PHY251 Practical #2

THE SPRING: Hooke's Law

OBJECTIVES:

- To investigate how a spring behaves when it is stretched under the influence of an external force. To verify that this behavior is accurately described by Hooke's Law.
- To measure the spring constant k.

THEORY

An ideal spring is remarkable in the sense that it is a system where the generated force is **linearly dependent** on how far it is stretched. Hooke's law describes this behavior, and you would like to verify this in lab today. Hooke's Law states that to extend a string by an amount Δx from its previous position, one needs a **force** F which is determined by $F = k\Delta x$. Here k is the **spring constant** which is a quality particular to each spring. Therefore in order to verify Hooke's Law, you must verify that the force F and the distance the spring is stretched are proportional to each other (that just means linearly dependent on each other). The constant of proportionality is k.

In our case the external force is determined by attaching a mass m to the end of the spring. The mass will of course be acted upon by gravity, so the force exerted downward on the spring will be $F_g = mg$. See Figure 1. Consider the forces exerted on the attached mass. The force of gravity (mg) is pointing downward. The force exerted by the spring ($k\Delta x$) is pulling upwards. When the mass is attached to the spring, the spring will stretch until it reaches the point where the two forces are equal but pointing in opposite directions:

$$F_s - F_g = 0$$

or

$$k\Delta x = F_g = mg \qquad (1)$$

This point where the forces balance each other is known as the **equilibrium point**. The spring + mass system can stay at the equilibrium point indefinitely as long as no additional external forces act on it. The relationship (1) allows us to determine the spring constant k when m, g, and Δx are known or can be measured. This is how you will be determining k today.

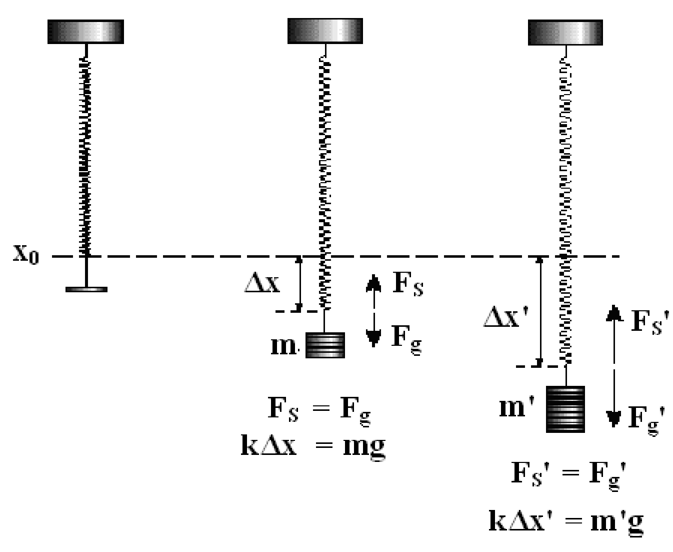

Figure 1: The spring in equilibrium.

PROCEDURE

The mass of the support table, m_0 is 50.0 g. Attach the support table for the masses to the spring. With the zero end of a meter stick on the lab table, measure the position of the end of the spring after the support table has been attached. This position is the initial position x_0.

Start the measurement with an attached mass of 120 grams. Then increase the mass in steps of 20 grams, making a total of 5 measurements. Measure the corresponding position of the spring for each mass. This results in a series of measurements m_i and x_i. To calculate the forces due to gravity and the spring calculate $\Delta x_i = x_i - x_0$ and $\Delta m_i = m_i - m_0$. Also calculate the error on the distance the spring extends, $\delta(\Delta x_i)$. The corresponding forces for gravity and the spring are $F_g^{'} = \Delta mg$ and $F_s^{'} = k\Delta x$. Right now you do not know k, so you will only have your spreadsheet calculate F_g for you. But remember, at equilibrium positions such as we are measuring, F_g equals F_s!

Graph F_g vs. Δx. Add error bars for Δx to your graph. Note that these error bars are horizontal. Now have the computer fit your plot with a best fit line. The slope and its uncertainty determine the spring constant k in Hooke's Law.

Uncertainties

To test the compatibility of a measurement and an expected value, $d \pm \delta d$ and $e \pm \delta e$, find the difference $D = |d - e|$ and calculate its uncertainty, $\delta D = \delta d + \delta e$. If $|D| \leq \delta D$, the two measurements are compatible.

Hand in:

- Your spreadsheet.
- The formula view of the spreadsheet.
- The graph with linear fit and error bars for Δx (comment on graph is not needed).
- Answers to the questions.

Questions:

1. Is your data consistent with Hooke's Law? Explain.
2. What value did you find for the spring constant k from your graph?
3. Is the spring constant you measured consistent with the value given to you by the lab instructor? Justify your answer by showing your work.
4. How would F_g and Δx change if this experiment was done on the moon where the gravitational acceleration is six times smaller than on earth?

Excel Data Table for the Practical Lab:

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g =	980	[cm /sec^2]	
$\delta(X\text{-}X_0)$ =	$2\delta X$		

Measure the values in the gray fields

Zero position of spring:

mass (m_0)	X_0	δX
g	cm	cm
50		

Insert units in the blue fields

Calculate values in the yellow fields

Spring extension vs. mass

Mass (m)	$m\text{-}m_0$	X	$X\text{-}X_0$	$\delta(X\text{-}X_0)$	Force (F_g)
120					
140					
160					
180					
200					

1dyne = 1g*cm/s²