# Lab 2: Simple Pendulum

Name: **Your Name**
Class: **PHYS 2125 (15921)**
Date: **2025-01-24**

# Objective

To determine the gravitational constant of Earth.

*Hint*: $g_{Earth} = 9.8 m/s^2$.

# Equipment

- (1) small A-base
- (1) long metal rod
- (1) short rod
- (1) 80cm length of string
- (1) calipers
- (1) clamp
- (1) 0.0635 meter aluminum cyliner as pendulum weight
- (1) 1 meter ruler
- (1) stopwatch

# Theory

The **period of oscilation** of a pendulum ($T$) is the amount of time required to complete a full cycle (*oscilation*). It is related to the **gravitational constant** ($g$) per the equation:

$$T = 2\pi\sqrt{\frac{L}{g}}$$

where:

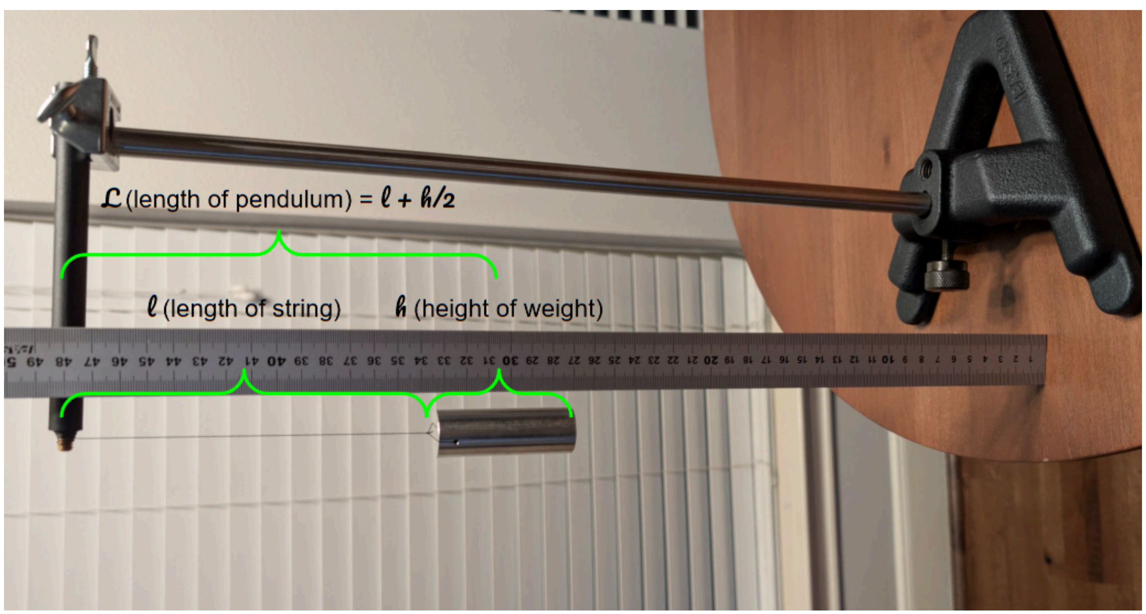
$T$ is the period of oscilation in $seconds$,
$L$ is the length of pendulum in $meters$, and
$g$ gravitational constant in $\frac{meters}{seconds^2}$

The value of $L$ is the sum of the distance from the pivot point to the weight ($l$) plus half the height of the weight ($h$).

$L = l + \frac{1}{2}h$
$l =$ length from the pivot point to the center of the swinging weight in $meters$
$h =$ height of the cylinder in $meters$

$$\begin{aligned} T &= 2\pi\sqrt{\frac{L}{g}} \\ T^2 &= 4\pi^2 - \frac{L}{g} \\ T^2 &= \frac{4\pi^2}{g}L \\ \frac{T^2}{L} &= \frac{4\pi^2}{g} \\ g &= \frac{4\pi^2}{\frac{T^2}{L}} \end{aligned}$$

By varying the length of the pendulum ($L$) ($x$-axis) and then measuring the effect on $T^2$ ($y$-axis) we can determine the relationship between the two, and use that value to calculate $g$.


ℒ (length of pendulum) = ℓ + h/2
ℓ (length of string)
h (height of weight)

# Procedure

The following procedure was followed.

## Initial Setup

The pendulum was constructed as follows.

1. A small cast iron A-base was placed on the table.
2. A 45cm steel rod was secured into the A-frame, raised up as much as possible to maximize the height.
3. The vertical mounting side of a steel clamp was secured at the very top of the rod.
4. A 15cm rod was attached to the horizontal side of the same steel clamp, to the far end of the smaller rod in order to maximize space for the swinging pendulum.
5. 6.35cm aluminum mass was secured with a string, ensuring minimal distance from the knot to the top surface of weight, and a symmetric placement of the knot in the center of that face.
6. The other end of the string was then secured to the small rod, opposite the clamp, by tightly wrapping the string beginning with the loose end.

## Trial (completed for each $l$)

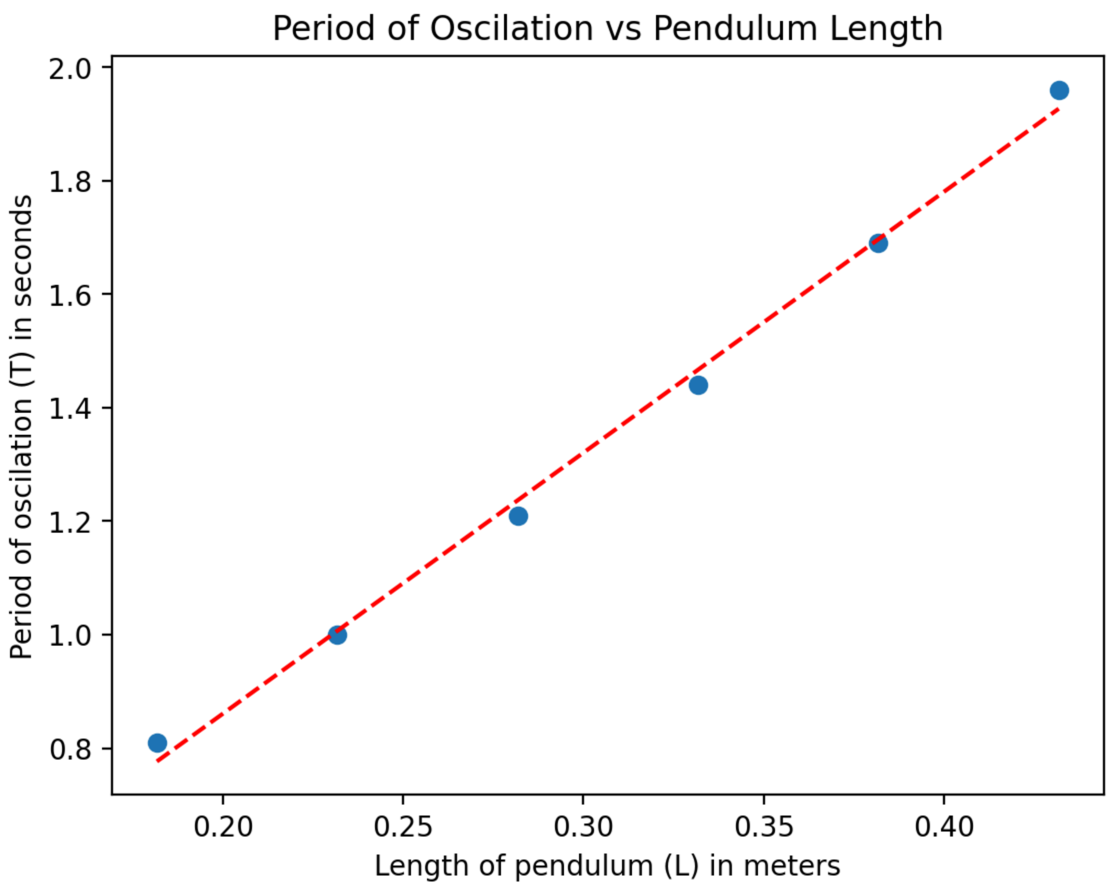
Each measurement was taken twice for each value of $l$.

1. The clamp securing the smaller rod was loosened and the smaller rod was rotated until the desired length ($l$) of the string was reached, at which point the clamp was resecured.
2. The pendulum was set swinging
3. A stopwatch was used to measure the time required to complete 5 oscilations (starting from one extreme and then back, 5 times). This is noted in the data as ($5T_1$). While the pendulum continued to swing a second measurement was taken in the same manner and noted as ($5T_2$).

# Data

| L (m) | l (m) | h (m) | $5T_1$ (s) | $5T_2$ (s) | $T_1$ (s) | $T_2$ (s) | T (s) | $T^2$ ($s^2$) | g ($m/s^2$) |
|---|---|---|---|---|---|---|---|---|---|
| **0.18175** | 0.15 | 0.0635 | 4.5 | 4.5 | 0.9 | 0.9 | 0.9 | 0.81 | 8.858275 |
| **0.23175** | 0.2 | 0.0635 | 5.0 | 5.0 | 1.0 | 1.0 | 1.0 | 1.0 | 9.149123 |
| **0.28175** | 0.25 | 0.0635 | 5.5 | 5.5 | 1.1 | 1.1 | 1.1 | 1.21 | 9.192598 |
| **0.33175** | 0.3 | 0.0635 | 6.0 | 6.0 | 1.2 | 1.2 | 1.2 | 1.44 | 9.095115 |
| **0.38175** | 0.35 | 0.0635 | 6.5 | 6.5 | 1.3 | 1.3 | 1.3 | 1.69 | 8.917684 |
| **0.43175** | 0.4 | 0.0635 | 7.0 | 7.0 | 1.4 | 1.4 | 1.4 | 1.96 | 8.69633 |
| **Average** | | | | | | | | | 8.984854 |

# Calculations




Using the least squares method a trend line is fit to the data with *slope* 4.60 and $y$*-index* -0.06, resulting in the equation $y = 4.60x + -0.06$.

# Results

$$
\begin{aligned}
g_{avg} &= 8.98\ m/s^2 \\
g_{avg}\ \sigma &= 0.18 \\
g_{avg}\ error &= -8.32\ \% \\
g_{graph} &= 8.58\ m/s^2 \\
g_{graph}\ error &= -12.43\ \% \\
g &= g_{avg} \pm g_{avg}\ error && = 8.98 \pm 8.32\% \\
&= g_{avg} \pm g_{avg}\ \sigma && = 8.98 \pm 0.18 \\
&= g_{graph} \pm g_{graph}\ error && = 8.58 \pm 12.43\%
\end{aligned}
$$

# Discussion

**What is the most challenging measurements during data collection and explain why? (4 pts)**

Your Answer to Question 1

**Why do you include half of the height of the cylinder for the length of the pendulum? (3 pts)**

Your Answer to Question 2

**What changes of the period of the pendulum you would expect, if you changed the mass of the pendulum? (3 pts)**

Your Answer to Question 3