2.4 Read

How Does Work Increase Potential Energy?

Think back to the windup toy and the Newton's cradle. How did you use work to increase the kinetic energy of each toy?

When you wound the windup toy, you did work to turn the key. But the work did not immediately become kinetic energy. The work was used to add potential energy to the toy. Only when you released the toy was the potential energy transformed into kinetic energy.

When you wind up a toy, the spring stores energy.

With the Newton's cradle, you did work when you pulled back the first steel ball. Then you held the ball in place before releasing it. At that moment, the toy had no kinetic energy because nothing was moving. The work you did (raising the ball) was stored as potential energy in the ball. When you released the ball, the potential energy was transformed into kinetic energy.

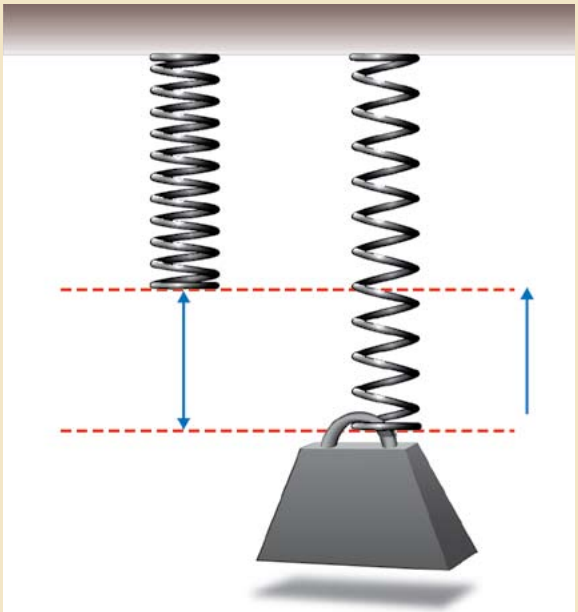
In both toys, you did work so that the object stored energy that could be transformed at a later time. What factors determine how much potential energy is stored in a toy? This is the question you will explore in this section.

How Is Elastic Potential Energy Stored?

When you wind up the windup toy, potential energy is stored in its spring. As you wind the spring tighter and tighter, the spring holds more potential energy. The kind of potential energy in the spring of a windup toy is elastic potential energy. Elastic potential energy is stored when something "stretchy" or "springy" is stretched or **compressed**. When you wind up the windup toy, you compress its spring. When you let go, the spring unwinds, and the toy moves.

compressed: squeezed or pressed together.

Elastic and rubber bands also store elastic potential energy. When you stretch a rubber band and then release it, its elastic potential energy is transformed to kinetic energy. The rubber band will fly across the room. The more you stretch the rubber band, the more elastic potential energy it has, and the faster it will fly.



Compressed springs and stretched springs both store elastic potential energy.

The bouncy ball stores elastic potential energy in a similar way. When the ball hits the floor, it is compressed, giving it elastic potential energy. When that elastic potential energy is released, it is transformed into kinetic energy, and the ball moves.

In general, if you see that an object can stretch or compress, you know that it can store elastic potential energy.

A windup music box or airplane stores elastic potential energy in its spring.

How Is Potential Energy Stored Using Gravity?

Newton's cradle shows how **gravity** is used to store and transform potential energy. You have lived with gravity your whole life, yet for most people it remains a mysterious force. Part of the mystery is that gravity acts at a distance. When Earth pulls a steel ball toward the ground, there is nothing visible that connects the ball and the ground. Yet the indicators of gravity are familiar. Any time you see an object falling or see the effort it takes to lift a weight, you are seeing indicators of gravity.

By now you know that work is done when a force acts through a distance to change an object's motion or position. Sometimes you do work to overcome gravity. Just think back to the last time you climbed three flights of stairs. You did a lot of work to lift your body higher. As you did this work, you applied an upward force using the muscles in your legs.

gravity: the force of attraction between any two masses. Near Earth's surface, gravity is the force that attracts objects toward the center of Earth.

When you lift the steel ball in Newton's cradle, you do work. This work is stored as potential energy in the ball. This type of potential energy is called gravitational potential energy—the energy an object stores because of its position above the ground. When you release the ball, its gravitational potential energy is transformed into kinetic energy, which is then transferred to the other balls.

You were able to control the amount of kinetic energy in the balls in the Newton's cradle by moving the steel ball higher or lower. If you lifted the ball higher, you did more work, so the ball stored more gravitational potential energy. This resulted in more kinetic energy when the released ball hit the other balls. When the greater amount of kinetic energy was transmitted through the other balls, the ball at the end of the line moved faster and higher.

You can control the amount of kinetic energy in the Newton's cradle by moving the steel ball higher or lower.

Conservation of Mechanical Energy

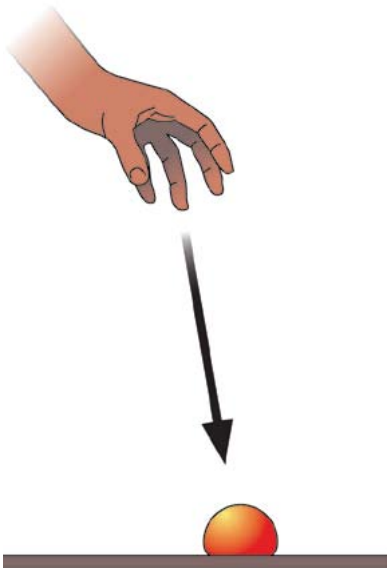
Think back to your experience with the bouncy ball. The ball can have kinetic energy from elastic potential energy and gravitational potential energy. When you lift the ball, you are doing work to increase its gravitational potential energy. When you then release the ball, gravitational energy is transformed into kinetic energy as the ball falls. When the ball hits the floor, the ball's shape changes as it flattens against the floor. The ball stops moving for an instant, so it no longer has kinetic energy. All of the ball's kinetic energy has been transformed into elastic potential energy. The ball then bounces upward, releasing its elastic potential energy, which is transformed back into kinetic energy, and so on. Many energy transformations keep the ball in motion.

Scientists often think about energy in terms of the total energy of a **system,** a collection of objects that interact. A system can have one object or many objects. If there are no forces that oppose motion, like friction or air resistance, and no energy is added to or removed from the system, then the **mechanical energy** of a system remains constant. Mechanical energy is the sum of the kinetic energy, gravitational potential energy, and elastic potential energy of a system. This concept is called the **conservation of mechanical energy.** Each time energy is transformed, all of the energy can be accounted for—none of the energy is lost.

system: a collection of objects that interact.

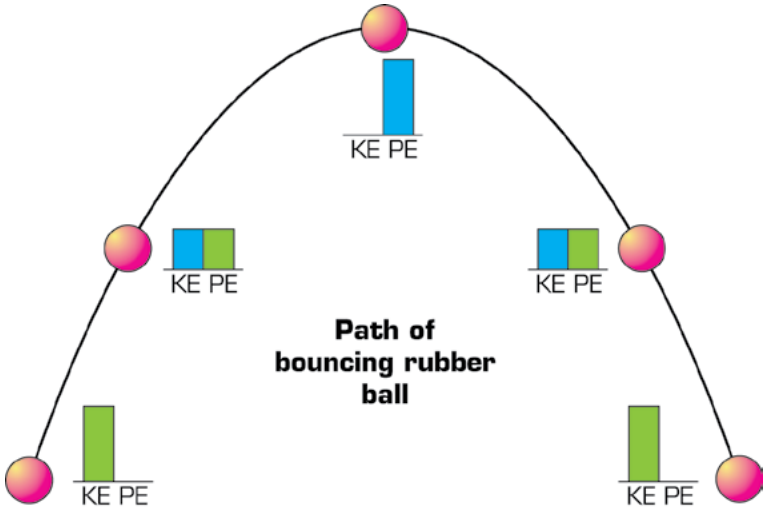
mechanical energy: the sum of the kinetic energy, gravitational potential energy, and elastic potential energy in a system.

conservation of mechanical energy: if there is no friction or air resistance, the mechanical energy of a system changes only if the system does work on something else or energy is added from outside the system.



When you release the ball, gravitational potential energy is transformed into kinetic energy as the ball falls.

It may help to think about what happens to the bouncy ball *after* it bounces upward and all of its energy is kinetic energy (KE). As the ball travels upward, it gains gravitational potential energy (PE) as it goes higher, but it also loses kinetic energy as it slows down. However, at each point, the sum of the gravitational potential energy and the kinetic energy is the same. When the ball reaches its peak, all of its energy is gravitational potential energy. Then as the ball falls, gravitational potential energy decreases (because height decreases) while kinetic energy increases (because speed increases). At each point in its path, the mechanical energy of the ball remains constant.



As the ball travels upward, it gains gravitational potential energy. What happens when the balls travels downward?

Reflect

Work with your group to answer these questions. Be prepared to share your answers with the class.

1. Think back to the step of the energy-transformation cartoon that you analyzed at the end of the last section. Was any potential energy stored or released during the step? Rewrite your description of the step from the last section if necessary, using what you have learned about gravitational and elastic potential energy.
2. How are potential energy and kinetic energy related?
3. What is the connection between work and energy?

Update the *Project Board*

You know a lot now about the relationships between potential energy and kinetic energy. Add what you know about the relationship between potential energy and kinetic energy to the *What are we learning?* column of the *Project Board*. Don't forget to add evidence to the *What is our evidence?* column. If you have new questions about potential energy, kinetic energy, or work, add them to the *What do we need to investigate?* column.

What's the Point?

Elastic potential energy is energy that is stored when an object, such as a spring, is stretched or compressed. When you release the spring, the potential energy is transformed into kinetic energy. Gravitational potential energy is energy that is stored by moving an object to a greater height above the ground. This energy is transformed into kinetic energy when the object is allowed to fall.

You can use work to add kinetic energy to a system or to increase potential energy in the system. Potential energy stored in any system can be released as kinetic energy. Kinetic energy can be transformed to do work or to increase potential energy. Sometimes energy is transferred without being transformed. This occurs when the balls in Newton's cradle transfer kinetic energy. Mechanical energy is the sum of the kinetic energy and potential energy in a system. The mechanical energy of a system remains constant if there is no friction or air resistance and no energy is added to or taken away from the system.

As a skydiver falls toward Earth, gravitional potential energy transforms into kinetic energy.