#1 Static Equilibrium of a Rigid Body

Pre-Lab Report

Lab section:

Name & Surname:

Table #:

***Before the Lab** complete this page YOURSELF! Hand it in **in the first 5 min**. of the session PERSONALLY!*

You MUST justify your answers and show all steps. NO COPYCAT answers, or NO credits!

Please read the relevant presentation on PHYS LAB Website.

Q1. Write down the 2 conditions that must be met for a rigid body to be in equilibrium and comment on them. Is there a third condition? **Justify your answer or no credits!**

(2nd Question is on the next page!)

Q2. Show dimensional analysis for Torque! **Show your formulae / derivation below <u>explicitly or no credits</u>!**

1

Lab Report

Lab section:

Name & Surname:

Table #:

***Complete this report YOURSELF except DATA taking parts! Use a pencil for plots only and a pen for the rest!* Show your work clearly, NO COPYCAT analysis allowed, or NO credits!**

OBJECTIVE : To study the equilibrium conditions of a body when there are forces applied on it.

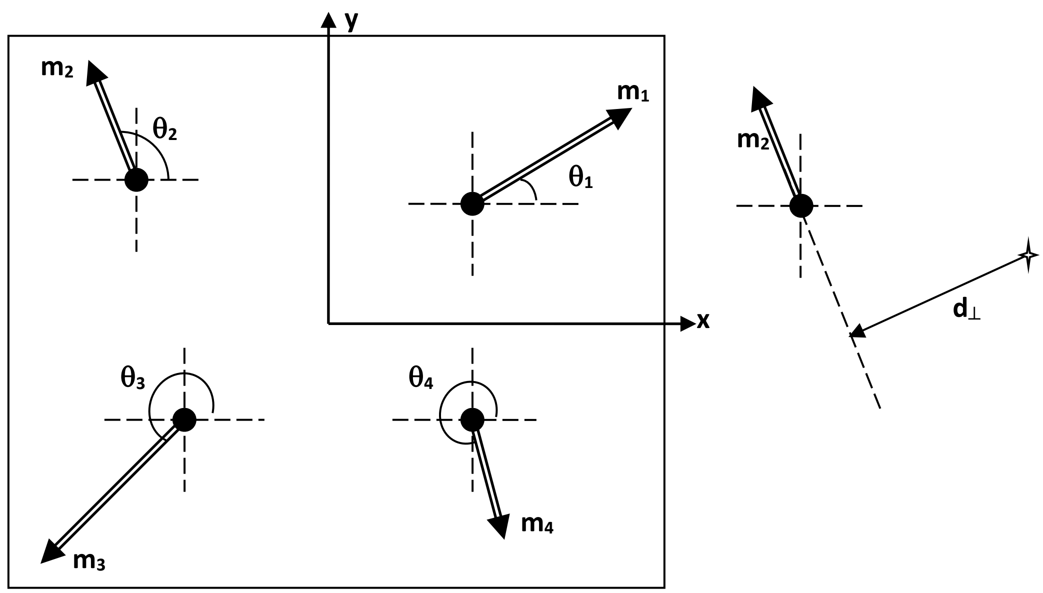
THEORY : A rigid body is in equilibrium when the total force and the torque acting on it are equal to zero:

$$\sum \vec{F} = 0, \sum \vec{\tau} = 0$$

or if we write these in component form:

$$\sum F_x = 0, \qquad \sum F_y = 0, \qquad \sum F_z = 0$$

$$\sum \tau_x = 0, \qquad \sum \tau_y = 0, \qquad \sum \tau_z = 0.$$



PROCEDURE :

1. Place a piece of paper on the movable disc and replace the center pin.
2. Insert four pegs, by punching through the paper, into four different holes in the disc, and place the strings over the pulleys.
3. Attach known masses to the free ends of three of the cords.

2

4. Adjust the angular position and the mass suspended from the fourth cord until the disc is in equilibrium when the pin is removed.
5. With a pencil, mark the positions of the strings and write the magnitude of each force.
6. Indicate the direction of the forces and determine whether the forces are balanced.
7. Choose any point on the data paper and compute the algebraic sum of torques about the chosen point.

DATA-TAKING

Description / Notation **Value & Unit**

MASS - 1:

Mass on the holder m_1 = ...

Perpendicular Distance
to the axis of rotation $d_{1\perp}$ = ...

Angle between the
x-axis and the Force θ_1 = ...

Direction : *Clockwise* ☐ *Counterclockwise* ☐

MASS - 2:

3

Mass on the holder m_2 = ...

Perpendicular Distance

to the axis of rotation $d_{2\perp}$ = ...

Angle between the

x-axis and the Force θ_2 = ...

Direction : *Clockwise* ☐ *Counterclockwise* ☐

MASS - 3:

Mass on the holder m_3 = ...

Perpendicular Distance

to the axis of rotation $d_{3\perp}$ = ...

Angle between the

x-axis and the Force θ_3 = ...

Direction : *Clockwise* ☐ *Counterclockwise* ☐

MASS - 4:

Mass on the holder m_4 = ...

Perpendicular Distance

to the axis of rotation $d_{4\perp}$ = ...

Angle between the

x-axis and the Force θ_4 = ...

Direction : *Clockwise* ☐ *Counterclockwise* ☐

4

CALCULATIONS

ΣF_x : ....

ΣF_y : ....

$\Sigma \tau_z$: ....

Consult to the resources for this experiment from PHYS LAB Website:

PHYL102 Intro

Presentation #1

PHYL102 Lab Book

Pre-Lab Report

Lab section:

Name & Surname:

Table #:

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Please read the relevant presentation on PHYS LAB Website.

Q1. Linearize the equation T = A Rn. When you plot the linearized form, what does n correspond to? What is the y-intercept? Explain! **Justify your answers, or no credits!**

(2nd Question is on the next page!)

Q2. Can we use this set of rings in the experiment to determine the gravitational acceleration? If yes, explain how! **Justify your answers, or no credits!**

1

Lab Report

Lab section:

Name & Surname:

Table #:

***Complete this report YOURSELF except DATA taking parts! Use a pencil for plots only and a pen for the rest!* Show your work clearly, NO COPYCAT analysis allowed, or NO credits!**

OBJECTIVE : To study a nonlinear phenomenon and determine the parameters related to the motion through a linear representation.

THEORY : Physics laws are based on experiments. We may obtain some relationships starting from the first principles or established physics laws through physical and mathematical reasoning. These relationships are accepted as valid laws if they are shown to be valid by all sorts of experiments. However, in some cases we may not know the underlying physical principle. We may have only our observation of the phenomenon. From the observation we may try to develop a relationship between the quantities that are being measured. Of course, if there are more than two quantities involved, we should set all the quantities to a constant value except two of them, and then measure one of these two by varying the value of the other quantity.

For example, in the periodic motion of metal rings placed on a knife edge fixed on the wall, there are several quantities; the radius, thickness of the rings, and the period of the oscillations are some of the quantities that we can think of. If we want to determine the relationship between the radius and the period of the oscillations, we should have rings made of the same material and thickness. Then we should let the rings oscillate and measure the period as a function of the radius, making sure that the initial amplitudes are the same. Once we obtain the data we can try different relationships between the period and the radius; linear, quadratic, cubic, etc. However, this would be a time consuming process. Instead we assume that the relationship is in the form of , which is not linear. By taking the logarithm (base-10) of both sides, we get . This is a linear expression whose slope and y-intercept can be easily obtained through graphical analysis. We can either plot the data on a log-log graph paper or the logarithm of the values on a regular graph paper. Then we can determine the exponent n from the slope of the straight line.

Establishing physics laws in this way produces expressions that are already validated by the experiment. Of course, we should still try to derive the same expression through logical reasoning and starting from the known and well established physics laws.

2

APPARATUS: A set of five metal rings, vernier calipers, stop watch, meter stick

PROCEDURE : Each one of the five metal rings is suspended successively from a knife edge. The rings are made to oscillate from side to side. The period of oscillations is determined by taking average over at least 10 oscillations. The mean diameter of each ring is also determined. After obtaining the data, you should plot them on a log-log graph paper and the logarithm of the values on a regular graph paper. Determine the slope and intercept from both plots and compare them. Report the average of both values.

3

DATA-TAKING

Description	Symbol (unit)	RING NUMBER				
		- 1 -	- 2 -	- 3 -	- 4 -	- 5 -
Inner Diameter *(first measurement)*	D_{i1} ( )					
Inner Diameter *(second measurement)*	D_{i2} ( )					
Average Inner Diameter	$\boldsymbol{D_{iave}}$ **( )**					
Outer Diameter *(first measurement)*	D_{o1} ( )					
Outer Diameter *(second measurement)*	D_{o2} ( )					
Average Outer Diameter	$\boldsymbol{D_{oave}}$ **( )**					
10 Periods	t ( )					

CALCULATIONS

Description	Symbol (unit)	RING NUMBER				
		- 1 -	- 2 -	- 3 -	- 4 -	- 5 -
Average Diameter	D_{ave} ( )					
One Period	T ( )					
Logarithm of D_{ave}	Log D_{ave}					
Logarithm of T	Log T					

4

1) Use **Log D** & **Log T** data set:

5

A) From the graph, choose two SLOPE POINTS other than data points,

SP_1 : (;)

SP_2 : (;)

B) Calculate "n" using SP_1 and SP_2,

n_1 = ...

....

C) By reading the *y*-intercept of the line from the graph, determine *A*,

$Intercept_1$ = ...

....

A_1 = ...

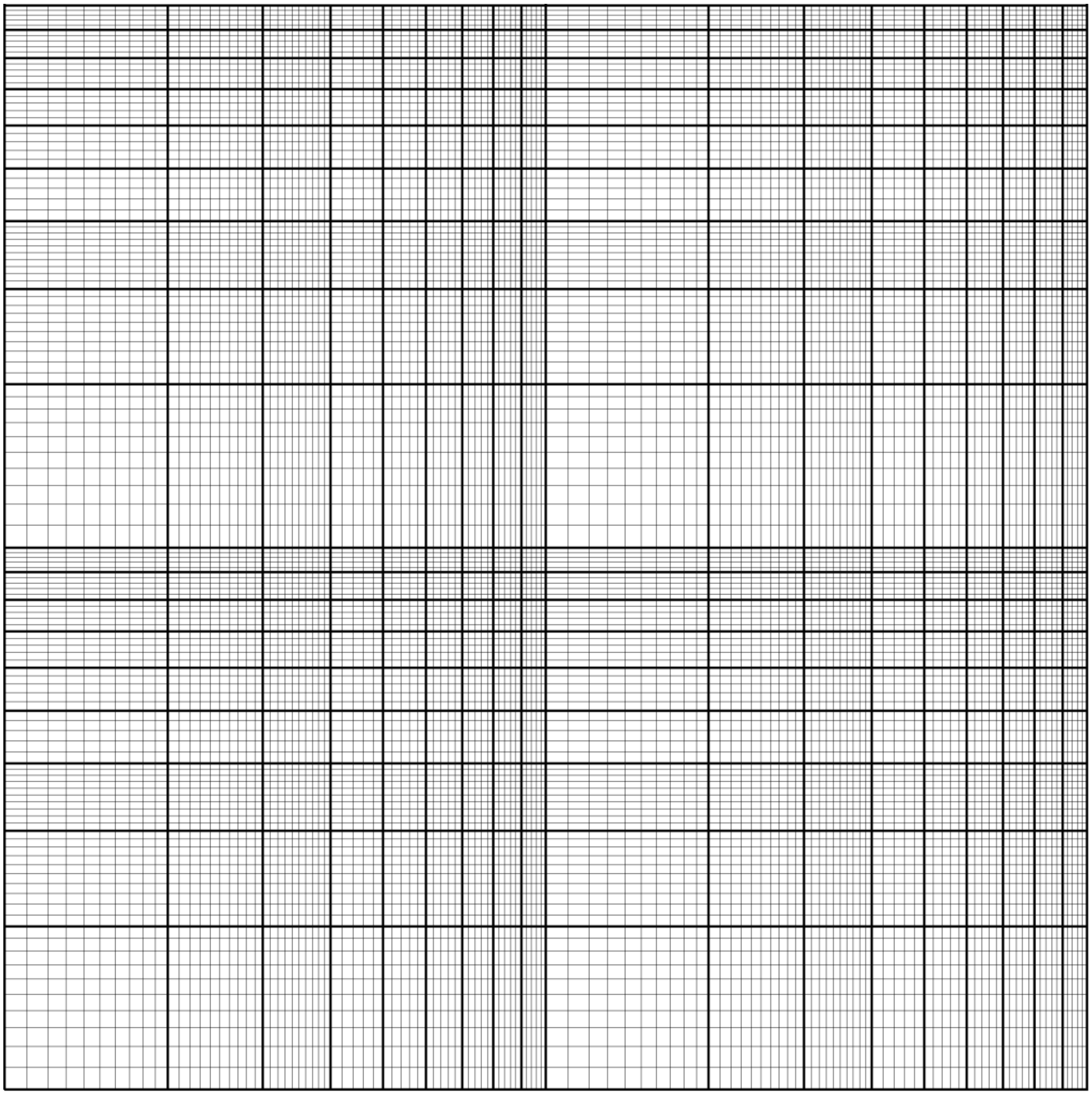
....

D (for T=1 sec) = ...

....

6

2) Use **D** & **T** data set:



A) **From the graph, choose two SLOPE POINTS other than data points,**

SP_1 : (;)

SP_2 : (;)

B) **Calculate "*n*" using SP_1 and SP_2** (*Show your calculations clearly)*

n_2 = ...

. . . .

7 **C) By reading the *y*-intercept of the line from the graph, determine *A*,**

(*Show your calculations clearly)*

Intercept$_2$ = ...

. . . .

A_2 = ...

. . . .

D **(for T=1 sec)** = ...

. . . .

RESULTS

Symbol		Calculations	Result	Dimension
n_{ave}	=	. . . .	. . . .	. . . .
A_{ave}	=	. . . .	. . . .	. . . .

Consult to the resources for this experiment from PHYS LAB Website:

PHYL102 Intro

Presentation #2

PHYL102 Lab Book

Pre-Lab Report

Lab section:

Name & Surname:

Table #:

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Q1. Explain the Parallel Axis Theorem. Give an example and apply the theorem. **Justify your answer, show calculations or no credits!**

(2nd Question is on the next page!)

Q2. Show dimensional analysis of Radius of gyration (k) and moment of Inertia (I). **Show your formulae / derivation below <u>explicitly or no credits</u>!**

#3 Physical Pendulum

1

Lab Report

Lab section:

Name & Surname:

Table #:

***Complete this report YOURSELF except DATA taking parts! Use a pencil for plots only and a pen for the rest!* Show your work clearly, NO COPYCAT analysis allowed, or NO credits!**

OBJECTIVE : To study the properties of the physical pendulum and to use the physical pendulum to determine the acceleration due to gravity.

THEORY : In simple pendulum we determined the expression for the period by solving the force equation with the assumption that the mass hanging at the end of the string is a point mass. Since we used a small ball our assumption was acceptable. When we have an object that is much larger and can not be treated as a point particle, we can still determine the period of oscillations if we hang this object from any point and let it oscillate. In this case we should write the torque equation and solve it. Of course we should know the moment of inertia of the object with respect to the point that the object is hung. Then the period of oscillations will be

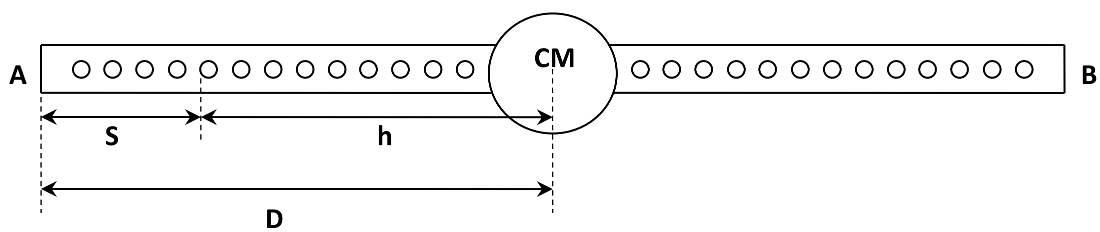


Figure 1. Physical pendulum.

$$T = 2\pi\sqrt{\frac{I}{Mgh}} \qquad (1)$$

where I is the moment of inertia about the axis of rotation or the point that the object is hung and h is the distance between this point and its center of mass. The moment of inertia about any given point can be expressed in terms of the moment of inertia about the center of mass using the parallel axis theorem:

$$I = I_{CM} + Mh^2 \qquad (2)$$

and I_{CM} can be written in terms of the radius of gyration k:

$$I_{CM} = Mk^2 \qquad (3)$$

Then combining these equations we can express the period as

$$\left(T = 2\pi\left[\frac{h^2 + k^2}{gh}\right]^{1/2}\right) \qquad (4)$$

This is equivalent to a simple pendulum with a length:

$$L = \left(h^2 + k^2\right)/h \qquad (5)$$

This simple pendulum is called “the equivalent simple pendulum” to the physical pendulum.

From the figure above we see that

$$h = D - S \qquad (6)$$

and plugging this into the expression for the period results in

$$T = 2\pi\left(\frac{k^2 + (D-S)^2}{g(D-S)}\right)^{1/2}. \qquad (7)$$

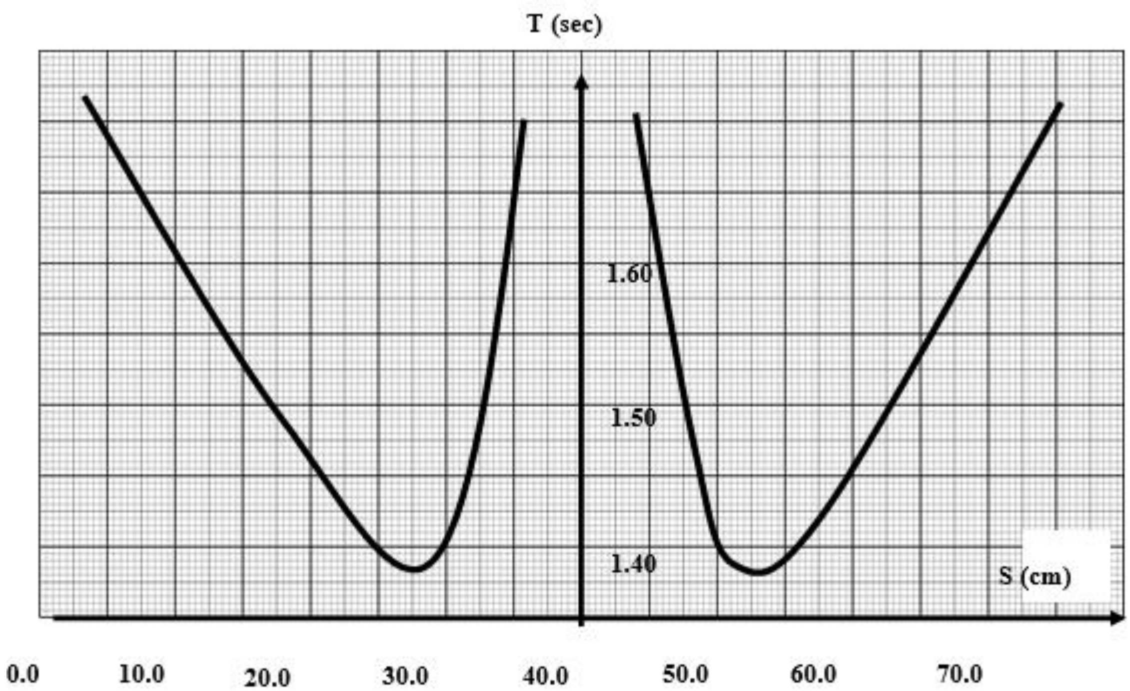


Figure 2. Plot of the period as a function of *S* (Equation (7)).

Plotting the period as a function of S will give us the graph in Figure 2. As you can see from the graph, there are four possible points for a specific period value that we can hang the pendulum. These four points collapse down to two for the minimum period. Radius of gyration is the distance at which the physical pendulum is hung to get the minimum period. We can determine the radius of gyration by measuring the period while varying the distance between the center of mass and the point that the pendulum is hung. Then we can simply read the distance corresponding to the minimum period from the graph. Radius of gyration is the distance between this point and the center of mass.

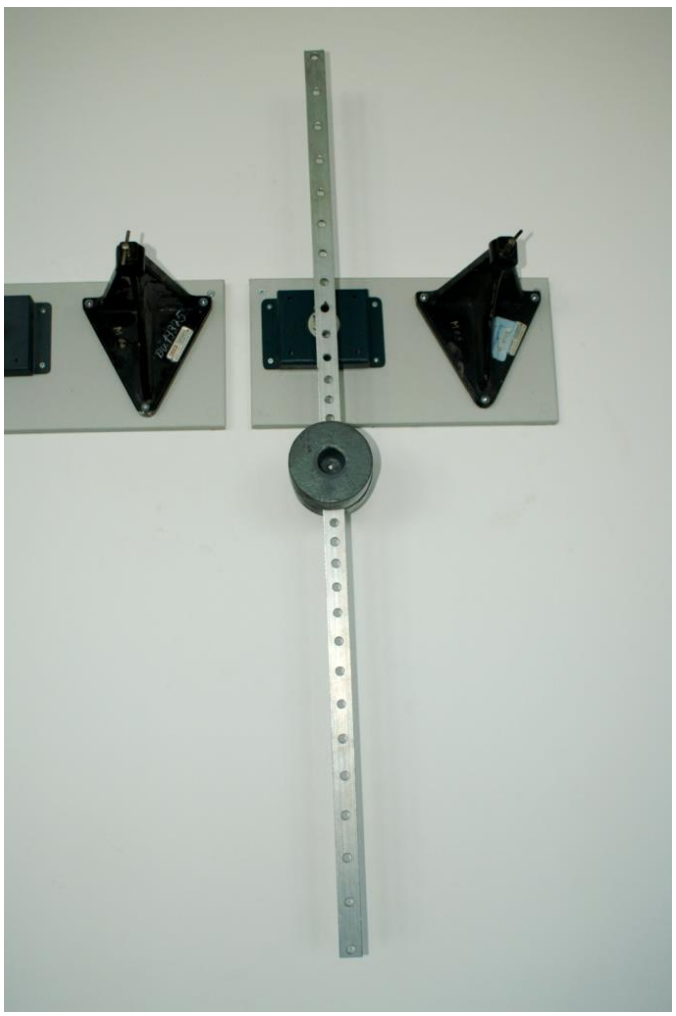
From the plot we can also see that the period of oscillations become infinite if we hang the object from its center of mass.

Because of the symmetry around the center of mass we can limit ourselves to one side of the center of mass. Equating the expressions for the two points that result in the same period:

$$2\pi\sqrt{\frac{(h_1^2+k^2)}{gh_1}} = 2\pi\sqrt{\frac{(h_2^2+k^2)}{gh_2}}, \qquad (8)$$

after simplifying we get:

$$\frac{h_1+k^2}{h_1} = \frac{h_2+k^2}{h_2}, \qquad (9)$$



and solving for k

$$k^2 = \frac{(h_1^2h_2 - h_2^2h_1)}{(h_1-h_2)} = h_1h_2 \qquad (10)$$

Hence, the period expression given in Equation (7) becomes

$$T = 2\pi\sqrt{\frac{(h_1+h_2)}{g}}$$

and similarly the length of the equivalent simple pendulum (Equation (5)) becomes

$$L = h_1 + h_2$$

APPARATUS: Physical pendulum, meter stick, stopwatch

PROCEDURE :

1. Support the pendulum on the knife edge at the hole nearest to one end of the bar. Observe the time for 10 full oscillations and determine the period. In the same way determine the period about an axis through each and every hole in the bar.

2. Remove the pendulum from its support and measure the distance of the various points of suspension from one end of the bar.
3. Record these values of ***S*** as a function of the corresponding values of period ***T***.
4. Plot the values of ***S*** versus period ***T*** and draw a horizontal line corresponding to a period ***T***. Determine the radius of gyration, *k*, from the graph.
5. Determine the length of the equivalent simple pendulum and calculate the gravitational acceleration using this value. Compare your result with the known value of *g*.

DATA

Description / Symbol			Value & Unit
Distance from one end to the center of the pendulum	***D***	=	. . . .
Mass of of the pendulum	***M***	=	. . . .
Acceleration due to gravity	g_{TV}	=	. . . .

5

DATA

Distance from one end of the pendulum to the suspension point *S* ( )	Time for 10 Period *t* ( )	One Period *T* ( )

6

PLOT *S* versus *T*:

7

Read from the Graph:

Description / Symbol			Value & Unit
Period (any chosen)	$\boldsymbol{T}$	=	. . . .
Minimum Period	$\boldsymbol{T_o}$	=	. . . .
Distance from the center to the first suspension point for T	$h_1 = D - S_1$	=	. . . .
Distance from the center to the second suspension point for T	$h_2 = S_2 - D$	=	. . . .
For minimum Period:	$h_o = D - S_o$	=	. . . .
Radius of Gyration	$k = h_o$	=	. . . .

CALCULATIONS and RESULT:

Description	Symbol		Calculations (show each step)	Result
Radius of Gyration	$k = \sqrt{h_1 h_2}$	=	. . . .	. . . .
Length of the Equivalent Simple Pendulum	L	=	. . . .	. . . .

8

Description/Symbol			Calculations (show each step)	Result
Moment of Inertia about the CM	$I_o = I_{CM}$	=	. . . .	. . . .
			. . . .	
Moment of Inertia Corresponding to h_1	$I_{(\text{for T})}$	=	. . . .	. . . .
			. . . .	
Moment of Inertia Corresponding to h_2	$I_{(\text{for T})}$	=	. . . .	. . . .
			. . . .	
Acceleration due to Gravity	g_{EV}	=	. . . .	. . . .
			. . . .	
% Error for *g*		=	. . . .	

Consult to the resources for this experiment from PHYS LAB Website:

PHYL102 Intro **Presentation #3** **PHYL102 Lab Book**

Pre-Lab Report

Lab section:

Name & Surname:

Table #:

***Before the Lab* complete this page YOURSELF! Hand it in *in the first 5 min*. of the session PERSONALLY!**

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Q1. Equation of motion for the system in this experiment is

$\frac{d^2x}{dt^2} + \omega^2 x = \frac{m_0}{m_{tot}} g$ where $\omega^2 = \frac{k}{m_{tot}}$. Show that $x(t) = \frac{m_0 g}{k} - A\cos(\omega t + \delta)$ satisfies this equation. Derive the velocity v(t) and acceleration a(t) from x(t). **Show your calculations below explicitly or no credits!**

(2nd Question is on the next page!)

Q2. What would be the amplitude of the simple harmonic motion be if the mass on the hanger were doubled? **Justify your answers, show calculations if needed or no credits!**

Q3. Calculate the acceleration of the car at time t=T/4 where T is the period of the motion. **Show your calculations, if any necessary, explicitly and justify your answer, or no credits!**

1

Lab Report

Lab section:

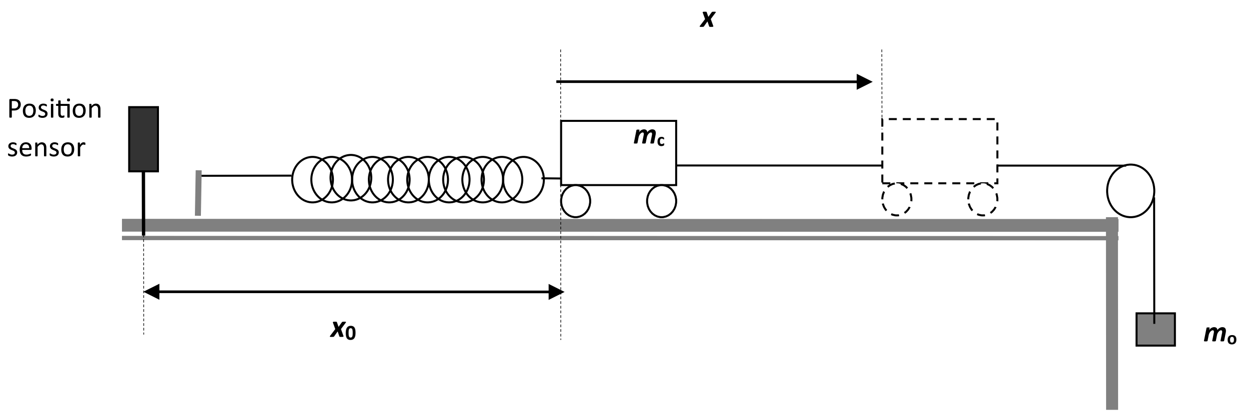
Name & Surname:

Table #:

***Complete this report YOURSELF except DATA taking parts! Use a pencil for plots only and a pen for the rest!* Show your work clearly, NO COPYCAT analysis allowed, or NO credits!**

OBJECTIVE : To investigate the resultant of two forces, one constant, the other depending on displacement from equilibrium (restoring force).

THEORY :



The system shown in the figure will be exhibiting a periodic motion due to the variable restoring force in the spring. If we write the equation of motion:

$$\frac{d^2x}{dt^2} + \omega^2 x = \frac{m_o}{m_{total}} g$$

$$m_{total} = m_c + m_o$$

then, the solution of this equation will be:

$$x(t) = \frac{m_o g}{k} - ACos(\omega t + \delta)$$

whose period of oscillation is given by

$$\omega^2 = \frac{k}{m_{total}}.$$

Derivative of the position with respect to time will yield the velocity as a function of time and the second derivative will give us the acceleration:

$$v(t) = A\omega Sin(\omega t + \delta)$$

$$a(t) = A\omega^2 Cos(\omega t + \delta)$$

Notice that when the magnitude of the velocity reaches its maximum the acceleration becomes zero and vice versa.

APPARATUS: Car and track system, position sensor, data logger, spring, hanger and mass set.

3

PROCEDURE :

1. Disconnect car from the spring and compensate for friction.
2. Fix the spring to the car; locate the point where no force is acting on the car, keeping the car stationary, and place mass ***m*** on the holder.
3. Place the position sensor at least 30 cm away from the car. Start the data logger at the desired rate (suggested value is 10 per second) and let the car go. The car first accelerates (***mg > kx***), attains its maximum velocity where ***mg = kx***, then decelerates (***mg < kx***) and finally stops to come back.
4. Using the data in the data logger's memory, calculate the average velocity for each interval.
5. **Plot** the **average velocity versus time** and **the total displacement versus time** curves.
6. From the velocity versus time graph, determine the maximum velocity which corresponds to zero acceleration and the corresponding time *t* and the period.
7. From the displacement versus time graph, determine the maximum displacement x_{eq}
8. Calculate other system parameters.

DATA

Description / Symbol	**Value & Unit**
Mass on the holder m=	. . . .
Initial distance of the Car x_0 =	. . . .
Number of the Cylinders in the Car =	. . . .
Data Taking Rate =	. . . .

DATA

Number of Intervals	t ( )	x ( )	Δx ( )	$v_{ave} = \Delta x / \Delta t$ ( )

5

6

READ FROM THE GRAPHS:

Description	Symbol	Value & Unit
Maximum velocity	v_{max} =	. . . .
Time Corresponding to to the max. Velocity	t =	. . . .
Equilibrium Displacement	$x_{eq.}$ =	. . . .

CALCULATIONS and RESULT:

Description / Symbol	Calculations (show each step)	Result	Dimension
Spring Constant k =	. . . .	. . . .	. . . .
	. . . .		
Period of Oscillation T =	. . . .	. . . .	. . . .
	. . . .		
Frequency of Oscillation ω =	. . . .	. . . .	. . . .
	. . . .		

7

Description / Symbol		Calculations (Show each step)	Result	Dimension
System Parameter	A =	. . . .	. . . .	. . . .
		. . . .		
Maximum Displacement	x_{max} =	. . . .	. . . .	. . . .
		. . . .		
Maximum Acceleration	a_{max} =	. . . .	. . . .	. . . .
		. . . .		
Total Mass	m_{total} =	. . . .	. . . .	. . . .
		. . . .		
Mass of the Car	m_{car} =	. . . .	. . . .	. . . .
		. . . .		

Consult to the resources for this experiment from PHYS LAB Website:

PHYL102 Intro

Presentation #4

PHYL102 Lab Book

Pre-Lab Report

Lab section:

Name & Surname:

Table #:

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Q1. Show the dimensional analysis for the Torsion Constant, κ. **Show your formulae / derivation below explicitly or no credits!**

Q2. How would the period of the oscillations be affected if you place another object on the disc while it is oscillating? Would the answer be different if you place the object before starting to oscillate? **Justify your answers, show calculations if needed or no credits!**

(3rd Question is on the next page!)

Q3. What would the uncertainty in determining the torsion constant k be if the period and the radius of the ring are determined with 1% uncertainties? Consult to the introduction part of your Lab Book or you may search for "Error propagation". **Show your calculations below <u>explicitly or no credits</u>!**

1

Lab Report

Lab section:

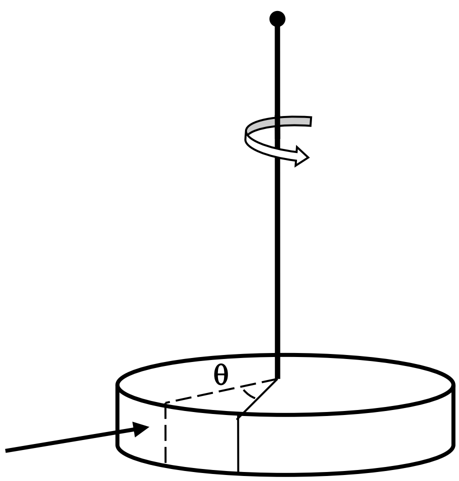
Name & Surname:

Table #:

***Complete this report YOURSELF except DATA taking parts! Use a pencil for plots only and a pen for the rest!* Show your work clearly, NO COPYCAT analysis allowed, or NO credits!**

OBJECTIVE : To study angular oscillatory motion and the dependence of the period of oscillation on the moment of inertia of the system.

THEORY :



We can study the angular harmonic motion in a torsional system where an object is attached to a straight rod and rotated to some angle initially. This initial rotation causes some torsion in the wire thereby producing a restoring torque. Resulting torque equation is similar to the force equations that we obtained for the simple harmonic oscillation; hence it has the same type of solution for the period:

$$T = 2\pi\sqrt{\frac{I}{\kappa}}$$

Below are the formulas to calculate the moment of inertia of uniform disk and ring masses:

$$I_{disk} = \frac{MR^2}{2}$$

$$I_{ring} = \frac{1}{2}M\left[\left(\overline{R}_{inner}\right)^2 + \left(\overline{R}_{outer}\right)^2\right]$$

Spring 2024

APPARATUS: Torsion pendulum, disk and ring masses, meter stick, stopwatch.

PROCEDURE :

Part 1:

1. Measure the time, t, for the disc to complete 50 oscillations, and determine the mean period of oscillation T.
2. Measure the diameter of the disk, compute the radius R for the disc.
3. By using this radius, compute the moment of inertia of the disc and the torsion constant of the rod.

Part 2:

1. Place the body whose moment of inertia is unknown, on the disc, measure the time to complete 50 oscillations, and determine the mean period of oscillation T.
2. Compute the sum of the moment of inertias of the disc and the body.
3. Evaluate the moment of inertia of the body.
4. Compute the theoretical value of moment of inertia and determine the percentage error.

3

Part 1: Moment of Inertia of the Disk

Description / Symbol			Value & Unit
Time for 50 oscillations	t	=	. . . .
Time for one oscillation	T	=	. . . .
Diameter of the disc	D_{disc}	=	. . . .
Radius of the disc	R_{disc}	=	. . . .
Mass of the disc	M_{disc}	=	. . . .

Part 2: Moment of Inertia of the Object & the Disc

Description / Symbol			Value & Unit
Time for 50 oscillations	t^*	=	. . . .
Time for one oscillation	T^*	=	. . . .
Outer diameter of the ring	D_{outer}	=	. . . .

4

Description / Symbol			Value & Unit
Outer Radius of the ring	R_{outer}	=	. . . .
Inner diameter of the ring	D_{inner}	=	. . . .
Inner Radius of the ring	R_{inner}	=	. . . .
Mass of the ring	M_{ring}	=	. . . .

CALCULATIONS:

Description			Calculations (show each step)	Result
Moment of Inertia of the disk (theoretical)	I_{disc}	=	. . . .	. . . .
			. . . .	
Torsion constant of the rod (emprical)	κ	=	. . . .	. . . .
			. . . .	

5

CALCULATIONS:

Description	Calculations (show each step)	Result
Total Moment of Inertia of the disk and the ring (emprical) I_{total} =	. . . .	. . . .
Moment of Inertia of the Ring (emprical) $I_{ring\text{-}EV}$ =	. . . .	. . . .
Theoretical value of the Moment of Inertia of the ring $I_{ring\text{-}TV}$ =	. . . .	. . . .

% Error for the Moment of Inertia of the object: . . . .

Consult to the resources for this experiment from PHYS LAB Website:

PHYL102 Intro

Presentation #5

PHYL102 Lab Book

Pre-Lab Report

Lab section:

Name & Surname:

Table #:

***Before the Lab* complete this page YOURSELF! Hand it in *in the first 5 min*. of the session PERSONALLY!**

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Please read the relevant presentation on PHYS LAB Website.

Q1. **In this experiment standing waves are going to be studied. Speed of the standing wave depends on the tension and the density (mass per unit length) of the string;** $v = \sqrt{\frac{T}{\mu}} = f\lambda$.

Explain this equation, define the elements in it and comment on the relation between them.
Justify your answer or no credits!

Q2. Give the definition of node. Discuss the relation between the node concept and the frequency of the wave on string. **Justify your answer or no credits!**

(3rd Question is on the next page!)

Q3. Show the dimensional **analysis** for μ. **Show your formulae / derivation below explicitly or no credits!**

1

Lab Report

Lab section:

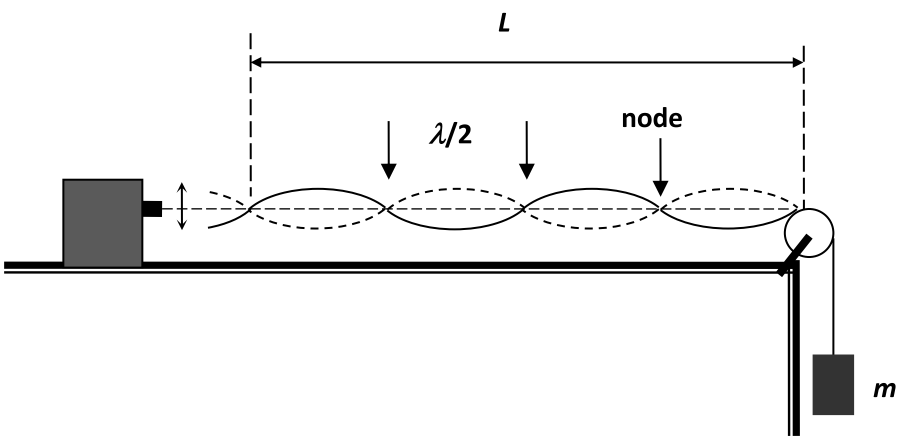
Name & Surname:

Table #:

***Complete this report YOURSELF except DATA taking parts! Use a pencil for plots only and a pen for the rest!* Show your work clearly, NO COPYCAT analysis allowed, or NO credits!**

OBJECTIVE : To study the standing waves in a cord, and to verify the equation for the velocity of a wave on a string.

THEORY :



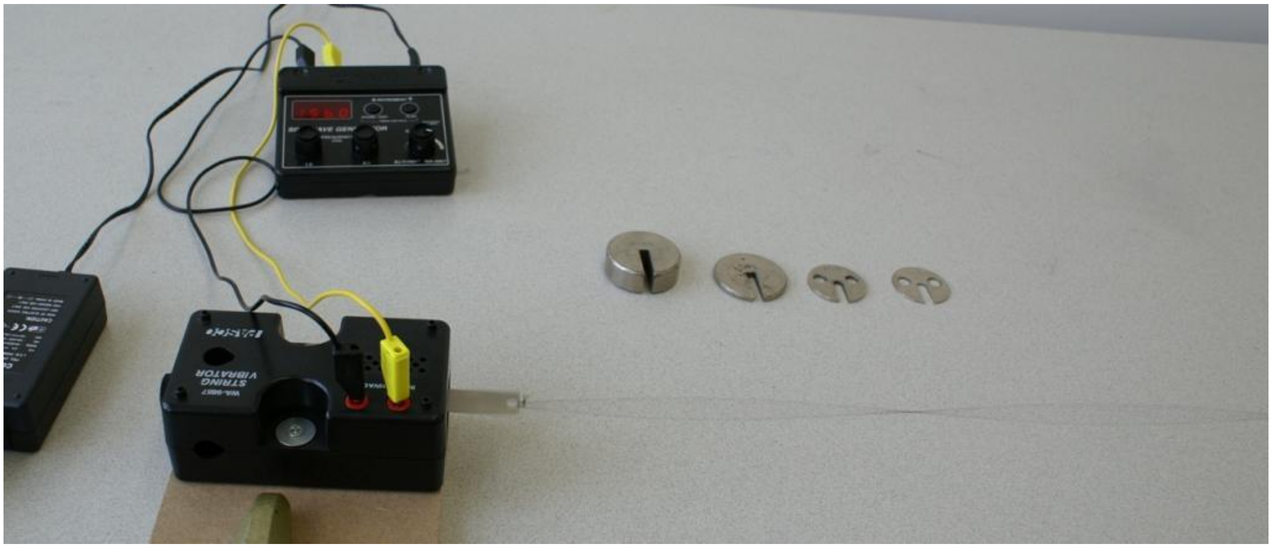
When a string fixed on both ends and under tension is excited on one end, there will be waves traveling along the string. If we continue to excite the string, the waves reflected from the other end will interfere with the waves traveling in the forward direction. If the length of the string is exactly equal to the integer multiples of the half wavelengths, there will be standing waves along the string. The points where the string is motionless are called *nodes* and the distance between successive nodes will be equal to the half wavelength. Speed and the wavelength of the waves traveling along the string depend on the tension and the mass per unit length of the string:

$$v = \left(\frac{T}{\mu}\right)^{\frac{1}{2}} = f\lambda$$

$$T = \mu\lambda^2 f^2$$

A Plot of the tension versus the square of the frequency data pairs that produce standing waves should follow a straight line whose slope is equal to the mass per unit length times the square of the wavelength. Tension on the string is provided by the masses placed on the hanger on the other end.

APPARATUS: String vibrator and its variable frequency power supply, hanger and mass set, string.



PROCEDURE :

1. Length of the cord between the vibration generator and the pulley is kept constant.
2. Place a mass on the mass holder and set the vibration generator in motion.
3. Arrange the frequency of the vibration generator until standing waves are clearly observed.
4. Determine the number of nodes and the wavelengths.
5. Record the frequency value along with the corresponding mass on the mass holder.
6. By keeping the **wavelength constant**, change the mass and read the corresponding frequency for clearly observed standing waves for 4 more times.
7. **Plot tension, *T*, versus** f^2 and determine the slope.
8. Calculate the mass per unit length for the cord.

3

DATA:

Description / Symbol			Value & Unit
Mass per unit length of the Cord	μ_{TV}	=	. . . .
Length of the Cord	L	=	. . . .
Acceleration due to gravity	g	=	. . . .

Mass, ***m*** **( )**	**# of λ / 2** ***(keep constant)***	**λ ( )** ***(keep constant)***	**Frequency,** ***f*** **( )**	**f^2** **( )**	**Tension** ***T = m.g*** **( )**

5

CALCULATIONS & RESULTS:

A) **From the graph, choose two SLOPE POINTS other than data points,**

SP_1 : (;)

SP_2 : (;)

B) **Calculate:**

SLOPE = ...

Description / Symbol	Calculations (show each step)	Result
Mass per unit length of the Cord μ_{EV} =	. . . .	. . . .
	. . . .	
% Error for μ =	. . . .	. . . .

Consult to the resources for this experiment from PHYS LAB Website:

PHYL102 Intro

Presentation #6

PHYL102 Lab Book

Pre-Lab Report

Lab section:

Name & Surname:

Table #:

***Before the Lab* complete this page YOURSELF! Hand it in *in the first 5 min*. of the session PERSONALLY!**

You MUST justify your answers and show all steps. NO COPYCAT answers, or NO credits!

Please read the relevant presentation on PHYS LAB Website.

Q1. The calorimeter used in this experiment does not have perfect insulation and some heat is lost to the surroundings. Estimate the effect of 10% heat loss (10% of the total heat exchanged) on the specific heat value you determine for the specimen. Consult to the introduction part of your Lab Book or you may search for “Error propagation”. **Show your calculations below explicitly or no credits!**

(2^{nd} Question is on the next page!)

Q2. Show the dimensional analysis for the specific heat. **Show your formulae / derivation below explicitly or no credits!**

Q3. In the heat exchange equations, the thermal effect of the thermometer is neglected; discuss the possible thermal effect of the thermometer or the thermal sensor in the results of the experiment. **Justify your answers, show calculations if needed or no credits!**

1

Lab Report

Lab section:

Name & Surname:

Table #:

***Complete this report YOURSELF except DATA taking parts! Use a pencil for plots only and a pen for the rest!* Show your work clearly, NO COPYCAT analysis allowed, or NO credits!**

OBJECTIVE : To measure the specific heat of a metal and to determine the unknown mass of an ice block, through the method of mixtures.

THEORY : It is experimentally shown that the heat absorbed by an object is directly proportional to the change in the temperature and the mass of the object. Proportionality constant is the specific heat of the material that the object is made of:

$$Q = mc\Delta T$$

If you use the SI unit system, the specific heat is defined as the amount of heat absorbed to increase the temperature by one centigrade for a 1 kg object. Unit for the heat is the same as Joule but in these calculations mostly calories are used (1 cal = 4.187 Joules).

When you place two objects at different temperatures in close contact, they will exchange heat until the temperatures are equal. The heat gained by one object is equal to the heat given by the other object since the energy is conserved. For example, if you have a calorimeter with a known mass m_c and specific heat c_c filled with water with mass m_w at a known temperature T_1. When you place a specimen into the water inside the calorimeter at a higher temperature T_2, assuming that there is no heat lost to the surroundings, we can write the following heat exchange equation:

$$m_s c_s (T_2 - T_3) = m_c c_c (T_3 - T_1) + m_w c_w (T_3 - T_1)$$

where T_3 is the final temperature of the mixture when it comes into equilibrium.

These expressions are valid unless there is no phase change. If there is a phase change involved, then the corresponding heat necessary for the phase change should be added into the appropriate side of the equation. For example, if we add a block of ice with a mass m_i at a temperature of T_i into the calorimeter mentioned in the previous paragraph, we should write the heat exchange as follows:

$$m_i c_i (0 - T_i) + m_i L_f + m_i c_w (T_4 - 0) = m_c c_c (T_3 - T_4) + m_w c_w (T_3 - T_4) + m_s c_s (T_3 - T_4)$$

since the heat of fusion, L_f, depends only on the mass. Temperature is constant during the phase change and the final temperature is T_4.

vAPPARATUS: Calorimeter, stirrer, thermometer, heater, water, specimen, ice, temperature sensor, data logger.

PROCEDURE :

Calorimeter = Inner vessel of calorimeter + stirrer

<u>Part 1:</u> Determine the mass of the calorimeter (*inner vessel of the calorimeter and the stirrer*), and the mass of the specimen and its container.

Put your sample in its container into a water boiler one-third full and heat it until the temperature is 95°C.

Add 80 g of water at room temperature to the calorimeter. Measure the initial temperature of calorimeter and water, $t_{i\text{-}cal}$ and $t_{i\text{-}w}$. Quickly pour the hot sample into the calorimeter and observe the temperature rise of the water and calorimeter combination. Note the highest temperature as equilibrium temperature, t_{1e}. Before calculating the specific heat of given metal, continue with Part 2.

<u>Part 2:</u> Get an ice block and drop it into the calorimeter immediately and keep the system closed and well mixed. The temperature will first drop, then it will stay stationary as the ice melts, and finally, it will decrease to the equilibrium temperature t_{2e}. Record this temperature.

Calculate the specific heat of metal and the mass of ice block.

DATA:

Description / Symbol			Value & Unit
Specific Heat of Water	c_w	=	....
Specific Heat of the Calorimeter	c_{cal}	=	....
Specific Heat of Ice	c_{ice}	=	....
Heat of Fusion of Ice	L_f	=	....

PART 1 – SPECIFIC HEAT OF METALS

Description / Symbol			Value & Unit
Mass of the Calorimeter	m_{cal}	=	....
Mass of Water	m_w	=	....
Mass of the Specimen + container	m_{s+con}	=	....

Mass of the

4

Specimen m_s = ...

Initial Temperature of the

Calorimeter $t_{i\text{-}cal}$ = ...

Initial Temperature

of Water $t_{i\text{-}w}$ = ...

Initial Temperature of the

Specimen $t_{i\text{-}s}$ = ...

Equilibrium

Temperature t_{1e} = ...

PART 2 – HEAT OF FUSION OF ICE

Description / Symbol	**Value & Unit**

Initial Temperature

of Ice $t_{i\text{-}ice}$ = ...

Initial Temperature of the

Calorimeter, Water and the

Specimen $t_{i\text{-}cal\ +\ contents}$ = ...

Equilibrium

Temperature t_{2e} = ...

5

CALCULATIONS:

For PART-1: **(NO NUMERICAL EVALUATION)**

Heat Lost: ....

....

Heat Gained: ....

....

Specific Heat of the Specimen: c_s = ...

For PART-2: **(NO NUMERICAL EVALUATION)**

Heat Lost: ....

....

Heat Gained: ....

....

Mass of Ice: $m_{ice\text{-}EV}$ =...

6

RESULTS:

Description	Calculations (show each step)	Result

Specific Heat

of the Specimen c_s =. . . . .

. . . .

Total Mass m_{total} = ...

Experimental Value of the Mass of Ice m_{ice-EV}=. . . . . …

. . . .

Measured Value of the Mass of Ice m_{ice-MV}=. . . . .

. . . .

% Error for the Mass of Ice:. . . . .

Dimensional analysis for the Specific Heat:. . . . .

Consult to the resources for this experiment from PHYS LAB Website:

PHYL102 Intro

Presentation #7

PHYL102 Lab Book

Pre-Lab Report

Lab section:

Name & Surname:

Table #:

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Q1. Adiabatic process can be described by the equation: $P.V^{\gamma} = C$ where C is for constant. Take the differential of both sides and consult the relations in your book to get the following relation. **Show your formulae / derivation below explicitly or no credits!**

$$\gamma = 4\pi^2 \frac{MV}{A^2 P T^2}$$

(2nd Question is on the next page!)

Q2. Show the Dimensional **Analysis** of γ. **Show your formulae / derivation below explicitly or no credits!**

1

Lab Report

Lab section:

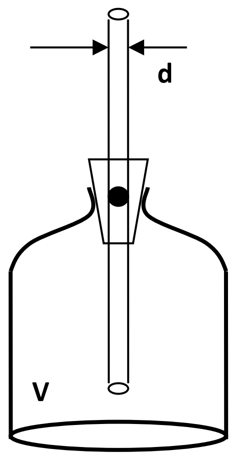
Name & Surname:

Table #:

***Complete this report YOURSELF except DATA taking parts! Use a pencil for plots only and a pen for the rest!* Show your work clearly, NO COPYCAT analysis allowed, or NO credits!**

OBJECTIVE : To determine the ratio of the specific heats of air, Cp / Cv.

THEORY : We can determine the ratio of the heat capacities air in a glass vessel by observing the oscillation of a steel ball inside the glass tube attached to the top of the glass bottle.



The pressure inside the bottle is given by:

$$P = p_o + \frac{Mg}{a}$$

where p_0 is the atmospheric pressure and M is the mass of the steel ball. This is the case when the ball is in equilibrium and it closes the opening completely but can move up and down easily. When the ball is disturbed away from the equilibrium position by an infinitesimal amount, dx, there will be a change in the pressure Δp. This change in the pressure applies a net force causing the ball to accelerate:

$$A\Delta P = M\frac{d^2x}{dt^2}$$

where A is the cross section of the glass tube. Changes in the pressure can be considered adiabatic, so that

$$PV^{\gamma} = cons.$$

where γ is the ratio of the specific heats. Through differentiation of this expression and using the expression for the volume change as Ax, we can show that the equation of motion can be expressed as:

$$\frac{d^2x}{dt^2} + \frac{\gamma PA^2}{MV}x = 0$$

where V is the volume of the bottle. Then the period of oscillations can be given as

$$T = 2\pi\sqrt{\frac{MV}{\gamma PA}}$$

and

$$\gamma = 4\pi^2 \frac{MV}{A^2PT^2}$$

By measuring all the quantities on the right you can determine the ratio of the specific heat of air.

APPARATUS: Cp/CV apparatus and a stopwatch.

PROCEDURE :

After cleaning the inside of the tube and the steel ball, drop the ball into the tube. Start the time when the ball is at its lowest position and determine the total time for as many oscillations as possible as long as the amplitude of the oscillation is greater than 2-3 cm.

3

DATA:

Description / Symbol **Value & Unit**

cm Hg h = ...

Density of Mercury ρ = 13.6 g / cm^3

Acceleration

due to gravity g = ...

Flask Number N = ...

Volume of the Flask V = ...

Diameter of the ball D = ...

Mass of the ball m = ...

# of Trials	# of Oscillations *(n)*	Time for n Oscillations ***t*** ( )	Time for One Oscillation (Period) ***T*** ( )
1			
2			
3			
4			
5			

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CALCULATIONS:

Description	Symbol	Calculations (show each step)	Result
Radius of the ball	R =	. . . .	. . . .
Cross sectional Area of the precision tube	A =	. . . .	. . . .
Atmospheric Pressure	P_o =	$\rho g h$ = ...	. . . .
Pressure inside the bottle at Equilibrium Position of the Ball	$P_e = P_o + \frac{mg}{A}$ =	. . . .	. . . .

Description	Symbol	Calculations (show each step)	Result
Average Period	$T_{average}$ =	. . . .	. . . .
		. . . .	
Ratio of Heat Capacities	$\gamma = C_p / C_v$ =	. . . .	. . . .

Consult to the resources for this experiment from PHYS LAB Website:

PHYL102 Intro

Presentation #7

PHYL102 Lab Book

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