

### Work

Read from **Lesson 1** of the **Work, Energy and Power** chapter at **The Physics Classroom**:

<http://www.physicsclassroom.com/Class/energy/u5l1a.html>  
<http://www.physicsclassroom.com/Class/energy/u5l1aa.html>

**MOP Connection:** Work and Energy: sublevel 1

- An **impulse** is a force acting over some amount of time to cause a change in momentum. On the other hand, **work** is a \_\_\_\_\_ acting over some amount of \_\_\_\_\_ to cause a change in \_\_\_\_\_.
- Indicate whether or not the following represent examples of work.


	Work Done?
a. A teacher applies a force to a wall and becomes exhausted. Explanation: _____ _____	Yes or No?
b. A weightlifter lifts a barbell above her head. Explanation: _____ _____	Yes or No?
c. A waiter carries a tray full of meals across a dining room at a constant speed. Explanation: _____ _____	Yes or No?
d. A rolling marble hits a note card and moves it across a table. Explanation: _____ _____	Yes or No?
e. A shot-putter launches the shot. Explanation: _____ _____	Yes or No?

- Work is a \_\_\_\_\_; a + or - sign on a work value indicates information about \_\_\_\_\_.
  - vector; the direction of the work vector
  - scalar; the direction of the work vector
  - vector; whether the work adds or removes energy from the object
  - scalar; whether the work adds or removes energy from the object



- Which sets of units represent legitimate units for the quantity *work*? Circle all correct answers.
 

a. Joule	b. N x m
c. Foot x pound	d. kg x m/sec
e. kg x m/sec <sup>2</sup>	f. kg x m <sup>2</sup> /sec <sup>2</sup>



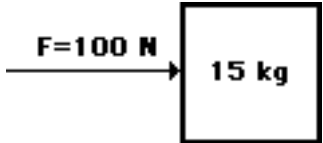
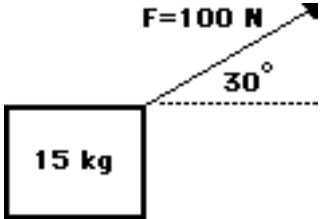
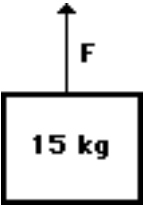
**BEWARE**

The amount of work ( $W$ ) done on an object by a given force can be calculated using the formula

$$W = F d \cos \Theta$$

where  $F$  is the force and  $d$  is the distance over which the force acts and  $\Theta$  is the angle between  $F$  and  $d$ . It is important to recognize that the angle included in the equation is not *just any old angle*; it has a distinct definition that must be remembered when solving such work problems.

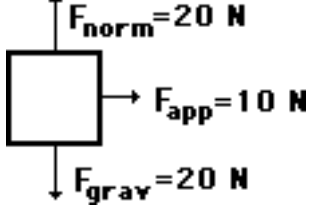
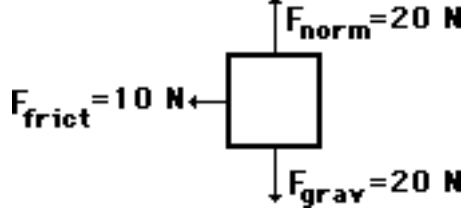
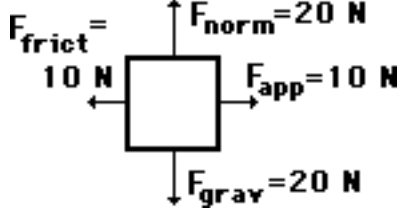
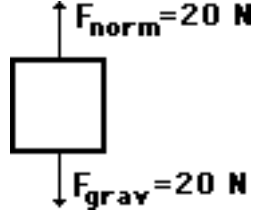
5. For each situation below, calculate the amount of work done by the applied force. **PSYW**

		
<p>A 100 N force is applied to move a 15 kg object a horizontal distance of 5 meters at constant speed.</p>	<p>A 100 N force is applied at an angle of <math>30^\circ</math> to the horizontal to move a 15 kg object at a constant speed for a horizontal distance of 5 m.</p>	<p>An upward force is applied to lift a 15 kg object to a height of 5 meters at constant speed.</p>

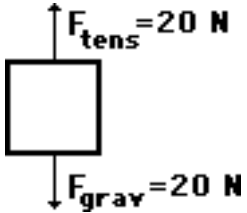
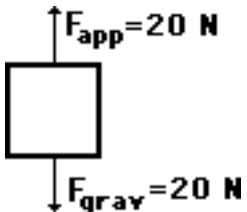
6. Indicate whether there is positive (+) or negative (-) work being done on the object.
- \_\_\_\_\_ a. An eastward-moving **car** skids to a stop across dry pavement.
  - \_\_\_\_\_ b. A freshman stands on his toes and lifts a **World Civilization book** to the top shelf of his locker.
  - \_\_\_\_\_ c. At Great America, a **roller coaster car** is lifted to the peak of the first hill on the Shock Wave.
  - \_\_\_\_\_ d. A catcher puts out his mitt and catches the **baseball**.
  - \_\_\_\_\_ e. A falling **parachutist** opens the chute and slows down.
7. Before beginning its initial descent, a roller coaster car is always pulled up the first hill to a high initial height. Work is done on the car (usually by a chain) to achieve this initial height. A coaster designer is considering three different angles at which to drag the 2000-kg car train to the top of the 60-meter high hill. Her big question is: which angle would require the most work?  
 \_\_\_\_\_ Show your answers and explain.

Angle	Force	Distance	Work
$35^\circ$	$1.15 \cdot 10^4 \text{ N}$	105 m	
$45^\circ$	$1.41 \cdot 10^4 \text{ N}$	84.9 m	
$55^\circ$	$1.64 \cdot 10^4 \text{ N}$	73.2 m	

8. The following descriptions and their accompanying free-body diagrams show the forces acting upon an object. For each case, calculate the work done by these forces; use the format of force • displacement • cosine( $\theta$ ). Finally, calculate the total work done by all forces.

Free-Body Diagram	Forces Doing Work on the Object Amount of Work Done by Each Force
<p>a. A 10-N force is applied to push a block across a frictionless surface for a displacement of 5.0 m to the right.</p> 	<p><math>W_{\text{norm}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}</math></p> <p><math>W_{\text{app}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}</math></p> <p><math>W_{\text{grav}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}</math></p> <p><math>W_{\text{total}} = \text{_____} \text{ J}</math></p>
<p>b. A 10-N frictional force slows a moving block to a stop along a horizontal surface after a displacement of 5.0 m to the right.</p> 	<p><math>W_{\text{norm}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}</math></p> <p><math>W_{\text{grav}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}</math></p> <p><math>W_{\text{frict}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}</math></p> <p><math>W_{\text{total}} = \text{_____} \text{ J}</math></p>
<p>c. A 10-N forces is applied to push a block across a frictional surface at constant speed for a displacement of 5.0 m to the right.</p> 	<p><math>W_{\text{norm}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}</math></p> <p><math>W_{\text{app}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}</math></p> <p><math>W_{\text{grav}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}</math></p> <p><math>W_{\text{frict}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}</math></p> <p><math>W_{\text{total}} = \text{_____} \text{ J}</math></p>
<p>d. A 2-kg object is sliding at constant speed across a frictionless surface for a displacement of 5.0 m to the right.</p> 	<p><math>W_{\text{norm}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}</math></p> <p><math>W_{\text{grav}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}</math></p> <p><math>W_{\text{total}} = \text{_____} \text{ J}</math></p>

Work, Energy, and Power

Free-Body Diagram	Forces Doing Work on the Object Amount of Work Done by Each Force
<p>e. A 2-kg object is pulled upward at constant speed by a 20-N force for a vertical displacement of 5.0 m.</p> 	$W_{\text{tens}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}$ $W_{\text{grav}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}$ $W_{\text{total}} = \text{_____} \text{ J}$
<p>f. A 2-kg tray of dinner plates is held in the air and carried a distance of 5.0 m to the right.</p> 	$W_{\text{app}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}$ $W_{\text{grav}} = \text{_____} \cdot \text{_____} \cdot \cos(\text{_____}) = \text{_____} \text{ J}$ $W_{\text{total}} = \text{_____} \text{ J}$

9. When a force is applied to do work on an object, does the object always accelerate? \_\_\_\_\_  
 Explain why or why not.

10. Determine the work done in the following situations.

a. Jim Neysweeper is applying a 21.6-N force downward at an angle of 57.2° with the horizontal to displace a broom a distance of 6.28 m.

b. Ben Pumpiniron applies an upward force to lift a 129-kg barbell to a height of 1.98 m at a constant speed.

c. An elevator lifts 12 occupants up 21 floors (76.8 meters) at a constant speed. The average mass of the occupants is 62.8 kg.

## Power

Read from **Lesson 1** of the **Work, Energy and Power** chapter at **The Physics Classroom**:

<http://www.physicsclassroom.com/Class/energy/u5l1e.html>

**MOP Connection:** Work and Energy: sublevel 2

### Review:

- A force acting upon an object to cause a displacement is known as \_\_\_\_\_.
  - energy
  - potential
  - kinetic
  - work
- Two acceptable units for work are \_\_\_\_\_. Choose two.
  - joule
  - newton
  - watt
  - newton•meter

### Power as a Rate Quantity:

- Power is defined as the \_\_\_\_\_ is done.
  - amount of work which
  - direction at which work
  - angle at which work
  - the rate at which work
- Two machines (e.g., elevators) might do identical jobs (e.g., lift 10 passengers three floors) and yet the machines might have different power outputs. Explain how this can be so.

- There are a variety of units for power. Which of the following would be *fitting* units of power (though perhaps not standard)? Include all that apply.
  - Watt
  - Joule
  - Joule / second
  - hp

- Two physics students, Will N. Andable and Ben Pumpiniron, are in the weightlifting room. Will lifts the 100-pound barbell over his head 10 times in one minute; Ben lifts the 100-pound barbell over his head 10 times in 10 seconds. Which student does the most work? \_\_\_\_\_ Which student delivers the most power? \_\_\_\_\_ Explain your answers.



- During the Powerhouse lab, Jack and Jill ran up the hill. Jack is twice as massive as Jill; yet Jill ascended the same distance in half the time. Who did the most work? \_\_\_\_\_ Who delivered the most power? \_\_\_\_\_ Explain your answers.



- An often-used equation for power is

$$\text{Power} = \text{force} \times \text{velocity}$$

Express an understanding of the meaning of this equation by using it to explain what type of individuals would be the best choice for lineman on a football team.


## Work and Power Calculations

Read from **Lesson 1** of the **Work, Energy and Power** chapter at **The Physics Classroom**:

<http://www.physicsclassroom.com/Class/energy/u5l1aa.html>

<http://www.physicsclassroom.com/Class/energy/u5l1e.html>

**MOP Connection:** Work and Energy: sublevels 1 and 2

1. Bart runs up a 2.91-meter high flight of stairs at a constant speed in 2.15 seconds. If Bart's mass is 65.9 kg, determine the work which he did and his power rating. **PSYW**
2. On a recent adventure trip, Anita Break went rock-climbing. Anita was able to steadily lift her 80.0-kg body 20.0 meters in 100 seconds. Determine Anita's power rating during this portion of the climb. **PSYW**
3. A physics teacher owns a family of squirrels. The squirrels have been trained to do push-ups in repetitive fashion. Being connected to an electrical generator, their ongoing exercise is used to help power the home. There are 23 squirrels in the family and their average mass is 11 kg. They do work on the "up" part of the push-up, raising their body an average distance of 5.0 cm. If the squirrels average 71 push-ups per minute, then determine the total amount of work done in one minute and the power generated by their activity. **PSYW**  

4. An elevator motor lifts 715 kg of mass to the height of the fourth floor of an office building (11.0 meters above ground level) at a constant speed in 9.35 seconds. Determine the power rating of the motor. **PSYW**

## Energy

Read from **Lesson 1** of the **Work, Energy and Power** chapter at **The Physics Classroom**:

<http://www.physicsclassroom.com/Class/energy/u511b.html>

<http://www.physicsclassroom.com/Class/energy/u511c.html>

<http://www.physicsclassroom.com/Class/energy/u511d.html>

**MOP Connection:** Work and Energy: sublevels 3 and 4

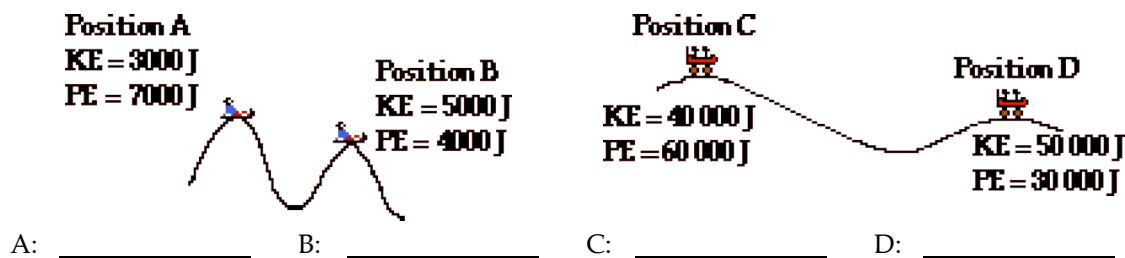
1. Read each of the following statements and identify them as having to do with kinetic energy (KE), potential energy (PE) or both (B).

KE, PE or B?	Statement:
_____	1. If an object is at rest, it certainly does NOT possess this form of energy.
_____	2. Depends upon object mass and object height.
_____	3. The energy an object possesses due to its motion.
_____	4. The amount is expressed using the unit joule (abbreviated J).
_____	5. The energy stored in an object due to its position (or height).
_____	6. The amount depends upon the arbitrarily assigned <i>zero level</i> .
_____	7. Depends upon object mass and object speed.
_____	8. If an object is at rest on the ground (zero height), it certainly does NOT possess this form of energy.

2. A toy car is moving along with 0.40 joules of kinetic energy. If its speed is doubled, then its new kinetic energy will be \_\_\_\_\_.  
 a. 0.10 J      b. 0.20 J      c. 0.80 J      d. 1.60 J      e. still 0.40 J
3. A young boy's glider is soaring through the air, possessing 0.80 joules of potential energy. If its speed is doubled and its height is doubled, then the new potential energy will be \_\_\_\_\_.  
 a. 0.20 J      b. 0.40 J      c. 1.60 J      d. 3.20 J      e. still 0.80 J
4. Which would ALWAYS be true of an object possessing a kinetic energy of 0 joules?  
 a. It is on the ground.      b. It is at rest.      c. It is moving on the ground  
 d. It is moving.      e. It is accelerating.      f. It is at rest above ground level  
 g. It is above the ground.      h. It is moving above ground level.
5. Which would ALWAYS be true of an object possessing a potential energy of 0 joules?  
 a. It is on the ground.      b. It is at rest.      c. It is moving on the ground  
 d. It is moving.      e. It is accelerating.      f. It is at rest above ground level  
 g. It is above the ground.      h. It is moving above ground level.
6. Calculate the kinetic energy of a 5.2 kg object moving at 2.4 m/s. **PSYW**
7. Calculate the potential energy of a 5.2 kg object positioned 5.8 m above the ground. **PSYW**
8. Calculate the speed of a 5.2 kg object that possesses 26.1 J of kinetic energy. **PSYW**

## Work, Energy, and Power

9. The total mechanical energy of an object is the \_\_\_\_\_.
- KE minus the PE of the object
  - PE minus the KE of the object
  - the initial KE plus the initial PE of the object
  - KE plus the PE of the object at any instant during its motion
  - final amount of KE and PE minus the initial amount of KE and PE
10. If an object moves in such a manner as to conserve its total mechanical energy, then \_\_\_\_\_.
- the amount of kinetic energy remains the same throughout its motion
  - the amount of potential energy remains the same throughout its motion
  - the amount of both the kinetic and the potential energy remains the same throughout its motion
  - the sum of the kinetic energy and the potential energy remains the same throughout its motion
11. Determine the total mechanical energy (TME) of the objects at positions A, B, C and D.



12. Calculate the total mechanical energy (TME) of a 5.2 kg object moving at 2.4 m/s and positioned 5.8 m above the ground. **PSYW**
13. Read the following descriptions and indicate whether the objects' KE, PE and TME increases, decreases or remains the same (=). If it is impossible to tell, then answer ???.
- A marble begins at an elevated position on top of an inclined ruler and rolls down to the bottom of the ruler.  
 KE: ↑ ↓ = ???    PE: ↑ ↓ = ???    TME: ↑ ↓ = ???
  - A marble is rolling along a level table when it hits a note card and slides to a stop.  
 KE: ↑ ↓ = ???    PE: ↑ ↓ = ???    TME: ↑ ↓ = ???
  - A cart is pulled from the bottom of an incline to the top of the incline at a constant speed.  
 KE: ↑ ↓ = ???    PE: ↑ ↓ = ???    TME: ↑ ↓ = ???
  - A physics student runs up a staircase at a constant speed.  
 KE: ↑ ↓ = ???    PE: ↑ ↓ = ???    TME: ↑ ↓ = ???
  - A force is applied to a root beer mug to accelerate it from rest across a level countertop.  
 KE: ↑ ↓ = ???    PE: ↑ ↓ = ???    TME: ↑ ↓ = ???
  - A pendulum bob is released from rest from an elevated position and swings to its lowest point.  
 KE: ↑ ↓ = ???    PE: ↑ ↓ = ???    TME: ↑ ↓ = ???
  - A car skids from a high speed to a stopping position along a level highway.  
 KE: ↑ ↓ = ???    PE: ↑ ↓ = ???    TME: ↑ ↓ = ???



### Work-Energy Relationships

Read from **Lesson 2** of the **Work, Energy and Power** chapter at **The Physics Classroom**:

<http://www.physicsclassroom.com/Class/energy/u5l2a.html>

**MOP Connection:** Work and Energy: sublevel 5

**Important Background:** As an object moves, either its total mechanical energy is conserved or mechanical energy is transferred to non-mechanical forms (such as thermal energy, light energy, electrical energy, etc.). Whether there is an energy transfer or an energy conservation depends on whether or not external (a.k.a. non-conservative) forces are doing work. If external forces (or non-conservative forces) are doing work, then the total mechanical energy of the object is not conserved - energy is transferred between mechanical and non-mechanical forms. On the other hand, if external forces do not do work, the total mechanical energy of the object is conserved.

1. Categorize the following force types as being either internal or external forces:  $F_{grav}$ ;  $F_{norm}$ ;  $F_{frict}$ ;  $F_{air}$ ;  $F_{app}$ ;  $F_{tens}$ ; and  $F_{spring}$ .

Internal Forces	External Forces

2. Identify the following as being either always true (AT), never true (NT) or might be true (MBT).

AT, NT, MBT?	Statement:
	a. If gravity does work upon an object, then its total mechanical energy (TME) is conserved.
	b. If gravity is the only force doing work upon an object, then its total mechanical energy (TME) is conserved.
	c. If a normal force acts upon an object, then its TME will change.
	d. If sliding friction does work upon an object, then its TME will decrease.
	e. If only external forces are doing work upon an object, then its TME will be conserved.
	f. If both internal and external forces are doing net work upon an object, then more information is needed to tell if its TME will be conserved.
	g. If a quantity such as the total mechanical energy is conserved, then that means that it does not change over the course of a motion.

3. Consider the three situations below. Identify whether or not the total mechanical energy (TME) is being conserved. Then indicate if external forces (non-conservative) are doing work.



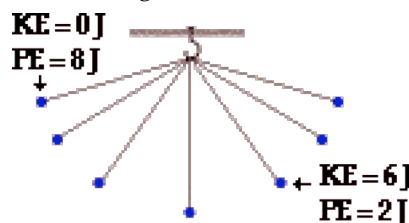
TME Conserved? \_\_\_\_\_

Ext. forces doing work? \_\_\_\_\_



TME Conserved? \_\_\_\_\_

Ext. forces doing work? \_\_\_\_\_







TME Conserved? \_\_\_\_\_

Ext. forces doing work? \_\_\_\_\_

## Work, Energy, and Power

4. For each statement, identify which forces ( $F_{\text{grav}}$ ;  $F_{\text{norm}}$ ;  $F_{\text{frict}}$ ;  $F_{\text{air}}$ ;  $F_{\text{app}}$ ;  $F_{\text{tens}}$ ; and  $F_{\text{spring}}$ ) are doing work. Then state whether the total mechanical energy will be conserved.

<p>a. A bungee jumper rapidly decelerates as he reaches the end of his spring-like bungee chord. Ignore the effect of air resistance.</p>  <p>Forces doing work? _____</p> <p>TME Conserved?    Yes        No</p>	<p>b. A girl releases a softball from rest from a height of 2 meters above the ground; the ball free-falls to the ground.</p>  <p>Forces doing work? _____</p> <p>TME Conserved?    Yes        No</p>
<p>c. A weightlifter briskly raises a 200-pound barbell above his head.</p>  <p>Forces doing work? _____</p> <p>TME Conserved?    Yes        No</p>	<p>d. A swimmer pushes off the blocks to accelerate forward at the beginning of a race.</p>  <p>Forces doing work? _____</p> <p>TME Conserved?    Yes        No</p>

For questions #5-#14, a physical situation is described. For each situation determine whether the total mechanical energy (TME) of the object (in **bold-face text**) is conserved, increases, or decreases.

- \_\_\_\_\_ 5. A force is applied to a **root beer mug** to accelerate it across a level counter-top.  
 a. TME conserved            b. TME increases            c. TME decreases
- \_\_\_\_\_ 6. A force is applied to a **cart** to raise it up an inclined plane at constant speed.  
 a. TME conserved            b. TME increases            c. TME decreases
- \_\_\_\_\_ 7. A **marble** starts from rest and rolls down an inclined plane. Ignore friction.  
 a. TME conserved            b. TME increases            c. TME decreases
- \_\_\_\_\_ 8. A **physics student** runs up a flight of stairs at constant speed.  
 a. TME conserved            b. TME increases            c. TME decreases
- \_\_\_\_\_ 9. A **baseball** makes its flight through the air. (Neglect  $F_{\text{air}}$ .)  
 a. TME conserved            b. TME increases            c. TME decreases
- \_\_\_\_\_ 10. A **coffee filter** is released from rest and falls with a terminal velocity.  
 a. TME conserved            b. TME increases            c. TME decreases
- \_\_\_\_\_ 11. A **car** skids to a stop while traveling down a steep hill.  
 a. TME conserved            b. TME increases            c. TME decreases
- \_\_\_\_\_ 12. A **pendulum bob** is tied to a string and swings back and forth. (Neglect  $F_{\text{air}}$ .)  
 a. TME conserved            b. TME increases            c. TME decreases
- \_\_\_\_\_ 13. A **marble** hits a note card and slides to a stop.  
 a. TME conserved            b. TME increases            c. TME decreases

### Work-Energy Bar Charts

Read from **Lesson 2** of the **Work, Energy and Power** chapter at **The Physics Classroom**:

<http://www.physicsclassroom.com/Class/energy/u5l2c.html>

**MOP Connection:** Work and Energy: sublevel 6

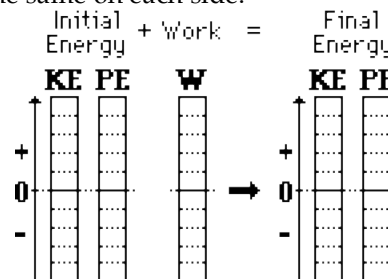
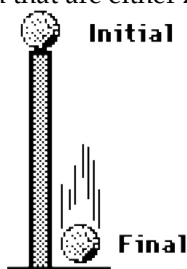
The work-energy relationship is the most important relationship of the unit. The work done by external forces ( $W_{ext}$ ) is related to the total mechanical energy of the initial ( $TME_i$ ) and of the total energy of the final state ( $TME_f$ ) of a system as follows:

$$TME_i + W_{ext} = TME_f$$

Your goal should be to combine your understanding of kinetic energy, potential energy, and work with the above equation in order to analyze physical situations involving energy changes and transformations and to solve computational problems involving work and energy. One tool that will assist in the analysis of physical situations is a work-energy bar chart. A work-energy bar chart represents the amount of energy present in a system by means of a vertical bar. The length of a bar is representative of the amount of energy present; a longer bar representing a greater amount of energy. According to the work-energy theorem, the initial mechanical energy (kinetic and potential) plus the work done on the system by external forces equals the final mechanical energy (kinetic and potential). Consequently, the sum of the bar heights for any initial condition must equal the sum of the bar heights for the final condition.

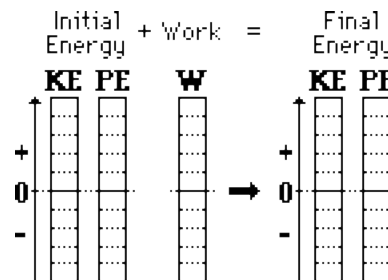
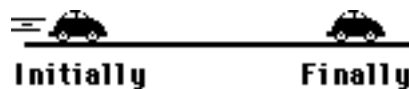
Complete the following work-energy bar charts based on the given statement. Then cross out or cancel any terms in the work-energy equation that are either zero or the same on each side.

1. A ball falls from the top of a pillar to the ground below. The initial state is the ball at rest at the top of the pillar and the final state is the ball just prior to striking the ground. Ignore  $F_{air}$ .



$$KE_i + PE_i + W_{ext} = KE_f + PE_f$$

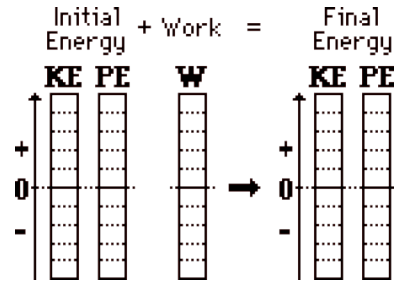
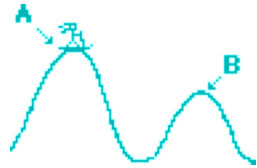
2. A car skids from a high speed to a stop with its brakes applied. The initial state is the car traveling at a high speed and the final state is the car at rest. The force of friction does work on the car, thus changing the total mechanical energy.



$$KE_i + PE_i + W_{ext} = KE_f + PE_f$$

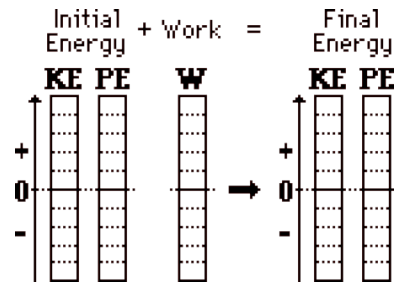
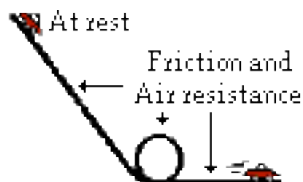
## Work, Energy, and Power

3. A skier starts from rest on top of hill A and skis into the valley and back up onto hill B. The skier utilizes her poles to propel herself across the snow, thus doing work to change her total mechanical energy. The initial state is on top of hill A and the final state is on top of hill B. Ignore frictional forces.



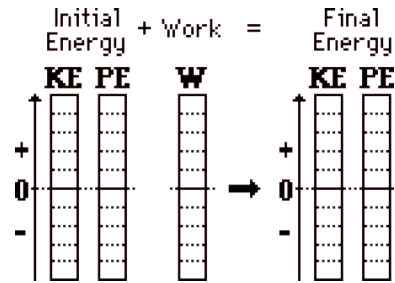
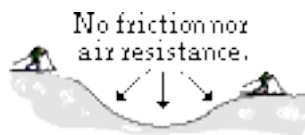
$$KE_i + PE_i + W_{ext} = KE_f + PE_f$$

4. A Hot Wheels car starts from rest on top of an inclined plane and rolls down the incline through a loop and along a horizontal surface. The initial state is the car at rest on top of the hill and the final state is the car in motion at the bottom of the hill. Friction and air resistance have a significant effect on the car.



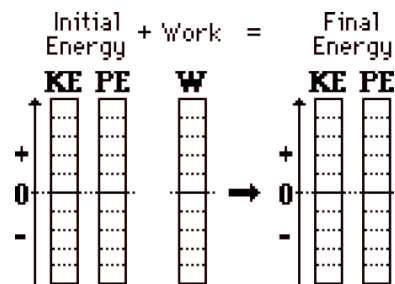
$$KE_i + PE_i + W_{ext} = KE_f + PE_f$$

5. A moving cross-country skier skis from the top of a hill down into a valley and up a second smaller hill. The initial state is the skier in motion on top of the first hill and the final state is the skier in motion on top the second hill. He uses his poles to propel himself. Ignore the effect of friction and air resistance.



$$KE_i + PE_i + W_{ext} = KE_f + PE_f$$

6. Ben Laborin applies a force to push a crate from the bottom of an inclined plane to the top at a constant speed. The initial state is the crate in motion at the bottom of the hill and the final state is the crate in motion at the top of the hill. Ignore frictional effects.



$$KE_i + PE_i + W_{ext} = KE_f + PE_f$$

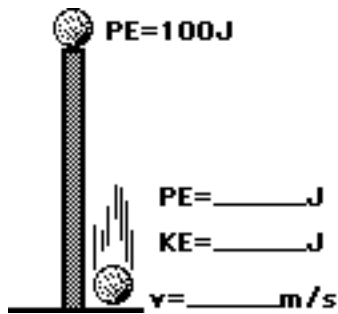
### Energy Concepts

Read from Lesson 2 of the Work, Energy and Power chapter at The Physics Classroom:

- <http://www.physicsclassroom.com/Class/energy/u5l2b.html>
- <http://www.physicsclassroom.com/Class/energy/u5l2bb.html>
- <http://www.physicsclassroom.com/Class/energy/u5l2bc.html>

MOP Connection: Work and Energy: sublevel 7, 8, 9 and 10

- Consider the falling motion of the ball in the following two frictionless situations. For each situation, indicate the forces doing work upon the ball. Indicate whether the energy of the ball is conserved and explain why. Finally, simplify the work-energy equation and use it to find the kinetic energy and the velocity of the 2-kg ball just prior to striking the ground.



Forces doing work?

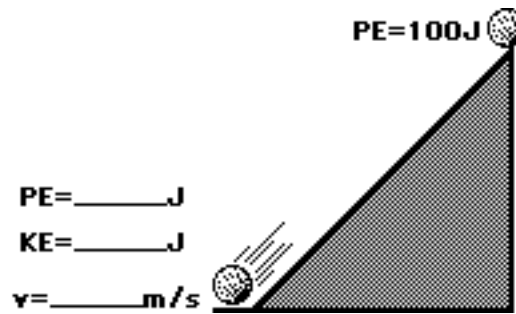
\_\_\_\_\_

TME Conserved: Yes or No?

Explanation: \_\_\_\_\_

\_\_\_\_\_

$$KE_i + PE_i + W_{ext} = KE_f + PE_f$$



Forces doing work?

\_\_\_\_\_

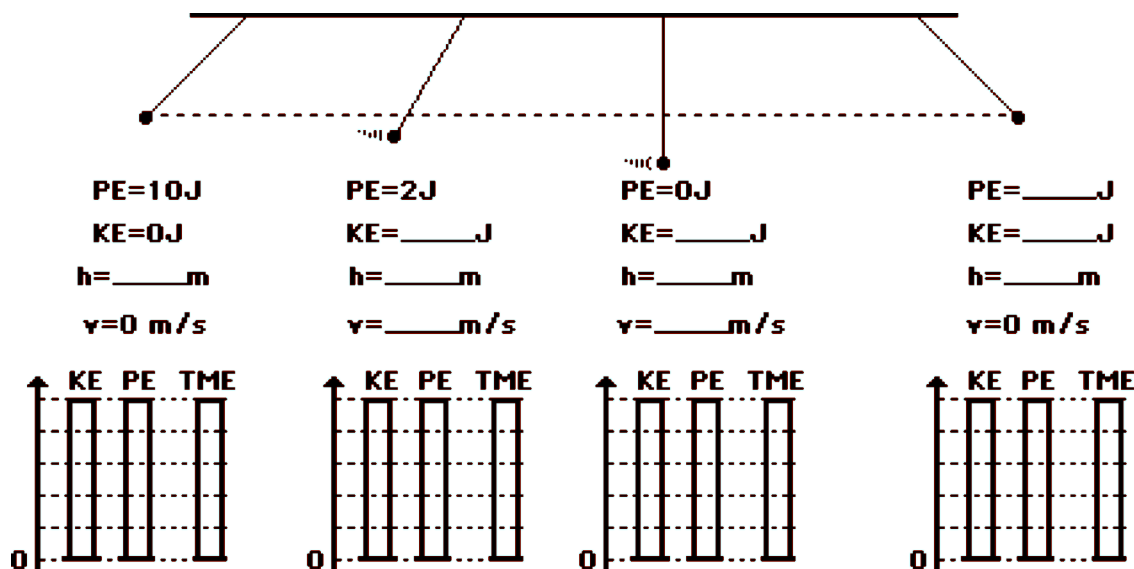
TME Conserved: Yes or No?

Explanation: \_\_\_\_\_

\_\_\_\_\_

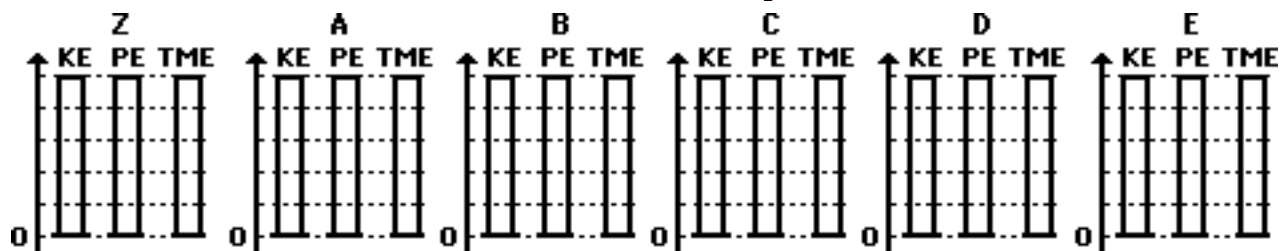
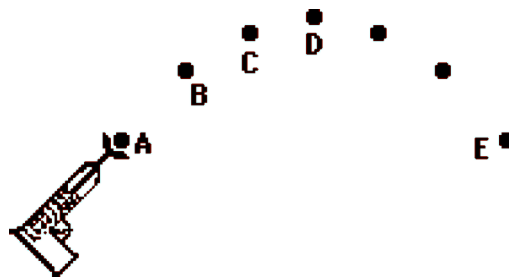
$$KE_i + PE_i + W_{ext} = KE_f + PE_f$$

- Use the work-energy relationship to fill in the blanks for the following system ( $m=2$  kg). Neglect frictional forces. Finally, darken in the bars of the bar chart in order to demonstrate the amount of kinetic energy (KE), potential energy (PE) and total mechanical energy (TME).

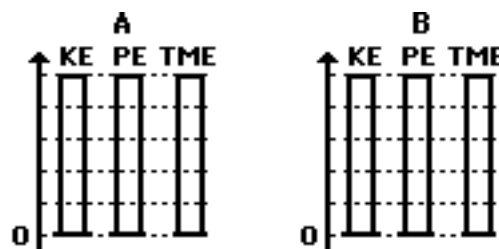
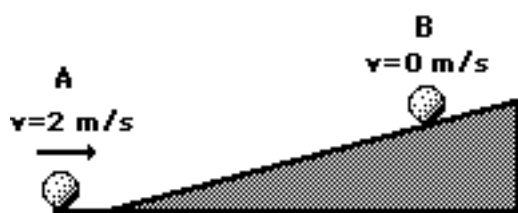


## Work, Energy, and Power

3. A dart is launched from a dart gun and subsequently follows a parabolic path typical of any projectile. Five positions in the trajectory of the dart are marked and labeled in the diagram at the right. For each of the five positions and for position Z, fill in the work-energy bar chart in the space below.



4. A 2-kg ball moving at 2 m/s is rolling towards an inclined plane. It eventually rolls up the hill to a position near the top where it momentarily stops prior to rolling back down the incline. Assume negligible friction and air resistance. Construct a energy bar chart for the ball.



Simplify the equation below by canceling terms that are either zero or constant. Then use the equation to determine the height to which the ball rises along the incline before stopping.

$$\frac{1}{2} \cdot m \cdot v_i^2 + m \cdot g \cdot h_i + F \cdot d \cdot \cos \theta = \frac{1}{2} \cdot m \cdot v_f^2 + m \cdot g \cdot h_f$$

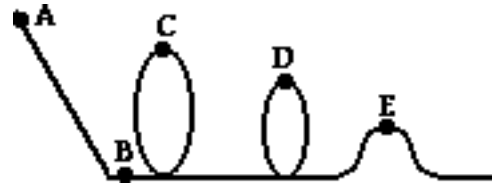
5. Three identical balls approach three different "frictionless" hills with a speed of 2 m/s. In which case - A, B, or C, (or a tie) - will the ball roll the highest? \_\_\_\_\_ Explain your answer.



6. Fill in the blanks in the following sentence:

An object starts from rest with a potential energy of 600 J and free-falls towards the ground. After it has fallen to a height of one-fourth of its original height, its total mechanical energy is \_\_\_\_\_ J, its potential energy is \_\_\_\_\_ J, and its kinetic energy is \_\_\_\_\_ J.

Consider the diagram at the right in answering the next three questions. Five locations along a roller coaster track are shown. Assume that there are negligible friction and air resistance forces acting upon the coaster car.



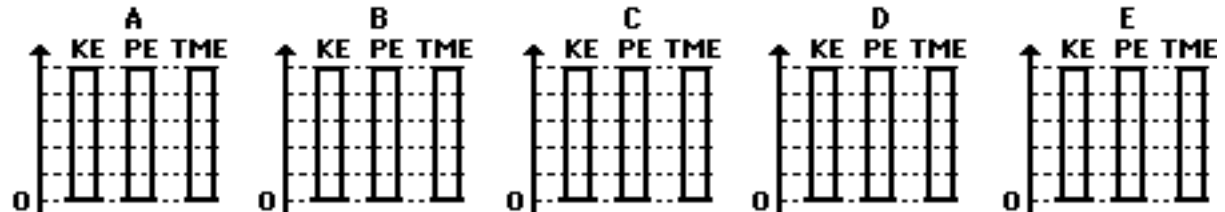
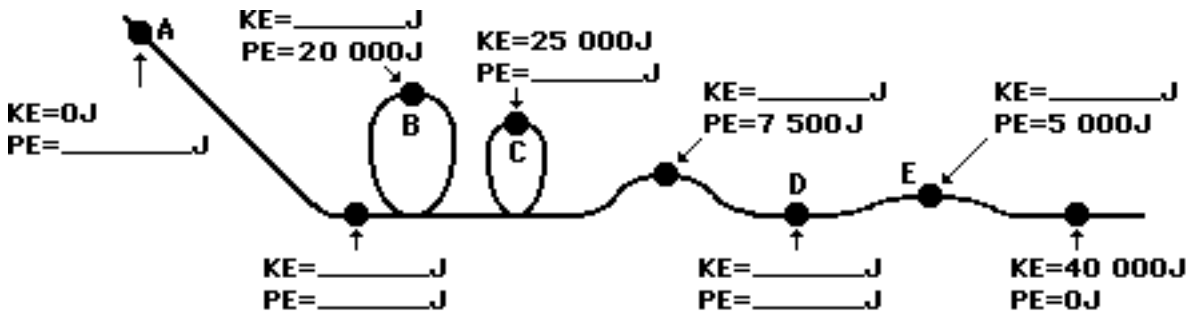
- Rank the five locations in order of increasing TME (smallest to largest TME). Use < and or = signs between the blanks.
- Rank the five locations in order of increasing PE (smallest to largest PE). Use < and or = signs between the blanks.
- Rank the five locations in order of increasing KE (smallest to largest KE). Use < and or = signs between the blanks.

\_\_\_\_\_ letter \_\_\_\_\_ sign \_\_\_\_\_ letter \_\_\_\_\_ sign \_\_\_\_\_ letter \_\_\_\_\_ sign \_\_\_\_\_ letter

\_\_\_\_\_ letter \_\_\_\_\_ sign \_\_\_\_\_ letter \_\_\_\_\_ sign \_\_\_\_\_ letter \_\_\_\_\_ sign \_\_\_\_\_ letter

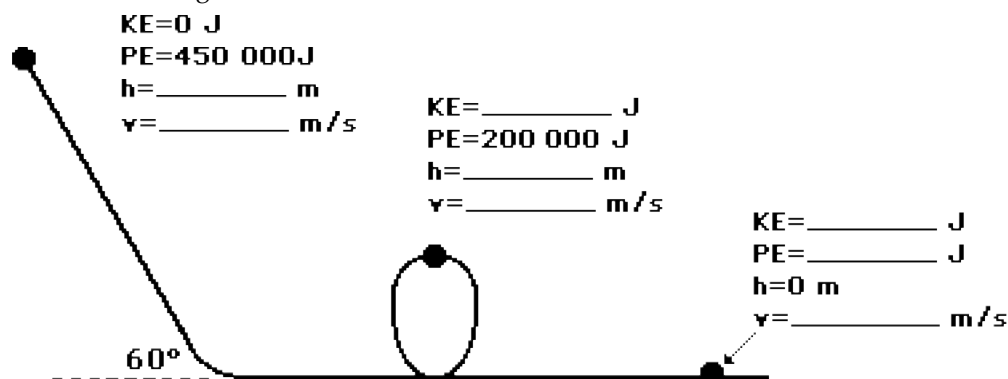
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10. Use the law of conservation of energy (assume no friction nor air resistance) to determine the kinetic and potential energy at the various marked positions along the roller coaster track below. Finally, fill in the bars of the bar charts for positions A, B, C, D, and E.

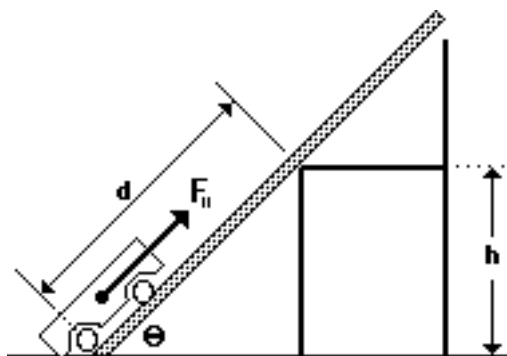


## Work, Energy, and Power

11. Use the law of conservation of energy (assume no friction) to fill in the blanks at the various marked positions for a 1000-kg roller coaster car.



12. In a physics lab, a 3.0-kg cart was pulled at a constant speed along an inclined plane (with a force parallel to the plane) to a height of 0.500 m. The angle of incline was altered in each consecutive trial. It was found that each angle required the same amount of work to elevate the cart to the same height. Use your understanding of work, energy and dynamics to fill in the following table. (HINT:  $F_{\text{app}} = F_{\text{parallel}} = m \cdot g \cdot \sin \theta$ .)

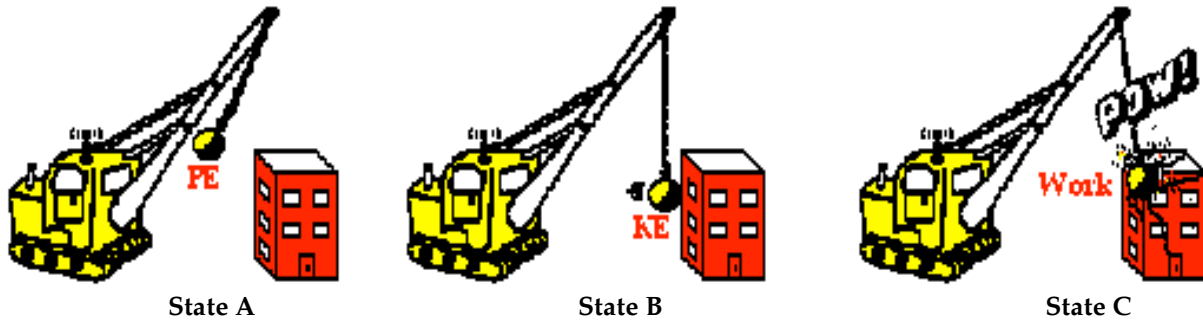


	$\theta$ (°)	h (m)	$\Delta PE$ (J)	$F_{\text{parallel}}$ (N)	d (m)	Work (J)
a.	15	0.500 m				
b.	20	0.500 m				
c.	25	0.500 m				
d.	35	0.500 m				
e.	45	0.500 m				

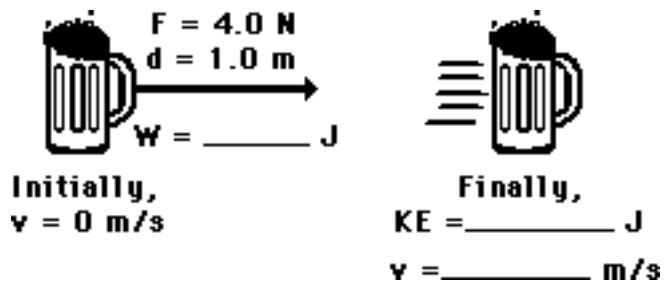
Show sample calculations below:



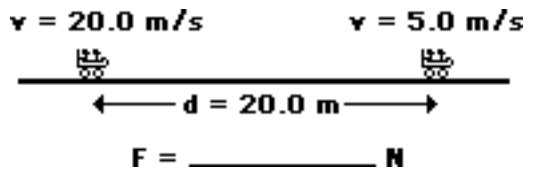
13. A wrecking ball is raised above its highest point (State A), possessing 6000 J of PE relative to its lowest location (State B). The wrecking ball strikes a building and comes to a resting position (State C). Determine the kinetic energy of the wrecking ball at state B. \_\_\_\_\_ Determine the work done on the wrecking ball in going from State B to State C. \_\_\_\_\_



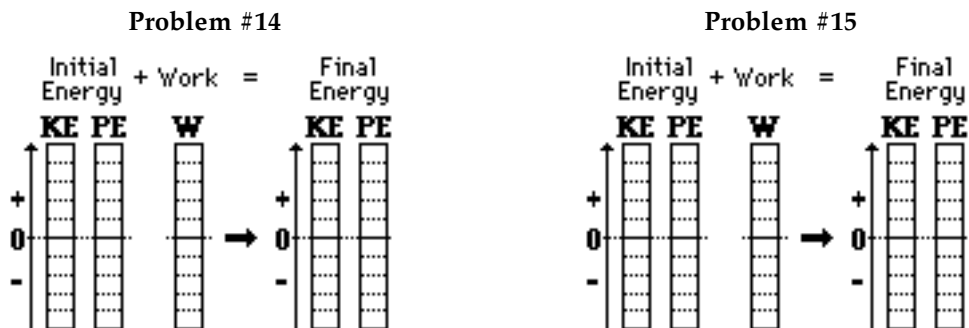
14. Pete Zaria applies a 4.0-N force to a 1.0-kg mug of root beer to accelerate it over a distance of 1.0-meter along the counter top. Determine the work done by Pete on the mug and the mug's final kinetic energy and final velocity. PSYW



15. A 600-kg roller coaster car (includes passenger mass) is moving at 20.0 m/s. The hydraulic braking system in the track applies an external force to slow the car to a speed of 5.0 m/s over a distance of 20.0 meters. Determine the force that acts upon the car. PSYW

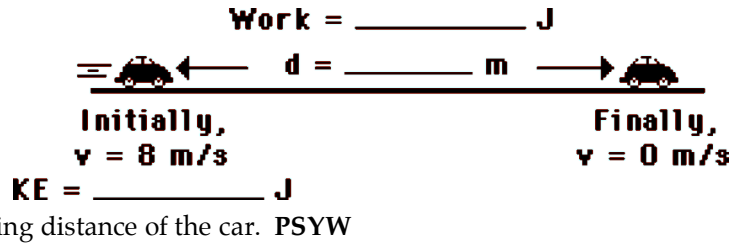


16. Construct work-energy bar charts for problems #14 and #15.



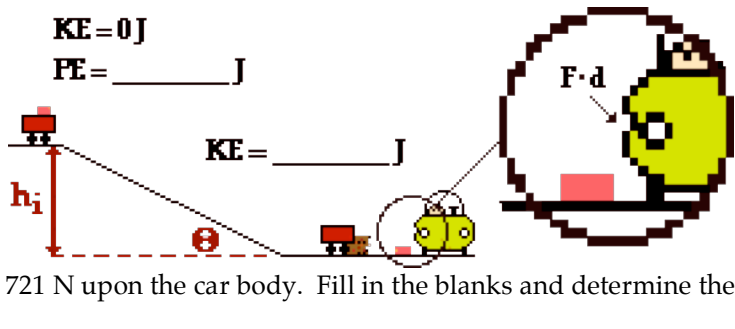
**Work, Energy, and Power**

17. Vera is driving her 1000-kg car at a speed of 8.0 m/s. When Vera slams on the brakes, the ground exerts a 8000-N frictional force to bring the car to a stop. Determine the initial kinetic energy of the car, the work done by friction on the car, and the stopping distance of the car. PSYW

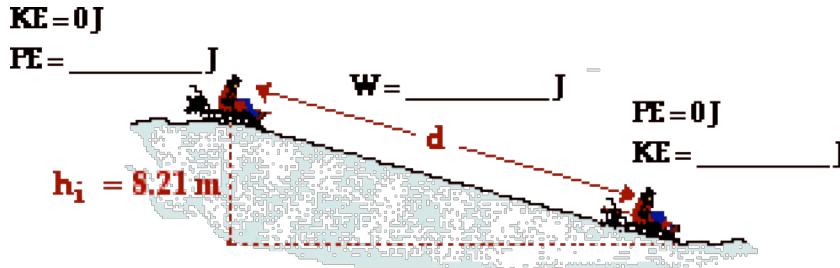


18. If Vera's speed (in question #17) were increased to 24.0 m/s, then what would be the new stopping distance? \_\_\_\_\_ In other words, how many times greater is the stopping distance if the speed is tripled? \_\_\_\_\_ Explain.

19. A 0.750-kg peach can is at rest in a shopping cart at the edge of a hill. A strong wind sets it into motion, sending down a 6.32-meter high hill. The cart hits a tree stump. But the peach can, being in motion, continues in motion until it finally collides with a car. Upon impact, the peach can exerts an average force of 721 N upon the car body. Fill in the blanks and determine the depth of the dent.



20. A 56.9 kg sledder descends an 8.21-meter high hill, encountering a friction force of 11.7 N. Fill in the blanks and determine the speed of the sledder after traveling the 31.7 meters to the bottom of the hill.



## Work-Energy Calculations

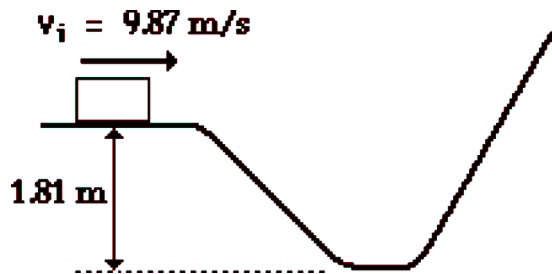
Study **Lesson 2** of the **Work, Energy and Power** chapter at **The Physics Classroom**:

<http://www.physicsclassroom.com/Class/energy/u5l2bc.html>

For the following questions, begin with the work-energy equation, cancel terms, substitute and solve.

1. A glider is gliding through the air at a height of 416 meters with a speed of 45.2 m/s. The glider dives to a height of 278 meters. Determine the glider's new speed.

$$KE_i + PE_i + W_{\text{ext}} = KE_f + PE_f$$



2. A box with mass  $m$  is sliding along on a friction-free surface at 9.87 m/s at a height of 1.81 m. It travels down the hill and then up another hill.  
a. Find the speed at the bottom of the hill.

$$KE_i + PE_i + W_{\text{ext}} = KE_f + PE_f$$

- b. Find the maximum vertical height to which the box will rise on the opposite hill.

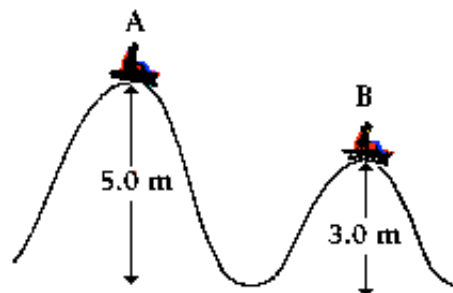
$$KE_i + PE_i + W_{\text{ext}} = KE_f + PE_f$$

3. A 1423-kg car is moving along a level highway with a speed of 26.4 m/s. The driver takes the foot off the accelerator and the car experiences a retarding force of 901-N over a distance of 106 m. Determine the speed of the car after traveling this distance.

$$KE_i + PE_i + W_{\text{ext}} = KE_f + PE_f$$

4. A sledder starts from rest atop a 5.0-m high hill (A). She sleds to the bottom and up to the top of the adjacent 3.0-m high hill. How fast is the sledder going at point B? Ignore friction.

$$KE_i + PE_i + W_{\text{ext}} = KE_f + PE_f$$



## Work, Energy, and Power

5. A 4768-kg roller coaster train full of riders approaches the loading dock at a speed of 17.1 m/s. It is abruptly decelerated to a speed of 2.2 m/s over a distance of 13.6 m. Determine the retarding force that acts upon the roller coaster cars.

$$KE_i + PE_i + W_{\text{ext}} = KE_f + PE_f$$

6. A catcher's mitt recoils a distance of 12.9 cm in bringing a 142-gram baseball to a stop. If the applied force is 588 N, then what was the speed of the baseball at the moment of contact with the catcher's mitt?

$$KE_i + PE_i + W_{\text{ext}} = KE_f + PE_f$$

7. An unknown force is applied to a 12 kg mass. The force acts at an angle of 30 degrees above the horizontal. Determine the force acting if the force acts for a horizontal displacement of 22 meters and increases the 12 kg mass's speed from 11 m/s to 26 m/s.

$$KE_i + PE_i + W_{\text{ext}} = KE_f + PE_f$$

8. A physics teacher exerts a force upon a 3.29-kg pile of snow to both lift it and set it into motion. The snow leaves the shovel with a speed of 2.94 m/s at a height of 0.562 m. Determine the work done upon the pile of snow.

$$KE_i + PE_i + W_{\text{ext}} = KE_f + PE_f$$

9. A 250.-gram cart starts from rest and rolls down an inclined plane from a height of 0.541 m. Determine its speed at a height of 0.127 m above the bottom of the incline.

$$KE_i + PE_i + W_{\text{ext}} = KE_f + PE_f$$

10. A 4357-kg roller coaster car starts from rest at the top of a 36.5-m high track. Determine the speed of the car at the top of a loop that is 10.8 m high.

$$KE_i + PE_i + W_{\text{nc}} = KE_f + PE_f$$