Swinging Pendulums

Summary
This activity demonstrates how potential energy (PE) can be converted to kinetic energy (KE) and back again. Given a pendulum height, students calculate and predict how fast the pendulum will swing by understanding conservation of energy and using the equations for PE and KE. The equations are justified as students experimentally measure the speed of the pendulum and compare theory with reality.

Materials for each group:

- 2 stopwatches
- masking tape (not scotch tape)
- 10 feet of string or fishing line
- heavy object or weight (to tie to string)
- calculator
- scale (if mass of heavy object or weight is unknown) (1per class)

Introduction:

Students will prove that the transformation of energy occurs by calculating the theoretical value of velocity at which a pendulum should swing and comparing it to a measured value.

Three equations will be used in this activity:

$$PE = m \cdot g \cdot h$$
$$KE = \tfrac{1}{2}\, m \cdot V_t^{\,2}$$
$$V_m = distance \div time$$

where m is mass (kg), g is gravity (10 m/s^2), h is height (meters), V_t is the calculated velocity (m/s), and V_m is the measure velocity (also m/s). To make the calculations simpler, use the metric system for measurements and calculations. This way, we can approximate gravity as 10 m/s^2 and not worry about the English system's wacky units of mass.

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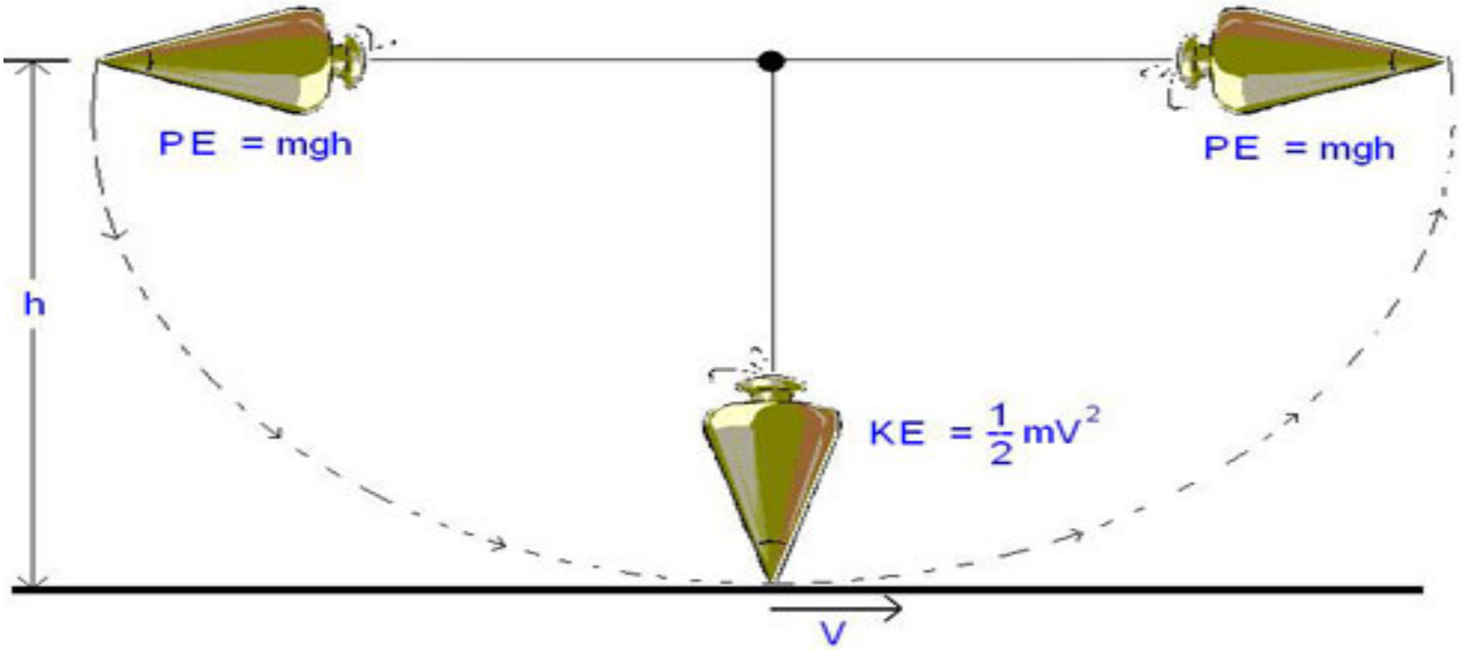

Preparation:

- Gather materials.
- Designate several areas, depending on the size of your class, for pendulums to swing.
- Tie the string(s) or line(s) to the ceiling about 2 inches from a wall, leaving enough slack to reach the ground.

Activity:

1. Divide students into groups of 4 and hand out the worksheet.
2. Each group measures and records the mass or weight of their object.
3. Each group picks an arbitrary height at which they will release their pendulums. This should range from 15-40 cm (.15-.4 m) from the floor.
3. Calculate the potential energy. Each team member should do this, as a way to verify the result.
4. Calculate the theoretical velocity, V_t , at the bottom of the swing.

   Remember, KE @ the bottom of the swing equals PE @ the top of the swing.

6. If your students do not know algebra yet, derive *Vt* for them.
7. Each group moves to a designated area and ties their weight to the string/line so that it barely misses the ground while hanging.
8. Place two pieces of tape on the wall on opposite sides of the hanging pendulum and record the distance between the two pieces.

- The distance should range from 30-50 cm (.3-.5m). Choose a larger distance

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for a higher height (i.e., h = 40 cm → distance = 50 cm).
- The pendulum should rest in the middle of the two pieces of tape.

8. One or or two students pull back the weight until it reaches one of the pieces of tape.
9. Two students synchronize two stopwatches, each holding one, and start timing when the pendulum is released.
10. The first student stops his/her stopwatch when the pendulum passes over the opposite piece of tape and the second student stops his/her watch when it returns back to the initial piece of tape.
11. Record both times and calculate the difference in time.
12. Repeat the experiment four times so students can exchange roles. Complete the worksheet. How close were the values for the theoretical velocity and the measured velocity?

Lesson Closure:

Restate that both potential energy and kinetic energy are forms of mechanical energy. Potential energy is the energy of position and kinetic energy is the energy of motion. A ball that you hold in your hand has potential energy, while a ball that you throw has kinetic energy. These two forms of energy can be transformed back and forth. When you drop a ball, you demonstrate an example of potential energy changing into kinetic energy.

Explain that energy is an important engineering concept. Engineers need to understand the many different forms of energy so that they can design useful products. An electric pencil sharpener serves to illustrate the point. First, the designer needs to know the amount of kinetic energy the spinning blades need in order to successfully shave off the end of the pencil. Then, the designer must choose an appropriately-powered motor to supply the necessary energy. Finally, the designer must know the electrical energy requirements of the motor in order for the motor to properly do its assigned task.

Assessment:

Pre-Lesson Assessment

Discussion Questions: Solicit, integrate and summarize student responses.

- What are examples of dangerous unsafe placement of objects? (Possible answers: Boulders on the edge of a cliff, dishes barely on shelves, etc.).

Post-Introduction Assessment

Question/Answer: Ask the students and discuss as a class:

- What has more potential energy: a boulder on the ground or a feather 10 feet in the air? (Answer: The feather because the boulder is on the ground and has zero potential energy. However, if the boulder was 1 mm off the ground, it would probably have more potential energy.)

Lesson Summary Assessment

Group Brainstorm: Give groups of students each a ball (example, tennis ball). Remind them that energy can be converted from potential to kinetic and vice versa. Write a question on the board and have them brainstorm the answer in their groups. Have the students record their answers in their journals or on a sheet of paper and hand it in. Discuss the student groups' answers with the class.

- How can you throw a ball and have its energy change from kinetic to potential and back to kinetic without touching the ball once it relases from your hand? (Answer: Throw it straight up in the air.)

Calculating: Have students practice problems solving for potential energy and kinetic energy:

- If a mass that weighs 8 kg is held at a height of 10 m, what is its potential energy? (Answer: PE = (8 kg)*(9.8 m/s^2)*(10 m) = 784 $kg*m^2/s^2$ = 784 J)
- Now consider an object with a kinetic energy of 800 J and a mass of 12 kg. What is its velocity? (Answer: v = sqrt(2*KE/m) = sqrt((2 * 800 J)/12 kg) = 11.55 m/s)

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