Experiment
7

Energy Storage and Transfer: Elastic Energy

PART 1 – ELASTIC ENERGY

As Richard Feynman described it, energy is the currency of the universe. If you want to speed it up, slow it down, change its position, make it hotter or colder, bend it, break it, whatever, you'll have to pay for it (or be paid to do it). This is the first of a series of experiments in which you will investigate the role of energy in changes in a system.

If you grasp one end of a rubber band and pull on the other, you realize that the stretched rubber band differs from the same band when it is relaxed. Similarly, if you compress the spring in a toy dart gun by exerting a force on it, you know that the state of the compressed spring is different from that of the relaxed spring. By exerting a force on the object through some distance you have changed the energy state of the object. We say that the stretched rubber band or compressed spring stores *elastic energy* – the energy account used to describe how an object stores energy when it undergoes a reversible deformation. This energy can be transferred to another object to produce a change – for example, when the spring is released, it can launch a dart. It seems reasonable that the more the spring is compressed, the greater the change in speed it can impart to the toy dart.

If we want to *quantify* the amount of energy stored by a spring when it is deformed, we must first study the relationship between the force applied and the extent to which the length of the spring is changed.

OBJECTIVES

- Determine the relationship between the applied force and the deformation of an elastic object (spring or rubber band).
- Determine an expression for the elastic energy stored in spring or rubber band that has been compressed or stretched.

MATERIALS

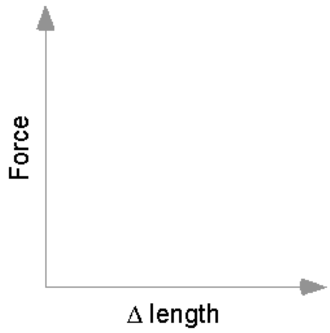
Vernier data-collection interface
Logger *Pro* or LabQuest App
Vernier Dual-Range Force Sensor
Vernier Dynamics Track
standard cart

Vernier Bumper and Launcher Kit (recommended) **or**
lightweight (3–4 N/m) extensible spring **or**
heavy rubber band

PRE-LAB INVESTIGATION

Examine whatever elastic systems (hoop, extensible spring, or rubber band) are available to you. Apply varying force to the system and note the deformation.

On the axes to the right, sketch a graph of the applied force *vs*. the change in length, based on what you felt.



PROCEDURE

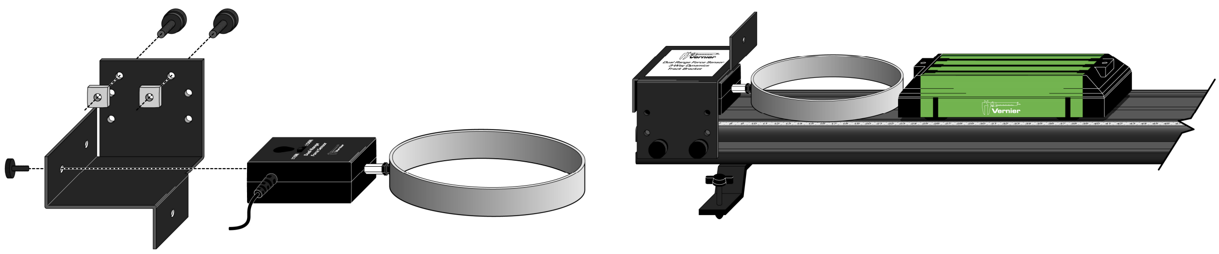
1. Connect the Dual-Range Force Sensor to the interface and start the data-collection program.

2. Check to see if the sensor is working by applying a gentle force to the hook.

3. Devise a quick test to determine which range of the Force Sensor you should use.

4. For this experiment, you will collect data in the Events with Entry mode. Enter **Change in Length** as the Name. While there are a number of variables one could use to represent the change in length, physicists have adopted the convention of using *x* for this quantity. Enter **x** as the Short Name and **m** as the Units. This is the distance that the hoop spring is compressed or the extensible spring or rubber band is stretched.

5. Replace the hook end of the Dual-Range Force Sensor (DFS) with the hoop spring bumper.[1] Attach the DFS to the bumper launcher assembly as shown.



   Note: Shown inverted for assembly.

6. Attach the bumper launcher assembly near one end of a Vernier dynamics track. Place the cart on the track and position it so that the cart bumper just makes contact with the hoop spring bumper. Note the position of the rear of the cart; this represents the 0 value of spring compression. It may help to adjust the track adaptor so that 0 position falls on a "convenient" value on the scale. It is important that you sight the scale from a position directly above the cart so as to avoid parallax error.

7. Push gently on the hoop with the cart. If the force is negative, reverse the direction in the data-collection program.

8. With the cart just touching the hoop spring bumper, zero the force sensor.

[1] If this type spring is not available, your instructor will show you how to use an alternate arrangement to collect data for this experiment.

9. Begin data collection. Without compressing the spring, enter **0** for the value of *x*.

10. Now, compress the spring in equal increments, collecting a data point each time, until you have sufficient data points to determine a relationship. Be careful not to compress the hoop spring more than half of its diameter; doing so will damage the spring.

EVALUATION OF DATA

1. If the relationship between force and the change in length appears to be linear, fit a straight line to your data. If possible, print a copy of your data table and graph.

2. Write the equation that represents the relationship between the force, *F*, applied to the spring and its change in length, *x*.

3. Write a statement that describes the relationship between the force you applied to the spring and the extent to which it was compressed (stretched).

4. If you were to double the change in length of the spring, what effect would that have on the force required to produce this change?

5. Examine the slope of the graph (units as well as numerical value). Write a statement describing what the slope tells you about the spring. In your class discussion, you will give a name to this quantity.

6. Now write the general equation describing the relationship between the applied force and the change in the length of the spring.

7. As you learned in kinematics experiments, the area under a curve can also have physical significance. In this case, the area represents the work that was done on the spring as you applied a force parallel to the change in the spring's length. This work you did increased the *elastic energy* stored in the spring. Noting the shape of the area, write an equation relating the elastic energy to the applied force, *F*, and the change in length of the spring, *x*.

8. Now, replace the variable *F* with an equivalent expression from the general equation you wrote in Step 4. After you simplify the equation you will have derived a general equation for the elastic energy stored in a spring.

9. Determine the energy stored by the spring when it was compressed 0.020 m. Do this both algebraically, using the equation you derived in Step 7, and graphically, by finding the area under this portion of the curve. How do these values compare?

10. If you were to double the change in length of the spring, what effect would this have on the energy stored by the spring? Explain.