Physics 1D03: Lab 1

SIMPLE AND PHYSICAL PENDULUMS

Lab Objectives

- Understand the theory behind a simple and physical pendulum.
- Determine uncertainties in the lab and propagate uncertainties for multivariable equations.
- Expose oneself to Microsoft Excel and spreadsheet software.
- Experimentally determine the period of a simple pendulum with a variable length and angle.
- Justify the experimental results of the simple pendulum with theoretical predictions through the analysis of the gravitational constant g.
- Experimentally examine the behavior of a physical pendulum with Capstone software.

Equipment

Physical Pendulum using PASCO Capstone Software

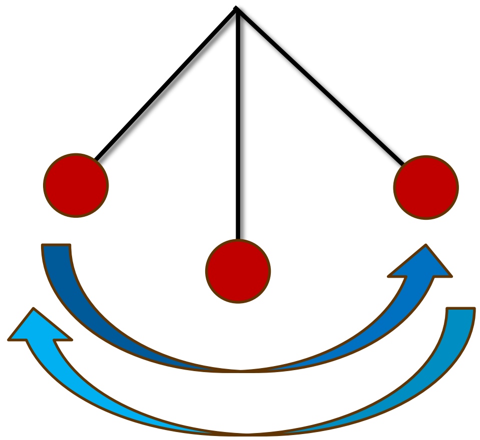
Simple Pendulum (heavy mass on string)

Stop-Watch, protractor, and ruler

Part 1: The Simple Pendulum
Part A

Part A: Preliminary Study

- We first want to understand what the uncertainties in our experiment are
- Start by setting the length of the pendulum to 10cm
- You and a partner will take turns releasing the pendulum and timing how long it takes for the mass to swing 1, 5, and 10 times
  - Record the times and period in your report ***with uncertainties***
  - ***Make sure to have a TA come and check your answers***

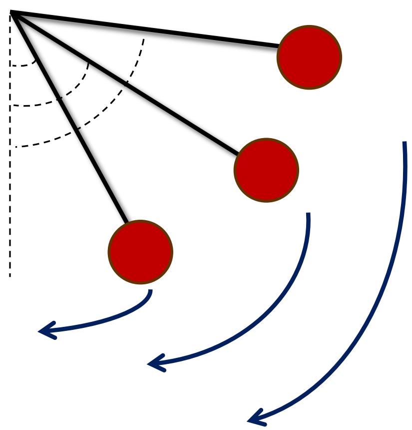


- How do you think the uncertainty in your recorded time relates to the uncertainty of a single swing?

Part 1: The Simple Pendulum
Part B

Part B: Variation with Amplitude

- We now want to see how changing the amplitude of the pendulum affects the period
- Pick a convenient length to set the pendulum at to measure 10 swings
- Measure the time for a small amplitude (~5^o) and record your results
  - Repeat for 5 more angles varying between 5^o and 60^o
- Using Excel, you can plot the results for T vs. θ

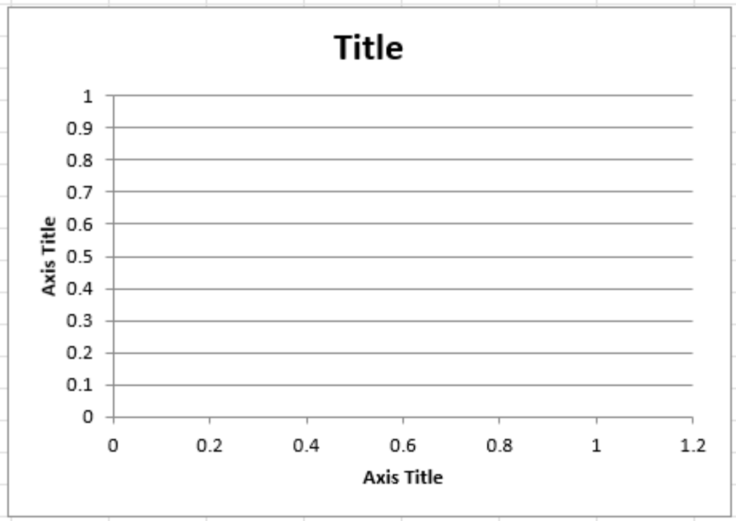


Part B: Variation with Amplitude

Error in time for 10 Swings (s)	Error in Period δT (s)
	0

Amplitude (degrees)	Time for 10 Swings ( )	Period ( )
		0
		0
		0
		0
		0
		0

Input data in these boxed

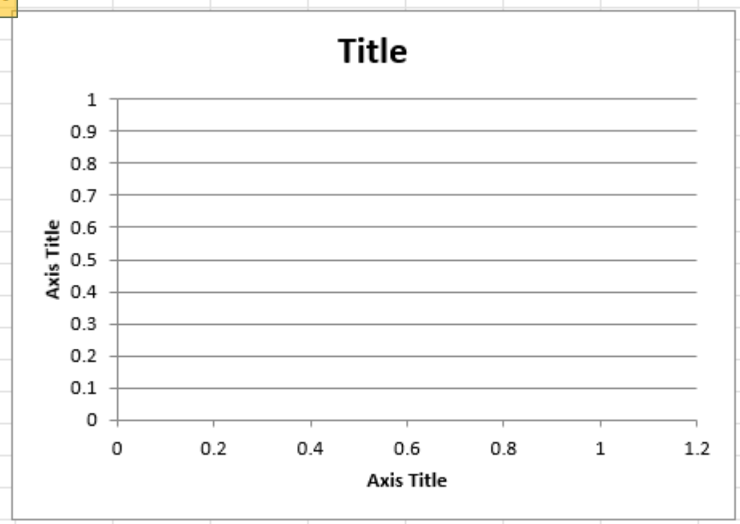


Part B: Variation with Amplitude

Error in time for 10 Swings (s)	Error in Period δT (s)
	0

Amplitude (degrees)	Time for 10 Swings ( )	Period ( )
		0
		0
		0
		0
		0
		0

Results will automatically be calculated here

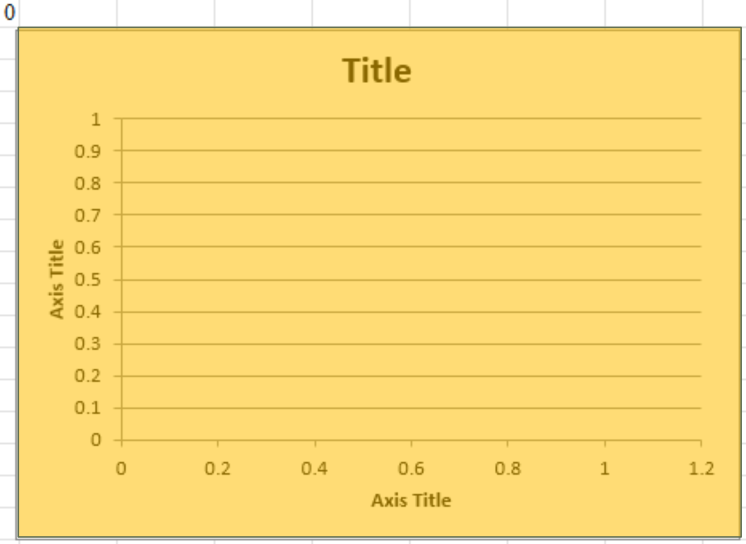


Part B: Variation with Amplitude

Error in time for 10 Swings (s)	Error in Period δT (s)
	0

Amplitude (degrees)	Time for 10 Swings ( )	Period ( )
		0
		0
		0
		0
		0
		0

Plot appears here
(Make sure to properly label/scale your plot, then copy-paste it into your report)



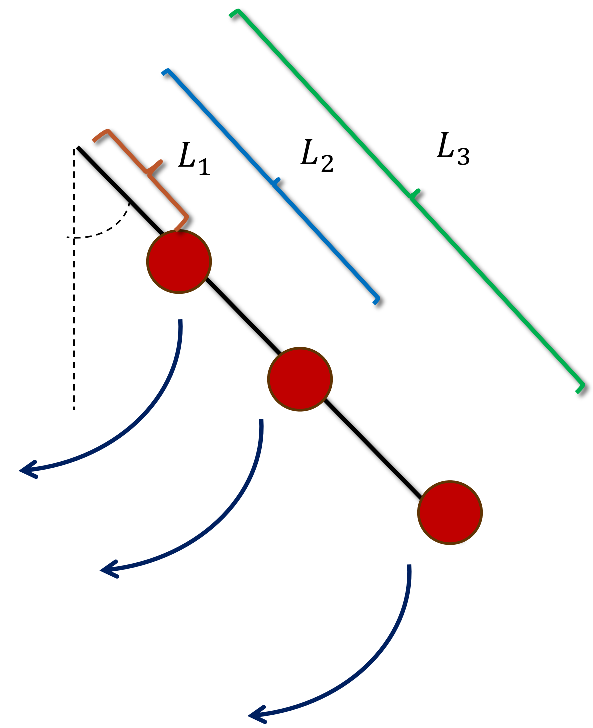
Part 1: The Simple Pendulum
Part C

Part C: Variation with Length

- Goal is to calculate the gravitational constant g using two methods

Method 1)

- Select a convenient angle to swing the pendulum
- Set the length of the string to 10cm and measure the time for 10 swings
  - Record your results and calculate the period
  - Repeat for 4 **more evenly spaced** lengths (for a total of 5), varying between 10cm and 80cm



Part C: Variation with Length

- Calculate T^2 (period squared) and g (gravitational constant) **only using the first set of measurements (ie. only the data from the 10cm run)**

$$g = \frac{4\pi^2 l}{T^2}$$

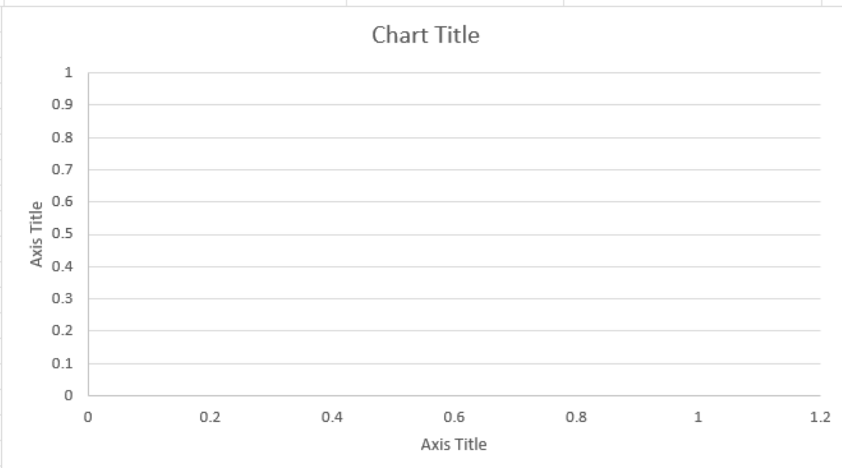
- Then find the equations that calculate the uncertainties for the period squared and gravitational constant , $\delta(T^2)$ and $\delta(g)$
  - Remember to use your error propagation rules here!
- Use these equations to calculate the uncertainties in T^2 and g again using the first set of measurements only

- We can now use Excel to compare our answer

Part C: Variation with Length

Error in length (cm)	Error for Time of 10 swings (s)	Error in Period δT (s)

Length *l* (cm)	Time for 10 swings (s)	Period *T* (s)	Period Squared T^2 (s^2)	Error in T^2 (s^2)	Gravitational constant *g* (m/s^2)	Error in Gravitational constant δg (m/s^2)
		0	0	0	#DIV/0!	#DIV/0!
		0	0	0	#DIV/0!	#DIV/0!
		0	0	0	#DIV/0!	#DIV/0!
		0	0	0	#DIV/0!	#DIV/0!
		0	0	0	#DIV/0!	#DIV/0!
					Average g:	Average δg:
					#DIV/0!	#DIV/0!

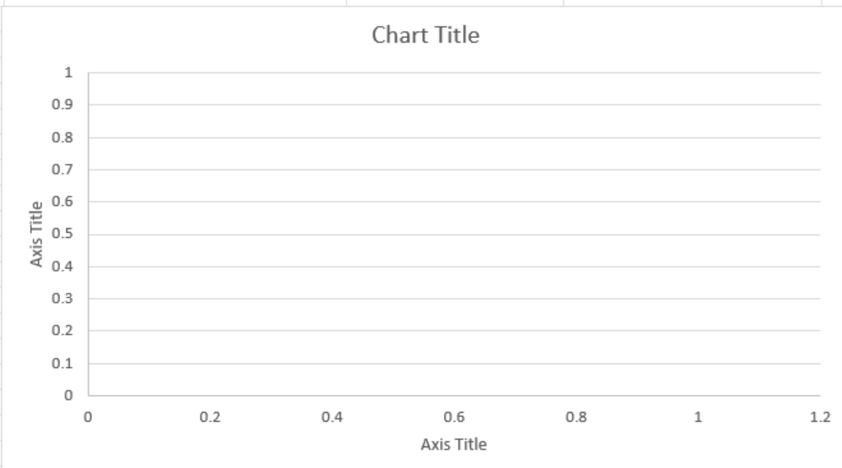


Input data in these boxed

Part C: Variation with Length

Error in length (cm)	Error for Time of 10 swings (s)	Error in Period δT (s)

Length *l* (cm)	Time for 10 swings (s)	Period *T* (s)	Period Squared T^2 (s^2)	Error in T^2 (s^2)	Gravitational constant *g* (m/s^2)	Error in Gravitational constant δg (m/s^2)
		0	0	0	#DIV/0!	#DIV/0!
		0	0	0	#DIV/0!	#DIV/0!
		0	0	0	#DIV/0!	#DIV/0!
		0	0	0	#DIV/0!	#DIV/0!
		0	0	0	#DIV/0!	#DIV/0!
					Average g:	Average δg:
					#DIV/0!	#DIV/0!

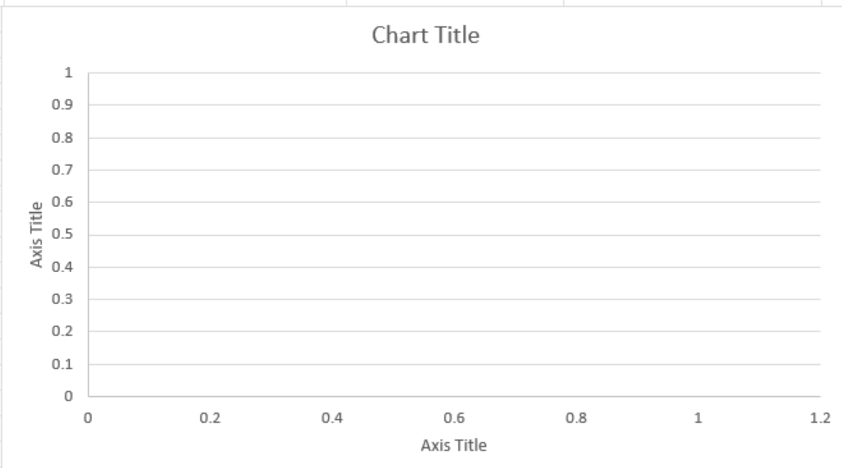


Results will automatically be calculated here

Part C: Variation with Length

Error in length (cm)	Error for Time of 10 swings (s)	Error in Period δT (s)

Length *l* (cm)	Time for 10 swings (s)	Period *T* (s)	Period Squared T^2 (s^2)	Error in T^2 (s^2)	Gravitational constant *g* (m/s^2)	Error in Gravitational constant δg (m/s^2)
		0	0	0	#DIV/0!	#DIV/0!
		0	0	0	#DIV/0!	#DIV/0!
		0	0	0	#DIV/0!	#DIV/0!
		0	0	0	#DIV/0!	#DIV/0!
		0	0	0	#DIV/0!	#DIV/0!
					Average g:	Average δg:
					#DIV/0!	#DIV/0!



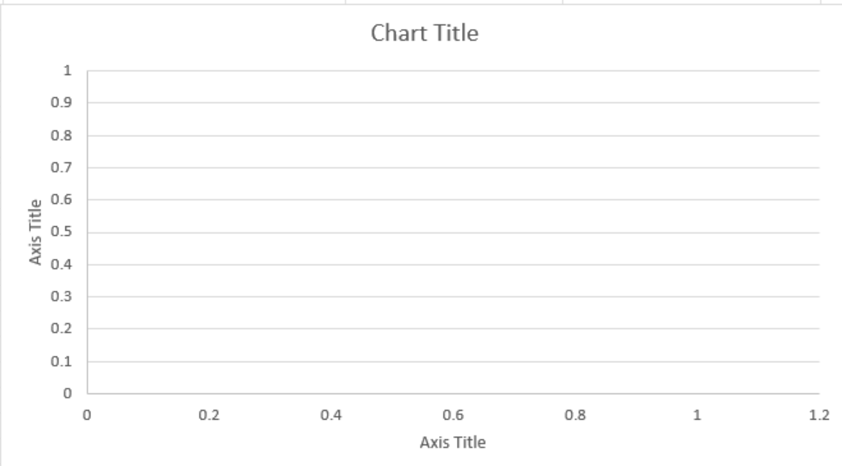
<u>Before continuing, make sure your calculations for the uncertainties agree with what Excel has!**</u>**

Have a TA come and check your calculations before moving forward.

Part C: Variation with Length

Error in length (cm)	Error for Time of 10 swings (s)	Error in Period δT (s)

Length *l* (cm)	Time for 10 swings (s)	Period *T* (s)	Period Squared T^2 (s^2)	Error in T^2 (s^2)	Gravitational constant *g* (m/s^2)	Error in Gravitational constant δg (m/s^2)
		0	0	0	#DIV/0!	#DIV/0!
		0	0	0	#DIV/0!	#DIV/0!
		0	0	0	#DIV/0!	#DIV/0!
		0	0	0	#DIV/0!	#DIV/0!
		0	0	0	#DIV/0!	#DIV/0!
					Average g:	Average δg:
					#DIV/0!	#DIV/0!



This average value of g is how we will determine the gravitational constant from our first method. Record this, and its uncertainty, in the report.

Part C: Variation with Length

- We can also calculate g using another approach

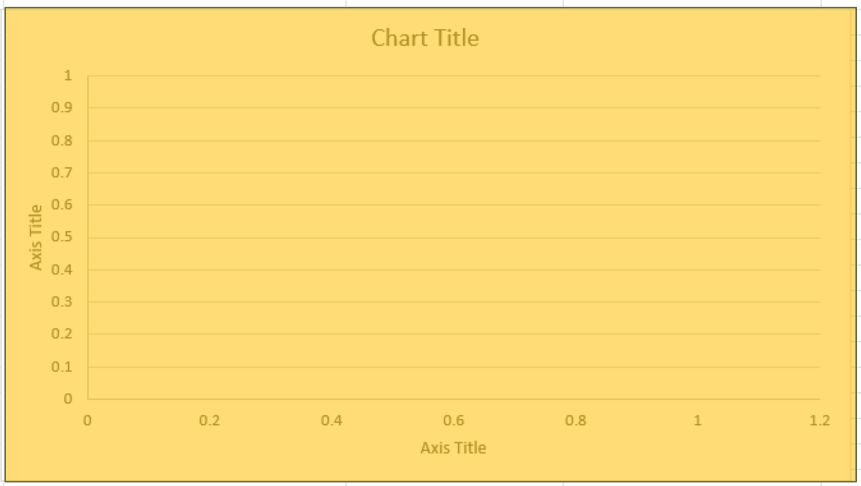
<u>Method 2)</u>

- Based off the collected data, we can plot the results on a "T^2 vs. length" graph and examine the line of best fit
- The Excel spreadsheet will automatically make the plot once you enter all your data
  - You will need to include a trendline for your graph
  - Instructions for doing so will be on the manual

Part C: Variation with Length

Error in length (cm)	Error for Time of 10 swings (s)	Error in Period δT (s)

Length l (cm)	Time for 10 swings (s)	Period T (s)	Period Squared T^2 (s^2)	Error in T^2 (s^2)	Gravitational constant g (m/s^2)	Error in Gravitational constant δg (m/s^2)
		0	0	0	#DIV/0!	#DIV/0!
		0	0	0	#DIV/0!	#DIV/0!
		0	0	0	#DIV/0!	#DIV/0!
		0	0	0	#DIV/0!	#DIV/0!
		0	0	0	#DIV/0!	#DIV/0!
					Average g:	Average δg:
					#DIV/0!	#DIV/0!



Plot for T^2 vs. length will appear here
(Properly label/scale your plot, then copy-paste it into your report)

Part C: Variation with Length

- The trendline would give you an equation of the form

$$T^2 = ml + b$$

Where m is the slope and b is the intercept

- Comparing with the equation

$$T^2 = \frac{4\pi^2}{g} l$$

We see that

$$slope\ for\ line\ of\ best\ fit = \frac{4\pi^2}{g}$$

- Solving for g this way will give us another way to find the gravitational constant

Part 2: The Physical Pendulum

Part 2: Physical Pendulum

- First check the pendulum bar is attached to the sensor using the hole at the end (see picture)
- Open the PASCO software on the desktop and create an "Angle (rad) vs. Time" plot
- Measure an angle of 15^{o} with the pendulum and start recording
- Release the pendulum and let it swing at least 15 times

Part 2: Physical Pendulum

- Using the PASCO software, find the time it took the pendulum to oscillate 10 times
- Calculate the period and record the results in your report **<u>with uncertainties</u>**
  - Hint: Would your uncertainties be the same in this case? What was causing the uncertainty in Part 1 of the experiment and is it the same here?

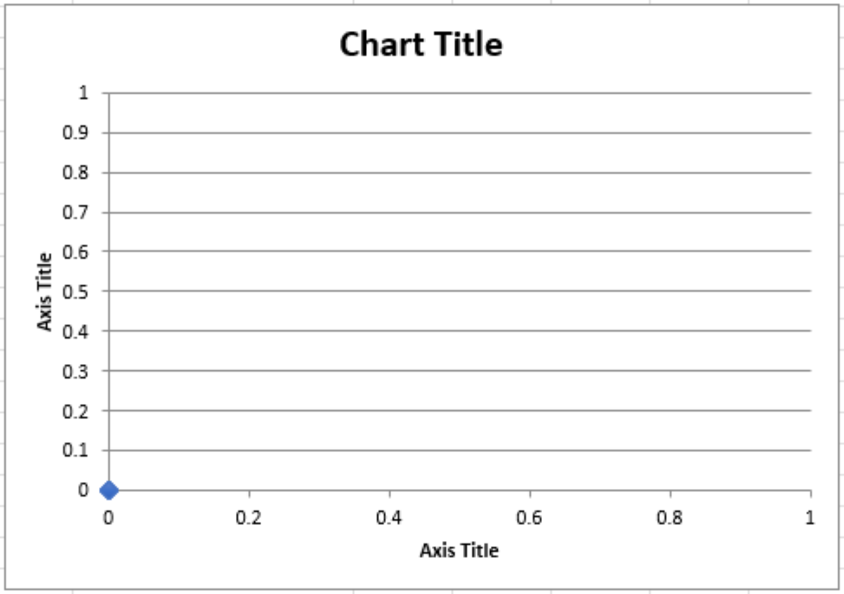
- Once done, move to the next hole of the pendulum bar and repeat the previous steps (see picture) for a total of 7 runs

Part 2: Physical Pendulum

Error in time ( )	Error in Period δT ( )	Length ( )	Distance between holes ( )	
				<input data here, and distance to centre of mass will automatically be filled

n	Distance to centre of mass ( )	Time for 10 swings ( )	Period T ( )
0	0		0
1	0		0
2	0		0
3	0		0
4	0		0
5	0		0
6	0		0

Input data in these boxed



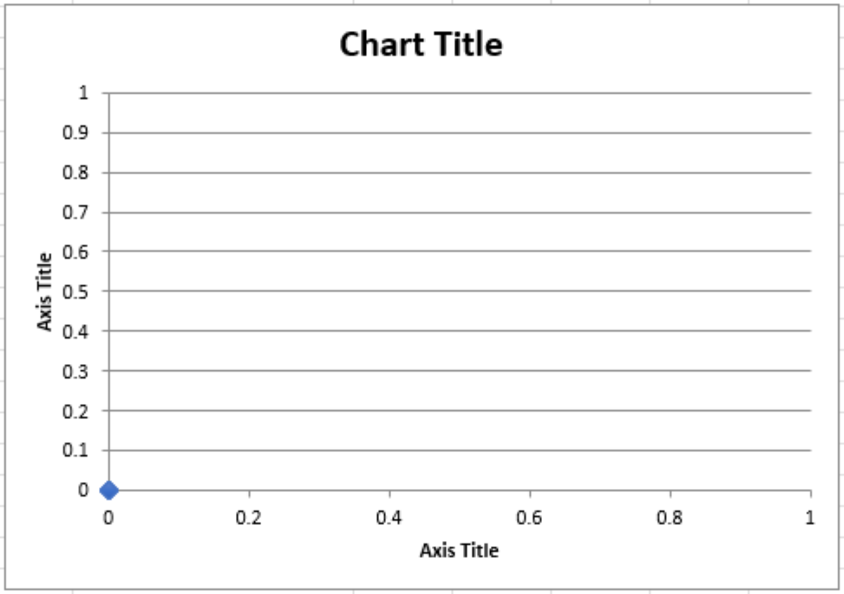
Part 2: Physical Pendulum

Error in time ( )	Error in Period δT ( )	Length ( )	Distance between holes ( )

<input data here, and distance to centre of mass will automatically be filled

n	Distance to centre of mass ( )	Time for 10 swings ( )	Period T ( )
0	0		0
1	0		0
2	0		0
3	0		0
4	0		0
5	0		0
6	0		0

Results will automatically be calculated here

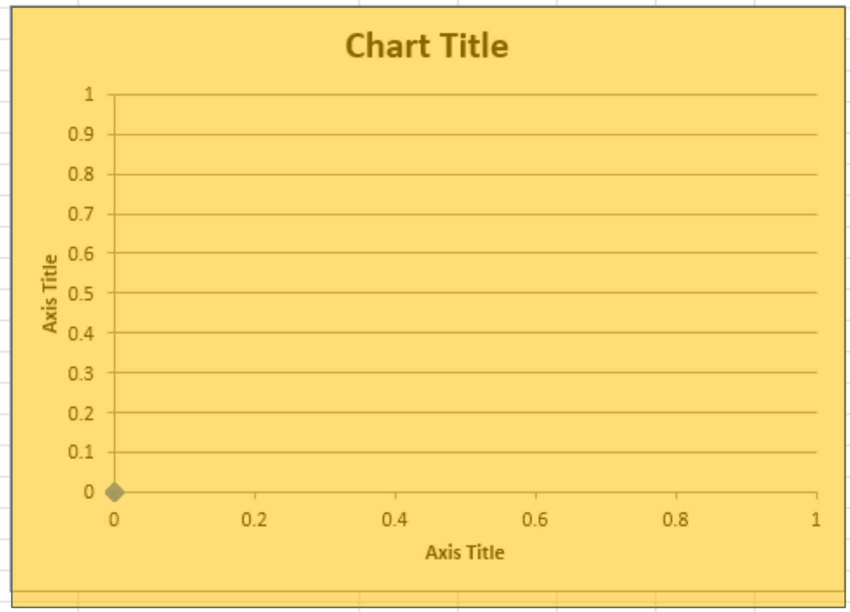


Part 2: Physical Pendulum

Error in time ( )	Error in Period δT ( )	Length ( )	Distance between holes ( )	
				<input data here, and distance to centre of mass will automatically be filled

n	Distance to centre of mass ( )	Time for 10 swings ( )	Period T ( )
0	0		0
1	0		0
2	0		0
3	0		0
4	0		0
5	0		0
6	0		0

Plot for 'Period' vs. 'Distance from Center of Mass' appears here
(Remember to label/rescale then copy-paste it into your report)



Good Luck!