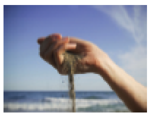
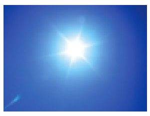
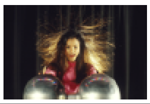
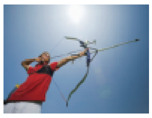
Section 5.3

Types of Energy and the Law of Conservation of Energy

Learning Goal: By the end of today, I will be able to use the conversation of energy principle to determine the kinetic energy and potential energy in a closed system.

Types of Energy (quick discussion)

Type of energy	Form (kinetic, potential, or both)	Description	Application/Example
mechanical energy	potential and kinetic	energy possessed by objects that are primarily affected by the force of gravity and frictional forces	
gravitational energy	potential	energy possessed by objects that are affected by the force of gravity; applies to all objects on Earth (and the universe)	
radiant energy (also known as light, light energy, or electromagnetic radiation)	potential and kinetic	energy possessed by oscillating electric and magnetic fields	
electrical energy (static electricity)	potential	energy possessed by accumulated static charges	

electrical energy (current electricity)	potential and kinetic	energy possessed by flowing charges (you will learn more about this in Chapter 11)	
thermal energy (sometimes incorrectly called heat energy)	potential and kinetic	energy possessed by randomly moving atoms and molecules (you will learn more about this in Chapter 6)	
sound energy	potential and kinetic	energy possessed by large groups of oscillating atoms and molecules	
nuclear energy (also known as atomic energy)	potential	energy possessed by protons and neutrons in atomic nuclei (you will learn more about this in Chapter 7)	
elastic energy (also known as spring energy)	potential	energy possessed by materials that are stretched, compressed, or twisted and tend to return to their original shape	
chemical energy (also known as bond energy, fuel energy, food energy, molecular energy, and internal energy)	potential	energy associated with bonds in molecules	

Energy Transformations

The conversion of energy is called energy transformation: the change of one form or type of energy into another.

For example, photosynthesis is a process involving energy transformations in a plant. In photosynthesis, plants transform radiant energy into the chemical energy stored in food molecules (food energy) such as glucose (a sugar) and starch. In the process, some of the radiant energy is also transformed into thermal energy. Animals, including humans, eat plants and transform the chemical energy in the plants into chemical energy in their muscles.

Muscles then transform this chemical energy into the kinetic energy of moving limbs, which do work on objects in the environment.

Law of Conservation of Energy

The total amount of energy in the universe is conserved. There is a certain total amount of energy in the universe, and this total never changes. New energy cannot be created out of nothing, and existing energy cannot disappear; the energy that exists can only be changed from one form into another. When an energy transformation occurs, no energy is lost.

$$E_{k1} + E_{g1} = E_{k2} + E_{g2}$$

Ideal system - NO losses

$$E_{k1} + E_{g1} = E_{Lost} + E_{k2} + E_{g2}$$

Non-Ideal system - there are losses in the form of friction, thermal, etc (Work has been done)

$E_m = E_{k1} + E_{g1}$ (total mechanical energy)

A 65 kg diver is about to jump from the 10m high diving board.

Calculate his potential and kinetic energy before, half way, and at the end of his jump(Ideal System)

Potential $E_g = mgd$ Kinetic $E_k = 0.5mv^2$

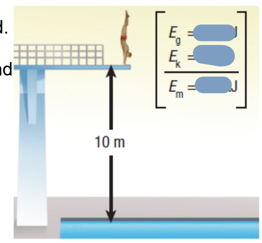


Figure 3 Phase 1: before the dive

Potential $E_g = mgd$ Kinetic $E_k = 0.5mv^2$

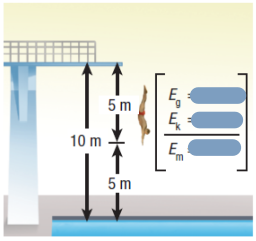


Figure 4 Phase 2: at the halfway point

Potential $E_g = mgd$ Kinetic $E_k = 0.5mv^2$

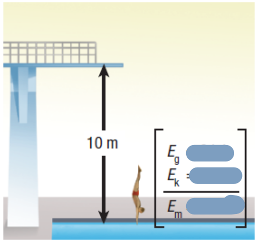


Figure 5 Phase 3: at the water's surface

Sample Problem 1

A 1.1 kg camera slips out of a photographer's hands while he is taking a photograph. The camera falls 1.4 m to the ground below.

(a) What is the camera's gravitational potential energy relative to the ground when it is in the photographer's hands?

(b) Using the law of conservation of energy, determine the camera's kinetic energy at the instant it hits the ground.

(c) Use the camera's kinetic energy to determine its speed at the instant it hits the ground.

Practice

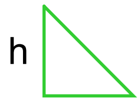
1. A 0.20 kg ball is thrown straight up from the edge of a 30.0 m tall building at a velocity of 22.0 m/s. The ball moves up to the maximum height and then falls to the ground at the base of the building. Use the law of conservation of energy to answer the following questions, assuming that the reference level for gravitational potential energy is ground level. T/I
   (a) What is the total energy of the ball at the start when it had a velocity of 22.0 m/s? [redacted]
   (b) What is the velocity of the ball at the maximum height? What is the maximum height of the ball? [redacted]
   (c) What is the velocity of the ball when it hits the ground? [ans: [redacted]

Non-Ideal Example

$$E_{k1} + E_{g1} = E_{Lost} + E_{k2} + E_{g2}$$

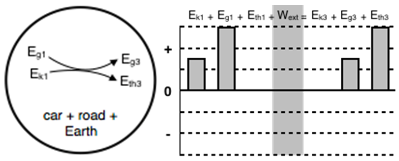
A 65 kg bike and rider are at rest at the top of a hill, she begins her ascent down a 200m long hill inclined at 35º.

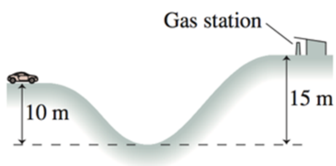
What is the kinetic and gravitational energy of the biker at the top of the hill?



If the bike-mountain slope uses up 20000 J of energy in friction (thermal energy), and dislodged dirt, what is the velocity of the bike rider at the bottom of the hill?

What average force of friction is working on the bike during the ride?





Example Question 1: A Mechanical System

A 1500 kg car travelling at 10 m/s runs out of gas while approaching the valley. The driver immediately puts the car in neutral so it will roll.

How far up the hill does the car roll?

Case 1 - no friction/losses $E_{k1} + E_{g1} = E_{Lost} + E_{k2} + E_{g2}$

Case 2 - Friction If the car coasts to a height of 5 m up the second hill, determine how much thermal energy has been created in the car + road + Earth system.

5.3 Questions

1. Describe the energy transformations occurring in each of the following situations: K/U
   (a) A ball falls from the top of a building.
   (b) An archer pulls a bow back and releases the arrow.
   (c) A firework explodes.
   (d) An incandescent light bulb comes on.
   (e) A gasoline lawnmower cuts the lawn.
2. A golf ball of mass 45.9 g is launched from a height of 8.0 m above the level of the green at a speed of 20.0 m/s. At the maximum height above the green, the ball is moving at 12 m/s. Assume there is no air resistance acting on the ball. Calculate the following for the golf ball: T/I
   (a) the total mechanical energy at the start (assume the level of the green to be the reference level)
   (b) the maximum height of the ball above the green
   (c) the speed of the ball when it strikes the green
3. Many roller coasters have loops where carts roll on a track that curves sharply up into the air. At the top, the people are upside down (and usually screaming). For safety reasons, many of these roller coasters must have a minimum speed at the top of the loop. In the roller coaster shown in **Figure 6**, the cart must have a minimum speed of 10.0 m/s at the top of the loop to make it around safely. Assuming that the roller coaster starts from rest at the top of the first hill and there is no friction on the roller coaster, what is the minimum height of the first hill? T/I

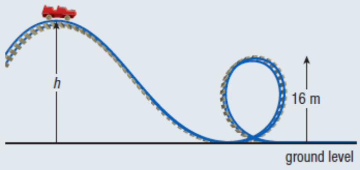


Figure 6

4. A net force acts on an object initially at rest, giving it an acceleration, a, while moving it a distance, Δd, forward across a horizontal surface. T/I C
   (a) Use kinematics equations to show that $v^2 = 2a\Delta d$.
   (b) The final total mechanical energy is $E_k = \frac{mv^2}{2}$. Substitute the equation for the final velocity into the equation for the final kinetic energy and simplify. What does this new equation prove?

Section 5.3 # 1, 2, 3