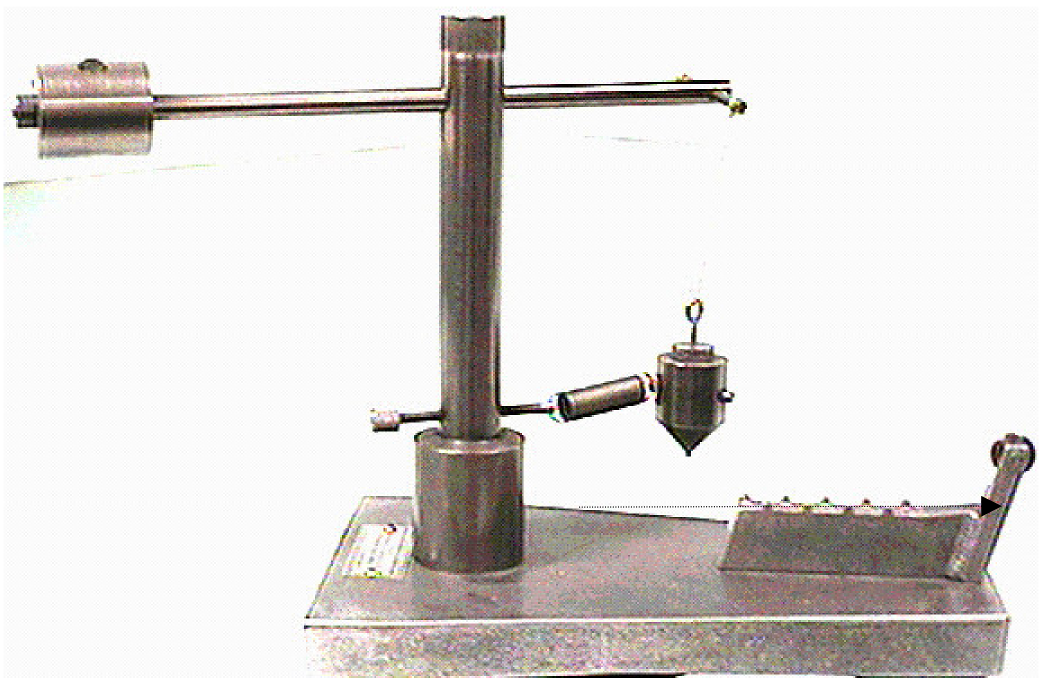
CENTRIPETAL FORCE

Introduction

The purpose of this lab is to use Newton's 2nd Law to predict the dynamic centripetal force on a rotating mass based on the measurement of the mass (**m**), radius of rotation (**r**), and the period of rotation (**T**). This force will then be measured statically and compared to the prediction of Newton's 2nd Law.

Equipment

Computer with Logger Pro SW	Slotted weights	Digital Scale
Vernier Lab Pro Interface	Ring stand	Meter stick
Photogate & connecting wires	Sting with hook (paper clip)	Clamps (2)
Weight hanger	Clamp, 90^{o} swivel	½" x 1-1/2 card



Theory

When an object of mass **m** is made to travel in a circular motion at constant linear speed **v** it is undergoing centripetal acceleration. A centripetal or center-seeking force is said to be acting upon the object. The force and acceleration are related by Newton's 2nd law,

$$\mathbf{F = ma} \qquad (1)$$

with the centripetal acceleration in the form:

$$a = v^2/r \qquad (2)$$

where **r** is the radius of the circular path of the object. Therefore the expression for the centripetal force can be written as:

$$F = mv^2/r. \qquad (3)$$

The magnitude of the linear velocity of the rotating object equals the circumference of the circular path of the object's motion divided by the period of the motion **T**:

$$v = 2\pi\ r/T$$

$$F = m\ 4\pi^2 r\ /T^2 \qquad (4)$$

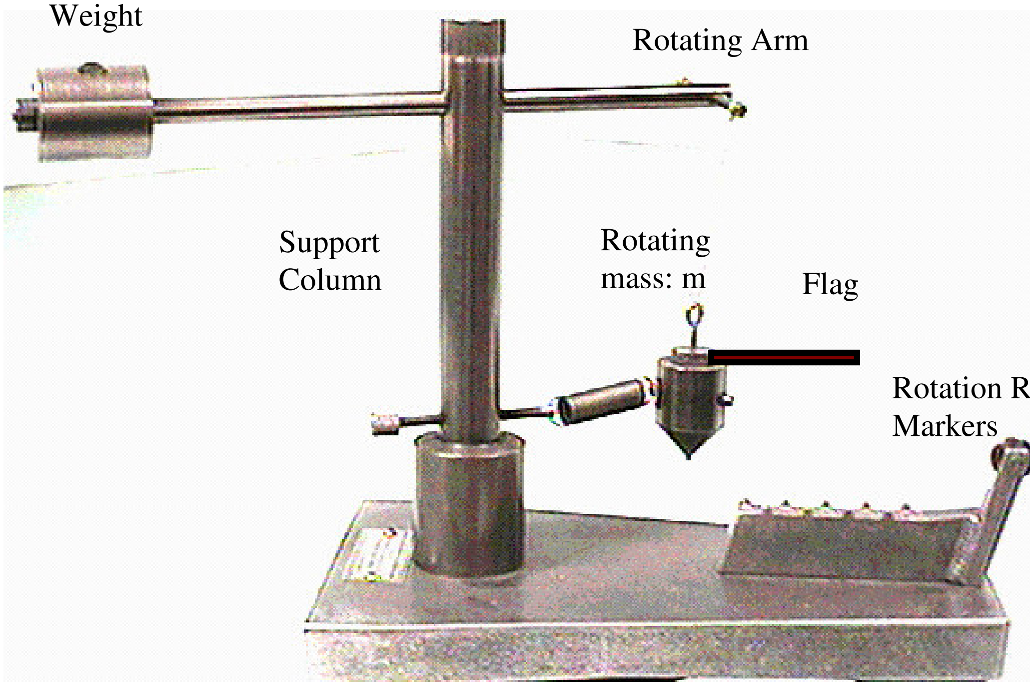
In the first portion of this experiment, you will dynamically determine the values of the period **T** and the radius **r** by rotating a support bar with a mass hanging from it and timing multiple revolutions. A spring attached to the mass supplies the centripetal force. You will need the values of the period **T** and the radius **r** in order to compute the value of the centripetal force. Putting these values into equation (**4**) above gives an experimental value for centripetal force. (The radius is marked on the apparatus.)

In the second portion of the experiment, the apparatus will not be rotating and the value of the centripetal force will be determined statically. A string will be attached to the mass, and the string will pass over a pulley. The spring will be stretched by weights on a weight hanger attached to the string running over the pulley. (The pulley is shown in the photo, but the string and weights are not.)

Equipment Procedures

Different versions of the Centripetal Force apparatus: The older version of the apparatus is shown in the picture on the first page of this lab and has a solid metal base. The second and third versions have three leveling adjustment screws in the wooden base. The second the screws themselves contact the table while the third version has black plastic feet end the bottom of the leveling screws that make contact with the surface of the table. This difference in the various apparatus is at the heart of the trade off between level operation and stability.

Centripetal Force	**1st Ed.**	**2nd Ed.**	**3rd Ed.**
Platform	Metal	Wood	Wood
Leveling Screws	None	Metal screws	Metal Screws w/ plastic feet
Clamping to Table	Not needed	Square on corner of lab table. Back off leveling screws.	Diagonal on corner of lab table so leveling screws don't touch the table.
Radius Marker	Fixed and labeled	Adjustable and unlabeled	Adjustable and unlabeled
Rotation	Turn from above	Knurled area on support rod.	Knurled area on support rod.



Experiment File: Under the **File** menu select the **Open** menu item. The **Experiments** folder will appear, double click on the **Probes and Sensors** folder, then double click on the **Photogate** folder and then, finally, double click on the **Pendulum Timer** file.

Flag Set Up: Install a "flag" on the top of the rotating mass and place a photogate in the circular path that the flag will follow so that the flag will break the beam once per revolution. This will not be the usual flag that was used in previous labs. A rectangular piece of thin cardboard (1/2" by 1-1/2") will do. The photogate in this program will function as an event timer. The event will be "the blocking of the beam" by the flag. The width of the flag doesn't matter because the program is counting the time between the beginning of every second blocking event.

Radius Adjustment: Detach the spring from the rotating mass. Loosen the screw in the top of the support column through which the rotating arm passes. Adjust the position of the rotating arm so that the mass hangs directly over the desired radius marker. Make sure there is enough clearance (about 2 millimeters) between the pointed tip on the bottom of the mass and the radius marker.

Rebalancing Procedure - Rotation Radius: Each time the rotation radius is changed the rotating arm needs to be rebalanced. With the support column screw still loosened, move the counter weight at the other end of the rotating arm either in or out until the rotating arm will balance with the screw loosened. Once the arm is balanced **tighten the support column screw securely**.

Flag Alignment Test: At this time (with the spring still detached), turn the rotating arm SLOWLY to ensure that the flag attached to the top of the rotating mass interrupts the photogate beam correctly. This flag will always rotate in the same horizontal plane so it is the vertical height of the photogate that needs to be adjusted so that the flag passes through the midpoint of the beam path. Re-attach the spring to the mass.

Experimental Procedure

Repeat both the **Dynamic** and **Static** portions of the experiment for **a total of five different radii**.

Data Collection (Dynamic): Rotate the apparatus at a constant speed by turning the top of the shaft with your fingers so that the pointed tip of the hanging mass continually passes squarely over the chosen radius mark. Assume this method gives a constant speed. Use the mouse to click the **Collect** button on the computer screen. Click the **Stop** button after about 20 revolutions. Use **Statistics** from the **Analyze Menu** to average the times. **NOTE:** The gate time measured is two times the period **T**. This is due to the nature of the pendulum that passes through the photogate twice per period while our rotating mass passes through the photogate once per period. All this means is that you need to divide your average gate time by 2 to get the correct period of the rotating mass.

The period **T** and the radius **r** are the basic data for computing the centripetal force. This is calculated by using the equation **(4)** given in the **Theory** section.

Data Collection (Static): During the **Static** portion of the experiment the apparatus is **not rotating**. You will measure the gravitational force, **Mg,** which causes the spring to stretch by the same amount that it was when the apparatus was rotating. This is accomplished by attaching a string to the mass, running the string over the pulley, and attaching a weight hanger with added weights to the other end of the string.

Repeat both the **Dynamic** and **Static** portions of the experiment for **a total of four different radii**.

Remember - Each time you change the radius **r**, you need to re-adjust the balance weight on the far end of the rotating arm.

Data Analysis

Find a percent difference between $F_S = Mg$ and $F_D = m\,4\pi^2 r / T^2$

The formula for the $\Delta F\%$ is

$$\Delta F\% = 2(F_D - F_S)\,100/(F_D + F_S)$$

Data Table

Rotating Mass = m = ______________________(kg)

Radius r (m)	Period T (sec)	F_D (N) (Dynamic)	M (kg)	F_S (N) (Static)	ΔF%

<u>Graphical Analysis</u>

Construct an X-Y Scatter chart with $\mathbf{F_S}$ on the vertical axis and $\mathbf{F_D}$ on the horizontal axis. Obtain the linear trendline and perform a LINEST analysis on the trendline. If the two quantities are the same, which should be the case, you should expect a slope of 1.00 and a y-intercept of 0.0.

<u>Lab Report</u>

This lab hand out will be your report. On the back of this page you can write up your analysis. Limit yourself to just this one page and include a **Results & Discussion** section and a **Summary** section. In your analysis list all possible sources of error. Your goal for this lab is to reduce all sources of error as much as possible and to achieve the best possible **ΔF%** values. Include your chart and LINEST analysis.