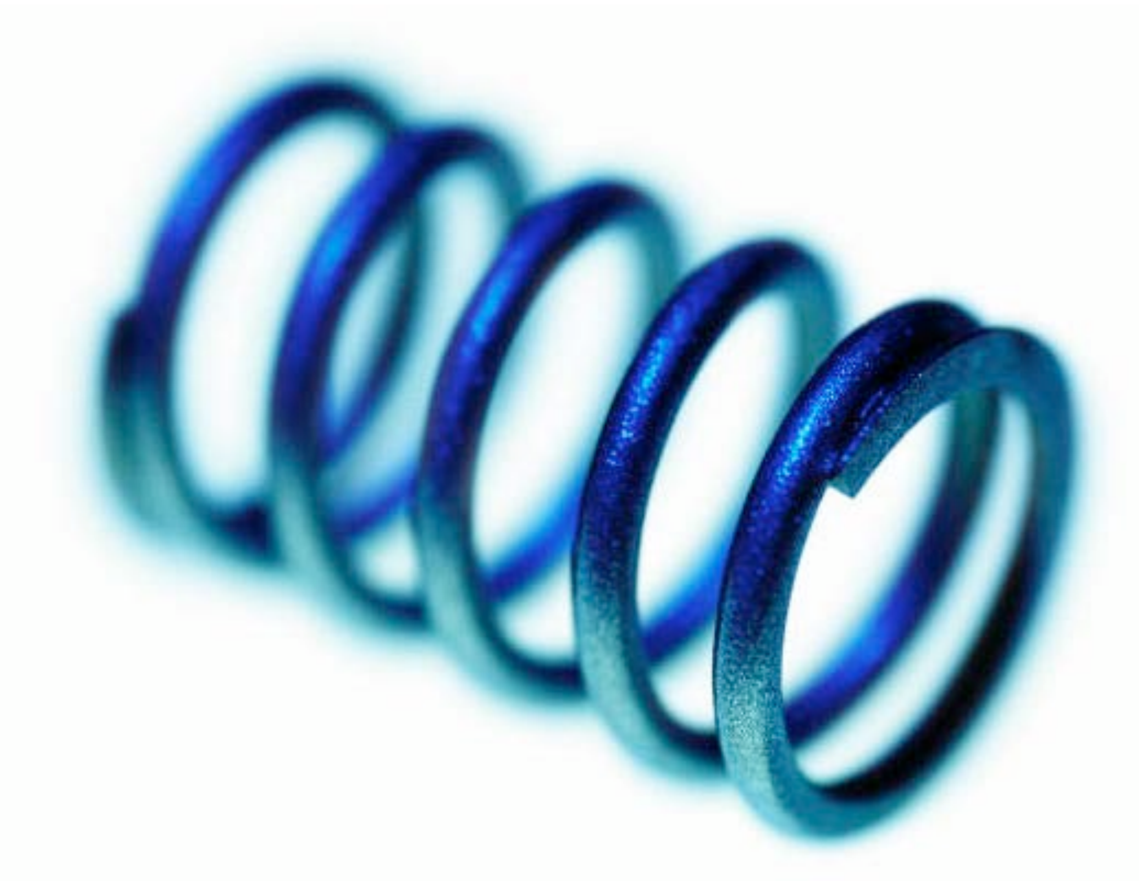
Introduction to Simple Harmonic Motion



Uncertainty and error analysis

Expected that you recall error information and uncertainty rules from Phys 1050.

- Linked on website and lab computers for reference.

Important to recall these uncertainty rules:

Adding and subtracting quantities with uncertainty:

If $z = x - y$ or $z = x + y$,

Then $\delta z = \delta x + \delta y$

Multiplying or dividing quantities with uncertainty:

If $z = x/y$ or $z = xy$

Then $\frac{\delta z}{z} = \frac{\delta x}{x} + \frac{\delta y}{y}$

Lab Report Format

All reports should follow this general structure:

- Title
- Objective
- Theory
- Apparatus & Methods
- Analysis & Result
- Conclusions

Prelab sections prepared **BEFORE** attending lab.

General notes on prelab work:

- Copy/Paste is NOT ACCEPTABLE.
- Reports should be your own work.
- Handwritten or typed is acceptable.
- If typed, print report template leaving space for your responses.

Prelab Sections

Title:

- Experiment title, name, student number.

Objective:

- Statement of purpose of the experiment.
- Sentence or two.

Theory:

- All necessary theory to be utilized.
- Equations with explanations of terms.
- In most cases, a paragraph or two.

Apparatus:

- Description of equipment to be used
- Basic explanation of how to use it.

15-20%

NO Signature; NO marks awarded for these sections

Prelab

LR Write experiment title, your name and student number at top of the page.

LR **Prelab 1:** Write the objective of this experiment.

LR **Prelab 2:** Write the relevant theory of this experiment.

LR **Prelab 3:** List the apparatus and sketch the setup.

! Have these ready to be checked by lab staff at the door on the day of your lab.

Introduction

The goal of this experiment is to familiarize ourselves with the physical properties of simple harmonic motion and collect data that will allow us to determine the parameters required to model a simple harmonic oscillator mathematically.

In general, any motion that repeats itself at regular intervals is called periodic or harmonic motion. Examples of periodic motion can be found almost anywhere; boats bobbing on the ocean, grandfather clocks, and vibrating violin strings to name just a few.

Simple Harmonic Motion (SHM) satisfies the following properties:

- Motion is periodic about an equilibrium position.
- The restoring force is proportional to and oppositely directed to a displacement from the equilibrium position.

Introduction

The displacement with respect to the equilibrium position *x* of a system undergoing SHM (as a function of time, *t*) can be described by

$$x(t) = A\cos(\omega t + \phi)$$

where

- A is the maximum displacement or **amplitude** of the motion,
- ω is the **angular frequency** of the motion, and
- ϕ is the **phase constant** or phase angle.

Similarly, the equations of velocity and acceleration are as follows:

$$v(t) = -A\omega\sin(\omega t + \phi) \quad ,$$

$$a(t) = -A\omega^2\cos(\omega t + \phi) \, .$$

Introduction

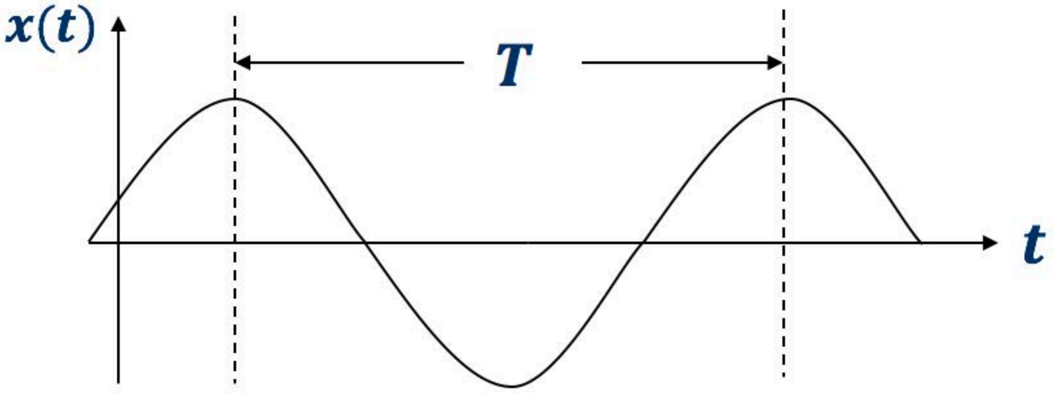
The angular, or circular, frequency ω is defined in terms of the frequency f:

$$\omega = 2\pi f \ .$$

The frequency is defined to be the number of oscillations that the system completes in one second.

The **period** T is the time taken for one complete oscillation, and can be expressed mathematically as

$$T = 1/f \ .$$

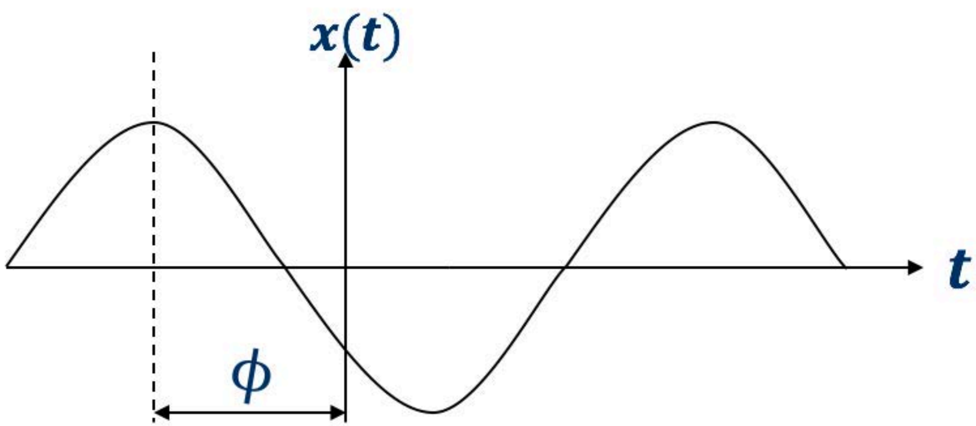


Phase Constant

The phase constant, ϕ, indicates where the initial starting point of the oscillation in terms of **radian** angle; where one full oscillation equates to an angle of 2π. Consider when $t = 0$,

$$x(0) = A\cos(\omega t + \phi) = A\cos(\phi) \ .$$

It is important to recognize that the position at $t = 0$ can be of any value between $-A$ to A. To account for where in an oscillation the initial position is, we use phase ϕ. Also, the period T would be the amount of time for a full oscillation of 2π.



Lab Report

Before collecting any data:

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Lab Report 1: Sketch the expected form for the graphs of position vs. time, velocity vs. time, and acceleration vs. time. Explain your reasoning.

HINT: Consider the equations for position, velocity, and acceleration given in the instructions above.

Apparatus and Setup

You have been provided with the following:

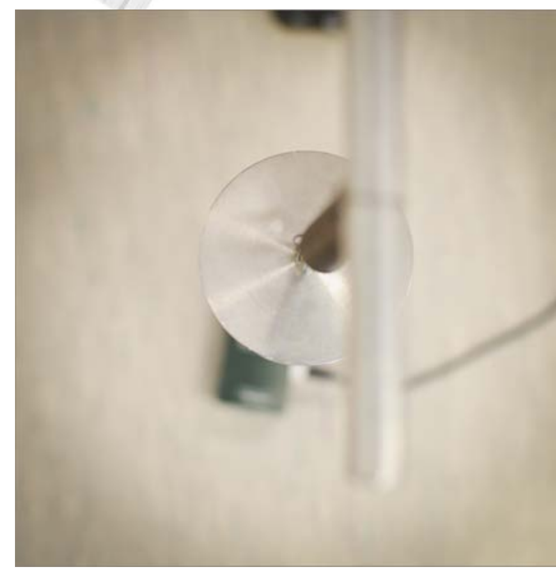
- Motion detector
- Aluminium cylinder
- Metre stick
- Spring
- Support rods
- Stopwatch
- Clamp
- Ring clamp

Motion detector

The motion detector is a device which measures the distance to the closest object.

Connect the motion detector to DIG/SONIC 1 of the LabPro.

Place the motion detector on the floor directly beneath the aluminium cylinder.

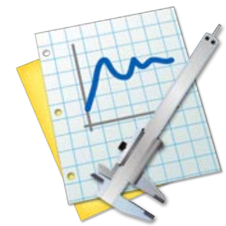


Position the motion detector carefully -- the narrow beam of ultrasound it emits can easily miss the hanging mass altogether.

Remember, the motion detector must always be between 15 cm and 100 cm below the mass for it to measure its motion reliably.

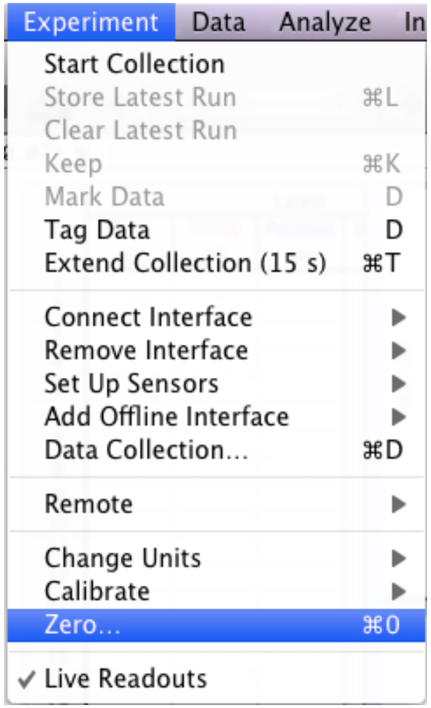
Data Collection

Click the icon to launch Logger Pro.



Before collecting any data, we have to zero the motion detector to set the equilibrium point of the oscillation.

Reduce the motion of the aluminium mass as much as possible, and then select **Zero** from the **Experiment** pull-down menu.



Data Collection

Logger Pro will display plots of the oscillating system for:

- Position vs time.
- Velocity vs time.
- Acceleration vs time.

Start your mass oscillating by **lifting** it a few centimetres and releasing it. Once the oscillation has stabilized, so that any wobble is minimized, hit the Collect button in Logger Pro.

LR

Lab Report 2: Do your graphs match the expected form? If they do not match, discuss any differences.

CP

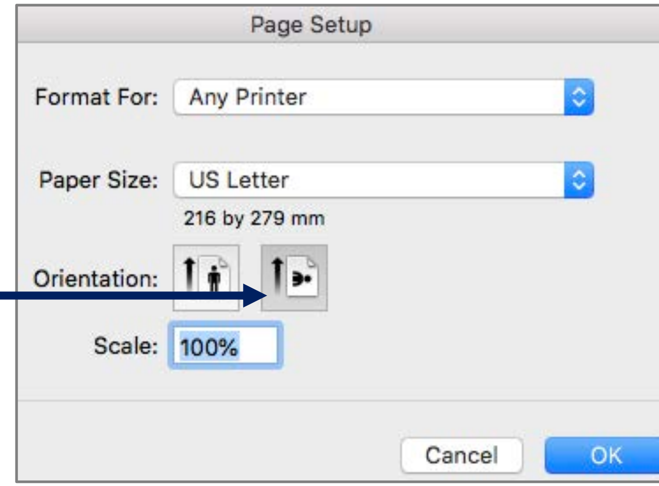
Have an instructor check your graphs and initial your lab report.

Data Analysis

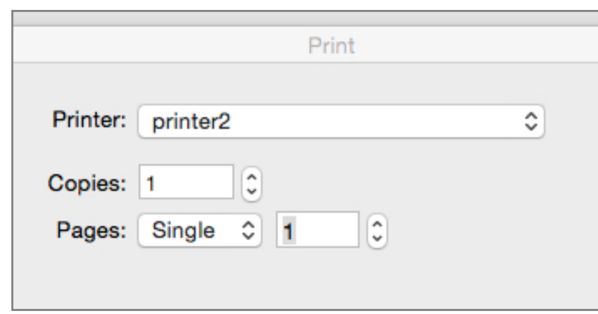
Right click and choose **Graph Options** and include titles on each graph explaining what each graph describes.

For the best printed graph:

Click **File** then **Page Setup** and choose the landscape orientation.



Click **File** then **Print**.



To select the only necessary page:
Click Pages and choose Single.

P

Include your printed graph with your report

Data Analysis

Logger Pro will display the coordinates of the plots if you click **Analyze**, and **Examine**, or click the  button. Move your cursor over your data and the coordinates on the plot will be displayed in a pop-up box.

Use your data to determine the following:

LR **Lab Report 3:** Determine the amplitude of oscillation and estimate the uncertainty. Indicate where the amplitude was measured on your printed graph.

LR **Lab Report 4**: Determine the period of oscillation and estimate the uncertainty. Indicate how the period was determined on your printed graph. Show all workings.

Data Analysis

LR

Lab Report 5: Calculate the angular frequency of the oscillator with its uncertainty.

LR

Lab Report 6: Using your data, measure $x(0)$ and use it to estimate ϕ for your system. Include all workings.

LR

Lab Report 7: Use the velocity equation and the calculated value of ϕ to calculate your value for $v(0)$.

LR

Lab Report 8: Measure $v(0)$ **from your data** and compare to your calculated value**.** Be sure to check the sign of the velocity. Comment and make any adjustments to ϕ to ensure the direction of velocity is correct.

Summary and Conclusions

LR **Lab Report 9:** Write the expressions for $x(t)$, $v(t)$, and $a(t)$ for the oscillator with values of A, ω, and ϕ as appropriate.

LR **Lab Report 10**: Briefly summarize your experiment, in a paragraph or two, and include any experimental results.

LR **Lab Report 11:** List at least two sources of experimental uncertainty and classify them as random or systematic.

! **Include your prelab, any printed copies of your graph, and all data analysis with your report.**