Student's Name: ________________________________ Student's Name: ________________________________

Lab day & time: ____________________ Date: ___________________

Pendulum (M9) - Data Sheets

(Show all calculations and write all results on the data sheets in ink)

Activity 1: Simple Pendulum *(2x1 p.= 2 p.)*

Part A. *Be sure to fill-in the correct units in the space provided:* (   )

Use the short black rod with the brass mass attached.

Length of the rod from the axis of rotation to the center of the brass cylinder:

L = __________ (   )

Time of first maximum (or minimum) on the time scale _________ (   )

Time of the maximum (or minimum) after ten periods __________ (   )

The average period of oscillations: T_{AV} = _____________ (   )

Print a copy of this graph. Find the selected maximum (or minimum) points on the printout and clearly mark these points with a pen (for example, circle them).

Part B. *Be sure to fill-in the correct units in the space provided:* (   )

In this part, we will use the average period of oscillations T_{AV} measured in Part A to calculate the acceleration due to gravity g_{exp} and to estimate the mass of the Earth.

The motion of the short black rod with brass cylinder attached can be described by the simple pendulum with period of oscillations given by equation (2) in the Theory section. We can rewrite the equation (2) to calculate the experimental value of g.

$$T = 2\pi\sqrt{\frac{L}{g}} \quad \Rightarrow \quad g_{\exp} = 4\pi^2 \frac{L}{T^2}$$

Next, use the length of your pendulum L from Part A and the average period of oscillations T_{AV} to calculate the acceleration due to gravity.

g_{exp} = _____________ (m/s^2)

Calculate the percent difference Δg between the measured value of the acceleration g_{exp} and the average, also known as the standard gravity value $g = 9.806$ m/s^2 .

$\Delta g = 100\%*|(g_{exp} - g)/ g| =$ _____________ (%)

Next, use the measured acceleration g_{exp} to estimate the mass of the Earth: M_{Earth}.

The acceleration due to gravity can also be written as:

$$g_{\exp} = G\frac{M_{Earth}}{r^2} \quad \Rightarrow \quad M_{Earth} = \frac{g_{\exp} * r^2}{G}$$

The mean radius of the Earth is approximately equal to $r = 6.37*10^6$ m and the universal gravitational constant G is equal to $G = 6.67*10^{-11}$ N*m^2/kg^2.

Calculate the approximate mass of the Earth.

$M_{Earth} =$ ______________ (kg)

Activity 2: Damped Pendulum *(1.5 p.)*

Wrap the rubber O-ring around the pulley and the metal rod as shown in Figure 3.

In the data table below, do <u>not write in the grayed</u> cells. Record the first five amplitude values for the damped pendulum.

Amplitude number n	Angular position amplitudes A_n ( )	Ratio of consecutive amplitudes squared $(A_{n+1}/A_n)^2$
1		
2		
3		
4		

5		
Average:		

Calculate the ratio of the two consecutive amplitudes squared = $(A_{n+1}/A_n)^2$. Next, calculate the average ratio of two consecutive amplitudes.

In the harmonic motion the energy of oscillations is proportional to the amplitude oscillations squared. Therefore, the average ratio of two consecutive values of energy is equal to:

$$\left(\frac{E_{n+1}}{E_n}\right)_{AV} = \left(\frac{A_{n+1}}{A_n}\right)^2_{AV} = = \_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

What percentage of the energy is lost during each period of oscillations? (use the above average value of the $\left(\frac{E_{n+1}}{E_n}\right)_{AV}$ ratio)

$$\left(\frac{E_n - E_{n+1}}{E_n}\right)_{AV} \times 100\% = \left(1 - \left(\frac{E_{n+1}}{E_n}\right)_{AV}\right) \times 100\% = \_\_\_\_\_\_\_\_\_\_\_\_\_\_ \ (\ \%\ )$$

Activity 3: Physical Pendulum *(1 p.)*

In this Activity we use the **blue rod <u>without</u> any brass cylinders attached**.

Length of the blue rod from axis of rotation to the end of the rod:

$L =$ ____________ (   )

Average value of the period of oscillations:

$T_{AV} =$ ______________ (   )

Calculate the theoretical value of the period using the <u>physical pendulum</u> equation (3). Show your work! (*use four significant figures*)

$T_{physical}$ = ________________ (   )

Calculate the theoretical value of the period using the measured length of the blue rod and the <u>physical pendulum</u> equation (3) from the Theory section. Use g = 9.80 m/s^2.

Calculate the percent difference between experimental value and the theoretical value of the period: Show your work.

$\Delta T = 100\%*|(T_{AV} - T_{physical})/ T_{physical}|$ = ___________ (%)

Using the same length of the blue rod pendulum L as you did for the calculation of the physical pendulum $T_{physical}$, calculate the theoretical value of the period T_{simple} using the <u>simple pendulum</u> equation (2). The simple pendulum model does not work for this type of pendulum with mass of the pendulum evenly distributed along the rod instead of being concentrated in one end of the pendulum. You should see a much larger difference between the experimental data (T_{AV}) and the theoretical prediction of the simple pendulum model, than that for the physical pendulum calculation. Use g = 9.80 m/s^2.

T_{simple} = ________________ (   )

$\Delta T = 100\%*|(T_{AV} - T_{simple})/ T_{simple}|$ = ____________ (%)

Which of the two theoretical models (simple pendulum and physical pendulum) describes the motion of a solid rod with better accuracy?

____

Remove the blue rod from the pendulum and re-attach the short, black rod back.

Complete the lab report and return it to the lab TA.