SUPERCHARGED SCIENCE

# Unit 5: Energy (Part 2)

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**Appropriate for Grades:**

Lesson 1 (K-12), Lesson 2 (K-12)

**Duration:** 6-15 hours, depending on how many activities you do!

**We covered some confusing stuff,** but don't feel bad if you're having trouble with it. It takes a while for this to sink in. In this Unit 5, we're going to talk about the two main categories of energy: potential and kinetic. We will talk about transfer of energy and we will also discuss conservation of energy and energy efficiency.

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# Materials for Experiments

**How many of these items do you already have?** We've tried to keep it simple for you by making the majority of the items things most people have within reach (both physically and budget-wise), and even have broken down the materials by experiment category so you can decide if those are ones you want to do. *NOTE: This material list is for the entire Experiment section online.*

**Ramp Races**
Several small balls of different weights (golf ball, racket ball, ping pong ball, marble etc.)
Good size container or mixing bowl
Flour or corn starch or any kind of light powder
Pie tin or other shallow container
Tape measure or yard stick
Optional: Spring scale or kitchen scale

**Roller Coasters & Bobsleds**
3 pieces ¾" pipe insulation (non-adhesive, black foam)
20 marbles
1 roll masking tape
Aluminum foil
Scissors
Gift wrap tube or clear fluorescent-lamp tube
Stopwatch, yardstick

**Catapult**
6 rubber bands
2 plastic spoons
9 tongue-depressor popsicle sticks
14 regular-size popsicle sticks
Hot glue gun and glue sticks
wooden clothespin
straw
wood skewer or dowel
Marshmallows, wadded up paper sheets or aluminum foil balls

**Pendulums**
Yardstick
A washer or a weight of some kind
Stopwatch
4 index cards (any size)
10 Thumb tacks (or brass fasteners)
Big, heavy hex nut
10' string or yarn
6 strong donut-shaped ring magnets

**P-Shooter**
Mechanical pencil (cheap kind)
2 thin rubber bands
Razor (get adult help)

**Optional Items for Grades 9-12:**
Baking potato (raw)
Protractor
Straw, string
Rock or key (to use as weight)
Stopwatch
Acrylic tubing (approx 1/2" dia)
¼" wood dowel (should fit inside acrylic tube)
Washer (make sure that the inner diameter of washer smaller than outer diameter of acrylic tube, so the washer cannot slide up the tube)

# Key Vocabulary

**Conservation of Energy** means that in a closed system energy can neither be created or destroyed.

**Energy** is the ability to do work. Energy can be transferred, in other words it can be changed from one form to another and from one object to another.

**Energy efficiency** is how much energy in a system is transferred to useless energy. The most common forms of useless energy are sound energy and heat energy.

**Force** is a push or a pull, like pulling a wagon or pushing a car.

**Gravitational potential energy** is the amount of energy something has due to its height above the ground. The higher it is and more mass it has the more gravitational potential energy it has. PE=mgh

**Kinetic energy** is energy of motion. The faster something is moving and/or the more massive it is the more kinetic energy it has. $KE=1/2\ mv^2$

**Mechanical advantage** is simply how many times easier it is to lift an object using a simple machine. Officially, mechanical advantage is the factor by which a mechanism multiplies the force put into it. A simple machine with a mechanical advantage of 100 could lift a 100 pound load with the effort of one pound.

**Potential Energy** is the amount of energy something can use to do work.

**Power** measures how quickly work can be done. Mathematically, power is work divided by time. Power can be measured in horsepower or Watts.

**Pulleys**, like all simple machines, sacrifice distance for force. The more distance the effort moves, the less force is needed to lift the load. The **pulley** is a very powerful **simple machine**.

**Simple machines** give you mechanical advantage. A major job of simple machines is to decrease the force needed to move something. The more pulleys that are rigged together, the more effective a pulley system can be.

**Work** is moving something against a force over a distance. Mathematically, work = force x distance. Work can be measured in Joules or calories.

 

# Unit Description

**In Part 1, we began our journey to understanding energy.** We discussed the fact that energy is the ability to do work. We defined work as moving an object over a distance against a force. We defined power as the amount of work done over time. We also, defined a few of the common energy units Joule, calorie, horsepower and Watt.

**We covered some confusing stuff,** but don't feel bad if you're having trouble with it. It takes a while for this to sink in. In this Unit 5, we're going to talk about the two main categories of energy: potential and kinetic. We will talk about transfer of energy and we will also discuss conservation of energy and energy efficiency.

 

# Objectives

## Lesson 1: Potential Energy

**All the different forms of energy** (heat, electrical, nuclear, sound etc.) can be broken down into two categories, potential and kinetic energy.

**Think of potential energy the "could" energy.** The battery "could" power the flashlight. The light "could" turn on. I "could" make a sound. That ball "could" fall off the wall. That candy bar "could" give me energy. Potential energy is the energy that something has that can be released. For example, the battery has the potential energy to light the bulb of the flashlight if the flashlight is turned on and the energy is released from the battery. Your legs have the potential energy to make you hop up and down if you want to release that energy (like you do whenever it's time to do science!). The fuel in a gas tank has the potential energy to make the car move.

### Highlights:

- Potential Energy is the amount of energy something can use to do work.
- Gravitational potential energy is the amount of energy something has due to its height above the ground. The higher it is and more mass it has the more gravitational potential energy it has. PE=mgh
- Energy can be transferred, in other words it can be changed from one form to another and from one object to another.
- Conservation of energy means that in a closed system energy can neither be created or destroyed.
- Energy efficiency is how much energy in a system is transferred to useless energy. The most common forms of useless energy are sound energy and heat energy.

# Objectives

## Lesson 2: Kinetic Energy

**Kinetic energy is the energy of motion**. Kinetic energy is an expression of the fact that a moving object can do work on anything it hits; it describes the amount of work the object could do as a result of its motion.

**Whether something is zooming,** racing, spinning, rotating, speeding, flying, or diving… if it's moving, it has kinetic energy. How much energy it has depends on two important things: how fast it's going and how much it weighs. A bowling ball cruising at 100 mph has a *lot* more kinetic energy than a cotton ball moving at the same speed.

Let's recap the highlights for kinetic as well as potential energy, so you can see how they are related.

### Highlights:

- Potential Energy is the amount of energy something can use to do work.
- Gravitational potential energy is the amount of energy something has due to its height above the ground. The higher it is and more mass it has the more gravitational potential energy it has. $PE=mgh$
- Kinetic energy is energy of motion. The faster something is moving and/or the more massive it is the more kinetic energy it has. $KE=1/2\ mv^2$
- Energy can be transferred, in other words it can be changed from one form to another and from one object to another.
- Conservation of energy means that in a closed system energy can neither be created or destroyed.
- Energy efficiency is how much energy in a system is transferred to useless energy. The most common forms of useless energy are sound energy and heat energy.

 

# Textbook Reading

This is the second part on energy. In Unit 4, we discussed the fact that energy is the ability to do work.

We defined work as moving an object over a distance against a force. We defined power as the amount of work done over time. We covered some confusing stuff, but don't feel bad if you're having trouble with it. It takes a while for this to sink in.

This lesson we're going to talk about the two main categories of energy: potential and kinetic. We will talk about transfer of energy and we will also discuss conservation of energy and energy efficiency.

## Potential Energy

All the different forms of energy (heat, electrical, nuclear, sound etc.) can be broken down into two categories, potential and kinetic energy.

My students have nicknamed potential energy the "could" energy. The battery "could" power the flashlight. The light "could" turn on. I "could" make a sound. That ball "could" fall off the wall. That candy bar "could" give me energy.

Potential energy is the energy that something has that can be released. For example, the battery has the potential energy to light the bulb of the flashlight if the flashlight is turned on and the energy is released from the battery. Your legs have the potential energy to make you hop up and down if you want to release that energy (like you do whenever it's time to do science!). The fuel in a gas tank has the potential energy to make the car move.

## Kinetic Energy

Kinetic energy is the energy of motion, an expression of the fact that a moving object can do work on anything it hits; it describes the amount of work the object could do as a result of its motion.

Let's try to put that a little more simply. Remember from last lesson that work is the amount of distance something travels against a force. A Joule is the amount of energy it takes to exert one Newton the distance of a meter. Also, remember that a Newton is a unit of force. It takes about one Newton of force to lift an apple. So if something has 10 Joules of kinetic energy it can apply a force of one Newton over a distance of 10 meters.

Here's an example: an arrow is shot from a bow and by the time it hits an apple it is traveling with 10

Joules of kinetic energy (kinetic energy is the energy of motion).

What's meant by kinetic energy is that when it hits something, it can do that much work on whatever is hit.

Soooo, back to the arrow, if the arrow hits that apple it can exert 10 Joules of energy on that apple. It takes about 1 Newton of force to move that apple so the arrow can move the apple 10 meters. One Joule equals one Newton x one meter so 10 Joules would equal one Newton x 10 meters.

It could also exert a force of 10 Newton's over one meter or any other mathematical calculation you'd like to play with there.

(This, by the way, is completely hypothetical. With the apple example we are conveniently ignoring a bunch of stuff like the fact that the arrow would actually pierce the apple, and that there's friction, heat, sound, and a variety of other forces and energies that would take place here.)

The formula for kinetic energy is 1/2 mass x velocity$^2$ or KE = 1/2 mv$^2$.

We'll be doing lots of experiments to make this clearer.

## Gravitational Potential Energy

There's one specific type of potential energy that's worth spending some more time on. That's gravitational potential energy. Gravitational potential energy is the energy something has due to gravity. This is the physics version of "what goes up, must come down".

If a ball is sitting on top of a book shelf, it has the potential to fall off. If the ball were to fall off the bookshelf it would potentially hit the floor with a certain amount of Joules of energy.

The formula for this is potential energy = mass x gravity x height, or PE=mgh.

Mass is the mass of the object, Gravity is the gravitational constant 10 m/s$^2$, and height is how high the object is above the ground.

The gravitational constant is how fast gravity accelerates things and we've generally been using 32 ft/s$^2$. However, since we're calculating Joules here, we need to use metric measurements. In metric the gravitation constant is 9.8 m/s$^2$. I tend to round that up to 10 m/s$^2$ to make the math a little simpler. So, let's say that a 1 kg ball is sitting on a 2 meter (about 6 feet) tall bookshelf.

That ball has: PE=mgh

PE= 1 kg x 10 m/s$^2$ x 2m
PE= 20 Joules

It has the potential to hit the floor with 20 Joules of energy.

## Transfer of Energy

Now's a good time to introduce another concept here, transfer of energy. Energy changes to other forms of energy all the time. The electrical energy coming out of a wall socket transfers to light energy in the lamp. The chemical energy in a battery transfers to electrical energy which transfers to sound energy in your personal stereo. In the case of the ball falling, gravitational potential energy transfers to kinetic energy, the energy of motion.

## Conservation of Energy

Energy cannot be created or destroyed in a closed system. A system is the place the energy is happening in. In this case, the system is the ball dropping and hitting the flour. If the system is closed, that means no energy can get in or escape from the system. Since that ball started with .7 Joules of energy, it hit the flour with .7 Joules of energy and transferred .7 Joules of energy to the flour. No energy was created or destroyed, just transferred within the system. As the ball dropped it lost potential energy because it kept losing height. Also, as the ball dropped it gained kinetic energy because it kept gaining speed. So, when the potential energy was .7 the kinetic energy was 0 (not moving). When the kinetic energy was .7 the potential energy was 0 (no height). All the energy transfers during the fall.

## Energy Efficiency

Now here's a question you may be asking yourself, "If energy is neither created or destroyed in a closed system then why doesn't a kid swinging on the playground swing go forever?

Ahhh, that's a very intelligent question. You must be very smart! Energy is neither created or destroyed, but it can be transferred into non-useful energy. In the case of the swinging kid (picture a pendulum), every swing loses a little bit of energy, which is why each swing goes slightly less high (achieves slightly less PE) than the swing before it.

Where does that energy go? To heat. The second law of thermodynamics states basically that eventually all energy ends up as heat. If you could measure it, you'd find that the string, and the weight have a slightly higher temperature then they did when they started due to friction.

The energy of your pendulum is lost to heat! If you could prevent the loss of energy to useless energy, you could create a perpetual motion machine. A machine that works forever!

There have been a lot of folks who have spent a lot of time trying to make a perpetual motion machine. So far, they have all failed. A perpetual motion machine is one that is said to be 100% energy efficient. In other words all the energy that goes into it goes to useful energy. Your pendulum could be said to be about 90% efficient. Very little energy is converted into useless energy. In most systems, energy is converted to useless heat and sound energy.

## Highlights for Energy

Potential Energy is the amount of energy something can use to do work.

Gravitational potential energy is the amount of energy something has due to its height above the ground. The higher it is and more mass it has the more gravitational potential energy it has. PE=mgh

Kinetic energy is energy of motion. The faster something is moving and/or the more massive it is the more kinetic energy it has. KE=1/2 $mv^2$

Energy can be transferred, in other words it can be changed from one form to another and from one object to another.

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# Activities, Experiments, Projects

## Lesson 1: Potential Energy

*Note: This section is an abbreviated overview of the experiments online.*

### Experiment: Whack-a-POW!

In this experiment, you're looking for two different things: first you'll be dropping objects and making craters in a bowl of flour to see how energy is transformed from potential to kinetic, but you'll also note that no matter how carefully you do the experiment, you'll never get the same exact impact location twice.

To get started, find several balls of different weights no bigger than the size of a baseball. Golf ball, racket ball, ping pong ball, marble etc. are good choices. Also fill a good size container or mixing bowl with flour or corn starch (or any kind of light powder). If you're measuring your results, you'll also need a tape measure (or yard stick) and a spring scale (or kitchen scale).

1. Fill the container about 2 inches or so deep with the flour.

2. Weigh one of the balls (If you can, weigh it in grams).

3. Hold the ball about 3 feet (one meter) above the container with the flour.

4. Drop the ball.

5. Whackapow! Now take a look at how deep the ball went and how far the flour spread. (If all your balls are the same size but different weights it's worth it to measure the size of the splash and the depth the ball went. If they are not, don't worry about it. The different sizes will affect the splash and depth erratically.

6. Try it with different balls. Be sure to record the mass of each ball and calculate the potential energy for each ball.

ach one of the balls you dropped had a certain amount of potential energy that depended on the mass of the ball and the height it was dropped from. As the ball dropped the potential energy changed to kinetic energy until, "whackapow", the kinetic energy of the ball collided with and scattered the flour. The kinetic energy of the ball transferred kinetic energy and heat energy to the flour.

**For Grades 9-12:**

**Calculate the gravitational potential energy of the ball.** Take the mass of the ball, multiply it by 10 $m/s^2$ and multiply that by 1 meter. For example, if your ball had a mass of 70 grams (you need to convert that to kilograms so divide it by 1000 so that would be .07 grams) your calculation would be

PE=.07 x 10 x 1 = .7 Joules of potential energy.

So, how much kinetic energy did the ball in the example have the moment it impacted the flour? Well, if all the potential energy of the ball transfers to kinetic energy, the ball has .7 Joules of kinetic energy.

## Experiment: Ball Bounce

Stack a tennis ball on top of a basket ball, and drop them both at the same height (with the tennis ball riding on the top). When the basketball hits the floor, the tennis ball goes *flying* while the basketball drops to a dead stop.

You can also try this with a large and small set of rubber bouncy balls. So what's going on? Why does the bottom ball nearly stop while the top one goes *way* higher than usual?

When you toss down a ball, gravity pulls on the ball as it falls (creating kinetic energy) until it smacks the pavement, converting it back to potential energy as it bounces up again. This cycles between kinetic and potential energy as long as the ball continues to bounce.

But note that when you drop the ball, it doesn't rise up to the same height again. If the ball did return to the same height, this means you recovered all the kinetic energy into potential energy and you have a 100% efficient machine at work.

But that's not what happens, is it? Where did the rest of the energy go? Some of the energy was lost as heat and sound. (Did you hear something when the ball hit the floor?)

Activities, Experiments, Projects

# Lesson 2: Kinetic Potential Energy

*Note: This section is an abbreviated overview of the experiments online.*

## Experiment: Go Go GO!!

This is a nit-picky experiment that focuses on the energy transfer of rolling cars. You'll be placing objects and moving them about to gather information about the potential and kinetic energy. We'll also be taking data and recording the results as well as doing a few math calculations, so if math isn't your thing, feel free to skip it.

You'll need to find a few toy cars (or anything that rolls like a skate), a board, book or car track, and measuring tape.

The setup is simple. Here's what you do:

1. Set up the track (board or book so that there's a nice slant to the floor).

2. Put a car on the track.

3. Let the car go.

4. Mark or measure how far it went.

As you lifted the car onto the track you gave the car potential energy. As the car went down the track and reached the floor the car lost potential energy and gained kinetic energy. When the car hit the floor it no longer had any potential energy only kinetic.

If the car was 100% energy efficient, the car would keep going forever. It would never have any energy transferred to useless energy. Your cars didn't go forever did they? Nope, they stopped and some stopped before others. The ones that went farther were more energy efficient. Less of their energy was transferred to useless energy than the cars that went less far.

**Where did the energy go?** To heat energy, created by the friction of the wheels, and to sound energy. Was energy lost? NOOOO, it was only changed. If you could capture the heat energy and the sound energy and add it to the the kinetic energy, the sum would be equal to the original amount of energy the car had when it was sitting on top of the ramp.

## Experiment: Simple Pulleys

Roller Coasters are a prime example of energy transfer. You start at the top of a big hill at low speeds (high gravitational potential energy), then race down a slope at break-neck speed (potential transforming into kinetic) until you bottom out and enter a loop (highest kinetic energy, lowest potential energy). At the top of the loop, your speed slows (increasing your potential energy), but then you speed up again and you zoom near the bottom exit of the loop (increasing your kinetic energy), and you're off again!

To make the roller coasters, you'll need foam pipe insulation, which is sold by the six-foot increments at the hardware store. You'll be slicing them in half lengthwise, so each piece makes twelve feet of track. It comes in all sizes, so bring your marbles when you select the size. The ¾" size fits most marbles, but if you're using ball bearings or shooter marbles, try those out at the store. (At the very least you'll get smiles and interest from the hardware store sales people.) Cut most of the track lengthwise (the hard way) with scissors. You'll find it is already sliced on one side, so this makes your task easier. Leave a few pieces uncut to become "tunnels" for later roller coasters.

Roller Coasters are a prime example of energy transfer. You start at the top of a big hill at low speeds (high gravitational potential energy), then race down a slope at break-neck speed (potential transforming into kinetic) until you bottom out and enter a loop (highest kinetic energy, lowest potential energy). At the top of the loop, your speed slows (increasing your potential energy), but then you speed up again and you zoom near the bottom exit of the loop (increasing your kinetic energy), and you're off again!

**Tips & Tricks**

*Loops* Swing the track around in a complete circle and attach the outside of the track to chairs, table legs, and hard floors with tape to secure in place. Loops take a bit of speed to make it through, so have your partner hold it while you test it out before taping. Start with smaller loops and increase in size to match your entrance velocity into the loop. Loops can be used to slow a marble down if speed is a problem.

*Camel-Backs* Make a hill out of track in an upside-down U-shape. Good for show, especially if you get the hill height just right so the marble comes off the track slightly, then back on without missing a beat.

*Whirly-Birds* Take a loop and make it horizontal. Great around poles and posts, but just keep the bank angle steep enough and the marble speed fast enough so it doesn't fly off track.

*Corkscrew* Start with a basic loop, then spread apart the entrance and exit points. The further apart they get, the more fun it becomes. Corkscrews usually require more speed than loops of the same size.

# Exercises

## Potential and Kinetic Energy

1. What is potential energy?

2. What is kinetic energy?

3. What is gravitational potential energy?

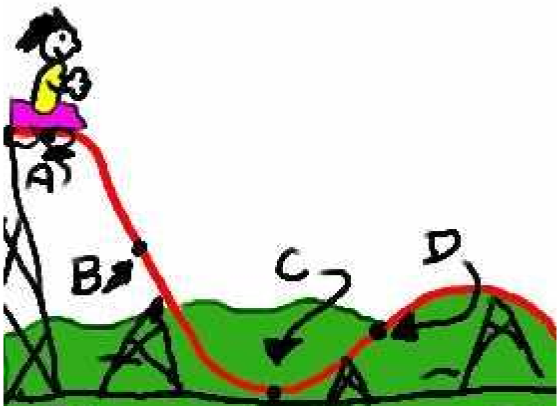
4. What does transfer of energy mean?

5. What is conservation of energy?

6.For the next six questions, use the image below.

Describe the potential and kinetic energy of this roller coaster.




Where is the potential energy greatest?

Where is the kinetic energy greatest?

Where is potential energy lowest?

Where is kinetic energy lowest?

Where is KE increasing, and PE is decreasing?

Where is PE increasing and KE decreasing?

7. What's energy efficiency?

8. Which is more energy efficient, a nice new Hot Wheel car or one that's been stepped on?

9. In most systems, where are the most common two sources of non-useful energy?

10. What is work?

11. What does a Newton measure?

12. What does a Joule measure?

# Answers to Potential and Kinetic Energy Exercises

1. Potential energy is the energy that something has that can be released.

2. Kinetic energy is the energy of motion. KE = 1/2 $mv^2$

3. Gravitational potential energy is the energy something has due to gravity. Gravitational Potential Energy = mgh

4. Energy can be changed from one form to another and from one object to another.

5. In a closed system energy can neither be created or destroyed.

6. See below…
    - Potential energy is greatest at a. The coaster is at it's highest point above the ground.
    - Kinetic Energy is the greatest at c. The coaster is going the fastest at this point.
    - Potential energy is lowest at c. The coaster is as low as it can get.
    - Kinetic energy is lowest at a. The coaster is not moving.
    - KE is increasing and PE is decreasing at b. The coaster is losing height so it's losing PE but it is gaining speed so it is gaining KE.
    - PE is increasing and KE is decreasing at d. The coaster is getting higher so it's gaining PE but it's losing speed so it's losing KE.

7. Energy efficiency is how much energy in a system is transferred to useless energy.

8. It depends on what you want the car to do! If you want the car to go far after leaving the track you want the brand new one. It will have less of the original potential energy transferred to heat since it will have less friction. However, if you want your car to generate heat, you want the stepped on one. It will have much more of its energy transferred to heat due to its high friction! (In other words, you need to be a bit careful with the term "useful" energy)

9. Sound energy and heat energy. Heat comes from the force of friction. Sound energy, as a matter of fact, also gets transferred to heat energy.

10. Work is defined as moving an object over a distance against a force. Work = force x distance

11. A Newton is a unit of force. How much force it takes to push or pull something. It takes about one Newton of force to lift an apple.

12. A Joule is a unit of energy. It takes one Joule to exert one Newton of force over a distance of one meter.