

# MARBLES AT WORK

## AT A GLANCE

Explore how potential energy transforms to kinetic energy and the ability to do work. Isolate variables and test how mass, height, and velocity affect the amount of work that is done.

### OBJECTIVES

Students will:

- Learn how potential energy transforms to kinetic energy
- Be able to explain work in a scientific context
- Manipulate variables and test hypotheses

### KEY VOCABULARY

potential energy, kinetic energy, work

### SUGGESTED GRADE

LEVELS: 4—8

### ILLINOIS STATE LEARNING GOALS

#### Late Elementary

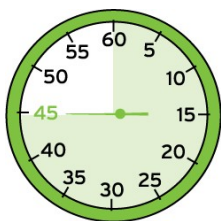
3: A, C; 6: D; 10: A, B; 11: A; 12: D

#### Middle/Junior High

3: A; 6: D; 10: A, B; 11: A; 12: D

### PACE YOURSELF

45 MINUTES



### ADVANCE PREPARATION

1. Cut cups in half lengthwise.
2. Make copies of the student data sheet.



### MATERIALS

#### Per Group:

a couple of thick books  
3 marbles  
1 ruler (ramp)  
1 paper or Styrofoam cup, cut in half lengthwise  
tape  
stopwatch



### WHAT YOU NEED TO KNOW

Energy can take on many different forms (e.g. thermal, sound, mechanical, etc.), but it can neither be created nor destroyed. Most forms of energy are a type of **kinetic** or **potential** energy. Kinetic energy, or moving energy, is the energy something has because of its motion—the energy a marble has when it is rolling on the floor. Potential energy is the energy that comes from the position of one object relative to the position of another—the energy a marble has when it is being held at the top of a ramp. In a scientific context, we do **work** when we apply force on an object and that object moves in the direction of the force you exert on it. For instance, when you push a marble and roll it across the floor, you are doing work which equals the change in kinetic energy of the marble—the marble moves!

Below is the formula for gravitational potential energy (in joules), where  $m$  is the mass of an object in kilograms,  $g$  is the acceleration due to gravity ( $9.8\text{m/s}^2$ ), and  $h$  is the height of the object above the surface:

$$\text{Gravitational potential energy} = mgh$$

The amount of gravitational potential energy an object has depends on its mass, and its height above the Earth's surface—the greater the height and the mass, the more gravitational potential energy the object has.

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The kinetic energy of an object depends on the mass of an object ( $m$ ) and its velocity ( $v$ ):

$$\text{Kinetic Energy} = \frac{1}{2} mv^2$$

The greater the object's mass and velocity, the more kinetic energy it has.



## WARM UP

Ask students if they can define what the word *work* means. Students will likely come up with definitions that correspond to the everyday use of the word work - "I worked really hard on that project" or "my parents went to work today". Explain that the definition of the word *work* in the context of science is different: in science, work is when we use a force to move an object. Give students a few seconds to think about this while you write the definition on the board. Now push really hard to move an object that won't move (like a wall). Ask students if you did work. If they say yes, point to the definition on the board and ask if the wall moved. Now take a marble and push it so that it rolls across a table. Did you do work that time? Explain that energy was transferred from you to the marble. The marble got kinetic energy — energy of motion — from you and moved: you did work!



## ACTIVITY

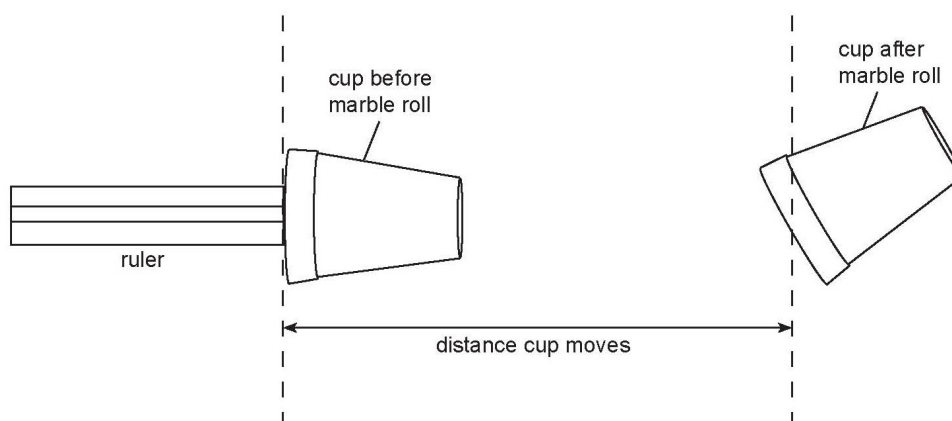
### Part I

1. Have students separate into groups of 4-5 students.
2. Place one of the half cups on its side on a smooth, level surface, so that it makes a cave with an opening on one side.
3. Take turns to roll a marble into the open end of the cup, and observe what happens when...
  - ... the marble hits the back of the cup
  - ... the marble is rolled at different speeds
  - ... the marble is rolled from different distances of the cup

### Part II

1. Stack 3 books on a level surface (a desk or the floor). Lean the ruler on the books so it makes a ramp. The ruler should be placed so that the lower numbers are at the base of the ramp. Fix the ruler in place with tape so it will not move from one experiment to the next
2. Place a half cup at the base of the ramp so that a marble rolling down the ramp will enter the cup and push it.
3. Position one marble at the top of the ruler (30 cm) and let it go.
4. How far did the cup move? Measure from the base of the ramp to where the cup came to rest. (NOTE: the cup may be at an angle to the ramp, so measure from a line that crosses the mid-point of the cup edge—see *image below*)

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5. Repeat the experiment 2 more times, so that you will have 3 measurements. Average your 3 measurements.
6. Now release the marble from  $\frac{3}{4}$  of the way up the ramp (at 22.5cm), halfway up the ramp (15 cm), and  $\frac{1}{4}$  of the way up the ramp (7.5 cm). Be sure to release the marble three times from each position on the ramp, and calculate an average.
7. Record all your measurements on the Student Worksheet table.

### Part III

1. Repeat the experiment above releasing 2 marbles together, instead of just 1. Place the marbles one behind the other on the ruler, making sure that the lead marble is at the correct spot on the ramp (i.e. 30, 22.5, 15, and 7.5 cm).
2. Record all your measurements on the Student Worksheet table.

### Part IV

1. Take away the cup from the ramp setup.
2. Measure a distance of 1 meter from the base of the ramp. Mark that distance with tape.
3. Use a stopwatch to time how long it takes for a marble to go from the base of the ramp to the 1-meter mark. Release the marble from the top (30cm),  $\frac{3}{4}$  of the way up (22.5 cm), half way up (15 cm), and  $\frac{1}{4}$  of the way up (7.5 cm). Make sure that you repeat the experiment 3 times at each ramp height.
4. Record all your measurements on the Student Worksheet table.

### CHECK FOR UNDERSTANDING



1. Which marble has the most kinetic energy—one moving fast or one moving slowly?
2. How did you measure the amount of energy a rolling marble has?
3. How did the height from which the marble was released on the ramp affect how much the cup moved?
4. How did the number of marbles (mass) released from the ramp affect how much the cup moved?
5. Which marble moves faster (has the greatest velocity) - one release from the top of the ramp, or one released from the middle of the ramp?

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## DIFFERENTIATED INSTRUCTION

To illustrate how the experiment should be conducted, and to ensure that the concept of energy transfer is clear from the beginning, the teacher may choose to demonstrate Part I of this activity.

To reinforce concepts and address misconceptions, the class should discuss the results of each part of this experiment after each part is completed.



## WHAT'S HAPPENING?

### Part I

When the marble is rolled into a cup, the cup moves in the direction the marble was rolling. The cup does not slide back smoothly—it moves a bit when the marble first hits, then stops, then moves again when the marble catches up and hits it again. The more energy the marble has, the farther the cup moves—when the marble is rolled with greater velocity or from closer up, the cup moves farther.

### Part II

When the marble is at the top of the ramp, it has potential energy due to its position within the Earth's gravitational field. Once the marble is released, the gravitational potential energy of the marble transforms to kinetic energy. When the marble hits the cup at the bottom of the ramp, energy is transferred from the marble to the cup causing the cup to move. This is work. Work equals the force applied across a distance which causes an object to move.

The gravitational potential energy of an object is the energy that object has because of its height above the Earth's surface. The higher the marble is on the ramp, the higher it is above the Earth's surface, and therefore the more potential energy it has. As a result, when the marble is released and the gravitational potential energy is transformed (primarily) to kinetic energy, the marbles released from higher up can move the cup farther.

### Part III

The gravitational potential energy of an object is also dependent on the object's mass. The greater the mass, the more potential energy an object has. As a result, when two marbles are released from a given position on the ramp, the marbles have twice the potential energy (and push the cup twice as far) as one marble would.

### Part IV

The kinetic energy of an object depends on the velocity of the object. A marble at the top of the ramp has more gravitational potential energy than one released lower on the ramp, and when that marble is released and begins to roll down the ramp, that potential energy is transformed into kinetic energy. That greater kinetic energy is evidenced in the greater velocity of the marble—the fact that the marble reaches the 1-meter mark fastest.



## INQUIRY WHEEL OPPORTUNITY

Use your inquiry wheel with your students to brainstorm dependent and independent variables in this experiment. Independent variables are the aspects of the experiment that you choose and manipulate. Dependent variables are the aspects of your experiment that result from those manipulations. The table below gives a few ideas:

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INDEPENDENT VARIABLES <i>How does the....</i>	DEPENDENT VARIABLES <i>Affect ...</i>
Angle of the ramp	How far the cup moves
Surface of the ramp (rough vs. smooth)	The velocity of the marble
Release point on ramp	The loudness of the sound the marble makes as it
Mass of the marble	

Remember to only change one independent variable at a time. For instance, if you want to measure what variables affect how far the cup moves, change only the angle of the ramp **or** release point on the ramp, *but not both at the same time*. If you change both independent variables, you will not be able to discern whether the results are due to the angle of the ramp or the release point. The inquiry wheel can help you separate the variables so you can test them one at a time and achieve scientifically relevant results.



## EXTENSIONS

### LANGUAGE ARTS

Record your observations in your science notebook. Did the height on the ramp impact how far the marbles travelled? Discuss with classmates and share the results.

### MATH

The formula for calculating the gravitational potential energy of an object is:

$$\text{Gravitational potential energy} = mgh$$

where  $m$  is the mass of an object (kg),  $g$  is the acceleration due to gravity ( $9.8 \text{ m/s}^2$ ),  $h$  is the height above the surface of the Earth, and the resulting energy measurement is in units of joules. What is the gravitational potential energy of a 6 kilogram rock held 15 meters above the surface? What about a 3 kilogram rock held 30 meters above the surface?

The formula for calculating the kinetic energy of an object is:

$$\text{Kinetic Energy} = \frac{1}{2} mv^2$$

where  $m$  is the mass of an object (kg),  $v$  is the velocity of an object, and the resulting energy measurement is in units of joules. Suppose you let that 6 kg rock that you are holding 15 meters above the surface go. From the law of conservation of energy, we know that energy cannot be created nor destroyed, so the potential energy of that rock being held in the air will transform into the kinetic energy of that rock falling through the air. Since you know the energy total from above, and you know the mass of the rock—can you calculate the velocity of the rock as it falls through the air?



## RELATED EXHIBITS

- *Science Storms*
- *Jolly Ball*