Flipping Physics Lecture Notes:

2019 #3 Free Response Question - AP Physics 1 - Exam Solution
http://www.flippingphysics.com/ap1-2019-frq3.html

This Experimental Design Question also works as a part of the AP Physics C: Mechanics curriculum.

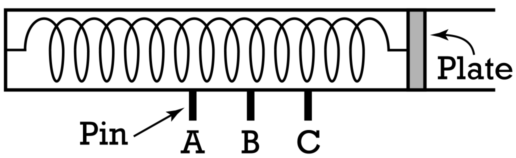

Figure 1. Uncompressed Spring

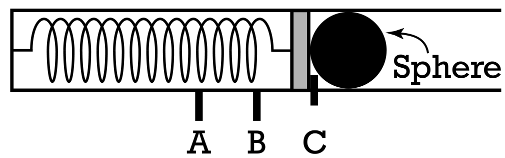

Figure 2. Compressed Spring

A projectile launcher consists of a spring with an attached plate, as shown in Figure 1. When the spring is compressed, the plate can be held in place by a pin at any of three positions A, B, or C. For example, Figure 2 shows a steel sphere placed against the plate, which is held in place by a pin at position C. The sphere is launched upon release of the pin.
A student hypothesizes that the spring constant of the spring inside the launcher has the same value for different compression distances.

(a) The student plans to test the hypothesis by launching the sphere <u>using the launcher</u>.
   i. State a basic physics principle or law the student could use in designing an experiment to test the hypothesis.

Conservation of Mechanical Energy

   ii. Using the principle or law stated in part (a)(i), determine an expression for the spring constant in terms of quantities that can be obtained from measurements made with equipment usually found in a school physics laboratory.

Set the horizontal zero line at the center of mass of the sphere. Launcher is oriented horizontally. Initial point is where the sphere is compressing the spring right before release. Final point is at the point where the sphere leaves the spring.

$$ME_i = ME_f \Rightarrow \frac{1}{2}kx_i^2 = \frac{1}{2}mv_f^2 \Rightarrow kx_i^2 = mv_f^2 \Rightarrow k = \frac{mv_f^2}{x_i^2}$$

(b) Design an experimental procedure to test the hypothesis <u>in which the student uses the launcher to launch the sphere.</u> Assume equipment usually found in a school physics laboratory is available.

In the table below, list the quantities and associated symbols that would be measured in your experiment. Also list the equipment that would be used to measure each quantity. You do not need to fill in every row. If you need additional rows, you may add them to the space just below the table.

Quantity to be Measured	Symbol for Quantity	Equipment for Measurement
mass of the sphere	m	*electronic balance*
initial displacement from equilibrium of the spring	x_i	*meterstick*
final speed of sphere	v_f	*motion sensor*

Describe the overall procedure to be used to test the hypothesis that the spring constant of the spring inside the launcher has the same value for different compression distances, referring to the table. Provide enough detail so that another student could replicate the experiment, including any steps necessary to reduce experimental uncertainty. As needed, use the symbols defined in the table and/or include a simple diagram of the setup.

- *Measure the mass of the sphere, m, with an electronic balance.*
- *Orient the launcher horizontally and load the sphere in the launcher.*
- *Record the initial position of the spring using the meterstick.*
- *Compress the spring to a pin position.*
- *Measure the displacement of the spring from equilibrium position,* x_i*, using the meterstick.*
- *Release the sphere and measure its speed,* v_f*, using the motion sensor.*
- *The maximum speed measured by the motion sensor is the final speed of the sphere.*
- *Conduct the experiment 12 times, 4 times at each pin location.*
    a. *Please do not miss the* "including any steps necessary to reduce experimental uncertainty" *part of the question. That is why the last step of the procedure is here.*
    b. *Also note that your procedure must* "use the launcher"! *It's even underlined, twice, in the question.*

(c) Describe how the experimental data could be analyzed to confirm or disconfirm the hypothesis that the spring constant of the spring inside the launcher has the same value for different compression distances.

Using our equation for the spring constant, we can create a graph of our experimental data to check our hypothesis:

$$k = \frac{mv_f^2}{x_i^2} \Rightarrow slope = \frac{rise}{run} \Rightarrow y - axis = mv_f^2 \ \& \ x - axis = x_i^2$$

The graph of the data should show a best fit line with a slope equal to the spring constant and a y-intercept near zero. If the slope and y-intercept are within experimental error, we have confirmed the student's hypotheses.

(d) Another student uses the launcher to consecutively launch several spheres that have the same diameter but different masses, one after another. Each sphere is launched from position A. Consider each sphere's launch speed, which is the speed of the sphere at the instant it loses contact with the plate. On the axes below, sketch a graph of launch speed as a function of sphere mass.

Rearrange our equation to solve for the final speed of the sphere:

$$k = \frac{mv_f^2}{x_i^2} \Rightarrow v_f^2 = \frac{kx_i^2}{m} \Rightarrow v_f = \sqrt{\frac{kx_i^2}{m}}$$

k and x_i *are both constants in this situation, therefore velocity as a function of mass will be an inverse relationship. As mass increases, velocity decreases. Like this:*