11.1 Efficiency

How efficient is the SmartTrack?

The conversion of potential energy to kinetic energy obeys the *law of conservation of energy*. This law states that energy cannot be created or destroyed, but can be converted from one form to another. As the Energy Car rolls down the track, its potential energy is converted into kinetic energy.

The law of conservation of energy does *not* require that 100 percent of the potential energy become kinetic energy. Other forms of energy conversion are also allowed. For example, friction converts some potential energy to heat and wear. The *efficiency* of a process is the ratio of the energy you get out of the process divided by the energy you start with. In this investigation, you will explore whether the conversion from potential to kinetic energy for a car rolling down a track is 100 percent.

In this investigation, you will:

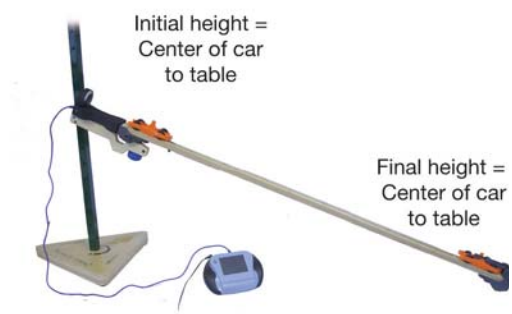
- calculate the kinetic and potential energy of the Energy Car at the top and bottom of the SmartTrack.
- compare results from cars of different masses.
- determine the efficiency of the SmartTrack.

Materials List

- SmartTrack
- Physics stand
- Energy Car
- Velocity sensor
- DataCollector

1 Setting up the SmartTrack

1. Attach the SmartTrack to the physics stand at the 10^{th} hole from the bottom.
2. Attach the velocity sensor to the top of the track and plug it into the DataCollector.



2 Collecting data

1. Turn on the DataCollector. At the home window, select data collection mode.
2. At the go window, choose setup at the bottom of the screen.
3. At the setup window, choose standard mode, 200 samples, and 50 Hz. This will allow the DataCollector to collect 50 samples of data from the velocity sensor each second.
4. Place the car (with no marbles) so it is against the starting peg at the top of the track. Tap go at the bottom of the setup screen on the DataCollector, and release the car.
5. When the car reaches the bottom of the track, press the button on the DataCollector enclosure to stop the experiment. Switch from meter to table and graph view to study your data.
6. Record the car's maximum velocity in Table 1.
7. Do two more trials of the experiment, record the velocities, and calculate the average.

8. Place the car at the top of the track so it is held in place by the starting peg. Secure the car at the top of the ramp withe the peg and measure the vertical distance from the center of the car to the tabletop (see photo on previous page). Record the height in meters in Table 1.
9. When the car reaches maximum velocity it is at the bottom of the track. Find the height of the car at the bottom of the track by measuring the vertical distance from the tabletop to the center of the car (see photo on previous page). Record the height in meters in Table 1.
10. Measure the mass of the car in kilograms and record in Table 1.

Table 1: Velocity, height, and mass data for car with no marbles

Trial	Velocity m/s	Initial height (m)	Final height (m)	Mass of car (kg)
1				
2				
3				
Average				

a. If you repeat this experiment with a car that holds two marbles, which values from Table 1 will change significantly?

11. Place two marbles in the car and repeat steps 1–10. Record your data in Table 2.

Table 2: Velocity, height, and mass data for car with two marbles

Trial	Velocity (m/s)	Initial height (m)	Final height (m)	Mass of car (kg)
1				
2				
3				
Average				

3 Potential and kinetic energy

The total energy of the car on the track is a combination of potential and kinetic energies. Potential energy, also known as stored energy, depends on the *height* of the car. Kinetic energy is related to motion and depends on the *velocity* of the car.

1. What is the velocity of the car at the instant you release it at the top of the track? Record this in Table 3. What is its kinetic energy? Record this in Table 3.
2. Copy the average velocities you found at the bottom of the track for each car in Table 3.

3. Calculate the potential and kinetic energy of the car at the top and bottom of the track. Record your results in Table 3.
4. The total energy at each position on the track is calculated by adding the potential and kinetic energies. Find the total energy at each position and record the results in Table 3.

Table 3: Potential, kinetic, and total energy of cars

# marbles in car	Location on track	Velocity (m/s)	Kinetic energy (J)	Potential energy (J)	Total energy (J)
0 marbles	top				
	bottom				
2 marbles	top				
	bottom				

4 Efficiency

You might not have realized it, but the SmartTrack is a simple machine that converts energy from one form to another. The energy put into any machine is called *input energy*. You provide the input energy to the car as potential energy when you lift the car up to the top of the track. The useful energy supplied by a machine is called *output energy*. Imagine that you use the track as an egg-breaking machine. You place an egg at the bottom and roll a car down the track. The output energy of the machine is the car's kinetic energy at the bottom of the track. The greater the kinetic energy, the greater the car's ability to do work on the egg and smash it.

The ratio of the output energy to the input energy for a machine is called its *efficiency*. An efficiency of 100 percent means that all of the input energy is converted to useful output energy. No machine is 100 percent efficient. Automobiles, for example, are typically only about 13 percent efficient.

EFFICIENCY (energy efficiency)

$$\varepsilon = \frac{E_o}{E_i}$$

Efficiency ε; ***Energy output*** (J) E_o; ***Energy input*** (J) E_i

a. Compare the total energy of each car at the top of the track to its total energy at the bottom. Did each car's total energy increase, decrease, or remain unchanged?

b. Calculate the efficiency for each car.

c. The law of conservation of energy states that energy cannot be created or destroyed. If the efficiencies were less than 100 percent, does this mean the law of conservation of energy is not true? Was energy lost? Where did the energy go? (*Hint*: The motion of the car includes rotation as well as linear.)

d. If the efficiency for the car with two marbles was 100 percent, how fast would it be moving at the bottom of the track?