CENTRIPETAL FORCE

OBJECTIVE:

The purpose of this experiment is to investigate the relationships between centripetal force, radius, mass and velocity for an object undergoing uniform circular motion.

METHOD:

In part I, Centripetal Force versus Velocity, you will vary the velocity of a rotating mass by changing the voltage to the electric motor as the centripetal force is continuously measured by the Force Sensor.
In part II, Centripetal Force versus Mass, the radius and velocity are held constant as the mass is varied. By adding additional drilled masses to the holder, the mass of the system is increased. Equal amounts of mass must also be added to the "fixed mass" to balance the arm as it rotates. Centripetal force is directly measured by the Force Sensor.

APPARATUS:

Centripetal Force Apparatus (that includes Electric Motor, Connecting Cable, Ball Bearing Swivel, Rotating Arm with Free and Fixed Mass Holders.), Lab Stand, Weights, Photogate, Force Sensor, Power Supply, Interface, Computer and DataStudio software.

THEORY:

If a body is moving at constant speed but its direction is changing, then it has been accelerated in a direction perpendicular to its motion. In particular, if the body moves in circle of radius, r, at a constant speed, v, then the acceleration is directed toward the center of the circle and has the magnitude,

$$a = \frac{v^2}{r} \tag{1}$$

The acceleration given by Eq.(1) is known as the centripetal acceleration. If the body has a mass m, then from Newton's 2nd law, $F = ma$, we write the centripetal force as,

$$F = \frac{mv^2}{r} \tag{2}$$

The above equation indicates that the centripetal force is directly proportional to the square of the velocity, the mass and inversely proportional to the radius of rotation.

PROCEDURE and CALCULATIONS:

Part I Centripetal Force vs. Velocity

1. First check the centripetal force apparatus. Setup showed as the Figure 1.

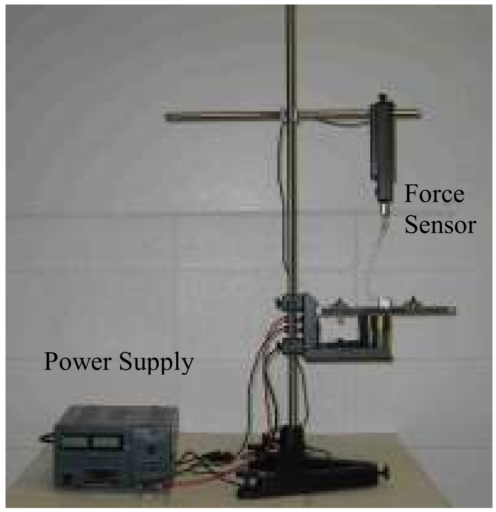

Figure 1 Equipment Setup

CAUTION: To avoid damaging the equipment, keep all cords away from the motor and rotating arm. Do not stand next to the motor or rotating arm or look at the rotating arm at eye level while it is rotating. To avoid possible injury from the rotating arm hitting the body, keep at least 1 foot distance from the motor and rotating arm when running the motor.

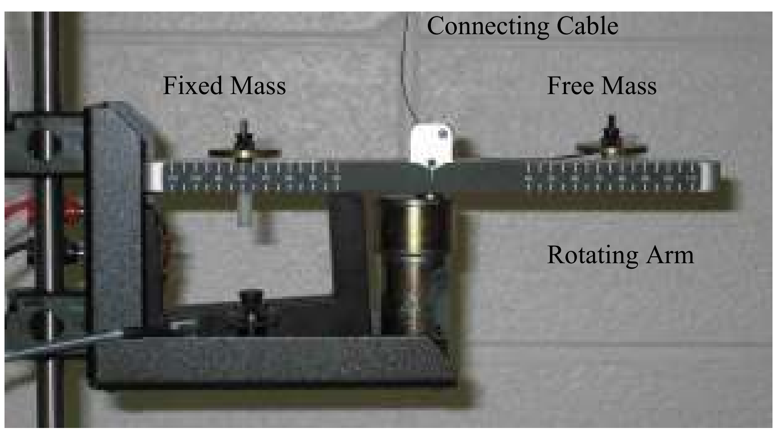

Figure 2 Free and Fixed Mass Holders

2. Add 20 grams mass to the free mass holder as showed on Figure 2; use the thumbscrew to hold the mass in place. Allow the "free mass" to slid freely along the groove. If the mass is not free to slide along the groove, significant frictional losses can be present.

3. Record the rotating mass.

   Rotating mass = added mass + mass of free holder.
   Note: mass of free holder = 4.0 g

4. Hold the free holder in place at 80 mm and carefully move the Force Sensor down or up along the rod to ensure the connecting cable is straight. The rotating radius is then 8 cm.

5. Add an equal amount mass (20 grams) to the fixed mass holder and use a thumbscrew to hold the mass at the same radius as the "free mass" to ensure balancing of the unit as it is rotating.

6. Turn on the interface first, and then turn on the computer. Double click the icon "Centripetal Force" and all DataStudio files will show on the scream. Choose and open the file named "Force_Vel Linear SW".

7. At the "Calculate" dialog box, enter the correct value for the radius in the <u>Experiment Constants</u> area. Type "0.080" and then click **Accept** button.

8. Turn on the power supply. Slowly increase the voltage. When the motor starts to rotate, click the **Start** button on the "DataStudio – Force_Vel Linear SW ds" window to start data recording.

9. Continually increase the voltage. The rotating speed rises in accordance with the changing voltage. Click the **Stop** button when the voltage reaches 8 volts. Then reduce the voltage back to 0 volts. The motor will stop.

10. A graph of all recording data automatically displays on the "Force vs. Velocity" window. Click the **Fit** menu button on the tool bar and then select **Quadratic Fit** on the fit menu. Does your data approximate a quadratic curved line? Print the graph.

11. Click **Smart Tool** button on the tool bar. The x-y cross will be displayed. Move the x-y cross arbitrarily to three points on the quadratic curved line, then record the X and Y values of those three points.

12. The X value is Velocity (V). The Force (F_r) is (Y value – C) where C is the Y value when V = 0. C appears in the Quadratic Fit data area on the graph.

13. Calculate the centripetal force using your recorded velocity (X value). Compare the calculated centripetal force (F_c) with the recorded force (F_r).

Suggested data table:

m = ______ kg   r = _______ m

	Record		Calculate	% differ. of F_c & F_r
	V	F_r	$F_c = mV^2/r$	
1				
2				
3				

Part II Centripetal Force vs. Mass

1. Close DataStudio window. Leave 20 g mass on the fixed and free holder. Keep radius for 0.08 m.

2. Double click file “Force_Mass SW” to open the “DataStudio - Force_Mass SW.ds” window.

3. At the “Calculate” dialog box, enter the correct value for the radius in the Experiment Constants area. Type “0.080” and then click **Accept** button.

4. Turn on the Power Supply. Set 7 volts for the output voltage value and then click the **Start** button on the tool bar to start data recording. Click the **Stop** button after few seconds.

5. Reduce the voltage to 0 volts. The motor will stop.

6. The recorded Force data, Run #1, will appear in the Data list on the “DataStudio - Force_Mass SW.ds” window. Drag it to Table in the Display list. The table will show up.

7. Click the **Statistic Menu** button (Σ) on the tool bar and select **Mean** from the statistic menu. Record the mean value of the Force.

8. Type the value of the mass including the mass of the holder and the mean value of force into “Force vs. Mass data” table in the Force vs. Mass window.

9. Repeat step 4 – 8 changing mass to 25 g, 30 g, and 35 g. Be sure to place an equal amount of mass on the “Fixed mass” holder.

10. The graph automatically shows Force vs. Mass. Click the **Fit** menu button and select **Linear Fit** from the fit menu. Does your data approximate a line? Print the graph. What is the mean of the slope?

11. Conclude the relation between centripetal force, velocity and mass using your data.