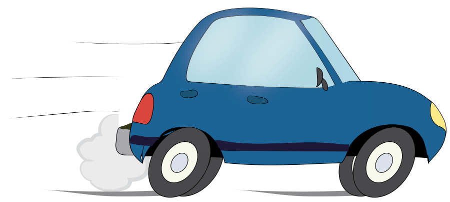
STUDENT ACTIVITY

Name: ____________________ Class: __________ Date: ____________

BALL OF ENERGY



MATERIALS NEEDED

Per group of 3 students

- One tennis ball or rubber racquet ball
- One stopwatch
- One calculator
- One clipboard

Per Student

- One copy of the "Ball of Energy" Student Activity sheet

Per Class

- At least one pan balance with metric gram masses or at least one electronic balance

Key Question(s)

- What happens to all of the energy in a falling ball when it hits the ground?
- How is the maximum kinetic energy of a moving object related to its maximum velocity?
- What happens to the energy in a moving vehicle when it crashes into another object?
- Why does a small increase in a vehicle's velocity result in a more dangerous crash?
- Where does the energy of moving objects "go" in a collision?

Did You Know?

In vehicle crashes, the more kinetic energy a vehicle has, the greater the risk of injury to a vehicle's occupants. And, as you already realize, damage to vehicles and injuries to vehicle occupants are both much greater in "high speed" crashes than they are in "low speed" crashes. In this activity, you will explore the relationship between an object's kinetic energy and it final crashing velocity to determine why high speed crashes are so dangerous.

Purpose

- To determine the maximum gravitational PE, maximum KE, and maximum velocity of a thrown ball
- To explain the relationship between a moving object's maximum KE and its maximum velocity
- To explain how KE is transferred or transformed when a ball hits the ground and when a vehicle crashes into another object
- To explain how small increases in a vehicle's velocity produce exponentially more energetic, and more dangerous, vehicle crashes

Procedure

1. Identify a specific group member to perform each of the following roles: measurer, thrower, and recorder. The "measurer" is responsible for using a balance to determine the mass of the ball and using the stopwatch to measure the total time the ball is in the air for each trial. The "thrower" is responsible for actually throwing the ball into the air using the same throwing style for each trial. And the "recorder" is responsible for recording all measurements in the data tables on the Ball of Energy Activity Sheet. After all measurements have been recorded, you should then work together as a group to complete the calculations and answer the Analysis Questions.

2. Before going outside, have the "measurer" measure the mass of your group's ball in kilograms and have the "recorder" record it in Table 1. If a balance is not available, your teacher will provide you with the average mass of your ball type for use in your calculations.

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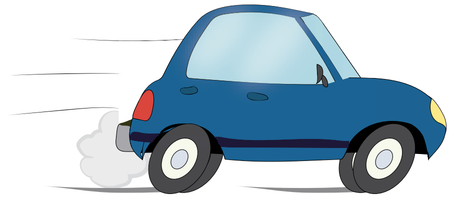

Procedure (continued)

3. Once you are outside, have reviewed the safety procedures and rules, and are in position, have the "measurer" use a stopwatch to time the ball from the instant the "thrower" releases it to the instant it hits the ground. The "recorder" should record this time in seconds as Total Air Time in Table 2.

4. Complete the ball throwing activity five times and record the total air time for each trial in Table 2.

5. After all 5 trials are completed, use a calculator and the information provided in Table 3 to work collaboratively with your group members and complete all of the calculations required in Table 2 and work with your group members to answer the Analysis Questions.

Data Tables

Table 1 - Information about the Ball

BALL TYPE	MASS OF BALL (KG)

Table 2 - Measurements and Calculations Related to the Ball Throw

	MEASUREMENTS	CALCULATIONS					
TRIAL #	TOTAL AIR TIME (s)	t_{up} (s)	t_{down} (s)	$d_{up} = ½ g t_{up}^2$ (m)	$PE_{max} = mgh_{max}$ (J)	$KE_{max} = PE_{max}$ (J)	v_{max} (m/s)
1							
2							
3							
4							
5							

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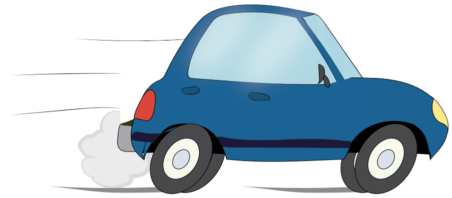

Data Tables (continued)

Table 3 - Variable Symbols, Definitions, Formulas, and Calculation Procedures

SYMBOL	DEFINITION	FORMULA	CALCULATION PROCEDURES AND UNITS
t_{up}	Time up	½ total air time	Divide the total air time by 2 (t_{up} = total air time ÷2). Measured in seconds (s)
t_{down}	Time down	½ total air time	$t_{up} = t_{down}$ (neglecting air resistance)
g	Acceleration due to gravity	$9.81\ m/s^2$	The rate of acceleration of any object moving under the sole influence of gravity (also known as free fall). Measured in meters per second per second (m/s^2).
d_{up}	Maximum distance up	$\frac{1}{2} g t_{up}^{2}$	Square the time up and multiply it by g (acceleration due to gravity). Then divide this total by 2 to determine the maximum distance upward (maximum height) the ball achieves during the throw. In this activity's calculations, $d_{up} = h_{max}$. Measured in meters (m).
PE_{max}	Maximum gravitational potential energy	mgh_{max}	Gravitational potential energy (PE) is energy due to the relative position of an object above the ground and is measured in joules (J). $PE_{max} = mgh_{max}$ where m = the mass of the ball in kilograms, g = acceleration due to gravity, and h = maximum height above ground (same as d_{up}). For the ball thrown in this activity, its maximum potential energy is at the top of it flight when it is at its greatest distance above the ground, which is why we use the value for maximum distance up (d_{up}) for h_{max}.
KE_{max}	Maximum kinetic energy	$KE_{max} = PE_{max}$	According to the Law of Conservation of Energy, for the thrown ball "system," the kinetic energy of motion (KE) during the ball's downward journey equals the potential energy the ball gains on its upward journey. Both KE and PE are measured in joules (J). If air resistance is neglected, the maximum potential energy gained by the ball on its upward journey is converted entirely to kinetic energy during its downward journey; therefore $PE_{max} = KE_{max}$.
v_{max}	Maximum crash velocity	$\sqrt{2gh}_{max}$	If velocity of an object cannot be directly measured, maximum crash velocity can be calculated using this formula: $v_{max} = \sqrt{2gh}_{max}$. Multiply g times h_{max} (same as d_{up}) then multiply that number by 2. Finally, take the square root of this total to determine the maximum crash velocity of the ball. Velocity is measured in meters/second (m/s).

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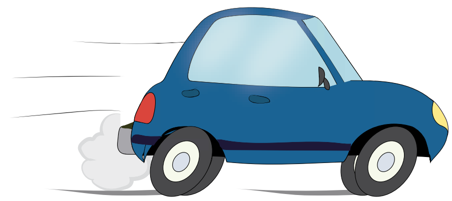

Answers to Analysis Questions

1. **According to the Law of Conservation of Energy, energy cannot be created or destroyed. Instead, it can be transferred to other objects in the same form OR it can be transformed from one type of energy to another (such as sound energy or heat energy). What do you think happened to all of the kinetic energy in the falling ball once it hit the ground?**

2. **The formula for determining the kinetic energy of any moving object is: $KE = 1/2mv^2$. If a car had a mass of 1,500 kg, use this formula to determine the total amount of kinetic energy it would have upon crashing into a wall at the following velocities:**

A. 20 miles per hour (which is equal to 8.94 m/s)

B. 40 miles per hour (which is equal to 17.88 m/s)

3. **For analysis question 1, how many times greater is the kinetic energy of the car traveling at 40 miles per hour compared to the car traveling at 20 miles per hour?**

4. **This example shows that when the velocity of a vehicle doubles (for example from 20 mph to 40 mph), its kinetic energy quadruples. Why?**

5. **At the Insurance Institute for Highway Safety's Vehicle Research Center, one of their head-on vehicle crash tests involves having a car with a single crash test dummy "driver" crash into a 320,000 pound stationary barrier at 40 miles per hour. Based on what you now know about the Law of Conservation of Energy and energy transfer and transformation, what do you think happens to all of the kinetic energy of the vehicle when it crashes into the barrier?**