Conservation of Elastic Potential Energy: How Do Springs Work?

Runaway trains and trucks rely on the law of conservation of energy to avoid catastrophic crashes. For example, an out-of-control truck slows on a highway off ramp as its kinetic energy becomes gravitational potential energy. Similarly, a subway train with failed brakes converts kinetic energy to elastic potential energy when it collides with a very large spring meant to prevent derailment. The elastic potential energy, kinetic energy, and gravitational potential energy associated with speeding trains and trucks may be modelled with a ramp, a spring, and a steel sphere.

Watch Video 1

The following mathematical equation describes how the change in potential energy of a spring is related to the change in gravitational potential energy of a steel sphere the spring propels up a ramp:

$$-\Delta PE_s = \Delta PE_g$$
$$-\tfrac{1}{2}kx^2 = mg(h_f - h_i)$$

You can use the apparatus in **Video 1** to gather the data needed to relate the two types of energy. Specifically, you can use the apparatus to collect height (h_f and h_i) and spring compression (x) data. **Video 2** demonstrates the experimental design in more detail.

Watch Video 2

Observe

The following data were collected using the apparatus in **Video 2**. In each trial, the initial and final heights of the steel sphere above the table were measured. The initial height of the sphere was determined by measuring the distance between the tabletop and midpoint of the sphere at its resting point against the launching mechanism. The final height of the sphere was measured at the point at which it stopped moving, as it was about to begin rolling down the ramp. The sphere was stopped and held at that point by using a ruler, and its final height above the table was measured. What kind of relationship do you observe between the compression of the spring and the change in height of the sphere? Does this relationship seem reasonable, or make sense? Explain.

Ramp Height (cm)	Compression (m)	Initial Height (m)	Final Height (m)	Change in Height (m)	PE_g (J)	Spring Constant (N/m)	PE_s (J)
74.0	0.0040	0.125	0.157	0.032	0.0210	716	0.00573
74.0	0.0140	0.116	0.300	0.184	0.121	716	0.0702
74.0	0.0245	0.109	0.475	0.366	0.241	716	0.215
74.0	0.0340	0.101	0.697	0.596	0.392	716	0.414

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Identify an Experimental Design Flaw

Data indicate that the elastic potential energies and gravitational potential energies are not exactly equal. Describe reasons for the differences between the values. How many trials should the scientist perform to ensure the data (the measurements of the sphere's height) are reliable?

Refine/Expand the Experiment

The data represent an experiment in which the ramp height (the distance between the elevated end of the ramp and the tabletop) was controlled, the compression of the spring was varied, and the change in height of the steel sphere was measured. Propose another experiment using the same apparatus that would allow you to explore the relationship between a different independent variable and the change in sphere height? Describe the results you would expect on carrying out the experiment.

Practice Scientific Reasoning

Would you expect more energy to be lost to friction at lower ramp heights or higher ramp heights? Explain.

Connect to Your World

What examples of elastic potential energy, besides those discussed in the videos, can you think of?

Learn More by Exploring These Links

The simulation at the following link allows for further exploration of the principle of energy conservation: https://phet.colorado.edu/en/simulation/energy-skate-park-basics

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At-Home Extension

Explore the relationship between gravitational potential energy and kinetic energy by setting up an inclined plane on a tabletop. A steel sphere or marble held on an inclined plane (on the edge of a table) has potential energy proportional to its height, or distance above the tabletop. When released, the sphere's potential energy transforms into kinetic energy as it rolls down the inclined plane and launches off the tabletop. Release the sphere from various heights above the tabletop and measure its horizontal travel distance once launched off the edge of the table. Construct a graph of the marble's height versus travel distance and use it as proxy to determine the relationship between the marble's potential and kinetic energies.

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