

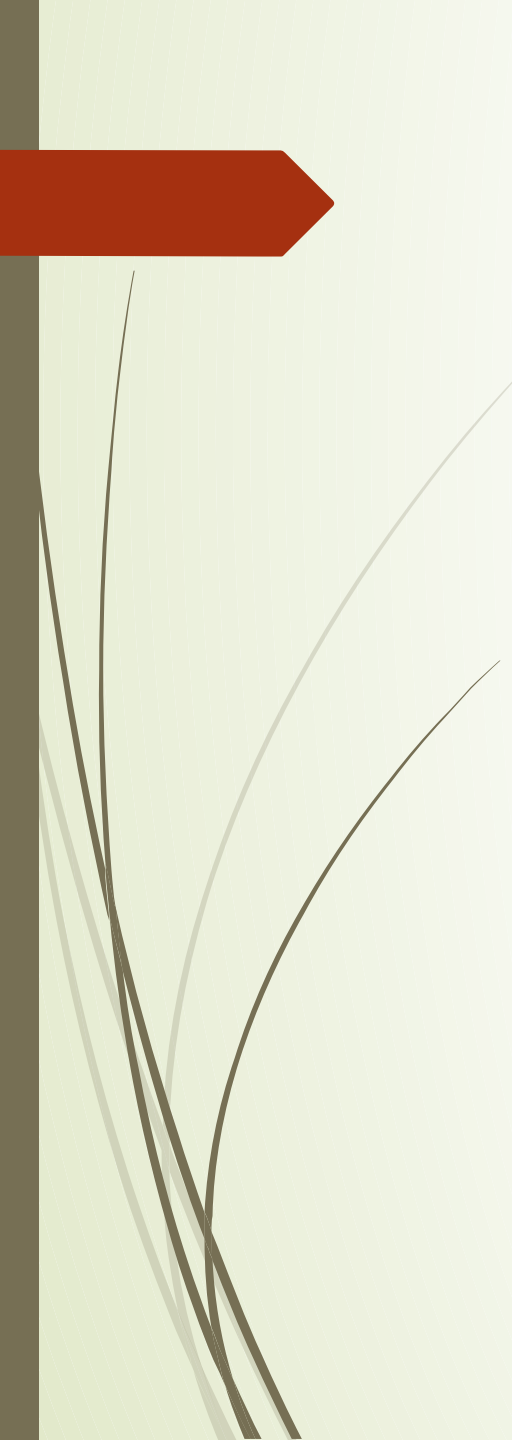
# The First Law of Thermodynamics: Kinetic and Potential Energy

By Shawn P. Shields, Ph.D.



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# The First Law of Thermodynamics



Before we can really begin talking about thermochemistry, we need to understand one of the most fundamental laws of science.

## **The Law of Conservation of Energy (1st Law)**

During any process, energy is neither created nor destroyed, but it can be converted from one form to another.

# Forms of Energy

▣ Kinetic Energy (KE)- The energy due to the **motion** of an object.

Described by the equation

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

Where KE is the kinetic energy (in J)

m is the mass of the object (in kg)

v is the velocity of the object (in m/s)

# Forms of Energy

▮ Potential Energy (PE)- The stored energy due to the **position** of an object.

One equation for potential energy is  $PE = mgh$

Where PE is the potential energy (in J)

m is the mass of the object (in kg)

g is the gravitational acceleration constant ( $9.81 \text{ m/s}^2$ )

h is the height above ground of the object (in m)

There are many equations to describe potential energy.

# Kinetic or Potential Energy?

Classify each of the following as kinetic or potential energy.

A stone sitting on a cliff

A stone falling from a cliff to the ground

An arrow flying toward a target

A bird perched on a pole



# Kinetic or Potential Energy?

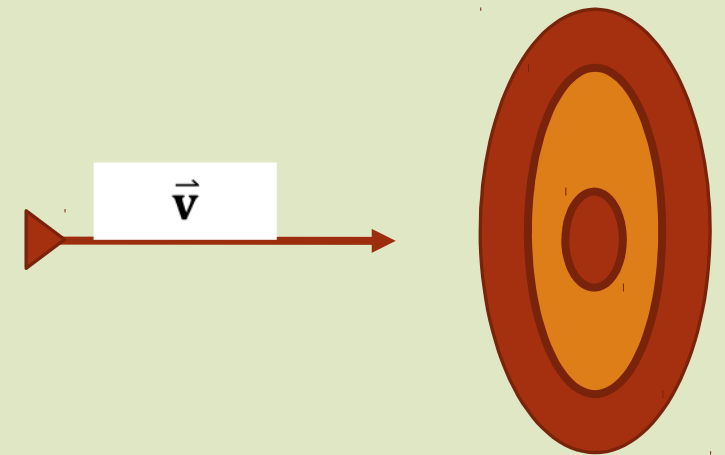
Classify each of the following as kinetic or potential energy.

A stone sitting on the cliff **PE**

A stone falling from a cliff to the ground **KE**

An arrow flying toward a target **KE**

A bird perched on a pole **PE**







# Other Forms of Kinetic or Potential Energy

Thermal energy- atomic and/or molecular motion in a substance

Radiant energy- energy from the sun in the form of electromagnetic radiation.

Electrical energy- flow of electrically-charged particles

Chemical energy- energy stored in chemical bonds

Nuclear energy- energy stored in the nucleus



# The Law of Conservation of Energy

□ Energy in a system can be interconverted between forms of kinetic and potential energy.

But, the total energy ( $E_{\text{TOTAL}}$ ) of the system remains constant for the system.

$$E_{\text{TOTAL}} = \text{KE} + \text{PE}$$

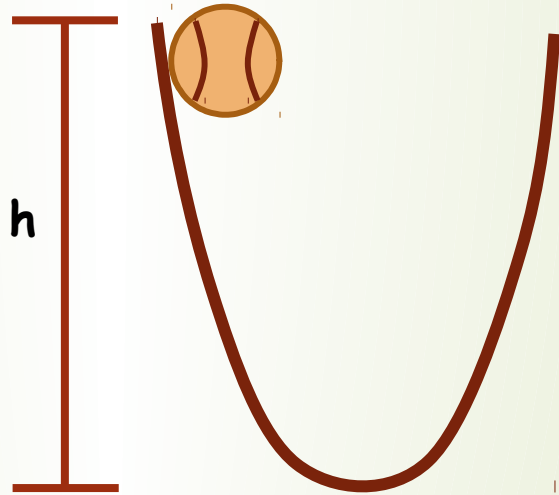


# Interconversion between PE and KE

Let's look at a ball on a ramp...

$$E_{\text{TOTAL}} = \text{KE} + \text{PE}$$

$$\text{PE} = mgh$$



A ball is placed on the end of a U-shaped ramp and held motionless.

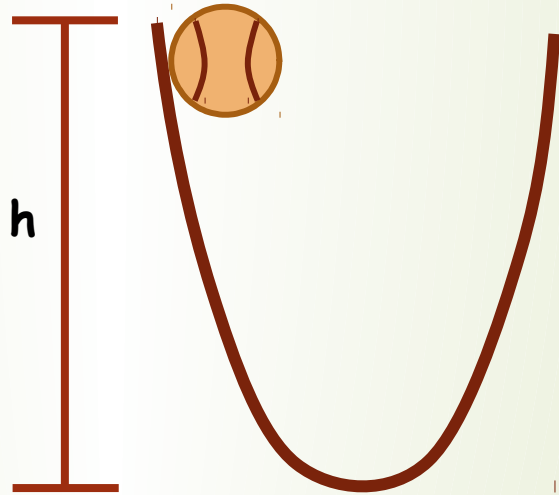
Is this PE or KE?

# Interconversion between PE and KE

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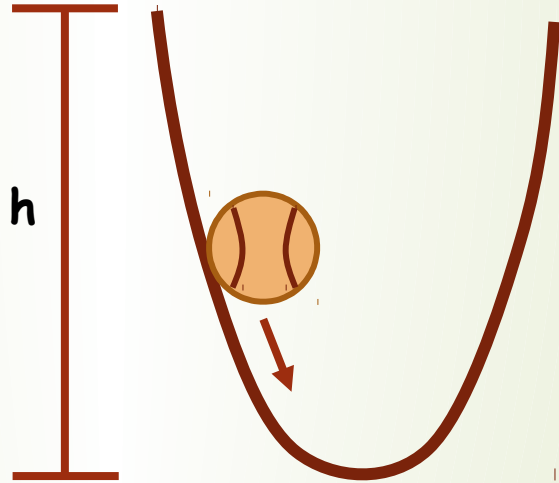
Only potential energy (since the ball is not moving!)

# Interconversion between PE and KE

Let's look at a ball on a ramp...

$$E_{\text{TOTAL}} = \text{KE} + \text{PE}$$

$$\text{PE} = mgh$$



Now, allow the ball to roll down the ramp.

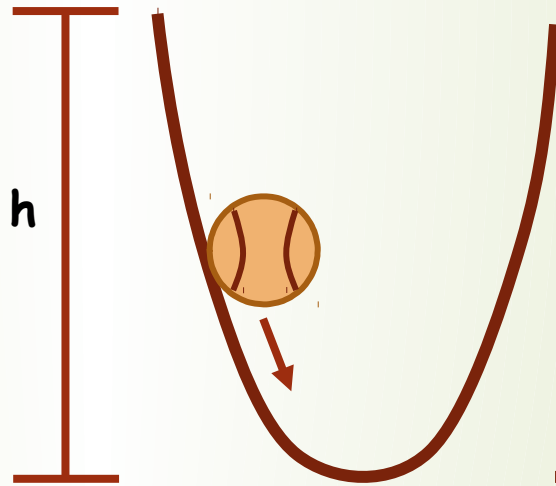
Does the ball have PE or KE or both?

# Interconversion between PE and KE

Let's look at a ball on a ramp...

$$E_{\text{TOTAL}} = \text{KE} + \text{PE}$$

$$\text{PE} = mgh$$



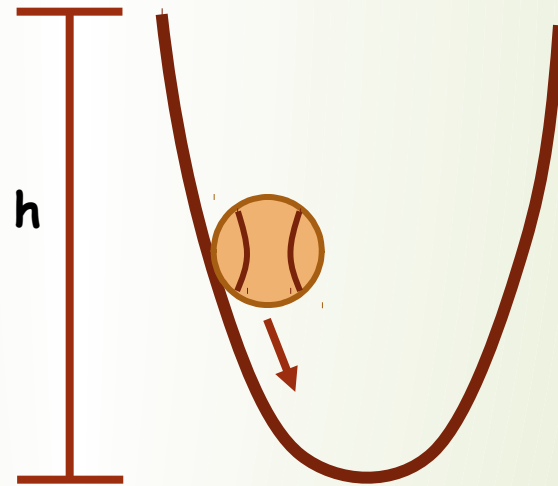
Now, allow the ball to roll down the ramp.

Does the ball have PE or KE or both?

**BOTH** potential energy (since the ball is still not at the bottom of the ramp), and it has kinetic energy because it is moving!

# Interconversion between PE and KE

What is going on?

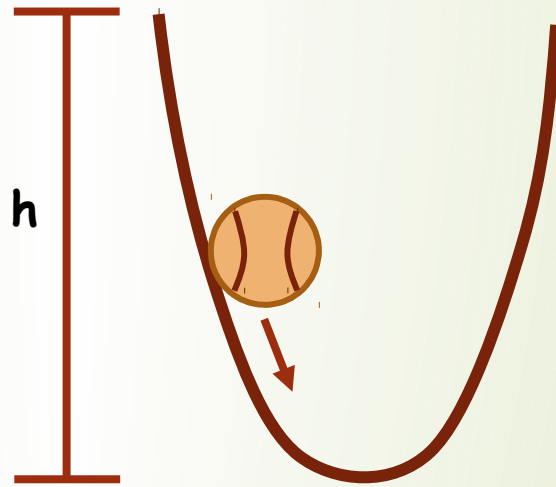


Potential energy is being converted to kinetic energy, but the total energy of the system remains constant!

$$E_{\text{TOTAL}} = \begin{matrix} \uparrow \\ \text{KE} \end{matrix} + \begin{matrix} \text{PE} \\ \downarrow \end{matrix}$$

# Interconversion between PE and KE

Where (on the ramp) is the potential energy completely converted to kinetic energy?

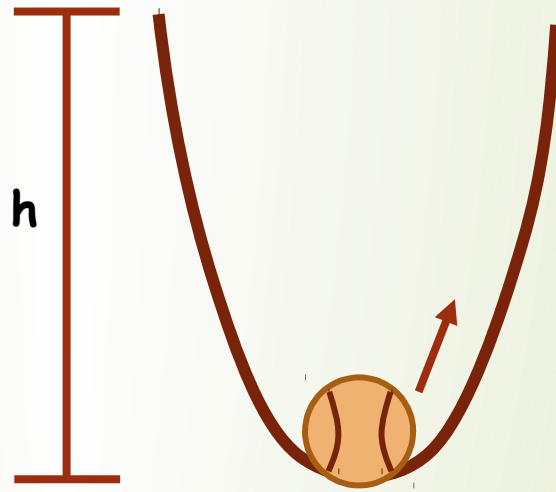


$$E_{\text{TOTAL}} = \text{KE} + \text{PE}$$



# Interconversion between PE and KE

Where (on the ramp) is the potential energy completely converted to kinetic energy?



$$E_{\text{TOTAL}} = \text{KE} + \text{PE}$$

At the bottom of the ramp!  
 $h = 0$ , so the potential energy is zero.

# Calculation Example of Interconversion of Energy

▮ Suppose a 5.8 g ball is thrown straight up in the air with an initial speed of 25 meters per second. What is the maximum height (in m) that the ball will rise?

(You may assume that there is no air resistance and the initial height of the ball is ground level,  $h_i = 0$ ).

$$E_{\text{TOTAL}} = \text{KE} + \text{PE}$$

# Calculation Example of Interconversion of Energy

▮ Suppose a 5.8 g ball is thrown straight up in the air with an initial speed of 25 meters per second. What is the maximum height (in m) that the ball will rise?

$$E_{\text{TOTAL}} = \text{KE} + \text{PE}$$

Let's ask ourselves a few questions...

**What type of energy does the ball start out with?**

**Can we figure out how much total energy there is in the system?**

# Calculation Example of Interconversion of Energy

▮ Suppose a 5.8 g ball is thrown straight up in the air with an initial speed of 25 meters per second. What is the maximum height (in m) that the ball will rise?

$$E_{\text{TOTAL}} = \text{KE} + \text{PE}$$

**What type of energy does the ball start out with?**

**Kinetic Energy only...the ball starts out at ground level, so there is no potential energy at first.**

**Can we use this information to figure out how much total energy there is in the system?**

# Calculation Example of Interconversion of Energy

▮ Suppose a 5.8 g ball is thrown straight up in the air with an initial speed of 25 meters per second. What is the maximum height (in m) that the ball will rise?

$$E_{\text{TOTAL}} = \text{KE} + \text{PE}$$

What type of energy does the ball start out with?

Kinetic Energy only...the ball starts out at ground level, so there is no potential energy at first.

**How much total energy is there in the system?**

**At the beginning of the throw, the total energy is equal to the kinetic energy!**

# Calculation Example of Interconversion of Energy

▮ Suppose a 5.8 g ball is thrown straight up in the air with an initial speed of 25 meters per second. What is the maximum height (in m) that the ball will rise?

$$E_{\text{TOTAL}} = \text{KE} + \text{PE}$$

**KE can be calculated using**

$$\text{KE} = \frac{1}{2}mv^2$$

**Where m is the mass of the ball (in kg) and v is its initial speed.**

**Remember to convert g to kg!**  $5.8 \text{ g} \left( \frac{1 \text{ kg}}{1000 \text{ g}} \right) = 0.0058 \text{ kg}$



# Calculation Example of Interconversion of Energy

▮ Suppose a 5.8 g ball is thrown straight up in the air with an initial speed of 25 meters per second. What is the maximum height (in m) that the ball will rise?

$$E_{\text{TOTAL}} = \text{KE} + \text{PE}$$

$$\text{KE} = \frac{1}{2}mv^2 = \frac{1}{2}(0.0058 \text{ kg})(25 \text{ m/s})^2 = 3.6 \text{ J}$$

**Therefore,**  $E_{\text{TOTAL}} = \text{KE} + \text{PE} = 3.6 \text{ J} + 0 = 3.6 \text{ J}$

# Calculation Example of Interconversion of Energy

▮ Suppose a 5.8 g ball is thrown straight up in the air with an initial speed of 25 meters per second. What is the maximum height (in m) that the ball will rise?

$$E_{\text{TOTAL}} = KE + PE$$

Now that we know the total energy of the system, let's think about the maximum height of the ball in this scenario.

When the ball is at its maximum height, what type of energy will be present?

# Calculation Example of Interconversion of Energy

▮ Suppose a 5.8 g ball is thrown straight up in the air with an initial speed of 25 meters per second. What is the maximum height (in m) that the ball will rise?

$$E_{\text{TOTAL}} = \text{KE} + \text{PE}$$

When the ball is at its maximum height, only *potential energy* will be present, and the total E will be equal to the PE.

Use  $\text{PE} = mgh$  to calculate the height of the ball.

# Calculation Example of Interconversion of Energy

▮ Suppose a 5.8 g ball is thrown straight up in the air with an initial speed of 25 meters per second. What is the maximum height (in m) that the ball will rise?


$$E_{\text{TOTAL}} = \text{KE} + \text{PE}$$

**Recall,  $\text{PE} = E_{\text{Total}} = 3.6 \text{ J}$**

**Therefore**

$$\text{PE} = mgh = (0.0058 \text{ kg}) (9.81 \text{ m/s}^2) h = 3.6 \text{ J}$$

$$h = \frac{3.6 \text{ J}}{(0.0058 \text{ kg}) (9.81 \text{ m/s}^2)} = 63 \text{ m}$$



# What You Should Be Able to Do (so far)

Describe and be able to recognize common forms of potential and kinetic energy.

Use the equations for kinetic and potential energy in calculations.

Use the law of conservation of energy (the 1st Law) in calculations involving the interconversion of PE and KE.