

Period 6 Activity Sheet Solutions: Energy and Work

6.1 How Do We Measure Work and Energy?

- a) Work is done when a force moves an object.

Work and energy are measured in units of joules. $1 \text{ joule} = 1 \text{ kg m}^2/\text{s}^2$

Force is measured in units of newtons. $1 \text{ newton} = 1 \text{ kg m}/\text{s}^2$

Explain why a joule can also be called a newton meter.

You can write the units of energy as $1 \text{ kg m}^2/\text{s}^2 = 1 \text{ kg m}/\text{s}^2 \text{ m} = 1 \text{ N m}$

The unit of energy and work (joule) is the produce of units of force (newton) times units of distance (meter).

- b) This activity illustrates the amount of energy in one joule.

Lift the 1 newton plastic apple up a distance of 1 meter. How much work did you do on the apple? **__1 joule__**

How much energy did you exert? (Assume no energy was wasted.) **_1 joule_**

6.2 How Does the Work Done Compare to Potential Energy Gained?

- a) **Work:** Your instructor will demonstrate potential energy with a pile driver.

- 1) The pile driver mass is 4 kilograms. What is its weight in newtons?

$$\text{Weight} = F = Mg = 4 \text{ kg} \times 9.8 \text{ m}/\text{s}^2 = 39.2 \text{ N}$$

- 2) How much force is necessary to raise the mass at a constant velocity?

39.2 N For motion at a constant velocity, the force pushing the mass up equals the force of gravity pulling the mass down.

- 3) To what height was the pile driver mass raised? _____

- 4) How much work was done to raise the mass to this height?

Use $W = M g h$ to find the joules of work done.

- b) **Potential Energy:**

- 1) How much potential energy did the mass have before it was raised? **__0__**

- 2) How much potential energy does the mass store when it is raised?

Ignoring wasted energy, the amount of stored energy equals the amount of work done to raise the mass. (Same answer as 6.2.a.4)

- 3) The mass is now allowed to drop. What form of energy does the mass have just before it hits the metal stand at the bottom? **__kinetic energy__**

- c) Group discussion question: Is the amount of energy the mass had just before it hits the same as the amount of gravitational potential energy it had when it was raised? Why or why not?

The mass has less kinetic energy just before it hits than gravitational potential energy before it falls. As it falls, most of its gravitational potential energy is converted into kinetic energy. However some potential energy is converted into wasted thermal energy from friction between the mass and the air molecules it pushes aside as it falls.

6.3 What Happens to Stored Potential Energy?

a) Your instructor will demonstrate the pile driver mass hitting a nail into a board.

- 1) If this pile driver exerts a force of 500 N to drive a nail into a board a distance of 3 cm, how much work does the pile driver do on the nail?

$$W = F D = 500 \text{ N} \times 0.03 \text{ m} = 15 \text{ joules}$$

- 2) If the 4 kg mass is raised to a height of 0.75 meters, how much potential energy does it store?

$$E_{pot} = M g h = 4 \text{ kg} \times 9.8 \text{ m/s}^2 \times 0.75 \text{ m} = 29 \text{ J}$$

- 3) Is the work done by the mass to pound the nail into the board the same, more, or less than the stored gravitational potential energy? less
- 4) Explain what happens to the rest of the stored potential energy when the mass falls and hits the nail.

As it falls, most of its gravitational potential energy is converted into kinetic energy. However some potential energy is converted into wasted thermal energy due to friction between the mass and the air molecules it pushes aside as it falls. When the mass hits the nail, some of its kinetic energy is converted into sound energy, some into thermal energy, and the rest goes into pushing the nail into the wood.

b) Your instructor will demonstrate the pile driver mass hitting a soda can. List the energy transformations that take place starting with the mass at rest at the top and ending with the mass at rest at the bottom.

As the mass falls, most of its gravitational potential energy is converted into kinetic energy of motion and the rest is converted into thermal energy. When the mass collides with the can, its kinetic energy is converted into the energy used to crush the can as well as into sound energy and thermal energy.

c) When the pile driver mass falls and hits the empty metal stand, what happens to the potential energy the mass had before it fell?

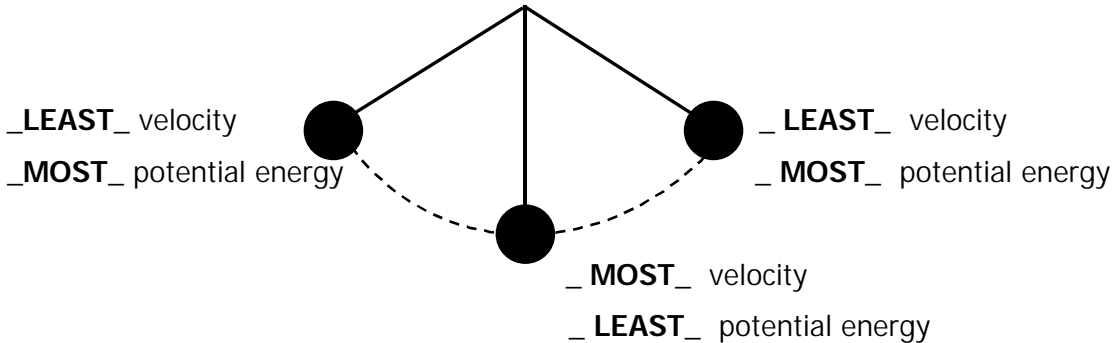
The potential energy is converted into kinetic and thermal energy as the mass falls. When the mass hits the metal stand, all of its kinetic energy goes into sound and thermal energy.

d) Group Discussion Question: You have seen the pile driver mass strike a nail, a soda can, and the empty metal stand. In which of these cases did the mass do work? Explain your answer.

When hitting the nail, the mass exerts a force on the nail to push it some distance into the wood. When hitting the can, the mass exerts a force on the can top, pushing it some distance to crush the can. The mass does work in both of these cases. When the mass hits the empty stand, it exerts a force on the metal stand, but it does not move the stand. Since the force has not been exerted over a distance, the mass does no work in this case. (Work = force x distance)

6.4 Kinetic Energy ↔ Potential Energy Conversions

- a) Your instructor will demonstrate a pendulum, in which a ball swings freely.
- 1) On the sketch of below, fill in the blanks with "MOST" or "LEAST" to indicate the ball's velocity and gravitational potential energy in each position.



- b) Your instructor will discuss the gravitational potential energy of a swinging ball.
- 1) If you release the ball from the height of your nose, why doesn't it swing back and hit you in the nose?

Most of the ball's gravitational potential energy goes into kinetic energy. However, some potential energy is wasted as thermal energy from friction as the ball collides with air molecules. Therefore, the ball has less kinetic energy on the return swing and cannot swing as high.

- 2) The click-clack machine has 5 balls. What happens to the balls' gravitational potential energy when 1, 2, 3, or 4 balls are raised and dropped? List the series of energy conversions that occur when one ball is raised and released.

As you raise one ball, chemical potential energy of your body is converted into gravitational potential energy of the ball. As the first ball drops, its gravitational potential energy is converted into kinetic energy. When the first ball collides with the balls at rest, some kinetic energy is transferred from the first ball to the second ball and eventually to the last ball, which swings upward. Some of the first ball's kinetic energy is converted into thermal and sound energy during the collision. As the last ball swings up, its kinetic energy is converted into gravitational potential energy. If two balls are raised, some of their kinetic energy is transferred to the balls at rest and the last two balls swing upward.

- 3) Would the click-clack balls swing forever? Does a swinging click-clack ball reach the same height with each swing? What eventually happens to the gravitational potential energy the ball started with?

With each swing, the ball's gravitational potential energy is converted into kinetic energy (causing another ball to swing up), sound energy, and thermal energy. With each swing, the ball rises to a lower height. Eventually all of the original gravitational potential is converted into thermal and sound energy, and the ball comes to rest.

- c) Use the curved plastic track to roll or slide the toy car, marble, ping pong ball, and a wooden block with smooth and rough sides. Make predictions first.

1) Which object wastes **the most** energy overcoming the force of friction?
Prediction: _____ **Answer:** rough wooden block

2) Which object wastes **the least** energy overcoming the force of friction?
Prediction: _____ **Answer:** marble

d) Group Discussion Question: Would it ever be possible for an object to roll higher than its original starting position? Explain why or why not.

An object released from rest on the curved track can never roll higher than its original starting position. To roll higher would require the object to gain energy. Since some energy is wasted by friction, objects do not roll up as high as their starting position. You could make the object roll higher by giving it a push, rather than simply releasing it.

6.5 How Is Energy Conserved?

a) Your instructor will demonstrate two rolling carts colliding with a barrier. Both carts have the same mass and the same frictional force with the table top.

1) Compare the velocities and the distances each cart travels after hitting the barrier.
One cart bounces off of the barrier with a faster velocity and rolls back nearly to its starting point. The other cart bounces off of the barrier with a slower velocity and stops closer to the wall.

2) Which cart has more kinetic energy after it hits the barrier – the cart that rolls a shorter distance or a longer distance? longer distance How do you know?

The cart that rolls a longer distance also bounced off of the barrier with a faster velocity. This cart has more kinetic energy because kinetic energy is proportional to the velocity squared. $E_{kin} = \frac{1}{2} M v^2$

3) Now watch the carts, without their outer covers, collide with the barrier. How can you explain the difference in the behavior of the carts after they hit the barrier?

More of the kinetic energy of motion of the rubber band cart is wasted vibrating the washers. Since the rubber band cart has less kinetic energy after the collision, it does not move as far away from the wall. The cart with rigid rods rolls farther away from the wall because less of its initial kinetic energy was wasted vibrating the washers.

4) Explain how energy was conserved when each cart collided with the barrier.

If each cart is pushed with the same force, both carts start with the same amount of kinetic energy. Their kinetic energy goes into moving against the force of friction with the floor and into vibrating the washers. Since the rubber band cart uses more energy vibrating the washers, it does not roll as far after the collision. The carts demonstrate what happens inside of a solid when kinetic energy is converted into the thermal energy of vibrating atoms and molecules.

6.6 How Is Friction Involved in Conservation of Energy?

- a) In this activity, we measure the work done against the force of friction by a toy truck pulling a block connected to a spring scale.
- 1) Once the truck and block are moving at a constant velocity, how much force does the truck exert on the block? _____
 - 2) Once the truck reached a constant velocity, how far did the truck pull the block?
 - 3) Calculate the amount of work the truck did to pull the block that distance.

use $W = F D$ _____

- 4) Place a 1 kilogram mass on top of the block. How much force does the truck exert on the moving block with the 1 kg mass on it? _____
- 5) How much work must the truck do to move the block with the 1 kg mass the same distance as in question 2?

use $W = F D$ _____

- 6) Why does the truck do more work when the 1 kg mass is added?

Adding mass to the block increases the force of friction between the block and the floor. The truck must exert a greater force to overcome the force of friction between the block and the floor.

- b) Group Discussion Question: When an object moves at a constant velocity across a level surface, all the work done is done against the force of friction. When the truck pulled the block at a constant velocity on the level floor, how much of the truck's work went into wasted energy? Would your answer change if the truck accelerated the block?

At a constant velocity, all of the truck's energy went into wasted thermal energy to do work against the force of friction between the floor and the block. If the truck exerts more force and accelerates the block, some of its energy would be wasted as thermal energy but some energy would go into the force necessary to accelerate the block.

6.7 More Examples of Energy Storage

- a) Examine the spring wound toys on your table.

- 1) What form of energy do they store?

Winding a spring stores strain energy in the compressed spring. As the spring unwinds, it converts strain energy into kinetic energy of motion.

- 2) Squeeze a small spring with your fingers. Describe the energy transformations that take place.

Chemical potential energy stored in your body is converted into the kinetic energy of motion of your fingers as they squeeze the spring, then into the kinetic energy of the spring as it compresses. The compressed spring stores strain energy.

- 3) The batteries on your table store potential energy in another form. What form of energy does a battery store? **__batteries store chemical potential energy__**

- b) Your instructor will demonstrate a water wheel. List the energy conversions that take place when the water flows over the wheel.

The gravitational potential energy of the water is converted into kinetic energy as the water flows down the tube. When the water hits the wheel, its kinetic energy is converted into the kinetic energy of the moving wheel. Some kinetic energy is converted into thermal energy due to friction between the water and the tube and in the moving parts of the wheel. The rest of its kinetic energy turns an axle that winds up a string and raises a 20 gram mass. The mass gains gravitational potential energy as it rises.

- c) How is thermal energy involved in the examples of the spring and the water wheel?

In both cases, energy is wasted as thermal energy.