Work, Power, and Energy

Chapter 6 - Work, Power and Energy (Page 216)

Types of Energy

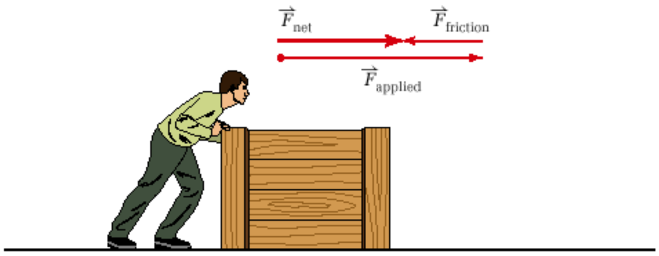
mechanical energy = kinetic energy + potential energy

Work

Work is a transfer of energy. Work is always done on an object and results in a change in that object. A force does work on an object if it causes the object to move.

Work is the product of the magnitude of an individual force acting on an object (not the net force acting on the object) and the magnitude of the displacement of the object. The force and displacement must be parallel to one another.

Figure 6.3 When you were determining the motion of objects in Chapter 4, you used the net force acting on the object. The net force is really the vector sum of all of the forces acting on the object. When calculating work, you determine the work done by one specific force, not the net force.



220 MHR • Unit 3 Momentum and Energy

$$\boxed{W = F_{\parallel}\Delta d} \longrightarrow \boxed{W = Fd}$$

W -> work

$F_{\parallel}$ -> magnitude of individual force

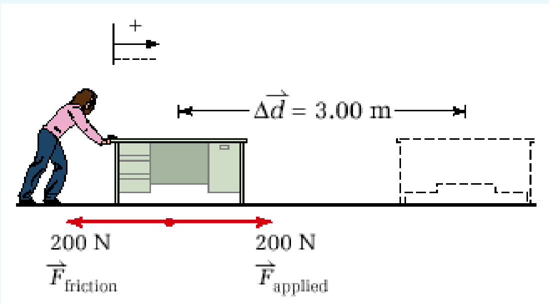
Δd -> magnitude of displacement

NOTE: Force and displacement are vectors. Work is a scalar.

MODEL PROBLEM

Determining the Amount of Work Done

A physics student is rearranging her room. She decides to move her desk across the room, a total distance of 3.00 m. She moves the desk at a constant velocity by exerting a horizontal force of 2.00×10^2 N. Calculate the amount of work the student did on the desk in moving it across the room.



Page 221, PP #1-3

PRACTICE PROBLEMS

1. A weight lifter, Paul Anderson, used a circular platform attached to a harness to lift a class of 30 children and their teacher. While the children and teacher sat on the platform, Paul lifted them. The total weight of the platform plus people was 1.1×10^4 N. When he lifted them a distance of 52 cm, at a constant velocity, how much work did he do? How high would you have to lift one child, weighing 135 N, in order to do the same amount of work that Paul did?

2. A 75 kg boulder rolled off a cliff and fell to the ground below. If the force of gravity did 6.0×10^4 J of work on the boulder, how far did it fall?

3. A student in physics lab pushed a 0.100 kg cart on an air track over a distance of 10.0 cm, doing 0.0230 J of work. Calculate the acceleration of the cart. (Hint: Since the cart was on an air track, you can assume that there was no friction.)

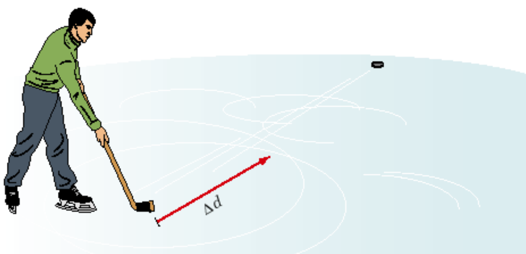
Three Cases
When No Work is Done
(Page 222)

Case 1: Applying a Force That Does Not Cause Motion

Consider the energy that you could expend trying to move a house. Although you are pushing on the house with a great deal of force, it does not move. Therefore, the work done on the house, according to the equation for work, is zero (see Figure 6.4). In this case, your muscles feel as though they did work; however, they did no work on the house. The work equation describes work done by a force that moves the object on which the force is applied. Recall that work is a transfer of energy to an object. In this example, the *condition* of the house has not changed; therefore, no work could have been done on the house.

Case 2: Uniform Motion in the Absence of a Force

Recall from Chapter 5 that Newton's first law of motion predicts that an object in motion will continue in motion unless acted on by an *external* force. A hockey puck sliding on a frictionless surface at constant speed is moving and yet the work done is still zero (see Figure 6.5). Work was done to start the puck moving, but because the surface is frictionless, a force is not required to keep it moving; therefore, no work is done on the puck to keep it moving.



Case 3: Applying a Force That Is Perpendicular to the Motion

Assume that you are carrying your physics textbook down the hall, at constant velocity, on your way to class. Your hand applies a force directly upward to your textbook as you move along the hallway. When considering the work done on the textbook by your hand, you can see that the upward force is perpendicular (i.e., at 90°) to the displacement. In this case, the work done by your hand on the textbook is zero (see Figure 6.6). It is important to note that your hand does do work on the textbook to accelerate it when you begin to move, but once you and the textbook are moving at a constant velocity, you are no longer doing work on the book.

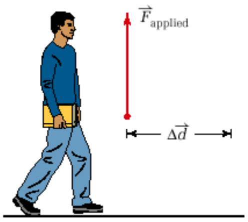
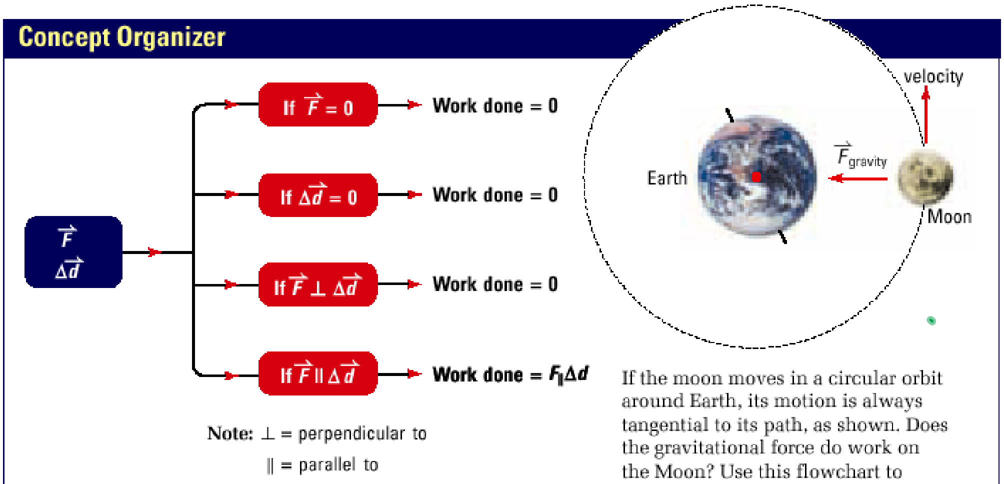


Figure 6.6 You are exerting an upward force (against gravity) on your book to prevent it from falling. However, since this force is perpendicular to the motion of the book, it does no work on the book.

Concept Organizer



If the moon moves in a circular orbit around Earth, its motion is always tangential to its path, as shown. Does the gravitational force do work on the Moon? Use this flowchart to determine the answer.

Figure 6.7 Making decisions about work done

P. 225.

PRACTICE PROBLEMS

4. With a 3.00×10^2 N force, a mover pushes a heavy box down a hall. If the work done on the box by the mover is 1.90×10^3 J, find the length of the hallway.

5. A large piano is moved 12.0 m across a room. Find the average horizontal force that must be exerted on the piano if the amount of work done by this force is 2.70×10^3 J.

6. A crane lifts a 487 kg beam vertically at a constant velocity. If the crane does 5.20×10^4 J of work on the beam, find the vertical distance that it lifted the beam.

7. A teacher carries his briefcase 20.0 m down the hall to the staff room. The teacher's hand exerts a 30.0 N force upward as he moves down the hall at constant velocity.
   (a) Calculate the work done by the teacher's hand on the briefcase.
   (b) Explain the results obtained in part (a).

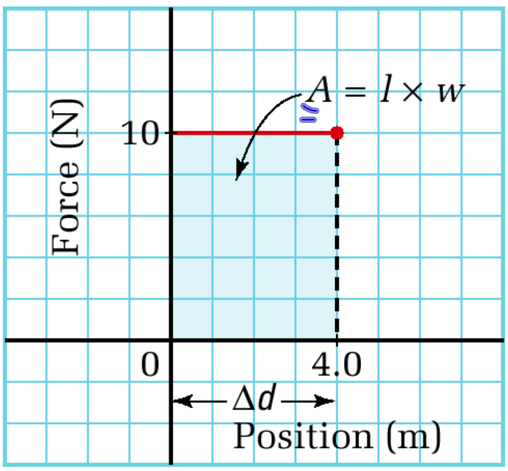
8. A 2.00×10^2 N force acts horizontally on a bowling ball over a displacement of 1.50 m. Calculate the work done on the bowling ball by this force.

9. The *Voyager* space probe has left our solar system and is travelling through deep space, which can be considered to be void of all matter. Assume that gravitational effects may be considered negligible when *Voyager* is far from our solar system.
   (a) How much work is done on the probe if it covers 1.00×10^6 km travelling at 3.00×10^4 m/s?
   (b) Explain the results obtained in part (a).

10. An energetic group of students attempts to remove an old tree stump for use as firewood during a party. The students apply an average upward force of 650 N. The 865 kg tree stump does not move after 15.0 min of continuous effort, and the group gives up.
    (a) How much work did the students do on the tree stump?
    (b) Explain the results obtained in part (a).

Work Done by Forces
(Page 225)

Force vs. Position



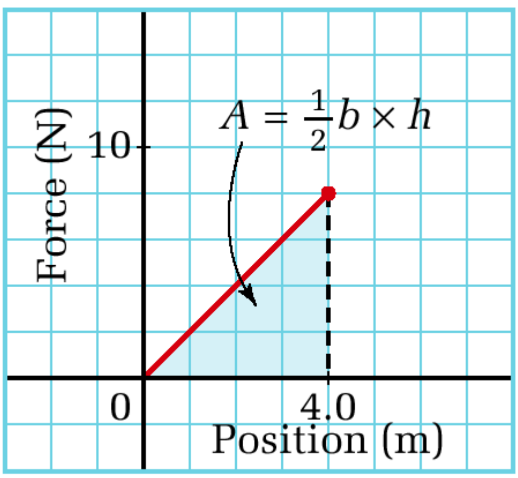
Constant Force

Area = l x w

Area = Fd

Area = Work

Force vs. Position



Force Not Constant
(increasing steadily)

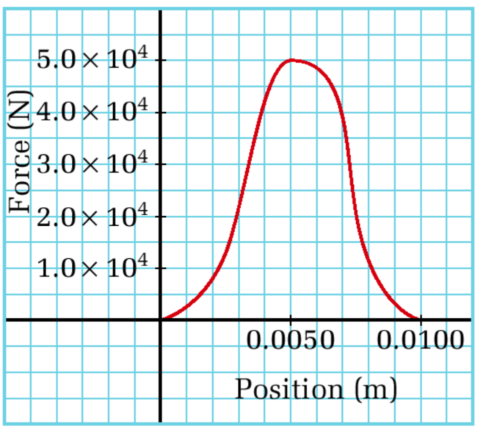
$A = \frac{1}{2}\, b \times h$

$A = \frac{1}{2}(dF)$ or $A = \frac{1}{2} Fd$

$W = \frac{1}{2} Fd$

* Average force is used.

Force vs. Position



Force Not Constant

Force changes. It reaches a maximum then falls back to zero.

Area = Work Done

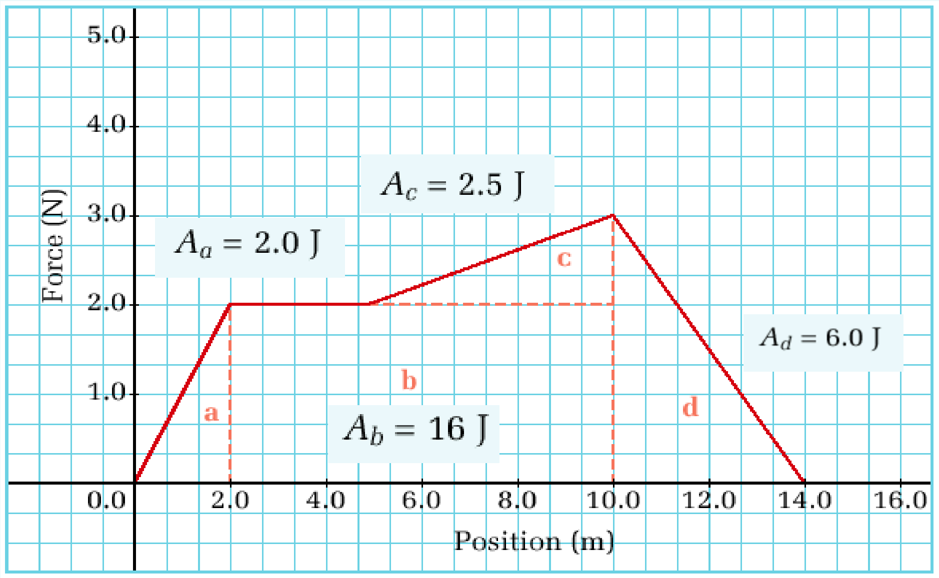
Use Calculus to find work.

DR

To find the work done, count the number of squares and estimate the area of the partial squares.

Estimating Work from a Graph

Determine the amount of work done by the changing force represented in the force-versus-position plot shown here.



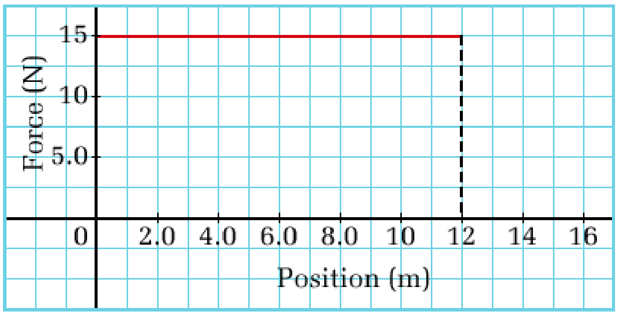
$$A_T = A_a + A_b + A_c + A_d$$
$$= 2.0\text{ J} + 16.0\text{ J} + 2.5\text{ J} + 6.0\text{ J}$$
$$= 26.5\text{ J}$$

$$W = 26.5\text{ J} \cong 27\text{ J}$$

PRACTICE PROBLEMS

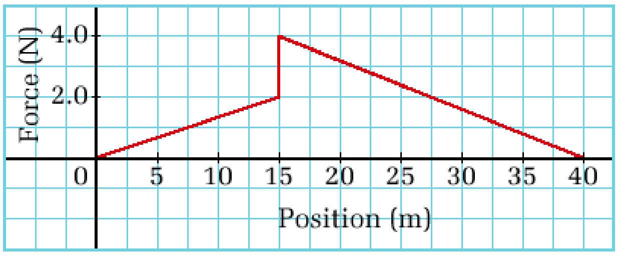
11. Determine the amount of work done by the forces represented in the four force-versus-position plots that follow.

A



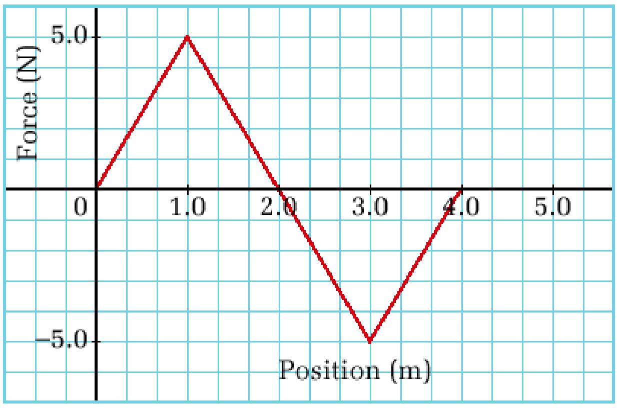
1.8×10^2 J

B



65 J

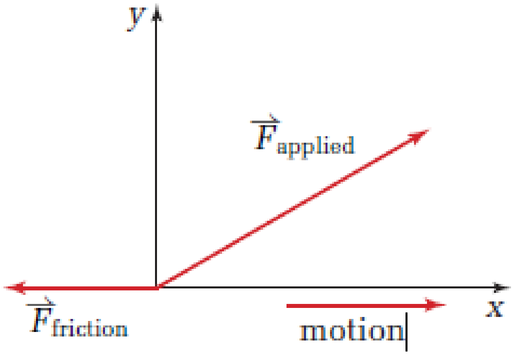
C

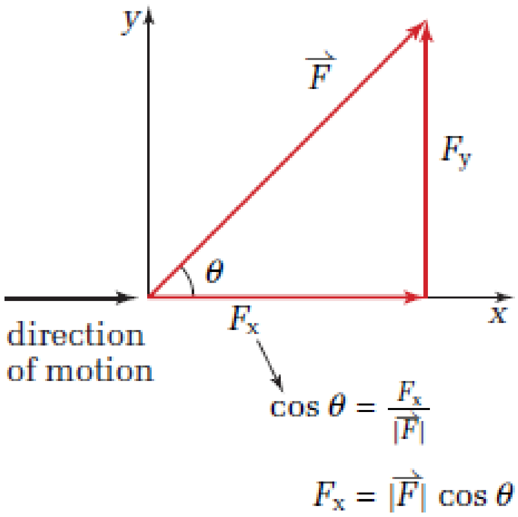


0 J

12. Draw a force-versus-position plot that represents a constant force of 60 N exerted on a Frisbee™ over a distance of 80.0 cm. Show the work done on the Frisbee™ by appropriately shading the graph.

☆





WORK

Work done when the force and displacement are not parallel and pointing in the same direction

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

θ is the angle between the force and displacement vectors. Note: Since work is a scalar quantity and only the magnitudes of the force and displacement affect the value of the work done, vector notations have been omitted.

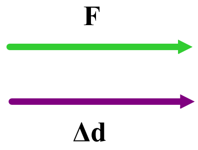
Positive and Negative Work
(Page 233)

Positive work is done when the force causing the displacement is in the **same** direction as the displacement. Positive work **adds** energy to an object.

Negative work is done when the force causing the displacement is in a direction **opposite** that of the displacement. Negative work **removes** energy from an object.

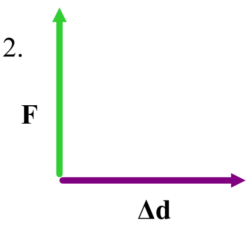
Examples

1.



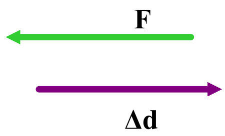
Maximum Positive Work

2.



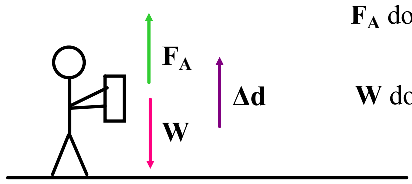
No Work is Done

3.



Maximum Negative Work

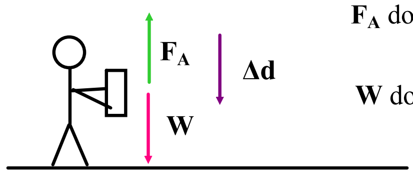
4.



F_A does __________ work.

W does __________ work.

5.



F_A does __________ work.

W does __________ work.

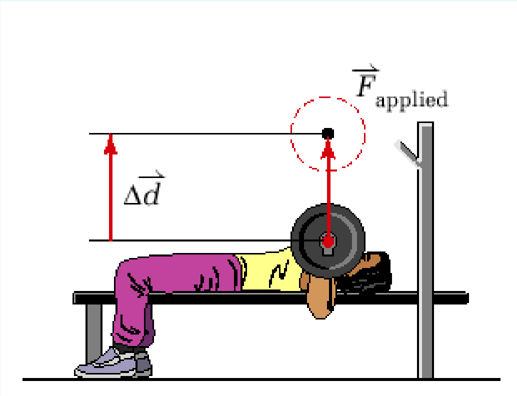
☆

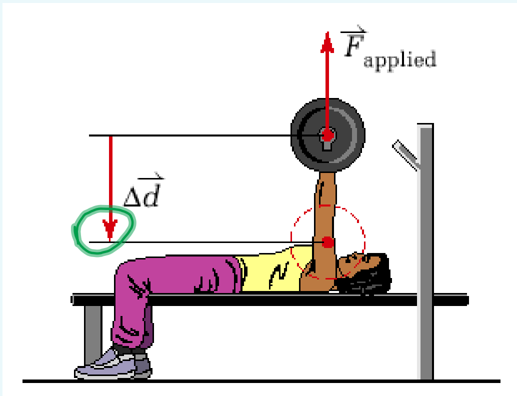
P.233

MODEL PROBLEM

Doing Positive and Negative Work

Consider a weight lifter bench-pressing a barbell weighing 6.50×10^2 N through a height of 0.55 m. There are two distinct motions: (1) when the barbell is lifted up and (2) when the barbell is lowered back down. Calculate the work that the weight lifter does on the barbell during each of the two motions.





Lifting

W = Fd

W = $(6.50 \times 10^2$ N)(0.55 m)

W = 3.2×10^2 J

F $\uparrow$ $\uparrow$ **Δd**

$\boxed{W = 3.2 \times 10^2 \text{ J}}$

Lowering

W = Fd

W = $(6.50 \times 10^2$ N)(0.55 m)

W = 3.2×10^2 J

F $\uparrow$ $\downarrow$ **Δd**

$\boxed{W = - 3.2 \times 10^2 \text{ J}}$

Page 235 # 14 - 18

Kinetic Energy
(Page 236)

Reminder: Kinetic energy is energy due to motion.

Check Units

$$\boxed{E_k = \frac{1}{2}mv^2}$$

E_k -> kinetic energy (J)
m -> mass (kg)
v -> velocity (m/s)

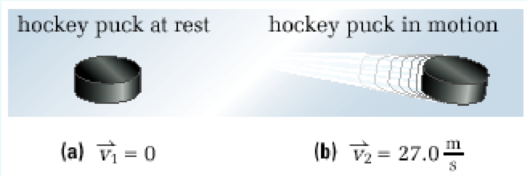
NOTE: When velocity is squared, it is no longer a vector so no vector notation is used in the kinetic energy equation.

Chapter 6 Work, Power, and Efficiency • MHR 237

MODEL PROBLEM

Calculating Kinetic Energy

A 0.200 kg hockey puck, initially at rest, is accelerated to 27.0 m/s. Calculate the kinetic energy of the hockey puck (a) at rest and (b) in motion.



$E_k = 0$ J $\qquad$ $E_k = 72.9$ J

PRACTICE PROBLEMS

238 MHR • Unit 3 Momentum and Energy

19. A 0.100 kg tennis ball is travelling at 145 km/h. What is its kinetic energy? 81J

20. A bowling ball, travelling at 0.95 m/s, has 4.5 J of kinetic energy. What is its mass?

10 Kg

21. A 69.0 kg skier reaches the bottom of a ski hill with a velocity of 7.25 m/s. Find the kinetic energy of the skier at the bottom of the hill.

1810 J

Work-Kinetic Energy Theorem
(Page 239)

The special relationship between doing work on an object and the resulting kinetic energy of the object is given by the work-kinetic energy theorem.

Assumptions:
- all work done on a system gives the system only kinetic energy
- a constant force gives the system a constant acceleration
- directions of force and displacement are parallel
- the object moves in a straight line

$$W = Fd$$

$$W = (ma)d$$

$$W = m\left(\frac{v_f - v_i}{t}\right)d$$

Note: $d = \frac{1}{2}(v_f + v_i)\,t$

$$W = m\frac{(v_f - v_i)}{\cancel{t}}\,\frac{1}{2}(v_f + v_i)\cancel{t}$$

$$W = \frac{1}{2}m\,(v_f - v_i)(v_f + v_i)$$

$$W = \frac{1}{2}m\,(v_f^2 - v_i^2)$$

$$W = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$

$$W = E_{kf} - E_{ki}$$

$$W = \Delta E_k$$

also

$$Fd = \Delta E_k$$

The equation describes how doing work on an object can change the object's kinetic energy.

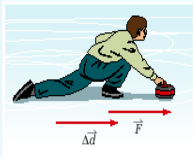
MODEL PROBLEMS

Applying the Work-Kinetic Energy Theorem

1. A physics student does work on a 2.5 kg curling stone by exerting 4.0×10^1 N of force horizontally over a distance of 1.5 m.

(a) Calculate the work done by the student on the curling stone.

(b) Assuming that the stone started from rest, calculate the velocity of the stone at the point of release. (Consider the ice surface to be effectively frictionless.)



a) 60 J
b) +6.9 m/s

2. A 75 kg skateboarder (including the board), initially moving at 8.0 m/s, exerts an average force of 2.0×10^2 N by pushing on the ground, over a distance of 5.0 m. Find the new kinetic energy of the skateboarder if the trip is completely horizontal. 3.4×10^3 J

•

PRACTICE PROBLEMS

22. A 6.30 kg rock is pushed horizontally across a 20.0 m frozen pond with a force of 30.0 N. Find the velocity of the rock once it has travelled 13.9 m. (Assume there is no friction.)

23. The mass of an electron is 9.1×10^{-31} kg. At what speed does the electron travel if it possesses 7.6×10^{-18} J of kinetic energy?

24. A small cart with a mass of 500 g is accelerated, uniformly, from rest to a velocity of 1.2 m/s along a level, frictionless track. Find the kinetic energy of the cart once it has reached a velocity of 1.2 m/s. Calculate the force that was exerted on the cart over a distance of 0.1 m in order to cause this change in kinetic energy.

25. A child's toy race car travels across the floor with a constant velocity of 2.10 m/s. If the car possesses 14.0 J of kinetic energy, find the mass of the car.

22) 11.5 m/s

23) 4.1×10^{6} m/s

24) 0.36 J; 3.6 N

25) 6.35 Kg

Potential Energy
(Page 247)

Reminder: Potential energy is the energy stored by an object due to its position or condition.

For all forms of potential energy, there is no absolute zero position or condition. Only changes in potential energy are measured. You must assign a reference position (or establish a reference line or zero line) to determine potential energy.

Gravitational Potential Energy

Gravitational potential energy is the potential energy an object has because of its position above Earth's surface.

$$\boxed{\Delta E_g = mg\Delta h}$$

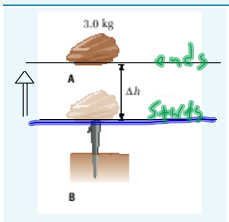
ΔE_g -> change in gravitational potential energy (J)
m -> mass (kg)
g -> acceleration due to gravity (m/s^2)
Δh -> change in height (m)

continued

MODEL PROBLEM p.249

Calculating Gravitational Potential Energy

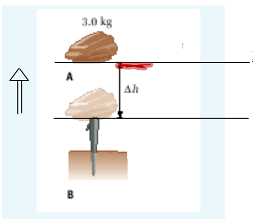
You are about to drop a 3.0 kg rock onto a tent peg. Calculate the gravitational potential energy of the rock after you lift it to a height of 0.68 m above the tent peg.



reference level -> $E_g = 0$ J, $h = 0$ m

must be stated

$E_g = mg\Delta h$
$E_g = mg(h_f - h_i)$
$E_g = (3.0\text{ kg})(9.80\text{ m/s}^2)(0.68\text{ m} - 0\text{ m})$
$E_g = 20$ J



reference level -> $E_g = 0$ J, $h = 0$ m

Textbook: Page 250, PP # 27 -29

250 MHR • Unit 3 Momentum and Energy

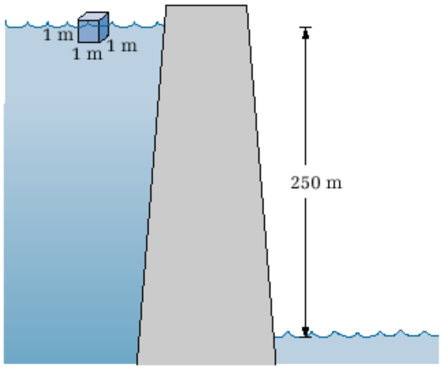
$E = mg\Delta h$

PRACTICE PROBLEMS

27. A framed picture that is to be hung on the wall is lifted vertically through a distance of 2.0 m. If the picture has a mass of 4.45 kg, calculate its gravitational potential energy with respect to the ground.

28. The water level in a reservoir is 250 m above the water in front of the dam. What is the potential energy of each cubic metre of surface water behind the dam? (Take the density of water to be 1.00 kg/L.) 1000 Kg

29. How high would you have to raise a 0.300 kg baseball in order to give it 12.0 J of gravitational potential energy?



Work-Gravitational Potential Energy Theorem
(Page 251)

Textbook: Page 254, PP # 30-33

PRACTICE PROBLEMS

30. A student lifts her 2.20 kg pile of textbooks into her locker from where they rest on the ground. She must do 25.0 J of work in order to lift the books. Calculate the height that the student must lift the books.

31. A 46.0 kg child cycles up a large hill to a point that is a vertical distance of 5.25 m above the starting position. Find
    (a) the change in the child's gravitational potential energy
    (b) the amount of work done by the child against gravity

32. A 2.50 kg pendulum is raised vertically 65.2 cm from its rest position. Find the gravitational potential energy of the pendulum.

33. A roller-coaster train lifts its passengers up vertically through a height of 39.4 m from its starting position. Find the change in gravitational potential energy if the mass of the train and its passengers is 3.90×10^3 kg.

$W = \Delta E_g$

$W = E_{gf} - E_{gi}$

$W = mgh_f - mgh_i$

$Fd = mgh_f - mgh_i$

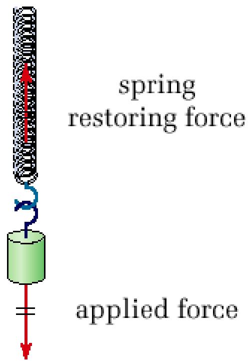
Elastic Potential Energy
(Page 254)

Many objects can stretch, compress, bend or change shape in some way. If an object can return to its original condition, it is said to be elastic. Since the object can undergo motion when the force causing the change in condition or state is removed, there must be stored energy due to its condition. This form of stored energy is called elastic potential energy.

Hooke's Law
(Page 256)

When a force causes a spring to stretch or compress, the spring exerts a force in a direction that will return it to its original length. The force that the spring exerts is called the restoring force and it is equal in magnitude to the applied force that stretches or compresses the spring and acts in a direction opposite to the applied force.

Physics
McGraw-Hill
Page 255



Hooke's Law: The restoring force is directly proportional to the extension or compression of a spring.

Restoring Force vs Extension

256

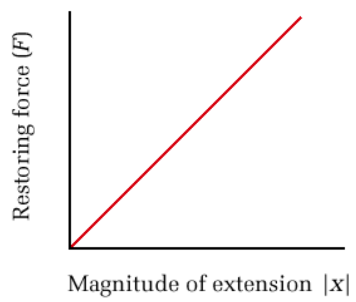


Figure 6.21 The relationship between the restoring force and the extension of a spring is linear.

$y = mx + b$

slope y-intercept

Hooke's Law - Restoring Force

$\boxed{F = -kx}$

F -> restoring force (N)
k -> spring constant (N/m)
x -> elongation or compression (m)

Hooke's Law - Applied Force

$\boxed{F_A = kx}$

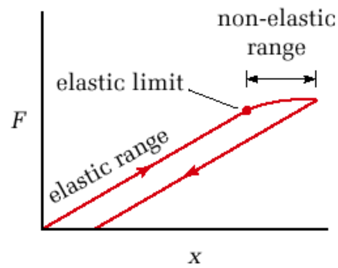
F_A -> applied force (N)
k -> spring constant (N/m)
x -> elongation or compression (m)

Before

After

PHYSICS FILE

A *perfectly elastic* material will return precisely to its original form after being deformed, such as stretching a spring. No real material is perfectly elastic. Each material has an elastic limit, and when stretched to that limit, will not return to its original shape. The graph below shows that when something reaches its elastic limit, the restoring force does not increase as rapidly as it did in its elastic range.



Chapter 6 Work, Power, and Efficiency • MHR 257

MODEL PROBLEM

Hooke's Law in an Archery Bow

A typical compound archery bow requires a force of 133 N to hold an arrow at "full draw" (pulled back 71 cm). Assuming that the bow obeys Hooke's law, what is its spring constant?

The spring constant of the bow is about $1.9 \times 10^2 \frac{\text{N}}{\text{m}}$.

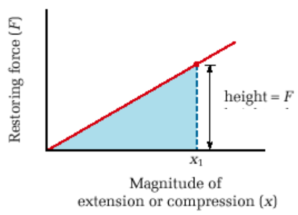
Textbook: Page 258, PP # 35-37

Restoring Force vs Extension (or Compression)
(Page 258)

The area under a Hooke's Law graph (restoring force vs. extension or compression) gives the amount of elastic potential energy stored in a spring (or any elastic substance).

Restoring Force vs. Extension

258



Area = elastic potential energy

Figure 6.22 The triangular area under the Hooke's law graph gives you the amount of elastic potential energy stored in the spring at any amount of extension.

$$A = \frac{1}{2}(\text{base})(\text{height})$$

$$A = \frac{1}{2}xF$$

$$A = \frac{1}{2}Fx$$

$$A = \frac{1}{2}(kx)x$$

$$A = \frac{1}{2}kx^2$$

$$\boxed{E_e = \frac{1}{2}kx^2}$$

perfectly elastic material

Ee -> elastic potential energy (J)
k -> spring constant (N/m)
x -> extension or compression (m)

P.259.

ELASTIC POTENTIAL ENERGY

The elastic potential energy of a perfectly elastic material is one half the product of the spring constant and the square of the length of extension or compression.

$$E_e = \frac{1}{2}kx^2$$

Quantity	Symbol	SI unit
elastic potential energy	E_e	J (joules)
spring constant	k	$\frac{\text{N}}{\text{m}}$ (newtons per metre)
length of extension or compression	x	m (metres)

Unit Analysis

$$\text{joule} = \frac{\text{newton}}{\text{metre}}\,\text{metre}^2 \qquad \text{J} = \left(\frac{\text{N}}{\cancel{\text{m}}}\right)\text{m}^{\cancel{2}} = \text{N}\cdot\text{m} = \text{J}$$

260 MHR • Unit 3 Momentum and Energy

MODEL PROBLEM

Elastic Potential Energy of a Spring

A spring with spring constant of 75 N/m is resting on a table.

(a) If the spring is compressed a distance of 28 cm, what is the increase in its potential energy?

(b) What force must be applied to hold the spring in this position?

Textbook: Page 261, PP #38-40

Power and Efficiency
(Page 262)

Power

Power is the rate at which energy is transferred or, in other words, the rate at which work is done.

$\boxed{P = \frac{\Delta E}{t}}$ $\boxed{P = \frac{W}{t}}$ $\boxed{P = \frac{Fd}{t}}$

P -> power
ΔE -> energy transferred (J)
W -> work done (J)
F -> force (N)
d -> displacement (m)
t -> time (s)

NOTE: Strong dray horses can lift 550 pounds a distance of 1.0 foot in 1.0 s. Power is sometimes stated in units of horsepower, hp.

$\boxed{1 \text{ hp} = 746 \text{ W}}$

http://www.stockportexpress.co.uk/ContentResources/936.$plit/C_58_ImageGallery_5071_Image.jpg

Any machine that does mechanical work or any device that transfers energy can be described by its power rating.

ie/ A 60 W bulb transforms 60 J of electric energy into thermal energy and light in 1.0 s.

Figure 6.24 Light bulbs and electric appliances are often labelled with a power rating.

The rate of energy transfer is often referred to as the power that is generated in doing work.

MODEL PROBLEMS

Calculating Power

1. A crane is capable of doing 1.50×10^5 J of work in 10.0 s. What is the power of the crane in watts?

Calculations

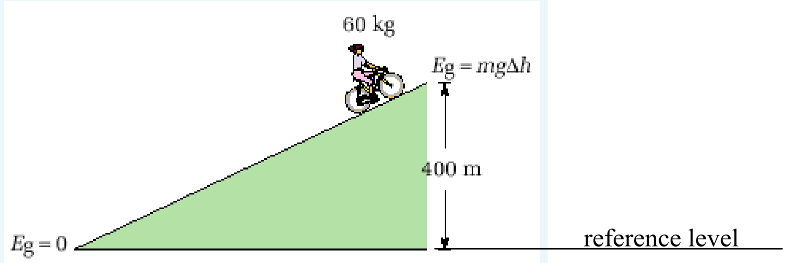
264 MHR • Unit 3 Momentum and Energy

MODEL PROBLEMS

2. **A cyclist and her mountain bike have a combined mass of 60.0 kg. She is able to cycle up a hill that changes her altitude by 4.00×10^2 m in 1.00 min. (Assume that friction is negligible.)**

(a) How much work does she do against gravity in climbing the hill?

(b) How much power is she able to generate?



266 MHR • Unit 3 Momentum and Energy

Textbook: Page 266 #41-43

PRACTICE PROBLEMS

41. A mover pushes a 25.5 kg box with a force of 85 N down a 15 m corridor. If it takes him 8.30 s to reach the other end of the hallway, find the power generated by the mover, in watts. (1.5×10^2 W)

42. A chair lift carries skiers uphill to the top of the ski run. If the lift is able to do 1.85×10^5 J of work in 12.0 s, what is the power of the chair lift in both watts and horsepower? (1.54×10^4 W, 20.6 hp)

43. A 75.0 kg student runs up two flights of stairs in order to reach her next class. The total height of the stairs is 5.75 m from the ground level. If the student can generate 200 W of power and has 20.0 s to reach her classroom at the top of the stairs, will the student be on time for class?

Efficiency
(Page 268)

Energy can be converted into forms that do no work or do not serve the intended purpose.

ie/ A lightbulb is designed to convert electric energy into light energy but some energy is transformed into thermal energy.

Transforming energy from one form to another always involves some loss of energy.

Efficiency is the ratio of useful energy or work output to the total energy or work input.

$$\boxed{\text{Efficiency} = \frac{E_o}{E_i} \times 100\%}$$

E_o -> useful energy (J)
E_i -> total energy (J)

$$\boxed{\text{Efficiency} = \frac{W_o}{W_i} \times 100\%}$$

W_o -> work output (J)
W_i -> work input (J)

PRACTICE PROBLEMS

44. A portable stereo requires 265 J of energy to operate the CD player, yielding 200 J of sound energy.

(a) How efficiently does the stereo generate sound energy? (75.5%)

(b) Where does the "lost" energy go?

45. A 49.0 kg child sits on the top of a slide that is located 1.80 m above the ground. After her descent, the child reaches a velocity of 3.00 m/s at the bottom of the slide. Calculate how efficiently the potential energy is converted to kinetic energy. (25.5%)

46. A machine requires 580 J of energy to do 110 J of useful work. How efficient is the machine? (19.0%)

47. An incandescent light bulb transforms 120 J of electric energy to produce 5 J of light energy. A florescent bulb requires 60 J of electrical energy to produce the same amount of light.

(a) Calculate the efficiency of each type of bulb. (i ->4%, f -> 8%)

(b) Why is the fluorescent bulb more efficient than the incandescent bulb?

48. A microwave oven transforms 345 J of radiant energy into 301 J of thermal energy in some food. Calculate the efficiency of this energy transformation. (87.2%)

Textbook: Page 274

Knowledge/Understanding
#2, 4, 5

Problems for Understanding
#17, 18, 20, 21, 23, 27, 30, 31

Chapter 7 - Conservation of Energy and Momentum
(Page 278)

Two Classes of Forces

1. Conservative Force - A conservative force does work on an object in such a way that the amount of work done is independent of the path taken. It depends only on the initial and final positions of the object. If the initial and final positions of the object are the same, no net work is done on the object. The force of gravity is a conservative force.

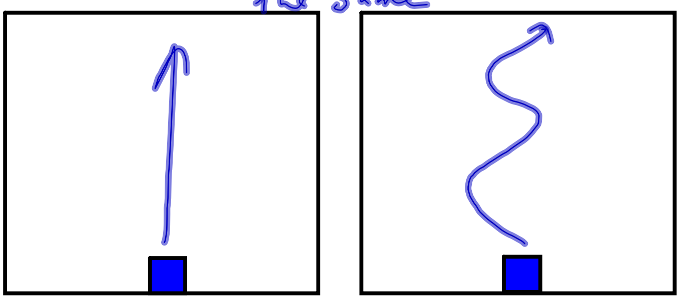
Example: Lifting a box from the floor to a table.

Path A Path B

2. Nonconservative Force - A nonconservative force does work that depends on the path taken. The force of friction is a nonconservative force.

Example: Pushing a box across a floor. Assume you are looking down on the box.

Path A Work is not the same Path B



The Law of Conservation of Energy
(Page 282)

If all the work done throughout a process is done by **conservative forces**, the total mechanical energy of the system after the process is equal to the total mechanical energy of the system before the process.

$$\boxed{E_{Ti} = E_{Tf}}$$

E_{Ti} - total initial energy (J)
E_{Tf} - total final energy (J)

Remember: Mechanical energy is a combination of kinetic and potential energy.

$$\underbrace{E_{ki}}_{\text{Kinetic}} + \underbrace{E_{gi} + E_{ei}}_{\text{potential}} = E_{kf} + E_{gf} + E_{ef}$$

Roller Coaster Model

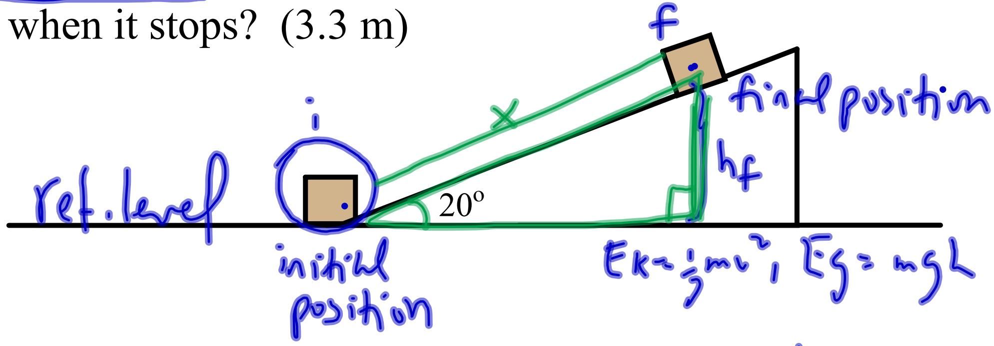
Materials: pencil, paper, flexible wire (2.0 m), bead or metal sphere

Design Rules:

1. There must be at least two loops on the track.
2. There must be at least two hills after the last loop.
3. The wire track must be able to stand by itself. The end of the track is to be taped to the floor.
4. To be successful, your "car" must travel to the end of the wire.

Plan your design on paper first. Construct a model using the wire. When you are ready to test your track, obtain a "car". If your design doesn't work, try again.

Example: A box is shot up a frictionless 20° incline with an initial speed of 8.0 m/s. How high above the floor will the box be when it stops? (3.3 m)



$$\underline{E_{ki}} + \cancel{E_{gi}} + \cancel{\underline{E_{ei}}} = \cancel{E_{kf}} + E_{gf} + \cancel{E_{ef}}$$

$$\frac{1}{2}mv_i^2 = mgh_f$$

$$h_f = \frac{1\cancel{m}v_i^2}{2\cancel{m}g}$$

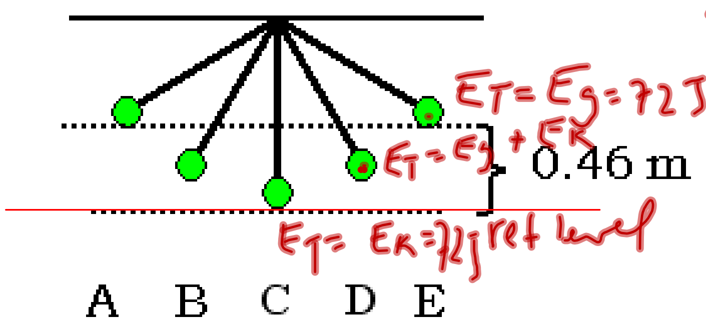
$$h_f = \frac{v_i^2}{2g}$$

$$h_f = \frac{(8.0)^2}{2(9.80)}$$

$$h_f = 3.3\,m$$

Example:

A pendulum is allowed to swing as shown in the diagram below. The bob has a mass of 16 kg and reaches a maximum height of 0.46 m.



a) What is the gravitational potential energy of the bob at position E?
b) What is the kinetic energy of the bob at position D? (Assume D is halfway between the highest and lowest positions of the pendulum.)
c) What is the velocity of the bob at position C?

a) $E_g = mg\Delta h$

$E_g = (16)(9.80)(0.46-0)$

$E_g = 72J$

b) $E_T = E_g + E_K$

$E_K = E_T - E_g$

$E_K = 72 - (16)(9.80)(0.23)$

$E_K = 72 - 36$

$E_K = 36J$

c) $E_K = \frac{1}{2}mv^2$

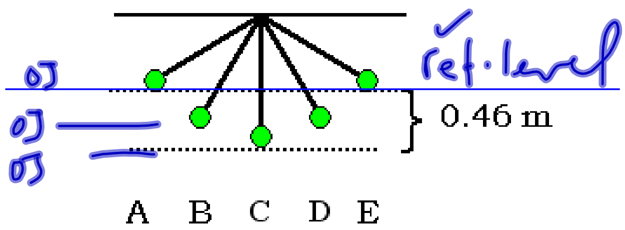
$72 = \frac{1}{2}mv^2$

$v = 3.0 m/s$

Example:

A pendulum is allowed to swing as shown in the diagram below. The bob has a mass of 16 kg and reaches a maximum height of 0.46 m.

⇒ a) $E_g = 0\,J$

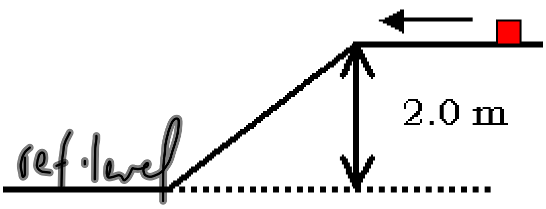


a) What is the gravitational potential energy of the bob at position E?
b) What is the kinetic energy of the bob at position D? (Assume D is halfway between the highest and lowest positions of the pendulum.)
c) What is the velocity of the bob at position C?

Example:

A 1.6 kg block slides along a frictionless horizontal surface at a constant speed of 4.5 m/s. The block then slides down a frictionless incline and over a second horizontal frictionless surface.

a) What is the kinetic energy of the block on the lower horizontal surface?
b) What is the speed of the block as it slides along the lower horizontal surface?



a) $E_{ki} + E_{gi} + \cancel{E_{ei}} = \boxed{E_{kf}} + \cancel{E_{gf}} + \cancel{E_{ef}}$

f

$\frac{1}{2}mv_i^2 + mgh_i = E_{kf}$

$E_{kf} = \frac{1}{2}(1.6)(4.5)^2 + (1.6)(9.80)(2.0)$

$E_{kf} = 48\text{ J}$ or $4.8\times10^1\text{ J}$

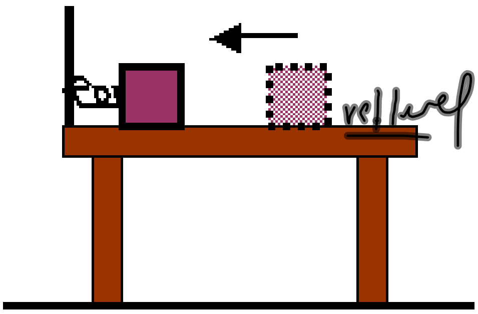
b) $E_{kf} = \frac{1}{2}mv_f^2$

$v_f = \sqrt{\frac{2E_{kf}}{m}}$

$v_f = 7.7\text{ m/s}$

Example:

An object is sliding along a frictionless table with an initial speed of 0.64 m/s. It strikes a coiled spring with a spring constant of 450 N/m and compresses it 7.8 cm. What was the mass of the object?



$$E_{ki} + \cancel{E_{gi}} + \cancel{E_{ei}} = \cancel{E_{kf}} + \cancel{E_{gf}} + E_{ef}$$

$$E_{ki} = E_{ef}$$

$$\cancel{\tfrac{1}{2}} m v_i^2 = \cancel{\tfrac{1}{2}} k x_f^2$$

$$m v_i^2 = k x_f^2$$

$$m = \frac{k x_f^2}{v_i^2}$$

$$m = \frac{(450)(0.078)^2}{(0.64)^2}$$

$$m = 6.7 \text{ kg}$$

Energy Transformations - Simulations

Energy In and Out of a System

Downhill Skiing

Roller Coaster

Regents Simulations

Roller Coaster

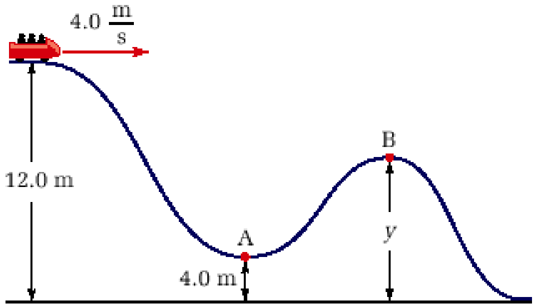
Sled

Pendulum

Dart

PRACTICE PROBLEMS

Use the following diagram for practice problems 1, 2, and 3.

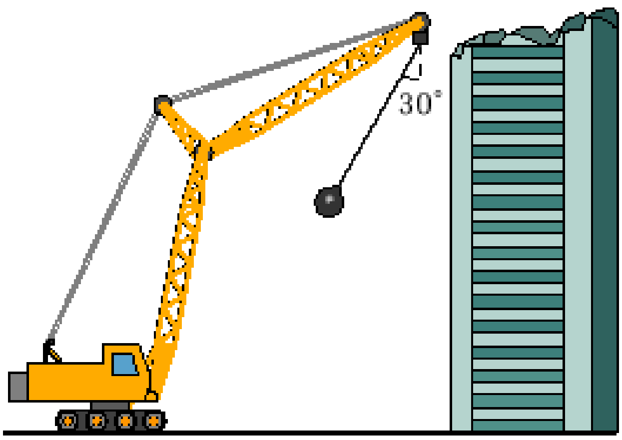


1. A car on a roller coaster is moving along a level section 12.0 m high at 4.0 m/s when it begins to roll down a slope, as shown in the diagram. Determine the speed of the car at point A.
2. What is the height of point B in the roller coaster track if the speed of the car at that point is 10.0 m/s?
3. What is the height of y if the speed of the roller coaster at B is 12.5 m/s?

☆

4. You throw a ball directly upward, giving it an initial velocity of 10.0 m/s. Neglecting friction, what would be the maximum height of the ball? (Explain why you do not need to know the mass of the ball.)

5. A wrecking ball, with a mass of 315 kg, hangs from a crane on 10.0 m of cable. If the crane swings the wrecking ball so that the angle that the cable makes with the vertical is 30.0°, what is the potential energy of the wrecking ball in relation to its lowest position? What will be the kinetic energy of the wrecking ball when it falls back to the vertical position? What will be the speed of the wrecking ball?



6. A 2.5 kg lead ball and a 55 g piece of lead shot are both dropped from a height of 25 m. Neglecting air friction, what is the kinetic energy of each object just before it hits the ground? What is the velocity of each object just before it hits the ground?

7. A 32 kg crate slides down a frictionless ramp. Its initial velocity at the top of the ramp was 3.2 m/s. Its velocity when it reached the bottom of the ramp was 9.7 m/s. The ramp makes an angle of 25° with the horizontal. How long is the ramp?

Textbook: Page 296, PP #9(a,b), 10, 11

Textbook: Page 329, PFU #21-23, 38, 39, 44, 54

<u>Bonus - 5 Points</u>

A ball of mass 6.0 kg is dropped from a height of 45 cm above a spring and compresses the spring by 12 cm. What is the spring constant of the spring?