Energy Storage and Transfer: Kinetic Energy

PART 2 – KINETIC ENERGY

In the first of this series of labs exploring the role of energy in change, you found that the energy stored in an elastic system was proportional to the square of the change in the length of the spring or rubber band deformed by the applied force. We called the energy stored in this way *elastic energy*.

This energy can be transferred to another object to produce a change—for example, when the spring is released, it can launch a toy dart. It seems reasonable that the more the spring is compressed, the greater the change in speed it can impart to the object. As the spring or band returns to its original shape, it transfers energy to the moving object. We say that the moving object stores energy in an account called *kinetic energy*. It seems reasonable that an object's kinetic energy is a function of its mass and velocity. It would be useful to determine a quantitative relationship between the kinetic energy and its velocity for a given mass.

OBJECTIVES

In this experiment, you will

- Recognize that the energy stored in an elastic system (spring, rubber band) can be transferred to another object, resulting in a change in the state of that object.
- Determine an expression for the kinetic energy stored in a moving body.

MATERIALS

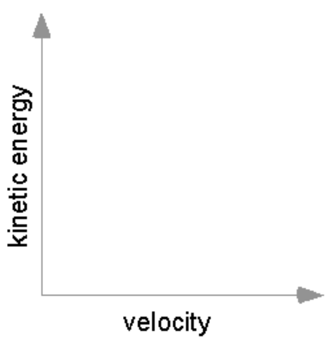
Vernier data-collection interface
LabQuest App
Vernier Photogate
cart with Cart Picket Fence

Vernier Bumper and Launcher
Kit (recommended) **or**
lightweight (34 N/m) extensible spring **or**
heavy rubber band

PRE-LAB INVESTIGATION

1. Examine the same elastic system (hoop or extensible spring, rubber band) that you used in the previous experiment. Change the length of the spring varying amounts, allow it to launch the dynamics cart, and note the speed of the cart.

2. On the axes on the right, sketch a graph of kinetic energy *vs.* the velocity of the cart, assuming that the energy in the spring is completely transferred to the cart.



PROCEDURE

1. Attach the same spring that you used in Experiment 7 to the Dynamics Track Bracket, then mount the bracket on the end of a Dynamics Track.[1]

2. Obtain the value of the spring constant, *k*, for the spring you used in the previous experiment.[2]

3. In your pre-lab discussion, you agreed on a way to adjust the level of the dynamics track to minimize the effect of friction on the transfer of energy from elastic to kinetic accounts. Make the necessary adjustment now.

4. Attach the Cart Picket Fence to the dynamics cart. Set up a photogate near the dynamics cart so that the flag on the fence interrupts the sensor shortly after the cart leaves the spring, as shown in Figure 1.

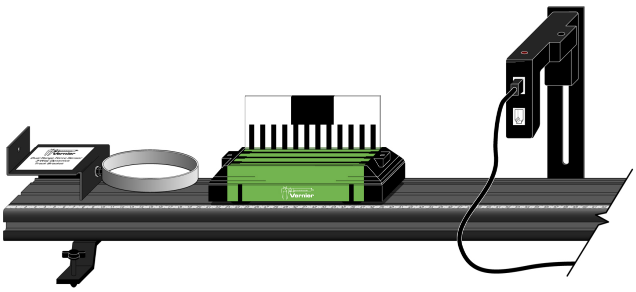


Figure 1

5. Determine the mass of your cart, fence, and any additional masses your instructor may have assigned you to use.

6. Start the data-collection program. Set up the photogate for Gate Timing. The length of the flag passing through the photogate is 0.05 m. The Gate State should read **Blocked** when the flag interrupts the sensor and **Unblocked** when it is moved beyond the sensor.

7. For this experiment, you will first collect velocity data for varying changes in spring length, *x*, and record these manually in your lab notebook. The change in length, *x*, is the distance that the hoop spring is compressed (or the extensible spring is stretched).

8. Consult with your instructor about appropriate values of change in length, *x*, for your apparatus. Begin data collection. Perform several trials for each change in length, *x*¸ and keep the three most consistent velocity values. Be sure to stop data collection after each trial and then begin again before the next trial. As before, it is important that you sight the scale from a position directly above the cart so as to avoid parallax error.

EVALUATION OF DATA

1. To evaluate the relationship between energy and velocity, disconnect the photogate and choose New from the File menu. Tap the Table tab to set up the columns **x** (the change in

[1] If you used an extensible spring or a rubber band in the previous lab, your instructor will show you an alternative way to set up the apparatus.
[2] If you used a rubber band to store energy in the previous lab, you will need to quickly collect *F* vs. *x* data again to make sure that the band's effective "spring constant" has not changed since the last use.

length of the spring) and **v** (the average of three consistent velocities of the cart as it passes through the photogate). You will enter these data manually. You also need a calculated column $\mathbf{E_{el}}$ (elastic energy). Your instructor may guide you in the design of this file.

2. Enter the data for change in length, *x*, and the average of the velocity values you obtained for each value of *x* during the experiment. Be sure to include (0,0) in your table.
3. Discuss how the system energy is stored once the spring returns to its original shape. Then you can change the header for the column $\mathbf{E_{el}}$ (elastic energy) to the appropriate form of energy.
4. Tap the Graph tab; from the Graph menu choose to show one graph with kinetic energy on the vertical axis and velocity on the horizontal. Write a statement that describes the relationship between the kinetic energy of the cart system and its average velocity.
5. If your graph of E_k vs. v is not linear, then you need to take steps to modify a column so as to produce a linear relationship. When you have done so, save your file and (if possible) print a copy of your original and then linearized graph.
6. Write the equation of the line that best fits your linearized graph. Take special care to get the units of the slope of this line correct.
7. In the previous lab, the SI unit of energy, joule, was defined as a N m. From your knowledge of the relationship between force and acceleration, express the joule in terms of its fundamental units (kg, m, s). Simplify the units of your slope as much as possible.
8. Prepare a summary of your analysis of data (whiteboard or chart paper). Include the original and linearized graph and the equation of the line of best fit. Also report the system mass. In your class discussion you will compare your findings with those of other groups.
9. When a quantity (in this case, kinetic energy) is a function of more than one variable, it is usually the case that the slope of the graph is related to the variable that was held constant during the experiment. Write a statement describing the relationship between the slope of the line and the mass of the system.
10. Write a general equation describing the relationship between an object's kinetic energy and its velocity.

EXTENSIONS

1. Suppose that you used a spring with a *k* value of 15.0 N/m to launch a lighter (250 g) dynamic cart. If the spring were compressed 0.0200 m, what should be the velocity of the cart when it left the spring?
2. If you were to double the compression of the spring in the previous question, what effect would that have on the cart's velocity? Explain.
3. Suppose you had not adjusted the track for friction as you did in the lab, and 20% of the elastic energy in Extension 1 went into internal energy instead. Determine the velocity of the cart with the reduced amount of kinetic energy.