SAN DIEGO MESA COLLEGE Name:______________________________

PHYSICS 195 LAB REPORT Date:________________Time:_______

TITLE: Oscillations Partners:______________________________

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Objective:

To study the interaction of the conservative forces produced by gravity and a spring acting upon mass, and to relate the period of oscillation to the inertial (mass) and elastic (spring) properties of the system.

Theory:

Hooke's law for a spring states that the magnitude of the applied force (F) exerted by a spring is related to the extension or stretch (x) that the spring has undergone by the equation:

$$(1)\ \boldsymbol{F = kx}$$

where k is called the spring constant.

A force can be applied to a vertical spring by hanging a mass m from it. The attached mass now causes the equilibrium length of the spring to increase. At this new equilibrium position, the spring has now been stretched a distance x down from its initial, unstretched position. When the system is in equilibrium Hooke's law then becomes:

$$F = ma \rightarrow mg = kx$$

A plot of weight versus stretch length yields a straight line with slope equal to k. When a mass m is attached to a horizontal spring, the system oscillates with a period T given by

$$(2)\ T = 2\pi\sqrt{\frac{m}{k}}$$

If the spring is vertically orientated and the mass m is hanging from it, the period of oscillation is given by the same expression, with the center of oscillation situated at the new equilibrium position.

Objective II:

To test the equation for the period of a torsion oscillator by using it to calculate the rotational inertia of a uniform plate and hollow cylinder. To determine empirically whether the theoretical relationship between the period and the diameter of a thin ring physical pendulum is correct.

Theory:

$$\textit{Torsion pendulum}: \quad \tau = -\kappa\theta \qquad \omega = \sqrt{\frac{\kappa}{I}} \qquad T = 2\pi\sqrt{\frac{I}{\kappa}}$$

$$T_{physical\ pendulum} = 2\pi\sqrt{\frac{I}{Mgd}}$$

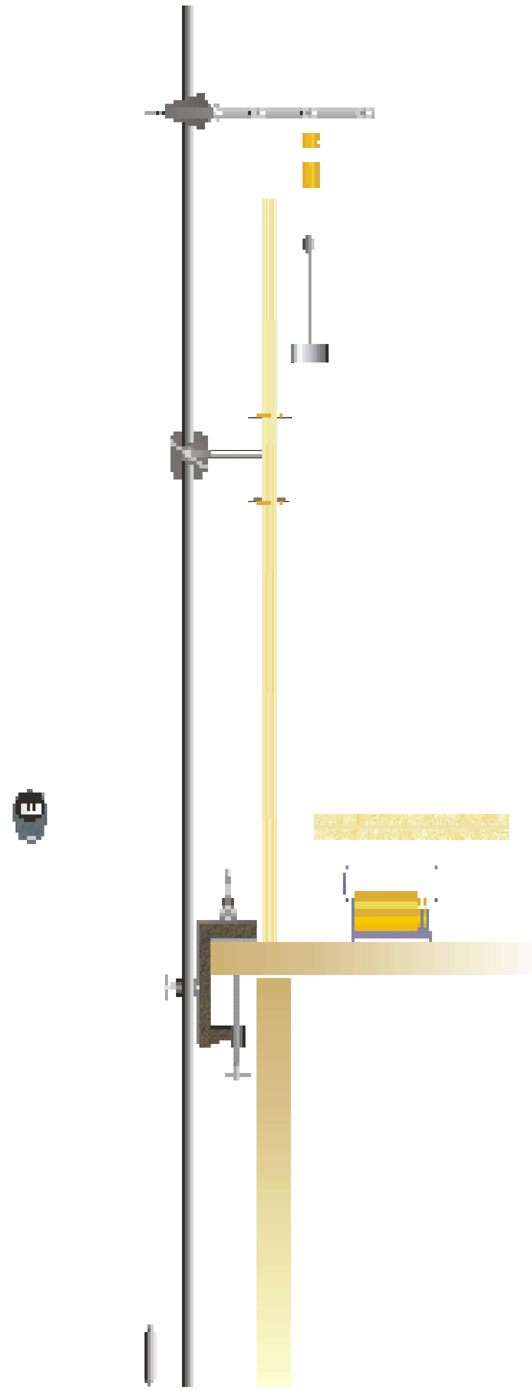
Equipment:

Torsion Rods	Steel Plate & Hollow Cylinder
Mass Set	Timer
Set of Ring Pendula	Table "V" clamp
Right-angle clamp	Plumb bob
2 meter rod	Meter stick
Pendulum clamp	Telescope holder
Springs	Mass hanger

Part I:

Determination of the Spring Constant

1. Record the location of the bottom of the spring relative to the scale on the meter stick. The meter stick can be repositioned by sliding it up in the "telescope holder" **and/or** you can adjust the height of the "pendulum clamp". Once you have the bottom of the spring positioned at a convenient spot on the meter stick scale, **don't change it**! Consider this to be x = 0 meters.
2. Hang the mass hanger from the spring. Record the position of the bottom of the hanger in your data table.
3. Add a 50g mass to the hanger, wait for it to stop moving and record the new position. Repeat this four more times.
4. Plot weight as a function of displacement and determine the spring constant k *Hint: Units!*



Part II:

Testing the Period of a Spring-Mass System

1. Determine the mass of your spring by placing it on the digital scale.
2. Place a 150g mass on the hanger to extend the spring.
3. Pull down on the hanger a small amount (~ 2 to 3cm) and release it. Record the time it takes to complete 10 oscillations. Repeat three times to get an average. Then determine the period.

Data: Part I: Calculation of the spring constant k

Mass on spring (kg)	Weight = mg (N)	x (m)
1. 0.05 kg (just the mass hanger)		
2. 0.10 kg		
3. 0.15 kg		
4. 0.20 kg		
5. 0.25 kg		
6. 0.30 kg		

Show a sample calculation with units.

k = slope of graph = ____________

Data: Part II:
Mass of your spring: __________grams

Oscillating mass m (kg)	Measured Period T (s)	Calculated Period T (s) Using $T_1 = 2\pi\sqrt{\frac{m}{k}}$	Calculated Period T (s) Using $T_2 = 2\pi\sqrt{\frac{m + 1/3\, m_S}{k}}$
Average Period:			

Show a sample of each calculation with units.

You may have noticed that the calculated periods which include a portion of the spring mass are closer to your measured values. By ignoring the mass of the spring in our derivation, we have introduced an error. Calculate the percentage of error between the calculated and experimental values using each of the following expressions:

% Error using $\frac{\lvert T_{meas} - T_1 \rvert}{T_1} * 100\%$	% Error using correction factor for spring mass $\frac{\lvert T_{meas} - T_2 \rvert}{T_2} * 100\%$

Show all calculations, with units.

Procedure: Part III: Torsion Oscillator Calibration

In this section, you will take the data necessary to determine the torsion constant of the torsion rod from the slope of a graph of the restoring torque of the rod as a function of twist angle.

1. In your data table, describe the rod used (i.e. thin steel, thick steel, or brass).
2. Load the torsion apparatus mass hanger with 500 grams. Now zero the scale on the apparatus to 0º. The apparatus is treated now as having a hanging mass of zero grams. The radius of the wheel is 0.075 m
3. Place mass increments of 200 grams on the mass hanger and record the twist angle θ in your data table. Continue this for mass increments of 200 grams.

Calibration Data

m(kg)	**F(N) = mg**	**τ (Nm) = mgr**	θ (degrees)	θ (radians)
0	0	0		
0.2				
0.4				
0.6				
0.8				
1.0				

Analysis: Part I

Use this information to prepare a graph of the torque as a function of the twist angle in radians. Use the graph to calculate the torsion constant κ.

rod description: ________________________ torsion constant = __________________________

Procedure: Part IV: Torsion Oscillator Data

DO NOT put the steel plate or hollow cylinder on the digital scale. Their mass is etched into each object. Record the mass of the plate and hollow cylinder as engraved on them, and measure their respective diameters to determine their radius of each object.

Mass of plate = ________________

Diameter of plate = ________________

Mass of hollow cylinder = ________________

Outer diameter of hollow cylinder = ________________

Inner diameter of hollow cylinder = ________________

1. Construction of the Torsion Oscillator: Carefully remove the rod from the torsion apparatus being careful not to bend the rod, and mount it to the bottom of the heavy steel plate.
2. Attach the other end of the rod to the wall bracket so that your torsion oscillator is free to rotate.
3. Set the system into oscillation and determine the period of vibrations for the plate attached to the torsion rod by measuring the time for 20 cycles of oscillation and averaging.
4. Repeat this measurement and calculate the average of the two periods. Carefully remove the rod from the wall bracket and set the hollow cylinder over the rod so that it rests on the metal plate concentric with the torsion rod. Now the plate and hollow cylinder together have a common axis of rotation.
5. Repeat the process of timing two cycles to arrive at the average period of oscillation.

Oscillation Data

Plate Only			**Plate and Hollow Cylinder**		
# Vibrations	Time (s)	T_1 = Period (s)	# Vibrations	Time (s)	T_2 =Period (s)
20			20		
20			20		
Average			Average		

Using the rotational analog of the equation for the period of SHM, $\omega = \sqrt{\frac{K}{I}}$ and $\omega = \frac{2\pi}{T}$, use the data table above to calculate the rotational inertia of the plate. Show all work, with units.

$\mathbf{I_{Plate}}$ = ____________________

Use the data table above to calculate the rotational inertia of the hollow cylinder. Since the plate and hollow cylinder have the same axis of rotation, $\mathbf{I_{Hollow\ cylinder} = I_{Plate\ +\ Hollow\ cylinder} - I_{Plate}}$

$\mathbf{I_{Hollow\ cylinder}}$ = ________________

Calculate the theoretical rotational inertia of the plate from its physical measurements and compare it with the value calculated from the oscillation measurements to find the % error between the two values.

Percent Error: __________

Calculate the theoretical rotational inertia of the hollow cylinder from its physical measurements and compare it with the value calculated from the oscillation measurements to find the % error between the two values.

Percent Error: __________

Procedure: Part V: Ring Pendula

1. Determine the average diameter of each ring pendulum by measuring the outside and inside diameters of the four largest ring pendula. The rings will be treated as a thin hoop of uniform radius for purposes of analysis.
2. Determine the average period of each ring pendulum by measuring the times required for 20 vibrations for two trial periods.

Data: Part VI

D_{inner} (cm)	D_{outer} (cm)	D_{AVE} (cm)	# cycles	Total Time(s)	PERIOD (s)
			20		
			20		
			20		
			20		

1. Plot the period of the ring pendulums as a function of their diameters on log-log paper in order to verify the relation between period and diameter: $T = CD^n$.
2. Use the slope and intercept from your graph to find the constants *n* and **C**. Write the equation that best fits your data in the form T = f(d), using the appropriate constants determined from the plot and proper units.
3. Use your value of C to calculate an experimental value of the acceleration due to gravity 'g' and compare it with the standard accepted value of 9.81 m/s^2 by calculating the percent error between the two values. (*Note: C = $\frac{2\pi}{\sqrt{g}}$)

Your g = ________________

Percent Error: ___________

4. Apply the physical pendulum equation to a ring pivoted on its edge to derive the equation for the period of a ring pendulum for small oscillations about the pivot point. Include a diagram showing the restoring torque acting on a ring pendulum displaced from equilibrium. Note that the rotational inertia for the ring about its support can be found by the parallel axis theorem.

Conclusion and Summary of Results:

Write a brief conclusion, including a brief discussion of the physics involved in this experiment, including possible sources of error, and indicate whether your results give support or validate the purpose of the lab exercise.