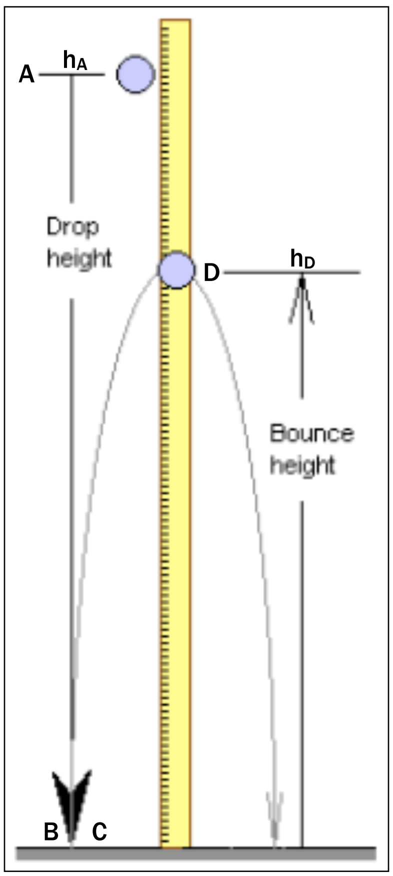
ENERGY AND MOMENTUM

INTRODUCTION

At the beginning of the 18th century, the European scientific community watched while Isaac Newton and Gottfried Leibniz slap-boxed over who invented the calculus. Turns out they both did, and what's more, they used this mathematical method as a tool for analyzing the physical world around them. Newton liked the idea of momentum as a fundamental conservable quantity, but Leibniz preferred the idea of energy as fundamentally conservable. Who was right? Turns out they both were.

By now we know that momentum and energy are not the same, although they can be calculated using formulas that look similar (since both require mass and velocity). We also know a thing or two about conservation, and that both momentum and energy are conservable quantities. However, the circumstances for energy conservation are not necessarily the same as for momentum conservation. By looking at a very simple experiment, we will be able to make a distinction between energy and momentum, and to identify the conditions of energy conservation and momentum conservation.

Another difference between Newton and Leibniz? Leibniz wore the wig.



OBJECTIVES

- Examine the difference between momentum and energy
- Quantify an object's energy and identify the type of energy it has
- Observe the conversion of potential energy into kinetic energy
- Calculate the momentum of a moving object
- Determine the amount of energy dissipated in a collision
- Use graphical methods to predict the outcome of an experiment

EQUIPMENT

- Meter stick
- Golf ball or ping–pong ball
- Balance

EXPERIMENTAL PROCEDURE

- Measure and record the mass of the ball in grams.
- Hold the ball center 20 centimeters above the table in front of a vertical meter stick.
- Drop the ball.
- Measure the maximum height of the first bounce. This requires attention, so you may need to practice once or twice.
- Record the drop height and bounce height in centimeters.
- Repeat the procedure for 40 cm and 60 cm release heights.
- Now drop the ball onto the floor from 80 cm, repeating the rest of the above procedure.
- Continue dropping the ball onto the floor for 100 cm, 120 cm, 140 cm, and 160 cm release heights.

DATA & ANALYSIS

If you have not already, construct a table for your data:

DROP HEIGHT h_A (cm)	BOUNCE HEIGHT h_D (cm)	DROP HEIGHT h_A (cm)	BOUNCE HEIGHT h_D (cm)	DROP HEIGHT h_A (cm)	BOUNCE HEIGHT h_D (cm)	DROP HEIGHT h_A (cm)	BOUNCE HEIGHT h_D (cm)
20		60		100		140	
40		80		120		160	

1. For each release height, find the initial potential energy of the ball (remember that $g = 980\ cm/s^2$):

$$PE_A = mgh_A$$

2. Calculate the potential energy of the ball when it reaches its bounce height h_D:

$$PE_D = mgh_D$$

3. As the ball falls from A to B, potential energy is converted to kinetic. Use energy conservation to fill in your table.
4. As the ball rises from C to D, kinetic energy is converted back to potential. Once again, use energy conservation to complete your table.

Drop Height h_A (cm)	PE at Point A (g·cm²/s²)	KE at Point B (g·cm²/s²)	PE at Point D (g·cm²/s²)	KE at Point C (g·cm²/s²)	Momentum at Point B p_B (g·cm/s)	Momentum at Point C p_C (g·cm/s)
20						
40						
etc.						

5. The momentum of the ball at points B and C can be found by combining kinematics with the definition of momentum. Calculate, then complete the table.

$$v_B = \sqrt{2gh_A} \qquad \text{and} \qquad v_C = \sqrt{2gh_D}$$

$$p_B = mv_B = m\sqrt{2gh_A} \qquad p_C = mv_C = m\sqrt{2gh_D}$$

6. Prepare a graph of bounce height vs. drop height. The bounce height (h_D, but let's call it b) belongs on the y–axis, and the drop height (h_A, but let's call it d) on the x–axis. Scale your axes carefully, and apply your scale consistently. Use an entire page; make your graph very large to maximize the accuracy of the scale. Label your axes (include units).
7. Use a ruler to draw the best fit line for the data. Do not force the line to pass through the origin or any other point; let the data decide where the line belongs! When the line is drawn, find the slope:

$$slope = \frac{(b_2 - b_1)}{(d_2 - d_1)}$$

where (d_1, b_1) and (d_2, b_2) are two points that are exactly on the line you have drawn. They do not have to be data points, but they do have to be on the line!

8. What will the bounce height (in cm) be for a drop height of 90 cm? Use your graph to make a prediction.
9. What will the bounce height be for a drop height of 200 centimeters? Predict from your graph.
10. What will the bounce height be for a drop height of 0 cm? Is this consistent with your graph, or does your graph predict something you would not expect? Does the explanation for this lie in some mystery of physics, or can it be explained by thinking about the data you collected (and its accuracy)?
11. Did the ball gain or lose energy between the drop (point A) the top of the first bounce (point D)? How much?If energy was gained, where did it come from? If lost, where did it go? Is the difference between your values attributable to the accuracy of your measuring (that is, if you were able to make an absolutely *perfect* measurement of both heights, would the numbers match up perfectly as well?)?
12. If total momentum must be conserved in any collision, why do your values for p_B and p_C differ? This is not about the accuracy of your measurements, this one's about the physics. Think about the idea of "total momentum," and ask yourself what *else* is involved in the collision besides the ball.
13. Remind yourself explicitly of when energy is conserved and when momentum is conserved by checking the appropriate boxes in the table.

Path	Momentum Conserved?	Gained or Lost?	Energy Conserved?	Gained or Lost?
From A to B				
From B to C				
From C to D				