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# Energy and Efficiency

## 1 Kinetic energy exchange

Table 1: Kinetic energy data

Mass of the car (kg)	Time before collision (sec)	Speed before collision (m/sec)	Time after collision (sec)	Speed after collision (m/sec)

## 2 Thinking about what you observed

- a. Describe the energy flows that occur between the car heading toward the rubber band and the car leaving the rubber band.

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- b. If the transformation of energy were perfect (100% efficiency) what would you expect the speed of the car to be before and after the collision with the rubber band?

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- c. Write down the formula for kinetic energy and use the formula to calculate the kinetic energy of the car before and after bouncing off the rubber band.

Mass of the car (kg)	Kinetic energy before collision (joules)	Kinetic energy after collision (joules)	Efficiency %

- d. Calculate the efficiency of the process of bouncing the car off a rubber band.

### 3 How does the efficiency change?

Table 2: Energy efficiency data

Mass of the car (kg)	Time before collision (Sec)	Speed before collision (m/sec)	Time after collision (Sec)	Speed after collision (m/sec)

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#### 4 Thinking about what you observed

- a. Calculate the efficiency of the rubber band for the different masses and speeds you tested.

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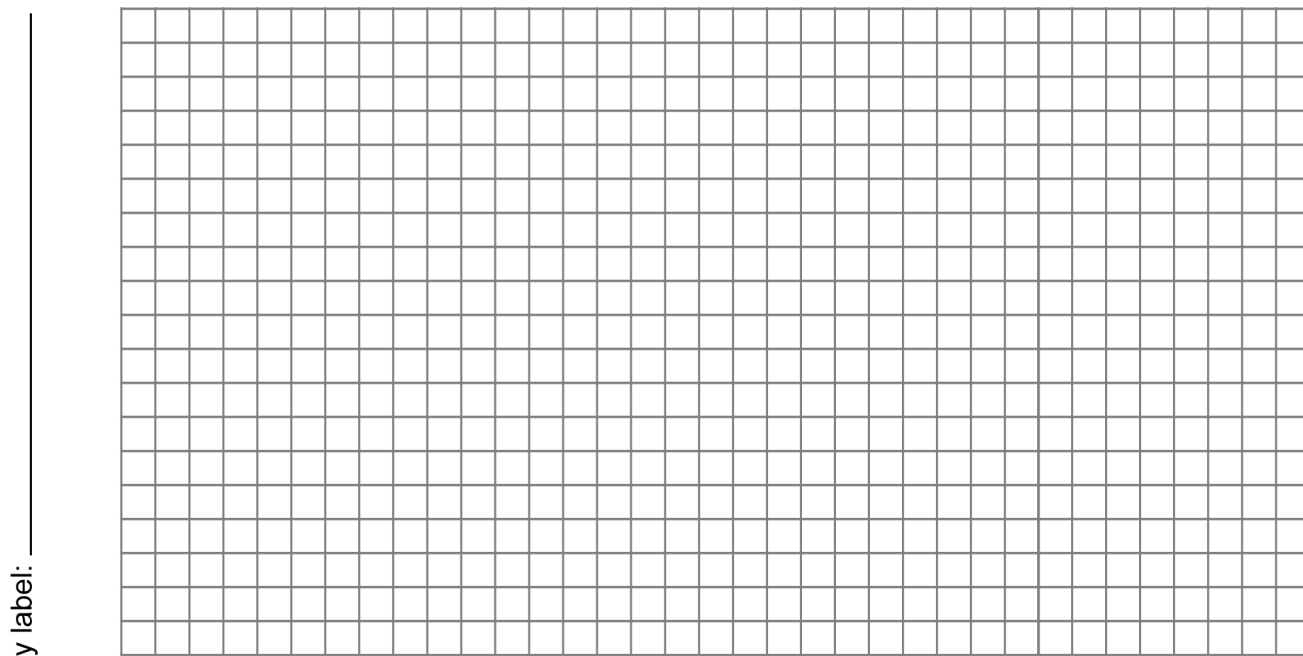
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- b. Plot a graph showing the efficiency on the vertical ( $y$ ) axis and the speed on the horizontal ( $x$ ) axis. How does the efficiency change with the speed of the car?

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c. Try changing the tension in the rubber band. Does this effect the efficiency?

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**5 How long does it take for the energy to be gone?**

There are no questions to answer in part 5.

# Energy Flow in a System

## 1 Tracing the energy through the system

Table I: Energy data

Drop Height (m)	Mass of car (kg)	Time before rubber band (sec)	Speed before rubber band (m/sec)	Time after rubber band (sec)	Speed after rubber band (m/sec)

## 2 Thinking about what you observed

a. What three forms of energy are most important to the motion of the car this system?

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b. Calculate the total energy of the car in joules at three places:  
 (1) At the top of the hill before it is dropped,  
 (2) At the photogate heading into the rubber band for the first time,  
 (3) At the photogate after bouncing off the rubber band.

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- c. Describe the three most important energy transformations that occur during the motion (other than friction).

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- d. Draw an energy flow diagram showing how the energy is appears in each of the three main transformations. Label any energy that is lost as “friction.”

- e. What percentage of its initial energy does the car have after passing through the photogate for the second time? Assume the car has “lost” any energy spent overcoming friction.

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- f. Where does the energy “lost” to friction go? Is the energy really destroyed?

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### **3 Improving the overall performance**

- a. Suggest a modification you can make to the system that would leave the car with a higher percentage of energy after the second pass through the photogate.

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- b. Explain why you believe your modification will result in higher energy efficiency.

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- c. Write down a few sentences giving a procedure to test your modification.

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### **4 Testing your idea**

- a. Design an experiment that will test your idea for improving overall energy efficiency. Write down a procedure for doing the experiment. Write down what data you expect to take and how the data will allow you to evaluate your idea.

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- b. Set up and do the experiment you designed.

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- c.** Analyze the results from your experiment. Compare the percentage of energy the car has after the second pass through the photogate to what it was in the earlier experiments. Your answer must use data from your experiment.

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- d.** Give at least one reason why the efficiency is higher, lower, or about the same compared to what it was.

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## ***Energy and Chemical Changes***

### **1 Reaction #1: Ammonium nitrate and water**

**Table 1: Time and temperature data for ammonium nitrate and water**

Record the temperature(°C) for each time (sec)									
0	10	20	30	40	50	60	70	80	90

### **2 Thinking about what you observed**

- a. Did the temperature go up, down, or stay the same when you did the experiment?

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- b. Why does a change in temperature indicate a change in energy?

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### **3 Reaction #2: Calcium chloride and water**

**Table 2: Time and temperature data for calcium chloride and water**

Record the temperature(°C) for each time (sec)									
0	10	20	30	40	50	60	70	80	90

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#### 4 Reaction #3: Vinegar and baking soda

**Table 3: Time and temperature data for vinegar and baking soda**

Record the temperature(°C) for each time (sec)									
0	10	20	30	40	50	60	70	80	90

#### 5 Thinking about what you observed

- a. A reaction that gives off energy is called exothermic. Which reaction(s) are exothermic? Support your answer with data.

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- b. A reaction that uses energy is called endothermic. Which reaction(s) are endothermic? Support your answer with data.

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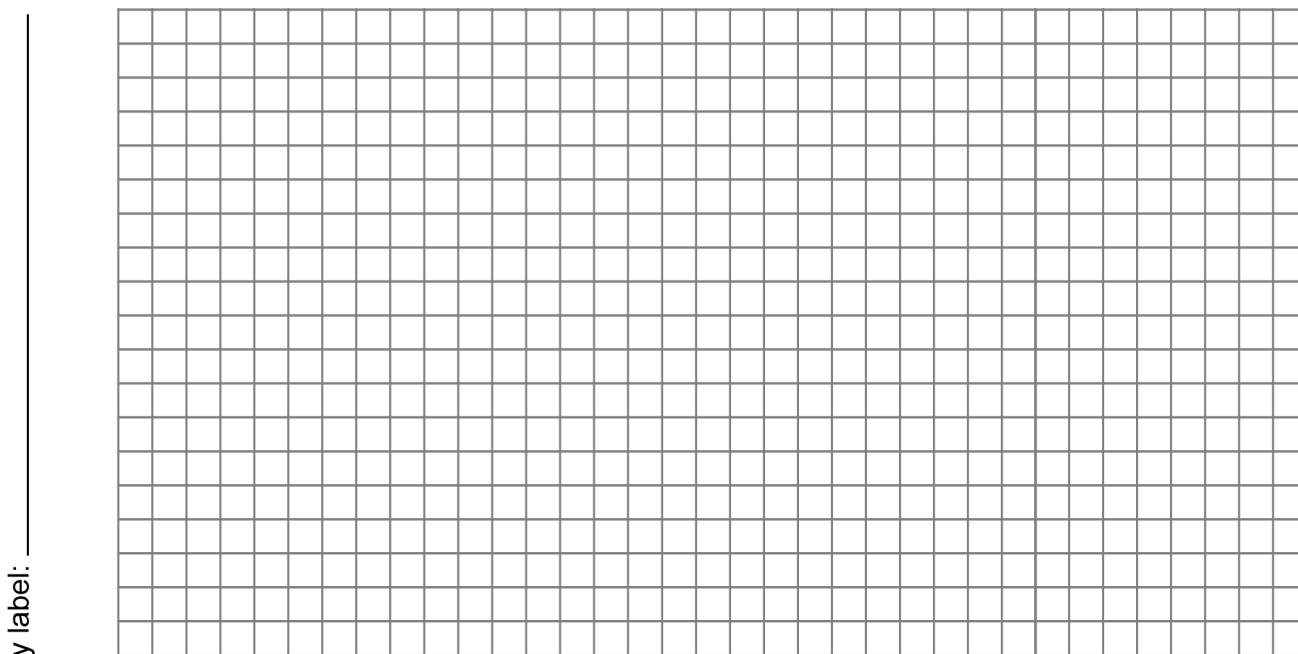
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- c. Graph time vs. temperature for each reaction on the same graph. Use a different color pen for each reaction.

**Title:** \_\_\_\_\_



- d. What does the graph show about energy changes in each reaction? Describe what is happening in each reaction based on the graph.

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- e. Cold packs can be purchased at your local pharmacy and are used to treat injuries. Which reaction is most likely the one used in cold packs? Explain your answer.

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- f. One of the solids you used in the reactions can be purchased at a hardware store and is used to melt snow and ice in winter. Which chemical is it? Explain your answer.

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# *Nuclear Reactions and Radioactivity*

## 1 Radioactivity

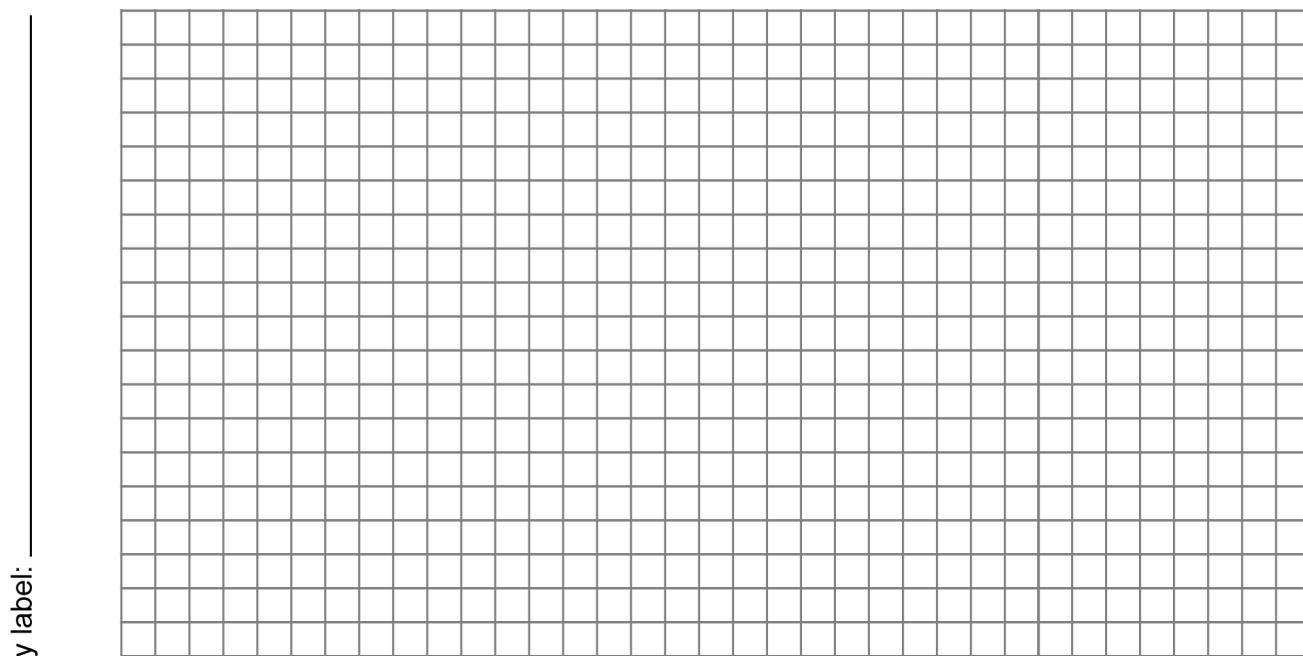
Table 1: Coin toss decay simulation

	Heads-up pennies	Tails-up pennies
Start	50	0
First toss		
Second toss		
Third toss		
Fourth toss		
Fifth toss		
Sixth toss		
Seventh toss		
Eighth toss		

## 2 Thinking about what you observed

- a. Make a graph showing the number of heads-up pennies on the y-axis and the number of tosses on the x-axis (0, 1, 2, 3,...).

Title: \_\_\_\_\_



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- b. On average, what percentage of pennies are lost on each toss? “Lost” means they came up tails and were removed.

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- c. How does the concept of half-life relate to the experiment with pennies? What does one half-life correspond to?

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### **3 Build a radioactive atom**

There are no questions to answer in part 3.

### **4 Thinking about what you did**

- a. Research what happens to  $C^{14}$  when it decays. What element does it become? What particles are given off?

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- b. What is the average time it takes for 50% of the  $C^{14}$  atoms in a sample to decay?

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- c. Suppose you have 50 atoms of  $C^{14}$  and you watch them for a very long time. How do the results of your penny-flipping experiment describe the number of  $C^{14}$  atoms?

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**d.** We actually find  $C^{14}$  in the environment. Research where it comes from.

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**e.** Describe two other types of radioactivity and give an example of each.

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**f.** (Challenge) You cannot predict when any one atom will decay, just as you cannot predict whether a penny will come up heads or tails. Why can you predict that 50% of the  $C^{14}$  atoms will decay every half-life?

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## ***Frames of Reference***

### **1 Demonstrating two frames of reference**

There are no questions to answer in part 1.

### **2 Thinking about what you observed**

- a. Imagine the person pushing the table was in a box, able only to see the car and track and nothing outside the box. What motion of the car do they see relative to themselves?

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- b. What motion of the car do the outside observers see relative to themselves?

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- c. There are two important frames of reference in this demonstration. What are they?

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- d. One frame of reference is in motion relative to the other. What is this motion?

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# ***Relativity***

## **1 An imaginary experiment with light - Special relativity**

There are no questions to answer in part 1.

## **2 Thinking about what you imagined**

The following are all questions for class discussion. They are challenging!

- a.** Describe the two reference frames that are important. Who is in each one?

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- b.** What is the relative motion between the two reference frames?

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- c.** Does the person on the ground see the light travel a distance that is longer, shorter, or the same compared to the distance seen by the person watching the light on the space ship?

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- d.** Prior to Einstein, speed was always calculated as the distance traveled divided by the time taken. Thinking this way, does the person on the ground see the light in the clock move faster, slower, or at the same speed compared to what the person in the space ship sees.

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- e. The theory of relativity requires that the speed of light be the same for all observers, regardless of relative motion. If the speed is the same, but the distance is different, what other variable must also be different in the two reference frames?

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- f. Do clocks on board the space ship run slower, faster, or at the same rate compared to clocks on the ground?

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### **3** General relativity

- a. Suppose “straight line” is defined as “the path of motion an object follows when the net force acting on it is zero”. Does this definition describe the same thing as your previous mathematical definition of a “straight line”?

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- b. Suppose you stretch a rubber sheet and place a heavy glass ball in the center. The glass ball depresses the sheet a few centimeters. A plastic ball is rolled in a straight line from the edge of the sheet as shown in the diagram. Sketch the path of the plastic ball as it passes by the glass ball.

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- c. Suppose the rubber sheet was completely transparent, and you could not see the glass ball either. Propose an explanation that would explain the observed path of the plastic ball using the idea of force.

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### **4** Einstein’s two theories

There are no questions to answer in part 4.