The purpose of this lab is to study simple harmonic motion of a system consisting of a mass attached to a spring. You will establish the relationship between period, mass, and spring constant.

Important! You need to print out the 1 page worksheet you find by clicking on this link and bring it with you to your lab session.

If you need the .pdf version of these instructions you can get them here.

### Equipment

- air track with springs and glider
- interface box
- photo gate
- weights
- 2 springs
- computer
- scale to weigh the glider
Introduction

In this lab the phenomenon of Simple Harmonic Motion will be studied for masses on springs. The physical basis of these oscillations is that the force exerted on the mass by the spring is proportional to and in the opposite direction to the displacement of the mass from equilibrium.

Part I Measurement of the Spring Constant
In this lab, you measure the spring constant $k$ of two springs attached a glider on an airtrack and attached to the end of the track. You measure the spring constant $k$ in Hooke’s law for the two springs combined. (The reason for mounting two springs is that these two springs are used in Part II and III of this lab.)

$$F = -kx$$
\[ (7.1) \]

The force $F$ is supplied by the weight suspended from the string (see Fig 2. above).

$$F = mg$$
\[ (7.2) \]

You suspend various weights from the string and measure the displacement of the glider from its equilibrium position define as the position when a 100 gram weight is suspended initially.

Attach a piece of string to the glider and lay it on the pulley with a mass $m$ of 100g suspended from the free end of the string as shown above. Record the position of your glider for the 100g weight and define this as your equilibrium position. Be sure that the string moves freely and does not scrape. Repeat with 4 other masses of 20g each for a total of four measurements. Make sure you are taking the difference between your position readings and the equilibrium position as your data. Enter the values for the additional mass $\Delta m$, the additional displacement $\Delta x$ and the additional force $\Delta F$ into Table 1 on your worksheet. Calculate for each of the 4 sets of numbers the slopes $k = \frac{\Delta F}{\Delta x}$ and enter them into Table 1.

Calculate the average $k$ and its absolute error $\Delta k$ (use (max – min)/2 for the error.) and write them on your worksheet.

**Part II Measurement of the Period of Glider/Spring System**
In this part, you measure the period $T$ of an oscillation caused by the two springs from Part I. The period of a mass-spring system is given by

$$T = 2\pi \sqrt{\frac{m}{k}} \quad (7.3)$$

You should note when we have both springs attached as we do in our experiment the $k$ in this equation is the sum of the spring constants of each spring. This sum is what we measured in the first part of the lab.

Remove the string from the glider and measure the mass $M$ of the glider with the scale and record it on your worksheet (neglect error in the mass $M$).

Attach the glider to the two springs and place the glider on the air track so that the 'metal flag' atop the glider is centered at the equilibrium position.

Get ready for data taking:

- Connect the photo gate output to the interface box by plugging its cable into the top socket (labeled “DIG/SONIC 1”) of the black interface box (“LabPro”).
- Turn on the computer and check the system by following these instructions: Double click the icon “Exp7_Period”. A window with a spreadsheet on the left (having “Time”, “State”, and “Period” columns and a graph labeled “Period”) comes up. On top is a window “Sensor Confirmation”.
- Click “Connect”, and again “Connect”.
- Test the photo gate: block the photogate beam with your finger and see the red light on the cross bar of the photogate turn on.
- Click OK.

You are ready for data taking now.

- Place a 20 gram weight on top of the glider. Click the green “Collect” icon on the PC terminal, displace the glider by $\sim 10$ cm and let go. Collect a few data points and click STOP. You see a plot with a constant period as time goes on on the graph. Take a value for the measured period $T_{\text{meas}}$ and enter it into Table 2 on your worksheet.

- Repeat the above three times, each time adding an additional 20 grams on top of the glider. Record the values of the total mass (glider and additional mass combined) and the periods into Table 2 of your worksheet.

Calculate the theoretical period $T_{\text{theor}}$ using the equation (7.3).

The error in $T_{\text{theor}}$ can be calculated from the the error in $k$ you estimate in Part I. From equation 7.3 and equation (1.8) of Lab 1, if we take into account only the error of the spring constant $\Delta k$ you can find that

$$\Delta T_{\text{theor}} = T_{\text{theor}} \frac{\Delta k}{k}.$$  

Use the plotting tool to plot $T_{\text{theor}}$ vs $T_{\text{meas}}$, including error bars for $T_{\text{theor}}$. Write your slope and its error on your worksheet.

x axis label (include units):
Part III Potential Energy in the Spring

In this part of the lab, you observe energy conservation. You will see that the maximum potential energy in the spring at maximum displacement from equilibrium equals the maximum kinetic energy when the glider goes through the equilibrium point.

\[ P_{E_{\text{max}}} = \frac{1}{2} k x_0^2 \] (7.4)

\[ K_{E_{\text{max}}} = \frac{1}{2} m v_0^2 \] (7.5)

The setup is the same as in Part II, but you use a different file to take data.

- Double click the icon “Exp7_Velocity”. A window with a spreadsheet on the left (having “Gatetime, Velocity, Sate columns and a graph labelled “Velocity”) comes up. On top is a window “Sensor Confirmation”.
- Click “Connect”, again “Connect”.
- Measure the width \( w \) of the flag on top of the glider and enter it in your worksheet, along with an estimate of the error in your measurement.
- Place the photo gate such that it is centered on the flag mounted on the glider.
- Displace the glider by \( \sim 30 \text{ cm} \) from equilibrium and enter the glider displacement \( x_0 \) from its equilibrium on your worksheet, along with an estimate of the error in your measurement.
- Click the green “Collect” icon on the PC screen and release the glider. Record a few velocities as the glider goes backwards and forwards through the photogate on the PC screen. You should see a slowly falling linear graph due to the gradual slow down of the glider due to friction. Enter the first velocity as the maximum velocity \( v_0 \) on your worksheet. Calculate it’s error. We neglect the error in the time, meaning that the relative error in the velocity is the same as the relative error in the flag width, i.e. \( \Delta v = v \frac{\Delta w}{w} \).

Now we need to check if energy is conserved.

- Calculate the maximum potential energy originally stored in the spring using equation (7.4) and...
write it on your worksheet. Also calculate the error \( \Delta P E_{\text{max}} = 2P E_{\text{max}} \frac{\Delta x_0}{x_0} \) and write that on your worksheet as well.

- Calculate the kinetic energy the object has when it is moving with its maximum velocity \( v_0 \) using equation (7.5) and write it on your worksheet. Also calculate the error \( \Delta K E_{\text{max}} = 2K E_{\text{max}} \frac{\Delta v_0}{v_0} \) and write that on your worksheet as well.

Do these values agree within error? What does this mean for conservation of mechanical energy in simple harmonic motion?