Physics 1021
Experiment 1

Introduction to Simple Harmonic Motion
Objectives

✔ In this experiment you will determine the force constant of a spring.

✔ You will measure the period of simple harmonic motion for six different masses and graph the results.

✔ You will use a motion detector to generate graphs of position, velocity, and acceleration for simple harmonic motion.
Introduction to SHM

Apparatus and Setup

The apparatus for this experiment consists of:

- hook
- lab pro
- masses
- metre stick
- motion sensor
- rods and clamps
- spring
- stopwatch

The setup is shown at right.
Finding the Spring Constant

- Using the metre stick, measure the length, \( L_1 \), of the spring (from the top hook to the bottom hook as shown).
- Record this value and its uncertainty in **Table 1**.
- Hang the 500.0 \( g \) mass from the spring.
- Calculate the weight, in newtons, of the 500.0 \( g \) mass and record in **Table 1**.
- Measure the new length, \( L_2 \), of the spring.
- Record this value and its uncertainty in **Table 1**.
Finding the Spring Constant

From Newton’s second law, the magnitude of the spring force (Hooke’s Law states that $F = -k\Delta x$) will equal the weight hanging from the spring, i.e.

$$W = k\Delta x = k(L_2 - L_1)$$

where $W$ is the weight of the 500.0 g mass and $L_2 - L_1$ is the change in length due to the 500.0 g mass.

**QUESTION 1:** Use your results from Table 1 to determine the spring constant. Don’t forget units and uncertainty. You may take $\delta m = \pm 0.2\,g$ and $\delta g = 0$. 
Introduction to SHM

Period squared vs mass

- Hang a 200.0 g mass from the spring.
- Lift the mass a few cm upwards and gently release to set the mass oscillating.
- Use the stopwatch to time 10 oscillations and record this time in Table 2.
- Have your partner repeat the timing of 10 oscillations and record the result in Table 2.
- Increase the hanging mass by 50.0 g and have both partners time 10 oscillations, recording the results in Table 2.
- Continue the procedure, increasing the mass by 50.0 g each time until there is 450.0 g hanging from the spring, recording your results in Table 2.
Period squared vs mass

- For each mass, determine the average time for 10 oscillations and record the results in Table 2.
- Using the average time, determine the period of oscillation and record your results in Table 2.
- Calculate period squared and record your results in Table 2.
Period squared vs mass

For help with these questions, refer to the Plotting and Interpreting Graphs section of your Laboratory Workbook.

**QUESTION 2:** Write the equation for the slope of a period squared vs mass graph. What do you predict for the intercept? Explain.

Remember that the equation of a straight line is $y = mx + b$. Compare this to the physics equation which relates mass to period squared to find the physical meaning of your slope and the intercept.

**QUESTION 3:** Using your result from Question 2, sketch the predicted shape of a period squared vs mass graph.

Do not use data! This is a theoretical prediction.
Period squared vs mass

Click the icon below to launch Graphical Analysis

Use Graphical Analysis to plot Period Squared (y-axis) vs Mass (x-axis).

Create a linear fit to your graph by clicking Analyze then Linear Fit. Find the uncertainty in your slope and intercept by double clicking on the pop up box and clicking the option to “Show uncertainty”.

Record the slope, intercept, and uncertainties in Table 3.

Print your graphs by clicking Print then Print Graphs.
Period squared vs mass

QUESTION 4: Use your expression from Question 3 to determine the spring constant $k$. Be sure to include units and uncertainty.

QUESTION 5: Write the range of values of $k$ and determine if it agrees with your results from Question 1? Comment on their agreement.

*E.g.* Writing the range of $L=1.0\pm 0.1\ cm$ means the value ranges from $0.9\leq L\leq 1.1$. If values agree, their ranges should overlap.
Introduction to SHM

\( x(t), v(t), \) and \( a(t) \) for SHM

Click on the icon to launch *LoggerPro*.

*LoggerPro* should display 3 graphs: position, velocity, and acceleration vs. time.
Hang the aluminium mass from the spring as shown in the photo.
Place the motion sensor directly under the mass.
Plug the motion sensor into DIG/SONIC 1 port of the LabPro.

Careful with the placement! The motion sensor must be directly under the mass in order to work properly.

With the mass still, click **Experiment**, then **Zero**, to zero the motion sensor.

Lift the mass a few centimeters upward and gently release to set the mass oscillating.

Allow oscillations to stabilize, click in LoggerPro to collect data.
Examine your data. Does it have the expected form? If your data is not satisfactory, repeat until it is.

Have an instructor check your graph and initial your book.

Print your graphs by clicking File, then Print. Attach both printed pages into Laboratory Workbook.

QUESTION 6: How does your intercept value compare with your predicted value? Comment on their agreement.
Data analysis - $x(t)$, $v(t)$, and $a(t)$

- On your printout draw a straight **vertical** line through the first maximum on $x$ vs $t$. Label this line “1” as shown to the right.

- Line number “2” will go through the zero position to the right of the first maximum of the position graph.

- Line number “3” will go through the minimum of the position graph.

- Line number “4” will go through the next zero on the position graph.
Data analysis - $x(t)$, $v(t)$, and $a(t)$

**QUESTION 7:** From your graph printout, indicate which numbered vertical line corresponds to the following conditions:

A) Displaced upwards and stopped.

B) Travelling upward at maximum speed.

C) Zero acceleration and moving up.

D) At equilibrium point and travelling down.

E) Maximum acceleration and displaced down.
QUESTION 8: Give at least two sources of error in this experiment and classify them as random or systematic.

✔ Check that you have completed all the tables of your Laboratory Worksheet.

✔ Make sure that you have answered all the questions completely.

✔ Attached to your Laboratory Worksheet should be the following graphs:

✔ Period Squared vs Mass (Graphical Analysis) Position, Velocity, and Acceleration vs Time (LoggerPro)