Simple Harmonic Motion Lab

You will set up a spring in a vertical position for the three objectives below.

Objectives
Objective 1: Testing whether the maximum displacement of SHM affects the period
Objective 2: Testing whether mass hanging affects the period
Objective 3: Finding spring constant using two methods: Hooke's law and the period of SHM

Day 1: Proposal (Paper copy) - due at the start of day 2

1. Materials (for all of the parts)
    a. List all the materials needed for your experiment
2. Variables (for each objective)
    a. Independent variable
    b. Dependent variable
    c. Controlled variable
3. Procedure (for each objective)
    a. Write a procedure for each of the objectives
4. Data table (for each objective)
    a. Make the data table for each part to be filled out during the lab

Objective 1: Testing whether the maximum displacement of SHM affects the period

1. Materials

Spring, clamp stand, 150g bob, meter stick, tape, stopwatch (or motion sensor application)

2. Variables

Variable Type	Variable	How it will be manipulated, measured, or controlled
Independent variable	Amplitude	Stretch or compress the mass up until a known position for five different initial displacements
Dependent variable	Period	Measure the total time for 10 cycles of oscillation and divide the measured time by 10
Controlled Variable	Mass	Use the same bob
	Spring constant	Use the same spring
	Temperature	Experiment in the same environment

3. Procedure

1) Attach the spring to the clamp stand in a vertical position using tape
2) Place the meter stick along the clamp stand next to the spring
3) Hook the 150g bob onto the spring and secure it using tape. Allow it to stabilize to its equilibrium position (take a reading of the initial position)
4) Vertically extend the center of the 150g bob by 0.02m downwards from the equilibrium position
5) Release bob and start stopwatch simultaneously
6) Measure the total time it takes for the 150g bob to oscillate 10 cycles using a stopwatch
7) Record the total time in the data table
8) Repeat steps 4 to 7 for four more trials
9) Repeat steps 4 to 8, but for successively increasing initial displacements to 0.04m, 0.06m, 0.08m, 0,10m

4. Data table

1) <u>Raw Data Table</u>

Maximum Displacement (m)	Total time for 10 cycles/oscillation (s)			
	Trial 1	Trial 2	Trial 3	Average
0.02	5.58	5.92	5.97	5.82
0.04	6.01	5.49	5.83	5.78
0.06	5.64	5.84	5.68	5.72
0.08	5.90	5.74	5.77	5.80
0.10	5.90	5.68	5.74	5.77

2) <u>Processed Data Table</u>

Maximum Displacement (m)	Period (s)
0.02	0.582
0.04	0.578
0.06	0.572
0.08	0.580
0.10	0.577

<u>Objective 2: Testing whether mass hanging affects the period</u>

1. Materials

Spring, clamp stand, (50g, 100g, 150g, 200g, 250g) bob, meter stick, tape, stopwatch (or motion sensor application)

2. Variables

Variable Type	Variable	How it will be manipulated, measured, or controlled
Independent variable	Mass of bob	Employing different masses ranging from 50g, 100g, 150g, 200g, 250g
Dependent variable	Period	Measure the total time for 5 cycles of oscillation and divide the measured time by 5
Controlled variable	Amplitude	Prior to the experiment, determine appropriate amplitude wherein damping is kept to insignificant levels, and a sustainable amplitude is achieved throughout oscillations. The goal is to keep the initial displacement at 0.04m, but if this is found to be unsustainable, a lower amplitude will be opted for.
	Spring constant	Use the same spring
	Temperature	Experiment in the same environment

3. Procedure

1) Attach the spring to the clamp stand in a vertical position using tape
2) Place the meter stick along the clamp stand next to the spring
3) Hook the 50g bob onto the spring and secure it using tape. Allow it to stabilize to its equilibrium position (take a reading of the initial position)
4) Vertically extend the center of the 50g bob 0.04m downwards from the equilibrium position
5) Release bob and start stopwatch simultaneously
6) Measure the total time it takes for the 50g bob to oscillate 10 cycles using a stopwatch
7) Record the total time in the data table
8) Repeat steps 4 to 7 for four more trials
9) Repeat steps 4 to 8, but for successively increasing masses to 100g, 150g, 200g, 250g

4. Data Table

1) Raw Data Table

Mass of bob (kg)	Total time for 10 cycles/oscillation (s)			
	Trial 1	Trial 2	Trial 3	Average
0.05	3.65	3.33	3.38	3.45
0.10	4.75	4.56	4.30	4.54
0.15	5.47	5.78	5.87	5.71
0.20	6.92	6.13	6.73	6.59
0.25	7.11	7.36	7.45	7.31

2) Processed Data Table

Mass of bob (kg)	Period (s)
0.05	0.345
0.10	0.454
0.15	0.571
0.20	0.659
0.25	0.731

Objective 3: Finding spring constant using two methods: Hooke's law and the period of SHM

3-1: Hooke's Law Method

1. Materials

Spring, clamp stand, (50g, 100g, 150g, 200g, 250g) bob, meter stick, tape

2. Variables

Variable Type	Variable	How it will be manipulated, measured, or controlled
Independent variable	Mass of bob	Employing different masses ranging from 50g, 100g, 150g, 200g, 250g

Dependent variable	Displacement	Measure the position of the base of the spring, and measure the new position of the base once the mass is attached
Controlled variable	Spring constant	Use the same spring
	Temperature	Experiment in the same environment

3. Procedure

1) Attach the spring to the clamp stand in a vertical position using tape
2) Place the meterstick along the clamp stand next to the spring
3) Measure the position of the base of the spring
4) Record the position measured on the data table.
5) Hook the 50g bob onto the spring and secure it using tape. Allow it to stabilize to its equilibrium position
6) Measure the position of the new base of the spring
7) Record the new position measured on the data table.
8) Repeat steps 3 to 7, but for successively increasing masses to 100g, 150g, 200g, and 250g

4. Data Table

1) <u>Raw Data Table</u>

Mass of bob (kg)	Weight of the bob (N)	Position		
		Equilibrium Position (m)	New position (m)	Displacement (m)
0.05	0.49	0.05	0.065	0.015
0.10	0.98	0.05	0.093	0.043
0.15	1.47	0.05	0.120	0.070
0.20	1.96	0.05	0.150	0.100
0.25	2.45	0.05	0.180	0.130

2) Processed Data Table

Weight of the bob (N)	Displacement (m)
0.49	0.015
0.98	0.043
1.47	0.070
1.96	0.100
2.45	0.130

3-2: Period of SHM Method

1. Materials

Spring, clamp stand, (50g, 100g, 150g, 200g, 250g) bob, meter stick, tape, stopwatch (or motion sensor application)

2. Variables

Variable Type	**Variable**	**How it will be manipulated, measured, or controlled**
Independent variable	Mass of bob	Employing different masses ranging from 50g, 100g, 150g, 200g, 250g
Dependent variable	Period	Measure the total time for 5 cycles of oscillation and divide the measured time by 5
Controlled variable	Amplitude	Prior to the experiment, determine appropriate amplitude wherein damping is kept to insignificant levels and a sustainable amplitude is achieved throughout oscillations. The goal is to keep the initial displacement at 0.04m, but if this is found to be unsustainable, a lower amplitude will be opted for.
	Spring constant	Use the same spring
	Temperature	Experiment in the same environment

3. Procedure

1) Attach the spring to the clamp stand in a vertical position using tape
2) Place the meter stick along the clamp stand next to the spring
3) Hook the 50g bob onto the spring and secure it using tape.
4) Vertically extend the center of the 50g bob 0.04m downwards from the equilibrium position
5) Release bob and start stopwatch simultaneously
6) Measure the total time it takes for the 50g bob to oscillate 10 cycles using a stopwatch
7) Record the total time in the data table
8) Repeat steps 4 to 7 for four more trials
9) Repeat steps 4 to 8, but for successively increasing masses to 100g, 150g, 200g, 250g

4. Data Table

1) Raw Data Table

Mass of bob (kg)	Total time for 10 cycles/oscillation (s)			
	Trial 1	Trial 2	Trial 3	Average
0.05	3.65	3.33	3.38	3.45
0.10	4.75	4.56	4.30	4.54
0.15	5.47	5.78	5.87	5.71
0.20	6.92	6.13	6.73	6.59
0.25	7.11	7.36	7.45	7.31

2) Processed Data Table

Mass of bob (kg)	Period (s)	$(\text{Period})^2$ (s^2)
0.05	0.345	0.119
0.10	0.454	0.206
0.15	0.571	0.326
0.20	0.659	0.434
0.25	0.731	0.534

Day 2 & 3: Data collection & Analysis (Electronic copy)

1. Check your data table with me

    Checked.

2. Collect data

a. If you changed any part of your procedure, make the change on the paper

    Revision completed.

b. Fill out the data table that you printed

    Data table filled above in Part 1.

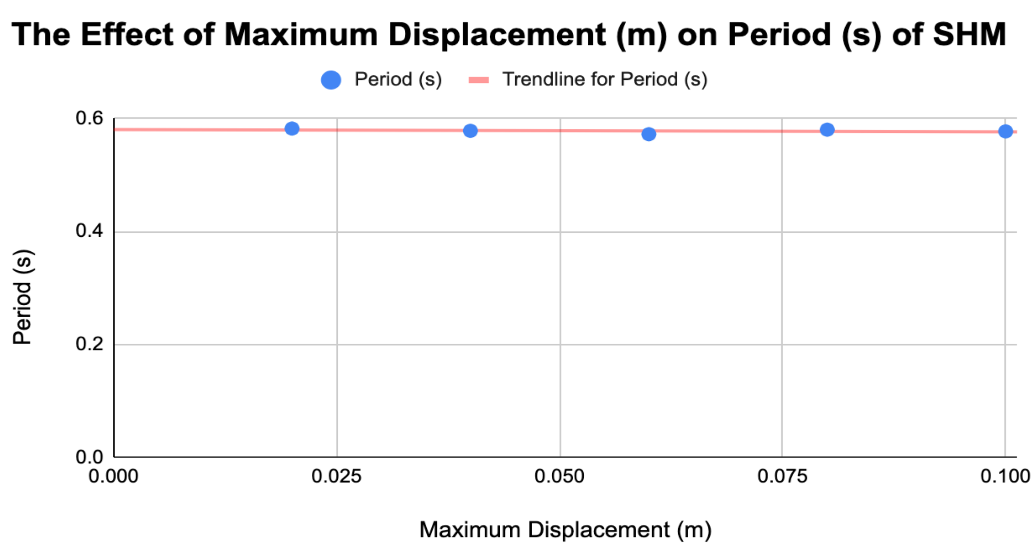
3. Start analyzing the data using graphs and/or calculations
(Write sample calculations where necessary) Analysis written below

Objective 1 Analysis

1) Processed (Calculated) Data Table from Part 1

Maximum Displacement (m)	Period (s)
0.02	0.582
0.04	0.578
0.06	0.572
0.08	0.580
0.10	0.577

2) Graph Dervied by Processed (Calculated) Data Table



3) Analysis from Data and Graph

Considering the processed data calculated from the raw data derived from the lab experiment in part 1, the period (s) of the vertical spring's simple harmonic motion is unaffected by the maximum displacement (m), as the value of the period is fairly constant while the maximum displacement, or amplitude, is increased as an independent variable.

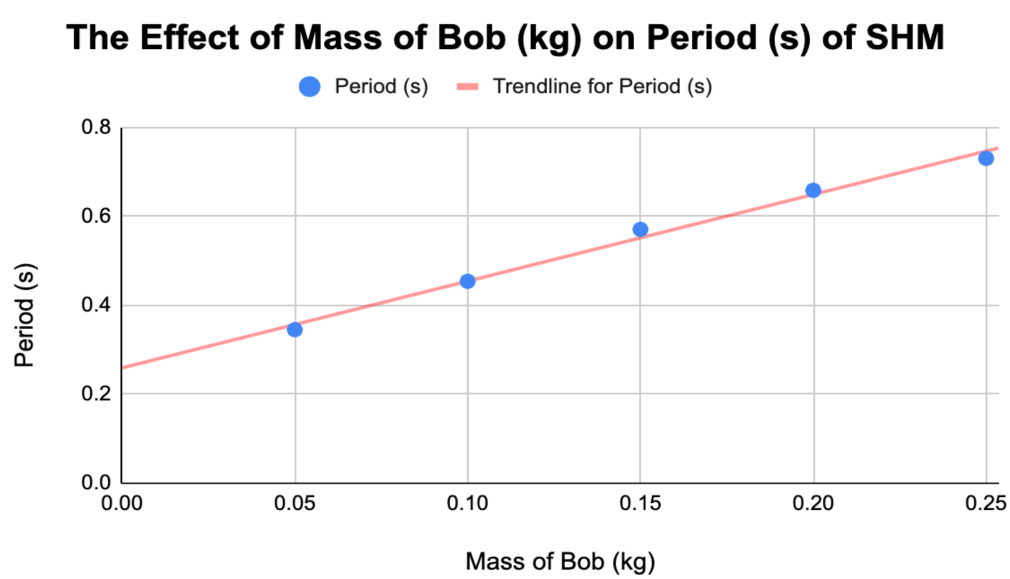
The graph derived from the processed (calculated) data of the lab experiment also shows a horizontal trendline, which represents the fact that the period (s) of the simple harmonic motion is constant regardless of the change of the maximum displacement (m). Therefore, the lab experiment clearly demonstrates that the maximum displacement does not affect the period of simple harmonic motion, disproving objective 1.

Objective 2 Analysis

1) Processed (Calculated) Data Table from Part 1

Mass of bob (kg)	Period (s)
0.05	0.345
0.10	0.454
0.15	0.571
0.20	0.659
0.25	0.731

2) Graph Dervied by Processed (Calculated) Data Table



3) Analysis from Data and Graph

Considering the processed data calculated from the raw data derived from the lab experiment in part 1, the period (s) of the vertical spring's simple harmonic motion is affected by the mass of the bob (kg). It is because the value of the period increases as the mass of the bob is increased as an independent variable throughout the experiment.

The graph derived from the processed (calculated) data of the lab experiment also shows a linear trendline. The period (s) of the simple harmonic motion increases while the mass of bob (kg) increases, which means that the mass of bob (kg) and the period (s) of the simple harmonic motion has a proportional relationship to each other. Therefore, the lab experiment clearly demonstrates that the mass of the object does affect the period of simple harmonic motion, eventually proving objective 2.

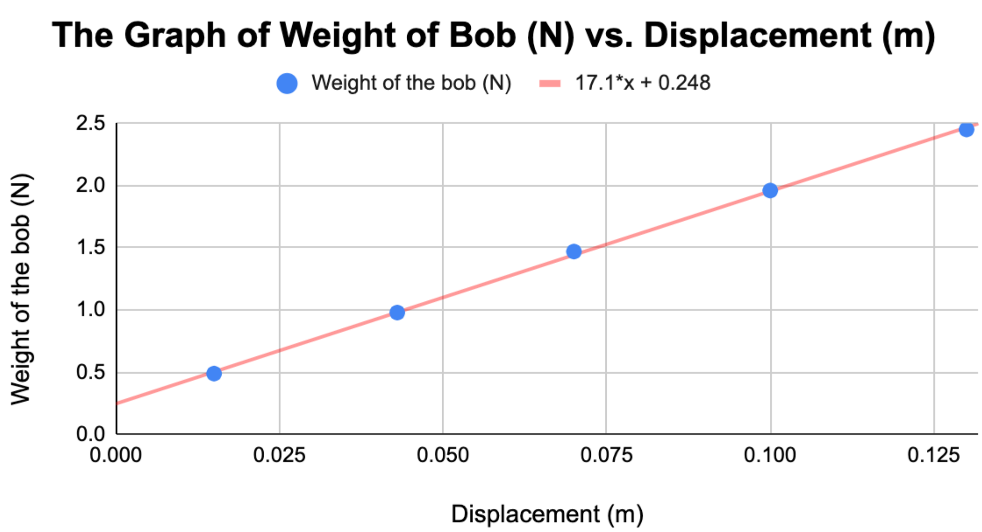
Objective 3 Analysis

3-1 Analysis) Finding Spring Constant using Hooke's Law

1) Processed (Calculated) Data Table from Part 1

Weight of the bob (N)	Displacement (m)
0.49	0.015
0.98	0.043
1.47	0.070
1.96	0.100
2.45	0.130

2) Graph Derived by Processed (Calculated) Data Table



3) Calculation & Analysis

Hooke's Law Formula: $F = - kx$ (F: force, k: spring constant, x: displacement)

If mass is hanged on vertical spring, then the formula could be changed as below:
$mg = - kx$ (m: mass of bob, g: gravitational field strength)

Disregarding the minus sign since it only represents direction, mg is the weight of the bob (N) and x is the displacement (m).

Therefore, graphing the weight of bob (N), mg, in the y-axis, and the displacement (m), x, in the x-axis would derive a linear graph that has a slope value equal to the spring constant k.

According to the graph above, the slope is 17.1. Therefore, the spring constant k is $17.1\ N/m$.

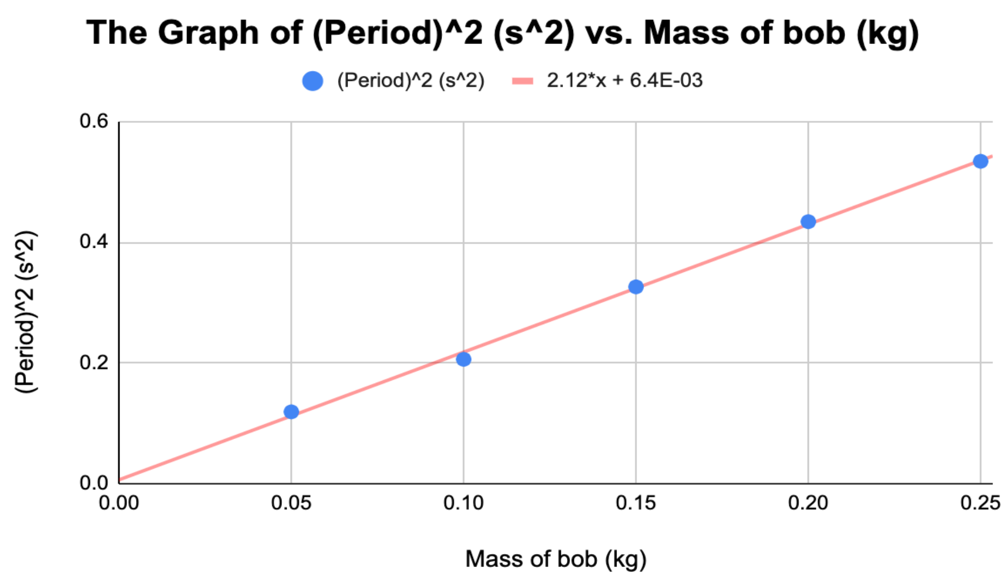
Objective 3-1 Result: $k = 17.1\ N/m$

3-2 Analysis) Finding Spring Constant using Period of Simple Harmonic Motion

1) Processed (Calculated) Data Table from Part 1

Mass of bob (kg)	Period (s)	$(\text{Period})^2$ (s^2)
0.05	0.345	0.119
0.10	0.454	0.206
0.15	0.571	0.326
0.20	0.659	0.434
0.25	0.731	0.534

2) Graph Derived by Processed (Calculated) Data Table



3) Calculation & Analysis

Period of a Spring in Simple Harmonic Motion Formula: $T = 2\pi\sqrt{\frac{m}{k}}$

(T: period, m: mass of bob, k: spring constant)

If both sides of the formula above is squared, the equation is $T^2 = \frac{4\pi^2 m}{k}$.

Graphing the square of the period (s), T^2, in the y-axis and the mass of bob (kg), m, in the x-axis would derive a linear graph. Its slope would have a value equal to $\frac{4\pi^2}{k}$ referring to the formula above.

Assessing the variable s for the slope of the graph, the equation could be written as $s = \frac{4\pi^2}{k}$.

Finally, the equation could be organized as the following:

$k = \frac{4\pi^2}{s}$.

According to the graph above, the slope is 2.12. Therefore, the spring constant k is

$\frac{4\pi^2}{s} = \frac{4\pi^2}{2.12} = 18.6\ N/m$.

Objective 3-2 Result: $k = 18.6\ N/m$

4. Write 3 sources of error in point form

As a result, our group has set the experiments in order to find the effect of both amplitude and mass on period. Even though we kept changing our independent variables, such as maximum vertical displacement and mass, and repeated three trials for each independent variable to derive the average values with reduced error, the following minor sources of error were unavoidable:

1) Stretching the spring in accurate length (Human Error)

When setting the maximum vertical displacement in objectives 1, 2, and 3, we had to hold the meterstick by our hands to measure the specific lengths for the experiments. However, the meterstick was slightly tilted, and it frequently moved back and forth while measuring due to the tremor in our hands. In addition, the human eye cannot perfectly see the units on the meterstick, so the length of the stretched spring might have been slightly different for each experiment. The mistake in measuring the vertical displacement from the equilibrium position might have been critical because it could affect the result of every objective due to inaccurate measurements.

2) Error in time measurement due to human reaction time (Human Error)

When measuring the time to derive the period for objectives 1, 2, and 3-2, there would have been some errors regarding the measured time values since it is impossible to measure the exact time for ten cycles of spring oscillations due to human reaction time. Although we conducted multiple trials for each condition during the lab experiment to reduce these sorts of errors, it is impossible to completely eliminate these human errors as we used a manually-controlled stopwatch to measure the time values. Therefore, the error in time measurement due to human reaction time could be one source of error that might have derived an inaccurate measurement and result, especially in objective 3-2, where we had to find the exact value of the spring constant.

3) The spring-mass system does not oscillate completely vertically (Systematic Error)

When measuring the period or the displacement of the spring-mass system for objectives 1, 2, and 3, the spring did not oscillate completely vertically, and this might have affected the results of the experiment as a systematic error. Although our group members stretched the spring initially as vertically as possible and attached the spring and bob tightly to reduce this error, it is unlikely that the initial swing started completely perpendicular to the bottom of the clamp. Also, as the spring oscillated, it swung not only up and down but also slightly sideways on the left and right. This phenomenon might have led to more energy dissipation of the system than expected and might also have affected the period measurement throughout the experiments. Therefore, the fact that the spring-mass system did not oscillate completely vertically might have been a possible source of error in our lab.