \\
& E_{\mathrm{k}}=0.1172 \mathrm{~J}
\end{aligned}
$$

$$
E_{\mathrm{k}}=\frac{1}{2} m v^{2}
$$

$$
v=\sqrt{\frac{2 E_{\mathrm{k}}}{m}}
$$

$$
v=\sqrt{\frac{2(0.1172 \mathrm{~J})}{0.018 \mathrm{~kg}}}
$$

$$
v \cong 3.6 \frac{\mathrm{~m}}{\mathrm{~s}}
$$

33. (a) The block will be travelling at $2.3 \mathrm{~m} / \mathrm{s}$ at the instant that it leaves the spring. Conservation of mechanical energy

$$
\begin{aligned}
& E_{\mathrm{k}}^{\prime}+E_{\mathrm{e}}^{\prime}=E_{\mathrm{k}}+E_{\mathrm{e}} \\
& \frac{1}{2} m v^{2}+0=0+\frac{1}{2} k x^{2} \\
& v=\sqrt{\frac{k x^{2}}{m}} \\
& v=\sqrt{\frac{\left(555 \frac{\mathrm{~N}}{\mathrm{~m}}\right)(0.12 \mathrm{~m})^{2}}{1.5 \mathrm{~kg}}} \\
& v \cong 2.3 \frac{\mathrm{~m}}{\mathrm{~s}}
\end{aligned}
$$

(b) A frictional force of -5.3 N opposes the block's motion.

$$
\begin{aligned}
& E_{\mathrm{k}}=\frac{1}{2} m v^{2} \\
& E_{\mathrm{k}}=\frac{1}{2}(1.50 \mathrm{~kg})(2.308)^{2} \\
& E_{\mathrm{k}}=3.9951 \mathrm{~J}
\end{aligned}
$$

The work done by friction will bring the block to rest, reducing its kinetic energy to zero.

$$
\begin{aligned}
& W=\Delta E_{\mathrm{k}} \\
& W=F_{\mathrm{f} \Delta d} \\
& F_{\mathrm{f}}=\frac{W}{\Delta d} \\
& F_{\mathrm{f}}=\frac{-3.9951 \mathrm{~J}}{0.75 \mathrm{~m}} \\
& F_{\mathrm{f}} \cong-5.3 \mathrm{~N}
\end{aligned}
$$

34. The maximum height to which the child will bounce is 45 cm .

Conservation of mechanical energy

$$
\begin{aligned}
& E_{\mathrm{g}}^{\prime}+E_{\mathrm{e}}^{\prime}=E_{\mathrm{g}}+E_{\mathrm{e}} \\
& m g \Delta h+0=0+\frac{1}{2} k x^{2} \\
& \Delta h=\frac{k x^{2}}{2 m g} \\
& \Delta h=\frac{\left(4945 \frac{\mathrm{~N}}{\mathrm{~m}}\right)(0.25 \mathrm{~m})^{2}}{2(35 \mathrm{~kg})\left(9.81 \frac{\mathrm{~m}}{\mathrm{~s}^{2}}\right)} \\
& \Delta h=0.45 \mathrm{~m}
\end{aligned}
$$

35. The maximum distance that the block falls is 0.096 m .
$E_{g}^{\prime}$ is zero at the maximum distance that the block falls, and the velocity of the block is zero at this point, as the block changes direction. Let this point also be the zero or reference point for gravitational potential energy.

$$
\begin{aligned}
& E_{\mathrm{k}}^{\prime}+E_{\mathrm{g}}^{\prime}+E_{\mathrm{e}}^{\prime}=E_{\mathrm{k}}+E_{\mathrm{g}}+E_{\mathrm{e}} \\
& 0+0+\frac{1}{2} k x^{2}=0+m g \Delta h+0
\end{aligned}
$$

The height, $\Delta h$, through which the mass falls is the same as the distance, $x$, that the spring stretches. Therefore, let $\Delta h=x$.

$$
\begin{aligned}
& \frac{1}{2} k x^{2}=m g x \\
& \frac{1}{2} k x=m g \\
& x=\frac{2 m g}{k} \\
& x=\frac{2(2.2 \mathrm{~kg})\left(9.81 \frac{\mathrm{~m}}{\mathrm{~s}^{2}}\right)}{\left(450 \frac{\mathrm{~N}}{\mathrm{~m}}\right)} \\
& x \cong 0.096 \mathrm{~m}
\end{aligned}
$$

36. $P=\frac{W}{\Delta t}$

$$
\begin{aligned}
& =\frac{7.0 \times 10^{2} \mathrm{~J}}{2.0 \mathrm{~s}} \\
& =3.5 \times 10^{2} \mathrm{~W}
\end{aligned}
$$

37. (a) $E=P \Delta t$

$$
\begin{aligned}
& =(150 \mathrm{~W})(1800 \mathrm{~s}) \\
& =2.7 \times 10^{5} \mathrm{~J}
\end{aligned}
$$

(b) $E=P \Delta t$

$$
\begin{aligned}
& =(900 \mathrm{~W})(1800 \mathrm{~s}) \\
& =1.6 \times 10^{6} \mathrm{~J} \\
& \cong 2 \times 10^{6} \mathrm{~J}
\end{aligned}
$$

(c) $E=P \Delta t$

$$
\begin{aligned}
& =(2000 \mathrm{~W})(1800 \mathrm{~s}) \\
& =3.6 \times 10^{6} \mathrm{~J} \\
& \cong 4 \times 10^{6} \mathrm{~J} \\
& =P \Delta t \\
& =\left(2.5 \times 10^{6} \mathrm{~W}\right)(1800 \mathrm{~s}) \\
& =4.5 \times 10^{9} \mathrm{~J}
\end{aligned}
$$

(d) $E=P \Delta t$
38. (a)

(b) $a=\frac{f_{\text {net }}}{m}$

$$
\begin{aligned}
& =\frac{F \cos \theta}{m} \\
& =\frac{(15 \mathrm{~N})\left(\cos 35^{\circ}\right)}{12 \mathrm{~kg}} \\
& =1.0 \frac{\mathrm{~m}}{\mathrm{~s}^{2}}
\end{aligned}
$$

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

$$
\begin{aligned}
& =\left(0 \frac{\mathrm{~m}}{\mathrm{~s}}\right)(3.0 \mathrm{~s})+\frac{1}{2}\left(1.0 \frac{\mathrm{~m}}{\mathrm{~s}^{2}}\right)(3.0 \mathrm{~s})^{2} \\
& =4.5 \mathrm{~m}
\end{aligned}
$$

(d) $W=F \cos \theta \Delta d$

$$
\begin{aligned}
& =(15 \mathrm{~N})\left(\cos 35^{\circ}\right)(4.5 \mathrm{~m}) \\
& =55.3 \mathrm{~J} \\
& =55 \mathrm{~J}
\end{aligned}
$$

(e) $P=\frac{W}{\Delta t}$

$$
\begin{aligned}
& =\frac{55.3 \mathrm{~J}}{3.0 \mathrm{~s}} \\
& =18 \mathrm{~W}
\end{aligned}
$$

39. $\quad P_{\text {in }}=\frac{E}{\Delta t}$

$$
\begin{aligned}
& =\frac{m g \Delta h}{\Delta t} \\
& =\frac{(3000 \mathrm{~kg})\left(9.81 \frac{\mathrm{~N}}{\mathrm{~kg}}\right)(15.0 \mathrm{~m})}{60 \mathrm{~s}} \\
& =7357.5 \mathrm{~W} \\
P_{\text {out }} & =P_{\text {in }} \times 74 \% \\
P_{\text {out }} & =5444.55 \mathrm{~W} \\
P_{\text {out }} & =5.44 \mathrm{~kW} \\
& \cong 5 \mathrm{~kW}
\end{aligned}
$$

