# Kinetic Energy
(Page 236)

Reminder: Kinetic energy is energy due to motion.

Check Units

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

$Kg\left(\frac{m}{s}\right)^2$

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

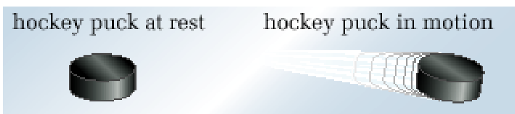
**NOTE**: When velocity is squared, it is no longer a vector so no vector notation is used in the kinetic energy equation.

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.**




(a) $\vec{v}_1 = 0$ (b) $\vec{v}_2 = 27.0\ \frac{m}{s}$

(a) $E_k = 0\ J$
$\frac{1}{2}(.2)(0)^2$

(b) $E_k = \frac{1}{2}(.2)(27)^2$
$= 72.9\ J$

$E_k = 0$ J $E_k = 72.9$ 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

20) $4.5 = \frac{1}{2}m(0.95)^2$

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

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

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

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

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

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

$$W = \Delta E_k$$

also

$$Fd = \Delta E_k$$

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

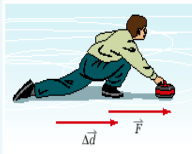
MODEL PROBLEMS

## Applying the Work-Kinetic Energy Theorem

1. A physics student does work on a 2.5 kg curling stone by exerting $4.0 \times 10^1$ 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

a) $W = Fd$

$= (40\,N)(1.5\,m)$

$= 60\,J$

b) $W = \Delta E_k$

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

$60 = \frac{1}{2}(2.5)v_f^2 - \frac{1}{2}(2.5)(0)^2 \rightarrow 0$

$60 = 1.25\,v_f^2$

$48 = v_f^2$

$\sqrt{48} = v_f \longrightarrow 6.9\,m/s = v_f$

2. A 75 kg skateboarder (including the board), initially moving at 8.0 m/s, exerts an average force of $2.0 \times 10^2$ 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. $3.4 \times 10^3$ J

$m = 75\,kg$
$v_o = 8.0\,m/s$
$F = 200\,N$
$d = 5\,m$

$W = \Delta E_K = E_{Kf} - E_{Ki}$

$\underbrace{Fd}_{W} = \underbrace{\frac{1}{2}mv_f^2 - \frac{1}{2}mv_o^2}_{\Delta E_K}$

$Fd = E_{Kf} - \frac{1}{2}mv_o^2$

$(200)(5) = E_{Kf} - \frac{1}{2}(75)(8)^2$

$1000 = E_{Kf} - 2400$

$3400\,J = E_{Kf}$

•

## 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 $9.1 \times 10^{-31}$ kg. At what speed does the electron travel if it possesses $7.6 \times 10^{-18}$ 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) $4.1 \times 10^6$ 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.

$$\Delta E_g = mg\Delta h$$

$\Delta E_g$ -> change in gravitational potential energy (J)
m -> mass (kg)
g -> acceleration due to gravity ($m/s^2$)
$\Delta h$ -> change in height (m)

continued

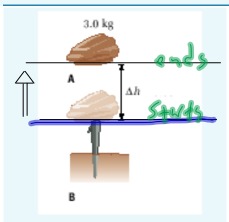


MODEL PROBLEM

p.249

**Calculating Gravitational Potential Energy**

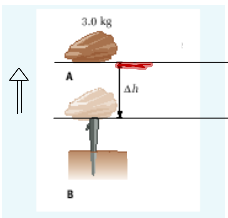
**You are about to drop a 3.0 kg rock onto a tent peg. Calculate the gravitational potential energy of the rock after you lift it to a height of 0.68 m above the tent peg.**




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

must be stated

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




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

☆

Textbook: Page 250, PP # 27 -29

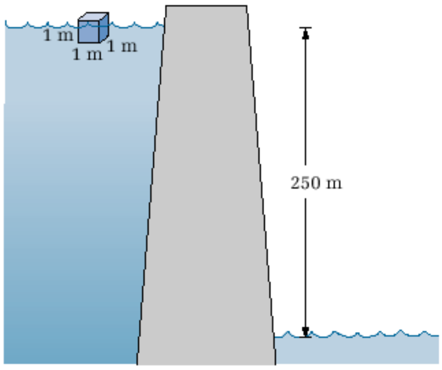


**PRACTICE PROBLEMS**

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.)

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)

$$W = \Delta E_g$$

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

$$W = mgh_f - mgh_i$$

$$Fd = mgh_f - mgh_i$$

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 $3.90 \times 10^3$ kg.

## 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.