

Lesson 2: Energy Transformations



Energy. This small label identifies what may be the broadest, most sweeping concept in all of the science disciplines. Although we all use the term in life, earth, and physical science classes at virtually every grade level, "energy" remains one of the hardest terms to succinctly define. Even Isaac Newton was unaware of the idea of energy. The very existence of the phenomenon we call energy was still being debated by scientists less than 150 years ago. Even today, energy is a tough concept to illustrate and explain because the only time it can really be seen, felt, or heard is when it is being transferred or transformed.

Energy [link to <http://www.energyquest.ca.gov/story/index.html>]

is defined as the ability to do work. And **work** [link to <http://www.energyquest.ca.gov/story/chapter01.html>] is the ability to apply a force (push or pull) over a distance. One of my students simply defined energy as "the stuff that makes things move." Underlying all forms of energy is a basic law of physics: the **law of conservation of energy**. This fundamental law has nothing to do with saving energy but what happens to energy when it is transformed or transferred. The law states that energy cannot be created or destroyed; it may be transformed (changed to another form) or transferred (moves within the same form), but the total amount of energy never changes. In other words, the total energy of the universe is constant.

However, as energy is transferred or transformed it becomes less organized and less orderly over time. This is called **entropy**. Therefore, in all energy transformations or transfers, the overall effect is that the energy is evenly distributed. For example, mixing hot and cold water to produce a lukewarm temperature.

Energy can be a tough concept to illustrate and explain because it comes in many forms and the only time it can really be seen, felt, or heard is when it is being transferred or transformed. For us to concretely observe the effects of energy, something has to happen.

Here are several forms of energy:

Potential - work done against a given force in changing the position of an object with respect to a reference position (includes gravitational and elastic)

Kinetic - work required to accelerate an object to a given speed

Thermal – total energies of all jostling molecules within an object

Electrical – involves forces and work from electrical charges

Chemical – energy stored in chemical bonds

Nuclear – energy stored in atomic nuclei

Electromagnetic – energy that travels through space in the form of electromagnetic waves (radio waves, TV waves, microwaves, infrared waves, light, ultraviolet waves, X-rays)

Thermal, electrical, chemical, electromagnetic energies are associated with the molecules that form the objects. Nuclear energy involves the energy within the nucleus of individual atoms. Potential and kinetic energy forms of mechanical energy are easier to see and discuss since it often deals with larger, visible objects.

To better describe an energy transfer or transformation, the National Science Education Standards classifies all energy in one of three conditions: 1) kinetic energy, which is energy of motion; 2) potential energy, which depends on relative position or condition; or 3) field energy, which is energy contained within a field, such as electromagnetic waves.

Measuring Mechanical Energy and Energy Transformations

Roller coasters have been around for over 100 years and they are still as popular as ever. Amusement parks all over the world are competing for your thrills and money. But most of these coasters have one thing in common. The first hill on every coaster (that uses gravitational potential energy) is the tallest hill on the ride. Why is the first hill so high? It is not there to give you more time to think about the upcoming drop! To discover the answer to this question and many more about energy conversions in roller coasters, conduct the simulation below and the classroom activities “Exploring Energy with Marble Roller Coasters.”

SIMULATION ACTIVITY: Roller Coaster Energy Transformations

(Adapted from lessons by Jaymin Jhaveri and G. Jones)

1. Load the simulation located from:
http://phet.colorado.edu/new/simulations/sims.php?sim=Energy_Skate_Park
2. Click on **Run Now!**
3. Modify the java applet as follows:
 - a. On the control column on the right-hand side: Enable “**Show Grid**” checkbox.
 - b. The show grid option enables/disables a virtual gridline assembly that allows you to better estimate the height (vertical position) of the skater.
 - c. Enable “**Show Pie Chart**” checkbox. Uncheck “with Thermal”
 - d. The show pie chart checkbox enables/disables an instantaneous or live pie chart representation of the skater’s total energy in terms of potential, kinetic and thermal energy.
4. Answer the questions below as you explore the simulation.

Simulation Questions:

1. Do you think the skater depicted in Figure 1 below starting at rest will be able to make it through the first hump (assume no friction)? Explain why or why not.

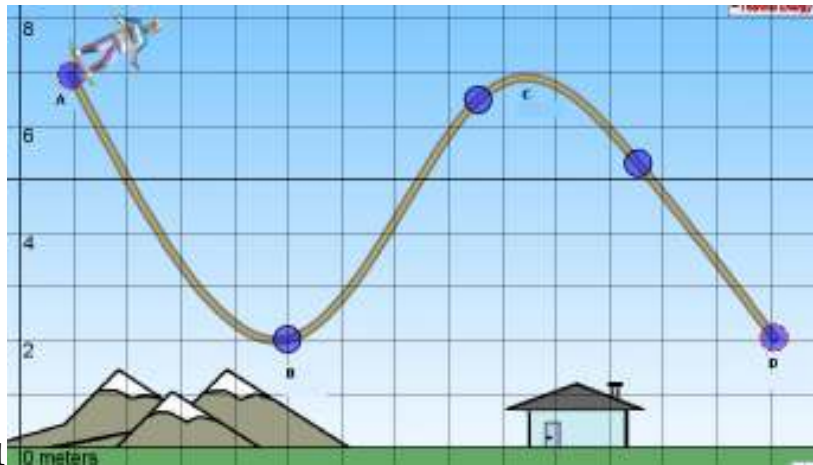


Figure 1

2. Predict the answer to Question #1 if friction were present. Explain your reasoning.
3. See if your predictions are correct by constructing the same track and then adding friction.
4. After you have constructed a similar track as seen in the figure, draw or describe the pie chart of the skater starting at rest at points A, B, C and D. Explain each of the pie charts that you draw. (This task can be performed easily by pausing the simulation via the pause button at the bottom when the skater is approximately at location A or B or C or D and then clicking on the step button several times).
5. Bring the skater back to point A and pause the simulation. Click the "Energy vs. Position" button to display the energy vs. position graph. Play the simulation after you have placed the skater back to point A. Observe the skater and pause the simulation when the skater is about to leave the track at point D. Sketch or describe the Total Energy, Potential Energy, and Kinetic Energy vs. position that you have obtained. You do not need to sketch the thermal energy. Explain why the total energy remains constant.
6. Assume that an engineer designs a new frictionless track shown in Figure 2 below. On the figure below label or describe at which points the skater will have maximum and minimum potential energy along with maximum and minimum kinetic energy. Will the skater reach the end of the track and fall of (the skater starts at rest)? Explain.

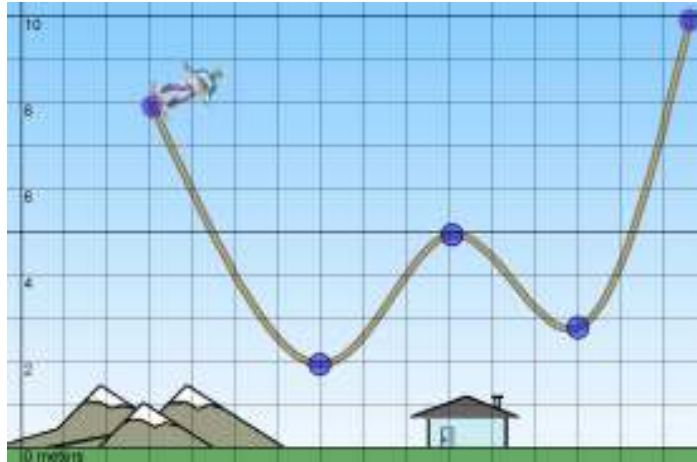


Figure 2

7. As part of a circus routine, the same track is used for a bulldog with mass = 15.0 kg (see Figure 3). What is the dog's speed at the bottom of the first valley?

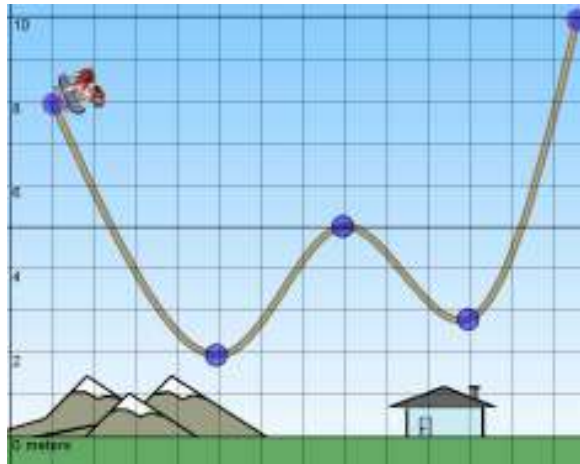


Figure 3

CLASSROOM ACTIVITY ICON: Exploring Energy with Marble Roller Coasters

1. Download the PDF files of the teacher lesson plans for **(see attached)**:
 - a. Activity #1 - "Crazy Coasters"
 - b. Activity #2 - "Over the Hill"
2. Assemble the materials. The track is tubular polyethylene that is used to insulate copper or iron pipes. It is available through Lowe's®, Home Depot®, hardware stores, or plumbing supply houses.
3. When purchasing the pipe insulation make sure it is pre-slit on one side (without adhesive) and is the following size:
 - a. 3/8" thick walls and six feet in length - should list that insulation fits 3/4" copper pipe (COP) or 1/2" iron pipe. For example: Home Depot® Stock #419-921 for Armstrong® Pipe Insulation Model# OEP07838
4. Preparing the Track **(see attached)** PDF file "Preparing the Track")

- a. Before the foam pipe insulation can be used for the activities, it must be split down the middle and cut to create two open-faced, six-foot long, roll-ways.
 - b. Using your finger or a pen, force open the pre-slit side of the track.
 - c. Using the pre-slit cut as a guide, cut the track length wise using a sharp razor knife or sharp scissors. Be careful to cut the track evenly in order to create two six-foot sections with equal-sized, side walls.
 - d. Tape sections of the track together by placing tape length-wise along the top and bottom of the track.
 - e. To start your coaster, tape the beginning of your track to a wall, desk, chair or cabinet. Place a marble in the groove and you're off and ROLLING!
5. Conduct the activities with your students or by yourself.

Post-Activity Questions

After completing Activity #1 "Crazy Coasters", answer the following questions:

1. Where does the marble get the initial energy it uses to travel through the coaster?
2. If a coaster contains loops, how were you able to get the marble to go around the loop?
3. Why did banking the curves (sloping the track laterally along the curve) keep the marbles from flying off the track?

After completing Activity #2 "Over the Hill," answer the following questions:

4. How is the gravitational potential energy of the marble calculated?
5. What are the SI units for potential energy? What is the difference between an erg and a joule?
6. At what point on the coaster does the marble have the greatest potential energy?
7. At what point on the coaster does the marble have the least potential energy?
8. At what point on the coaster does the marble have the greatest kinetic energy?
9. What happens to the marble's energy as it goes up a hill and slows down?
10. Would a marble ever be able to get over a hill higher than its initial starting height? Explain.

Marble roller coasters can help illustrate the concept of mechanical energy. A student's energy is used to do work on the marble by lifting it to its starting height on the track. This energy is not lost but transferred to the marble. The marble now has a higher energy level due to its higher position off the floor. This is called mechanical (or gravitational) potential energy. The higher the marble is raised against gravity, or the heavier the

marble, the higher its gravitational **potential energy** [link to <http://www.glenbrook.k12.il.us/gbssci/phys/Class/energy/u5l1b.html>].

When the marble is released the potential energy transforms into the energy of motion or mechanical **kinetic energy** [link to <http://www.glenbrook.k12.il.us/gbssci/phys/Class/energy/u5l1c.html>]. At no time can the marble have more kinetic energy than its original amount of potential energy. Throughout the marble's coaster ride it experiences a continual interchange of potential and kinetic energy as it rolls over the hills and through the loops. But at no time will the combination of the two be greater than the initial amount of potential energy at the marble's release height.

As a coaster glides over the hills and through the loops, the energy converts back and forth between kinetic energy and potential energy [link to <http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/energy/ce.html>]. A coaster can never go as high (or as fast) as it does on the first hill. Friction robs some of the coaster's kinetic energy and transforms it into heat. Since no additional energy is given to the coaster, this loss of kinetic energy prevents the coaster from climbing another equally tall hill. This is an example of the law of conservation of energy.

Therefore at any point of the ride, if you totaled the potential, kinetic, heat, and sound energy (plus any energy you, the track, or the air may absorb) their total would equal the original amount of energy the coaster had at the top of the first hill.

As the roller coaster [link to <http://www.learner.org/exhibits/parkphysics/index.html>] goes down the first hill some of its energy is transformed into other forms, this leaves less kinetic energy available to get it up the next hill. The second hill must be smaller than the first or the coaster will not go over it.

For further study

- Amusement Park Physics – A great site.
<http://www.learner.org/interactives/parkphysics/>
- The Science of Energy
This comprehensive resource has background information in the form of a self-guided tutorial, plans for inquiry-based lessons, biographies of scientists who contributed to our knowledge, and a collection of downloadable images.
<http://www.nsta.org/energy/>
- U.S. Department of Energy – Energy Efficiency and Renewable energy
http://www1.eere.energy.gov/kids/learning_saving.html

True or False Questions

1. The energy an object has by virtue of its position or condition is called its potential energy.
2. The energy an object has by virtue of its motion is called its kinetic energy.
3. Energy transforms from one form to another with no overall loss or gain.

Multiple Choice

Choose the best answer to each question.

4. Potential energy is the energy an object has because of its
 - A) speed.
 - B) position.
 - C) temperature.
 - D) density.
5. Kinetic energy is the energy an object has because of its
 - E) speed.
 - F) position.
 - G) size.
 - H) density.
6. As a pendulum swings back and forth
 - I) potential energy is transformed into kinetic energy.
 - J) kinetic energy is transformed into potential energy.
 - K) at the lowest part of its swing, its energy is all kinetic.
 - L) at the end points of its swing, its energy is all potential.
 - M) All of the above.
7. The amount of potential energy possessed by an elevated object is equal to
 - N) the force needed to lift it.
 - O) the distance it is lifted.
 - P) the power used to lift it.
 - Q) the work done in lifting it.
 - R) the value of the acceleration due to gravity.