PHYS 1401 – General Physics I
Laboratory # 2
Hooke's Law

INTRODUCTION

In the first part of this unit, we will be discussing and getting familiar with forces. Simply put, a force is a push or a pull. Some forces involve things touching (contact forces), while others do not require contact (force at a distance). In this experiment, we will investigate the forces exerted on and by a spring. These forces were first investigated by the British physicist Robert Hooke, and the equation he used to describe the so-called "elastic force" has been dubbed Hooke's Law:

$$\mathbf{F}_{\mathbf{Spring}} = -k\mathbf{x}$$

In this equation, F is the force exerted by something stretching or compressing the spring, and x is the distance that the spring is stretched or compressed from its "rest" position. The letter k represents the "spring constant," a number which essentially tells us how "stiff" a spring is. If you have a large value of k, that means more force is required to stretch it a certain length than you would need to stretch a less stiff spring the same length. Once you have determined the spring constant of a spring, you can use that k value for all future calculations, unless the spring is damaged in some way.

The negative sign is in the equation because force is a vector quantity. The negative sign tells us that the **direction** of the elastic force is always opposite to the direction of the stretching motion. In other words, if you stretch a spring downward, you feel the spring pull upward. If you want to stretch the spring out and hold it in place, you must apply the same amount of force the spring is, but in the *opposite* direction. That is, to stretch a spring with spring constant **k** a distance **x** and hold it there in equilibrium, you must apply a constant force with a size given by

$$\mathbf{F}_{\mathbf{Applied}} = +k\mathbf{x}$$

This force that you are applying exactly balances the opposite force exerted by the spring, to achieve an equilibrium situation. In this experiment, we will exploit this fact to find out the values of the spring constants of two springs.

PART 1: General Properties

Note that you have two springs for this lab, color-coded yellow and blue. The yellow spring should already be hanging next to the meter stick. The spring is hanging from a device called a force sensor, which is hooked to the computer. The sensor will tell the computer exactly how much force (measured in newtons) the spring is feeling.

We will not use the sensor for this part of the lab. Just pull a little on each spring (do not pull either to its limits!). Pull each spring out 10 centimeters from its “rest" position.

Question 1: Which spring is more difficult to stretch? Which spring do you think will have the higher spring constant?

Question 2: When you pull the spring out and hold it, you should feel a force being exerted on you by the spring. How does that force compare to the force you are applying? What makes you say that?

Question 3: If you let go of the spring, what will happen to it? Explain why, in terms of forces.

PART 2: Yellow Spring

The first thing we must do is calibrate the force sensor. Remove any springs hanging from the hook of the force sensor, and hit the “Collect” button. Notice that numbers appear on the left side of the screen, and a graph fills the rest. The numbers should be 0.000, or something close, like 0.004 or -0.002. If not, then ask your instructor or lab assistant how to calibrate the empty force sensor. Click on the “Collect” button again. The numbers should be closer to 0.000 now.

Hang the yellow spring from the force sensor next to the meter stick. Do not stretch the spring yet. Hit the “Collect” button on the computer screen and let the sensor record data for a brief time. Select ten data points and average them.

Question 4: What is the size of the force felt by the unstretched spring? Where does this force come from?

It is important to find out what this unstretched force is, because in this lab we are only concerned with the force that you exert on the spring. The total force of the spring is what the sensor measures, however, and what the computer displays. That force has two parts: the part the unstretched spring always feels, and the force that you will be exerting.

Question 5: Since the sensor only tells us the total force, how can you calculate the force that you are exerting alone, the applied force?

Now click on the “Collect” button and gradually stretch the spring. The force felt by the spring will be displayed on the graph, and as a stream of numbers on the right of the screen.

Question 6: How does the force change with distance stretched? Explain this behavior in terms of Hooke’s Law.

Now stretch the spring to 5 centimeters past its “rest length.” Click on the collect button and gather a few seconds worth of data. It’s very important to keep the end of the spring steady at all times. Values for the force should appear in the data table at the right of the screen. Average ten values and determine the force that you exerted on the spring. Dividing that force by the distance stretched (5 cm) should give the large spring’s spring constant, in units of newtons per centimeter (N/cm).

Repeat your observations for 10, 20, 30, 40, and 50 centimeters. Calculate a value for the spring constant each time. Average all six spring constant values. Construct a data table with the following information for each trial: length (x in cm), average force (F in N), spring constant (in N/cm). Remember to always report the appropriate number of significant figures for all your data.

Question 7: As you stretch the spring farther, what happens to the force you must exert? What happens to the force the spring exerts in response? Explain this in terms of Hooke’s Law.

PART 3: Blue Spring

Remove the yellow spring from the force sensor and replace it with the blue spring. First take force measurements for the unstretched spring, then readings for stretches of 5, 10, 20, 30, 40 and 50 centimeters. Determine a spring constant value for all trials, then an average spring constant. Create a data table as you did in Part 2 for this spring.

Question 8: Which spring was stiffer? Which spring really had the higher spring constant?

PART 4: Graphs

Create two graphs to finish the lab report, one for each spring. On each graph, the x-axis will be distance stretched, and the y-axis will be the force felt by the spring. Plot as many data points as you have on each graph. Draw the best line you can through all the data points. Calculate the slope (rise/run) for each line.

Question 9: What number is the slope of the graph roughly equal to? Explain this in terms of the Hooke's Law equation, and the standard equation of a line.

Bonus Question: Use your data to confirm or deny the statement that the simple version of Hooke's Law might not hold for small values of distance stretched.