PHYSICS 195 LAB: Centripetal Force and ΣF = ma

SAN DIEGO MESA COLLEGE

PHYSICS 195 LAB REPORT

Name________________________

Group #______

Time______ **Date**_____________

Partners __________________________

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TITLE: **CENTRIPETAL FORCE & NEWTON'S SECOND LAW**

REFERENCE:

OBJECTIVE: To determine if Newton's Second Law is a valid description of the force acting on a mass moving in a circular path at a constant speed.

THEORY: The magnitude of the velocity (the speed) of a particle in uniform circular motion is constant for a circular path of constant radius. The centripetal acceleration of the particle is given by:

$$a_c = \frac{v^2}{r}$$

where ***v*** is the linear speed and ***r*** is the radius of the circle.

If Newton's Second Law is valid for circular motion, the inertial mass of the particle can be found by measuring the centripetal acceleration as a function of the centripetal force.

$$\sum \vec{F}_c = m\,\vec{a}_c$$

Newton's Second Law is then tested by comparing the inertial mass of the particle with an independent measurement of the gravitational mass.

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In a similar manner, a constant resultant force acting on the particle can be determined by changing the inertial mass and measuring the centripetal acceleration. The force predicted by the relationship can then be compared with the known applied force.

Mass has been defined as the measure of inertia in standard units of the kilogram.

One Newton of force has been defined as the push or pull necessary to cause the velocity of a one-kilogram mass to change at the rate of one meter per second each second.

Procedure:

PART I: Centripetal acceleration $\mathbf{a_c}$ as a function of centripetal force $\mathbf{F_c}$ for a rotating bob.

You will be measuring the centripetal acceleration $\mathbf{a_c}$ as a function of centripetal force $\mathbf{F_c}$ for a rotation bob using three different springs at two different radii. The force exerted by the spring depends upon the amount that it is stretched, and therefore must be measured for each spring and each radius used in the experiment. Thus you will have a total of six data points to graph.

1. Firmly attach a 100-gram mass to the top of the black bob and set up the apparatus as shown in figure 1. (Both masses together will be referred to as the 'bob'). Use a bubble-level to level your apparatus. Set the radius marker at 17cm. Be sure that the upper arm and the radius marker are adjusted such that the bob is <u>directly over the marker</u> when the bob hangs straight down (see figure 1.). (It will be necessary to readjust the upper arm when the marker is changed to a new radius).

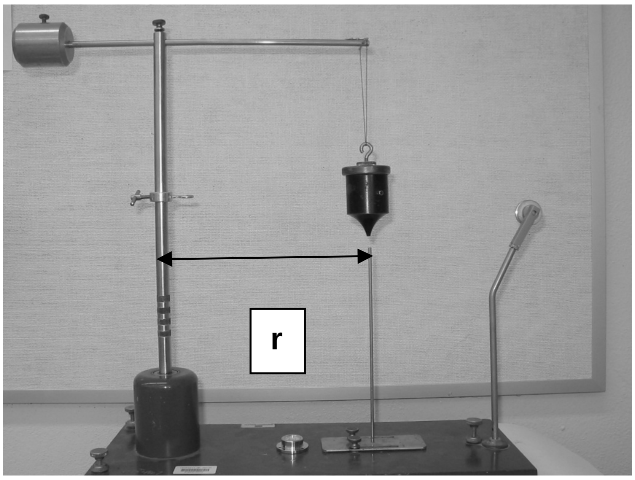

Fig. 1

2. Measure and record the radius **r** from the center of the axis of rotation to the tip of the marker. Measure the mass of the bob (w/ the 100-gram mass) on the precision balance and record it in your data table as M_{bob}.

The springs will be labeled as:

Weakest spring - #1
Medium spring - #2
Strongest spring - #3

3. Attach the spring #1 to the apparatus as in figure 2. Make sure that the spring is horizontally oriented when the bob is swung around in a circle and passing over the tip of the marker.
Continue to rotate the bob so that it passes directly over the marker. Using a timer, record the period of revolution of the bob. The period is the time required for one revolution, and is found by measuring the total time for 20 revolutions to average out speed variations, and dividing by 20.
Record the total time and period in your data table.

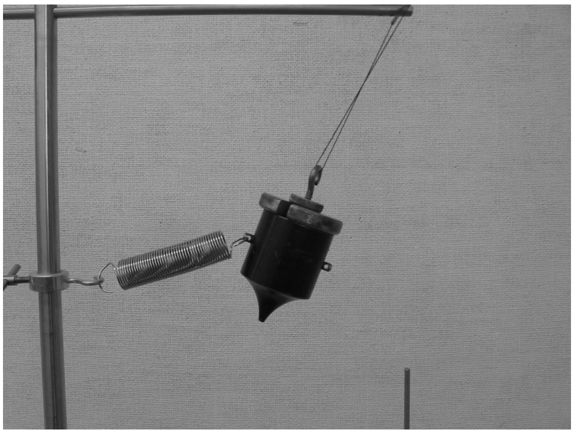

Fig. 2

Since the centripetal acceleration of the rotating bob is $a_c = \frac{v^2}{r}$, you will first have to calculate the speed **v** of the bob:

$$v = \frac{\text{distance}}{\text{time}} = \frac{2\pi r}{t}$$, where ***t*** is the period.

4. Remove spring #1 and replace with spring #2 and repeat step 3.

5. Remove spring #2 and replace with spring #3 and repeat step 3.

6. Connect a string to the bob and mass-hanger as shown in figure 3. You will measure the spring force by adjusting the weight (mg) until the bob is just over the marker. This is a static measurement, referred to as the spring calibration in the data table. Continue to add mass to the hanger until the bob is directly aligned over the radius marker. Record the hanging mass and weight (mg) in your data table.

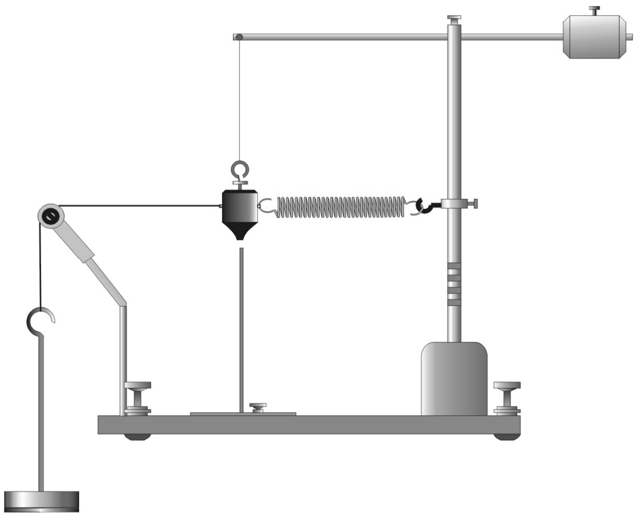

Fig. 3

7. Repeat this spring calibration in step 6 for the other two springs.

8. Do not cut the string (leave the string attached to the bob), but remove the spring and mass hanger. Now change the radius marker to a larger radius of 20 cm. Be sure that the upper arm and the radius marker are adjusted such that the bob is directly over the marker when the bob hangs straight down (see figure 1.)

9. Repeat step 6 in order to measure the spring calibration force for each spring at the new larger radius. Record all measurements in your data table.

10. Remove the string from the bob and repeat steps 3 through 5 with this larger radius. Record all measurements in your data table.

PART II: Centripetal acceleration a_c as a function of reciprocal mass M_{bob}.

Using the weakest spring (this will be your constant force) fixed at the smaller radius, vary the mass of the bob in 50-gram increments (starting with just the bob), and repeat the period measurements of Part I. Because the incremental mass change is small, extreme care must be taken to assure that accurate measurements are taken. Record all measurements in your data table.

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DATA:

PART I	$M_{bob+100g}$ =________grams					
***Spring force (from below) (N)**	**radius (m)**	**# of rev**	**total time**	**period**	**speed(m/s)**	**a_c (m/s^2)**
#1	0.170	20				
#2	0.170	20				
#3	0.170	20				
#1	0.200	20				
#2	0.200	20				
#3	0.200	20				

SPRING CALIBRATION:				Show your Sample Calculations:
Spring #	**Radius (meters)**	**hanging mass (kg)**	***Spring force (N) = mg**	
#1 weakest	0.170		@@	
#2 medium	0.170			
#3 strongest	0.170			
#1 weakest	0.200			
#2 medium	0.200			
#3 strongest	0.200			

PART II	Constant spring force = @@					
mass (kg)	**1/mass**	**# of rev**	**total time**	**period**	**speed (m/s)**	**a_c (m/s^2)**
empty bob		40				
		40				
		40				
		40				
		40				

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Analysis:

PART I: Centripetal acceleration a_c as a function of centripetal force F_c for a rotating bob.

GRAPHS: Construct a graph of the centripetal acceleration of the bob as a function of the net centripetal force on it.

Determine the slope of the first graph and write the equation of your line.
Ignore any intercept. *Do not forget proper units!*

Your slope = ________________

Briefly explain what the slope of this graph represents.

Determine the inertial mass of the rotating bob from the slope of your graph.

$m_{inertial}$ = ____________________

Compare (% error) the inertial mass of the bob with its gravitational mass as measured on the electronic balance.

$$\% \, Error = \frac{\left| m_{grav} - m_{inertial} \right|}{m_{grav}} * 100$$

Analysis: (cont.)

PART II: Centripetal acceleration a_c as a function of reciprocal mass M_{bob}

GRAPHS: Construct a graph of the centripetal acceleration of the bob as a function of the reciprocal mass of the bob M_{bob}.

Determine the slope of the second graph and write the equation of your line.
Ignore any intercept. *Do not forget proper units!*

Your slope = ___________________

Briefly explain what the slope of this graph represents.

Determine the constant centripetal force on the rotating bob from the slope of your graph.

Compare (% error) this centripetal force on the bob with the value you measured in Part I.

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. State and summarize your numerical results and indicate whether these results give support or validate the purpose of the lab exercise.

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TITLE: ____________________________

Part I:

Slope of the first graph: _________________

The equation of your line: ________________

The inertial mass of the rotating bob system: ________________

% Error: __________________

Part II:

Slope of the 2^{nd} graph: _________________

The equation of your line: ________________

The constant net centripetal Force on the rotating bob system (from the slope of your line):

____

% Error: __________________

Calculation of slope:

Calculation of slope: