# 6-2  Energy

## Potential and Kinetic Energy

*Vocabulary*    **Energy:** The ability to do work.

There are many different types of energy. This chapter will focus on only mechanical energy, or the energy related to position (**potential energy**) and motion (**kinetic energy**).

*Vocabulary*    **Potential Energy:** Energy of position, or stored energy.

An object gains gravitational potential energy when it is lifted from one level to a higher level. Therefore, we generally refer to the *change* in potential energy or $\Delta$PE, which is proportional to the change in height, $\Delta h$.

**$\Delta$ gravitational potential energy = (mass)(acceleration due to gravity)($\Delta$ height)**

or      $\Delta \text{PE} = mg\Delta h$

It is important to remember that gravitational potential energy relies *only* upon the vertical change in height, $\Delta h$, and not upon the path taken.

In addition to gravitational potential energy, there are other forms of stored energy. For example, when a bow is pulled back and before it is released, the energy in the bow is equal to the work done to deform it. This stored or potential energy is written as $\Delta \text{PE} = F\Delta d$. Springs possess elastic potential energy when they are displaced from the equilibrium position. The equation for elastic potential energy will not be used in this chapter.

*Vocabulary*    **Kinetic Energy:** Energy of motion.

The kinetic energy of an object varies with the square of the speed.

**kinetic energy =**      **(mass)(speed)$^2$**      or      KE =      $mv^2$

The SI unit for energy is the **joule.** Notice that this is the same unit used for work. When work is done on an object, energy is transformed from one form to another. The sum of the changes in potential, kinetic, and heat energy is equal to the work done on the object. Mechanical energy is transformed into heat energy when work is done to overcome friction.

## Conservation of Energy

According to the **law of conservation of energy,** energy cannot be created or destroyed. The total amount of mechanical energy in a system remains constant if no work is done by any force other than gravity.

In an isolated system where there are no mechanical energy losses due to friction

$$\Delta KE = \Delta PE$$

In other words, all the kinetic and potential energy before an interaction equals all the kinetic and potential energy after the interaction.

$$KE_o + PE_o = KE_f + PE_f \quad \text{or} \quad \left(\frac{1}{2}\right)mv_o^2 + mgh_o = \left(\frac{1}{2}\right)mv_f^2 + mgh_f$$

As a reminder, the terms with the subscript $_o$ are the initial conditions, while those with the subscript $_f$ are final conditions.

## Solved Examples

**Example 4:**  Legend has it that Isaac Newton "discovered" gravity when an apple fell from a tree and hit him on the head. If a 0.20-kg apple fell 7.0 m before hitting Newton, what was its change in PE during the fall?

**Solution:** For a given object, the change in PE depends only upon the change in position. The apple does not need to fall all the way to the ground to experience an energy change.

*Given:*  $m = 0.20$ kg                    *Unknown:* $\Delta PE = ?$
$\qquad\quad g = 10.0$ m/s$^2$                  *Original equation:* $\Delta PE = mg\Delta h$
$\qquad\quad \Delta h = 7.0$ m

*Solve:*  $\Delta PE = mg\Delta h = (0.20$ kg$)(10.0$ m/s$^2)(7.0$ m$) = $ **14 J**

**Example 5:**  A greyhound at a race track can run at a speed of 16.0 m/s. What is the KE of a 20.0-kg greyhound as it crosses the finish line?

*Given:* $m = 20.0$ kg                    *Unknown:* $KE = ?$
$\qquad\quad v = 16.0$ m/s                   *Original equation:* $KE = \left(\dfrac{1}{2}\right)mv^2$

*Solve:*  $KE = \left(\dfrac{1}{2}\right)mv^2 = \left(\dfrac{1}{2}\right)(20.0$ kg$)(16.0$ m/s$)^2 = $ **2560 J**

**Example 6:**  In a wild shot, Bo shoots a pool ball of mass m off a 0.68-m-high pool table, and the ball hits the floor with a speed of 6.0 m/s. How fast was the ball moving when it left the pool table? (Use the law of conservation of energy.)

*Given:* $v_f = 6.0$ m/s                    *Unknown:* $v_o = ?$
$\qquad\quad g = 10.0$ m/s$^2$                  *Original equation:* $\Delta KE = \Delta PE$
$\qquad\quad h_o = 0.68$ m
$\qquad\quad h_f = 0$ m

*Solve:*  $KE_o + PE_o = KE_f + PE_f$   or   $\left(\dfrac{1}{2}\right)mv_o^2 + mgh_o = \left(\dfrac{1}{2}\right)mv_f^2 + mgh_f$

Notice that mass is contained in each of these equations. Therefore, it cancels out and does not need to be included in the calculation.

$$v_o = \sqrt{\dfrac{\left(\dfrac{1}{2}\right)mv_f^2 + mgh_f - mgh_o}{\left(\dfrac{1}{2}\right)m}} = \sqrt{\dfrac{\left(\dfrac{1}{2}\right)v_f^2 + gh_f - gh_o}{\dfrac{1}{2}}}$$

$$= \sqrt{\dfrac{\left(\dfrac{1}{2}\right)(6.0 \text{ m/s})^2 + (10.0 \text{ m/s}^2)(0 \text{ m}) - (10.0 \text{ m/s}^2)(0.68 \text{ m})}{\dfrac{1}{2}}}$$

$$= \sqrt{\dfrac{18 \text{ m}^2/\text{s}^2 - 6.8 \text{ m}^2/\text{s}^2}{\dfrac{1}{2}}} = \textbf{4.7 m/s}$$

**Example 7:** Frank, a San Francisco hot dog vender, has fallen asleep on the job. When an earthquake strikes, his 300-kg hot-dog cart rolls down Nob Hill and reaches point A at a speed of 8.00 m/s. How fast is the hot-dog cart going at point B when Frank finally wakes up and starts to run after it?
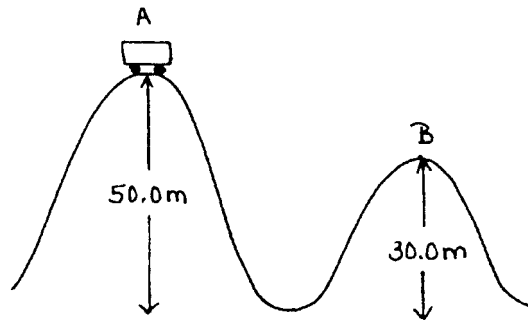


**Solution:** Because mass is contained in each of these equations, it cancels out and does not need to be included in the calculation. Also, the inclination of the hill makes no difference. All that matters is the change in height.

*Given:* $v_o = 8.00$ m/s  
$g = 10.0$ m/s$^2$  
$h_o = 50.0$ m  
$h_f = 30.0$ m

*Unknown:* $v_f = ?$  
*Original equation:* $\Delta KE = \Delta PE$

*Solve:* $KE_o + PE_o = KE_f + PE_f$  or  $\left(\dfrac{1}{2}\right)mv_o^2 + mgh_o = \left(\dfrac{1}{2}\right)mv_f^2 + mgh_f$

$$v_f = \sqrt{\frac{\left(\dfrac{1}{2}\right)mv_o^2 + mgh_o - mgh_f}{\left(\dfrac{1}{2}\right)m}} = \sqrt{\frac{\left(\dfrac{1}{2}\right)v_o^2 + gh_o - gh_f}{\dfrac{1}{2}}}$$

$$= \sqrt{\frac{\left(\dfrac{1}{2}\right)(8.00 \text{ m/s})^2 + (10.0 \text{ m/s}^2)(50.0 \text{ m}) - (10.0 \text{ m/s}^2)(30.0 \text{ m})}{\dfrac{1}{2}}}$$

$$= \sqrt{\frac{32.0 \text{ m}^2/\text{s}^2 + 500. \text{ m}^2/\text{s}^2 - 300. \text{ m}^2/\text{s}^2}{\dfrac{1}{2}}}$$

$$= \sqrt{464 \text{ m}^2/\text{s}^2} = \textbf{21.5 m/s}$$

## Practice Exercises

**Exercise 5:**  It is said that Galileo dropped objects off the Leaning Tower of Pisa to determine whether heavy or light objects fall faster. If Galileo had dropped a 5.0-kg cannon ball to the ground from a height of 12 m, what would have been the change in PE of the cannon ball?

Answer: ⎯⎯⎯⎯⎯⎯⎯⎯⎯

**Exercise 6:**  On June 5, 2007, Rags to Riches, became the first filly to win the Belmont Stakes horse race since 1905, running with an average speed of 16.23 m/s. If Rags to Riches and jockey Johnny Velazquez had a combined mass of 550.0 kg, what was their KE as they crossed the finish line?

Answer: ⎯⎯⎯⎯⎯⎯⎯⎯⎯

**Exercise 7:**  Brittany is changing the tire of her car on a steep hill 20.0 m high. She trips and drops the 10.0-kg spare tire, which rolls down the hill with an initial speed of 2.00 m/s. What is the speed of the tire at the top of the next hill, which is 5.00 m high? (Ignore the effects of rotation KE and friction.)
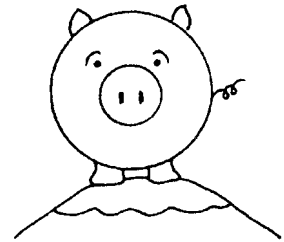
Answer: ⎯⎯⎯⎯⎯⎯⎯⎯⎯

**Exercise 8:**   A Mexican jumping bean jumps with the aid of a small worm that lives inside the bean. a) If a bean of mass 2.0 g jumps 1.0 cm from your hand into the air, how much potential energy has it gained in reaching its highest point.
b) What is its speed as the bean lands back in the palm of your hand?

Answer: **a.** ———————————

Answer: **b.** ———————————

**Exercise 9:**   A 500.-kg pig is standing at the top of a muddy hill on a rainy day. The hill is 100.0 m long with a vertical drop of 30.0 m. The pig slips and begins to slide down the hill. What is the pig's speed at the bottom of the hill? Use the law of conservation of energy.

Answer: ———————————

**Exercise 10:**   While on the moon, the Apollo astronauts enjoyed the effects of a gravity much smaller than that on Earth. If Neil Armstrong jumped up on the moon with an initial speed of 1.51 m/s to a height of 0.700 m, what amount of gravitational acceleration did he experience?

Answer: ———————————