# *Springs and Hooke's Law*

*Physics 114*

*Fall 2025*

The goal of this lab is to explore some properties of springs and test Hooke's law. First, you will use Hooke's law to measure the spring constant (also called the force constant) of a spring. Then, for a mass on a spring that is undergoing vertical oscillations, you will determine whether the period of oscillations depends on the amplitude and the mass.

## *Theory*

When a spring is stretched or compressed from its equilibrium length by an amount $\Delta x$, it exerts a restoring force $F$ in the opposite direction given by

$$F = k\Delta x$$

where $k$ is a property of the spring called the spring constant (also called the force constant). This relationship is called Hooke's law. Now, consider a mass $m_0$ that is suspended from a vertical spring at rest at a position $y_0$. If some additional mass $M$ is added to the end of the spring and the suspended mass is brought to rest, it can be shown that

$$(y - y_0) = \frac{1}{k} Mg$$

where $y$ is the new rest (equilibrium) position of the suspended mass and $g = 9.8\ \mathrm{m/s^2}$ is the acceleration due to gravity. Notice that $m_0$ does not appear in the formula.

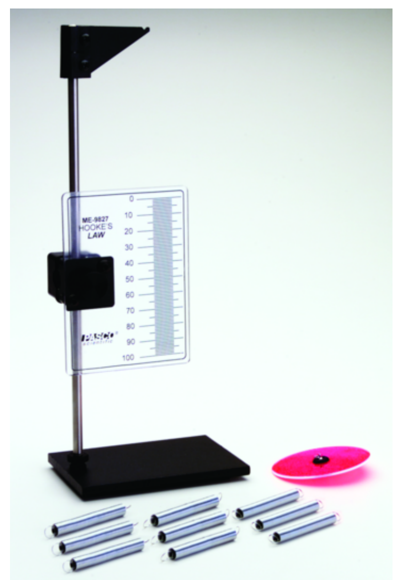


Figure 1: The apparatus consists of a sturdy base, a suspension point for the spring, and a vertical position scale.

## *Initial Setup*

Your instructor will give you a brief introduction to the apparatus (see Figure 1). Take care not to overstretch the spring and limit the mass so that the hanger does not go below the bottom of the position scale on the apparatus. If you have an older version of the apparatus, you will need to take care not to move the position scale - you may wish to tape it in place.

## *Part 1: Measuring the Spring Constant*

Add some mass plates to the hanger so that the position of the bottom of the hanger can be read from the position scale on the apparatus. You will want this position to be as close to zero as possible. Record this equilibrium position $y_0$ and the amount of mass $m_0$ that is suspended at this position.

Next, add some mass $M$ to the hanger, and, with the mass at rest, record the position of the bottom of the hanger $y$. Repeat this measurement for 8 different values of $M$, chosen so that the positions $y$ span the range of the position scale. Organize your measurements into a table, then plot $y - y_0$ (vertical axis) vs. $Mg$ (horizontal axis) and fit the data points to a linear trend line. Record the best fit slope of the trend line and its uncertainty, then use these results to report a measurement of the spring constant $k$ with its uncertainty. Verify your results with your lab instructor before proceeding.

**Question 1:** Theory predicts that the y-intercept of the best-fit trend line is zero. What is the y-intercept of your trendline? Is it consistent with zero, within uncertainties? If not, what might be the cause of the discrepancy?

## *Part 2: Period and Amplitude*

Load the spring with some mass so that the bottom of the hanger is positioned halfway down the position scale. Pull down on the mass by one or two centimeters, then let go and watch the motion. You should see the mass and spring oscillate up and down. The *period* of this motion is the time it takes for the system to complete one oscillation. The *amplitude* of the motion is the maximum displacement of the system from its rest position. If air resistance is negligible, conservation of mechanical energy tells us that the amplitude is equal to the initial displacement of the system before you let go of it.

Your goal in this part is to determine whether the period of the motion depends on the amplitude. Pull down on the hanger by 0.5 cm and let go. Use the stopwatch on your phone to time the period. To limit imprecision in starting and stopping the stopwatch, it is best to measure a large number of cycles and then divide by the number of cycles. For example, you could measure the time for the system to complete 30 oscillations, then divide this measurement by 30 to find the period. Be careful - it is easy to accidentally time 29 or 31 cycles instead of 30.

Repeat this measurement for at least five different amplitudes. Use increments of 0.5 cm or 1.0 cm for you amplitudes, but be careful to limit the amplitude so that the bottom of your hanger does not go higher than the position $y_0$ you used in Part 1. Plot the period (vertical axis) vs. amplitude (horizontal axis) and fit the data to a linear trendline. Adjust the vertical scale of your plot so that the origin is at the intersection of the axes. Record the slope of the trendline and its uncertainty.

**Question 2:** Does the period depend on the amplitude? Use your plot and the results from the linear fit to support your answer.

### *Part 3: Period and Mass*

Your goal in this part is to test two hypotheses for how the period could depend on the mass:

1. Hypothesis 1: The period is proportional to the total mass $M + m_0$
2. Hypothesis 2: The period is proportional to the square root of the total mass $\sqrt{M + m_0}$

Load the spring with some mass so that the bottom of the hanger is positioned about 2 cm below the position $y_0$ you used in Part 1. Record this mass, then pull the hanger down by 1 cm, let go, and measure the period of oscillations just as you did in Part 2. Repeat this measurement for 6-8 different masses, using masses that span the position scale of the apparatus. Next, make two plots:

1. Plot 1: period on the vertical axis vs. $M + m_0$ on the horizontal axis.
2. Plot 2: period on the vertical axis vs. $\sqrt{M + m_0}$ on the horizontal axis.

Fit the data on each plot to a linear trendline.

**Question 3:** Does your data prefer Hypothesis 1 or Hypothesis 2? Use your plots and the results from the linear fits to support your answer.

## *Informal Lab Report Guidelines*

Include the following in your informal lab report:

1. Three well-organized data tables containing your raw data, one table for each part of the lab. Be sure to include all quantities that you directly measure, as well as any calculated quantities used to make the plots. All quantities should have correct units and significant figures.
2. The plot of $y - y_0$ vs. $Mg$ from Part 1, the plot of period vs. amplitude from Part 2, and the two plots from Part 3. Each plot should have a title, axis labels with units, and a linear best fit line.
3. Report your measurement of the spring constant $k$ with its uncertainty in Part 1. Explain how you determined the uncertainty on $k$.
4. Answer Question 1 (the questions are in the right-hand margin of the procedure).
5. Answer Question 2. Your answer should include some quantitative discussion of uncertainties in the linear fit.
6. Answer Question 3.