

# Potential and Kinetic Energy : Teacher Notes

## Introduction

The focus of this investigation is to look at the two types of mechanical energy (kinetic and potential) and realize that the sum of the two is always conserved. Students will explore kinetic and potential energy while rolling a cart down a ramp at different heights. By using a SmartWheel and analyzing the resulting velocity versus time graphs, the students will investigate the complementary relationship between the different types of mechanical energy. By comparing different experimental results, the students are encouraged to explain existing relationships.

In addition, students will gain experience with inquiry skills, including:

- knowing that an object's motion can be described by tracing and measuring its position over time;
- realizing that an object's motion can be described and represented graphically according to its position, direction of motion, and speed;
- knowing that when a force is applied to an object, the object either speeds up, slows down, or goes in a different direction;
- identifying variables that can affect the outcome of an experiment;
- using technology (e.g., hand tools, measuring instruments, calculators, computers) and mathematics (e.g., measurement, formulas, charts, graphs) to perform accurate scientific investigations and communications;
- knowing that scientific investigations involve asking and answering a question;
- planning and conducting simple investigations (e.g., formulating hypotheses, designing and executing investigations, interprets data, synthesizing evidence into explanations, proposing alternative explanations for observations, critiquing explanations and procedures);
- establishing relationships based on evidence and logical argument (e.g., provides causes for effects);
- knowing that scientific inquiry includes evaluating results of scientific investigations, experiments, observations, theoretical and mathematical models, and explanations proposed by other scientists (e.g., reviewing experimental procedures, examining evidence, identifying faulty reasoning, identifying statements that go beyond the evidence, suggesting alternative explanations).

## Discussion Guide

### Using this Guide

This guide is designed to help you convert the investigations your students experience into solid learning. The "Overview" section mentions some of the learning issues raised by this content. These issues might come up in conversations with students anytime. The "Setting the Stage" section provides ideas for a discussion you might hold before beginning the investigations. This discussion is important to motivate and alert students to observations that might answer their questions. The "Wrap Up" section can be used after the investigations to help student reflect on what they have done. Taking time to reflect while the investigations are fresh in students' minds has been shown to substantially increase learning.

### Overview

This investigation introduces two new kinds of energy - - both mechanical. Kinetic energy (KE) is energy of motion. An object needs to be moving to have kinetic energy. Potential energy (PE) depends on position or where an object is. An object gains potential energy by moving against a force. If the force is gravity, you gain potential energy by being raised. If the force is a rubber band, you gain potential energy by pulling against the rubber band. As an object moves, it can trade potential energy for kinetic or the reverse. For instance, a cart that is picking up speed while rolling down a ramp is losing potential energy and gaining kinetic energy. A girl on a swing has potential energy at the ends of the swing, when the velocity (and kinetic energy) drops to zero. At the bottom of the swing, the girl is moving fastest, so the kinetic energy is high. Meanwhile the swing is at its lowest point, so its potential energy is lowest.

Even though energy can change from potential to kinetic, the amazing thing is that the total energy stays constant. If there is no friction, the sum of potential and kinetic energy doesn't change. The demonstration of this requires a bit of calculation, so we put it in the Further Investigations section. If at all possible, we highly recommend doing these calculations. The point is that students pick some different instants during the cart's motion. For each time, they calculate PE and KE. At each instant PE and KE are different, but their sum is always the same, within experimental error. This investigation and the previous one appear unrelated, but they are linked because KE and PE can be transformed into heat energy. To limit the number of concepts introduced at one time, we have put off experiments on this transformation until later investigations. If students ask how the heat energy of last investigation relates to PE and KE, ask them:

[Because the speed is constant, KE is constant. Going downhill means PE is decreasing. Where is the energy going? Into the brakes. Friction creates thermal energy which cause the brakes to get hotter.] [At first, it goes into speeding up the falling water, giving it KE. But at the bottom of the falls, the water crashes into rocks and slows down, losing its KE. Friction in the water converts the KE into heat energy and the water gets slightly warmer. Because water is hard to warm up, it gets only a fraction of a degree hotter.] [For the shuttle to descend, it must lose PE. If the shuttle simply headed down, it would pick up speed, converting PE to KE. But it has to slow down to land, so it must lose KE, too. It gets rid of this energy by generating friction

with the air. Air friction is increased by putting down flaps and the landing gear. All this friction generates heat energy that warms up the skin of the shuttle and the air, slightly. The shuttle is covered with ceramic blocks that get very hot on the outside but insulate the inside.]

### Setting the Stage

Most students have biked, so drawing on their experience from biking can help students realize that they already have rich experiences to bring to this study. This motivates students and helps them learn the content and realize that these ideas can be applied outside the classroom. Introduce the terms PE and KE in the context of biking. For instance, you can ask the following while having the students sketch out diagrams of hills and bikes for themselves: [Roll down a hill.] [Almost as high as you started.] [Exactly as high as you started.] [No, if there is no friction. You will coast up a long shallow hill or a steep short hill to the same height.] [Find a higher hill or deeper valley.] [It decreases until you reach the bottom of the hill.] [Energy of motion, or "kinetic energy". Note that kinetic is just another word for motion.] [At the bottom, when PE is least.]

### Wrap Up

To demonstrate the generality of the ideas in this investigation, you might have students think about their application to another context where there is not too much friction, such as riding a roller coaster or automobile, shooting an arrow, dropping a pumpkin, or traveling to the moon or Mars. Assign one context to each group and ask each to answer the following:

"Describe and draw a trip (or motion) that doesn't involve a motor or other power source. How does PE and KE change during the trip."

"If there were no friction, how would the trip be changed?"

"How does the object get the PE it started with?"

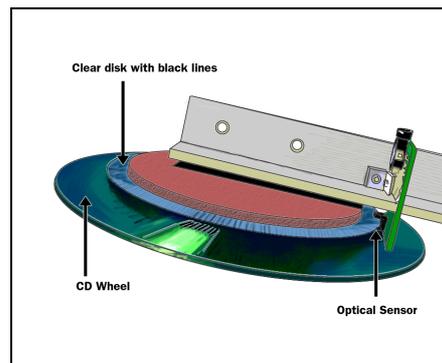
"Describe the forces needed to give the object its starting PE."

## Additional Teacher Background

The classic example of the smooth exchange of PE and KE is a pendulum. Let's say the relative gravitational PE is zero when the object is just hanging straight down. At the top of its swing, the object isn't moving, so it has no KE. But it does have PE because it's higher than the straight-down position. At the bottom of the swing, the object is moving at its fastest, so it has the most KE but no PE. If you calculated the sum of PE and KE at every instant, it would be constant.

The principle that energy can neither be created nor destroyed is one of the most important in physics. It has been widely tested and found to be true for all forms of energy at all different scales. It may not appear to be true in everyday life. A falling rock hits the earth and stops. Where did the energy go? A physicist would assert that the rock's kinetic energy changed entirely into heat energy - a warmed-up rock and piece of earth. When energy seems to "disappear", it usually is lost as heat energy into the environment.

The SmartWheel is also used in this investigation. Some sophisticated electronics are used to sense the rotation of the wheel and use that to generate a graph on the computer. An invisible infrared beam is directed through the clear plastic disk that has regular black lines printed on it. A sensor detects when a black line blocks the beam. Each time the beam is blocked means the wheel is turned a bit. The computer simply counts how many times the beam is blocked. There are actually two beams and this allows the computer to figure out which way the wheel is turning. If the wheel is turning one direction, the computer adds 1 each time the beam is blocked, but if it turns the other direction, it subtracts 1. The computer program interprets this information either as position (how many black lines go by) or as velocity (how fast the black lines go by).



## **Suggested Timeline**

The amount of time you spend on introductory discussions, data collection, and analysis, will determine your overall timeline. The following represents a possible timeline.

One class period - "Setting Up" discussion

One class period - Trial I: Rolling a cart down a hill

One class period - Trial II: Changing the starting height of the cart

One class period - Trial III: Bouncing a cart down and up a hill Bouncing a cart down and up a hill Bouncing a cart down and up a hill

One class period - Analysis and "Wrap Up" discussion

Additional days can be used for Further Investigations.