Central Force

Object: To study the centripetal (central) force acting on an object moving in a circle as a function of its angular speed.

Apparatus: Central force apparatus, force sensor, photogate, interface device, power supply, masses, setup hardware and wires.

Foreword

In order for an object of mass m to travel in a circle of radius r with an angular speed ω, it must experience a central force of magnitude.

$$F_c = mr\omega^2.$$

In this experiment, we will select a mass (m) and radius (r) of the circle this mass is to travel. As the mass (m) travels in a circle of radius (r) we will use a force sensor to monitor the central force and a photogate to determine the time for one revolution which allows the software to calculate the angular speed. We will then instruct the software to make a plot of the central force F_c as a function of the angular speed squared ω^2.

Procedure

Part I: Hardware Set-up

1. Plug a force sensor into analog channel A.
2. Plug a photogate into digital channel 1.
3. Run the leader from the force sensor, underneath the small white pulley, and connect it to the sliding masses (the one with the nylon washers on it). Make sure that the wire is straight down from the force sensor to the pulley. Try to get the wire parallel to the rotating arm. The force sensor will not get an accurate reading for centripetal force if these things are not done.
4. Make sure that the fixed mass (the one with the little white photogate "flag" sticking out of the bottom) is attached tightly at the same radius that the sliding mass reaches when the wire is taut.
5. Before you connect the power supply to the CF apparatus, plug in the power supply and turn it on. Turn the current knob all the way clockwise and turn the voltage knob all the way counterclockwise. The voltage display should read 0.00 Volts. Turn off the power supply. ***Failure to make these knob settings could cause the leader connecting the force sensor and the brass masses to break. This will result in a 10% grade deduction.*** Connect the 30V power supply to the CF apparatus with the black and red banana-banana cables. You will now be able to control the power to the motor by turning the voltage knob slowly clockwise.

Part II: Software Setup

1. Open the *DataStudio* Software.
2. Tell the software you have plugged a force sensor into analog channel A, and a smart pulley into digital channel 1.
3. Double click on the smart pulley. Click on the Measurements tab. Select Angular Velocity (rad/s). Unselect velocity. Click on the Constants tab. Change the spoke angle spacing to 360 degrees. This tells the computer that each time the light beam from the photogate is interrupted, the arm has swung around 360 degrees. Set the significant figures to 4.
4. Next we need to make sure that the force sensor reading will be positive. Double click on the Force Sensor icon to bring up the "**Sensor Properties**" menu. Under the calibration tab there are two areas labeled "**High Point**" and "**Low Point.**" In this area **do not modify** the field for the voltages, but change the field for the "**High Point Value**" to have a negative (**–50 N**) and change the field for the "**Low Point Value**" to be positive (**50.0 N**). Now the force sensor will record the pulling force as a positive value instead of a negative value.
5. Create a calculation to find ω^2. Type "Omega Squared = w^2" and click accept. Then define w as the data measurement angular velocity (rad/s) and click accept. Note: the software does not use the Greek alphabet so we are using w for ω.
6. Create a graph of Force vs. ω^2. Do this by dragging the graph icon to the force icon. Then drag the calculation Omega Squared to the x-axis.

Part III: Collecting Data

Caution: Keep items that you do not wish to be hit away from the rotating arm. Make sure that all of the wires are clear of the rotating arm. Failure to do so may result in a loss of points!

1. Turn the power supply on.
2. Tare the force sensor while the wire is still slack. Do this by pushing the tare button located on the face of the force sensor.
3. Click the Start button.
4. Turn the voltage on the power supply up slowly until you reach 8V.
5. Once you reach 8V, click the stop button and turn the power supply back down.

Part IV: Analyzing Data

1. On your graph, click the best fit icon, and choose a fit option that is appropriate for your graph. You now have a numerical value for the slope of your F vs. ω^2 graph.
2. Write down an algebraic expression for the physical significance of the slope from your F vs. ω^2 graph.
3. Plug in values for your algebraic expression that were used during the experiment.
4. Find the percent difference between the two values (Steps 1 and 3).
5. Determine any sources of possible error to explain the percent difference.
6. Perform a second experiment to determine a correction for some of the error you identified above.

Name: ______________________________ **Banner ID:** ______________________________

Lab Group ID: ______________________ **Number of Lab Partners:** _________________

Data Sheet
Central Force Lab

Write an algebraic expression that represents the physical significance of the slope of the Data Studio plot

Radius measured using the scale on the apparatus (a)	Radius determined from Data Studio Plot (b)	Percent Difference $= \frac{\lvert a-b \rvert}{(a+b)/2} x100\%$

Based on the divisions of the scale on the apparatus and where the scale is located with respect to what you are trying to measure, how accurately can you measure the radius expressed in +/- mm?

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For this particular apparatus, would a larger or smaller radius result in more experimental error? Explain:

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Are the values of the measured radius and the radius determined from the plot in reasonable agreement?

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2nd Experiment

It should be obvious that using the scale on the apparatus to measure the radius will result in an imprecise measurement of the radius. However, the imprecise radius measurement is not the only source of error. You may have noted that there is hardware securing the brass masses to the arm of the apparatus. The hardware securing the brass masses is not massless. By running a second trial, information from both trials can be used to estimate the mass of the hardware without using the inaccurate radius measurement. It is important to keep the radius constant for the remainder of the activity. Also, remember to ***TARE*** the force sensor before running the second trial. Be aware that the apparatus may not respond well when masses less than 10 grams are attached to the wire.

Please do not entirely remove the hardware securing the masses to the arms of the apparatus. Removing the hardware typically results in lost and/or damaged parts. It is very important that the hardware remain intact for other lab groups. Although the thumb nut may be removed to change the masses, do not remove the screw from the apparatus. We will not be weighing the hardware to determine the actual mass of the hardware; therefore, it is not necessary to remove it.

After running the second trial, generate two equations and express them in variable form using appropriate variables and/or subscripts. Solve the system of equations for the hardware mass (attach your work to your report). You may not use a numeric value for the radius to solve for the mass of the hardware.

Equation #1	
Equation #2	

Estimate of hardware mass: ____

Percentage of hardware mass as compared to 35 grams: ________________________

Taking into account the materials of the hardware, does your estimate of the hardware mass seem reasonable?

Clean-Up (10% grade deduction if not performed)
Return all Masses to the arms of the apparatus.
Turn off the power supply, unplug it, and wrap the power supply's cord.
Unplug the red and black banana-banana wires from the power supply and the apparatus.