5.4: Force and Circular Motion

Name: ____

Date: ______________________

Partners:____

Equipment

- *LabPro* Interface
- Centripetal Force Apparatus (CFA)
- Force probe
- *CentripetalForce* software file
- *Graphing* software file
- Two each of 5, 10, and 20 g masses

Introduction

According to Newton's first law, a body in motion will remain in motion with constant velocity if the net force acting on it is zero. Constant velocity means that both the speed and direction do not change. An object moving in a circular path with constant speed does not have a constant velocity because the direction of the velocity is constantly changing. This implies that an object moving at a constant speed in a circular path is accelerating.

According to Newton's second law, a non-zero net force is needed to cause acceleration. In the case of an object moving in a circular path the acceleration is directed toward the center of the circle. Therefore the net force is also directed toward the center. This net force is often called the *centripetal force*.

Since the acceleration of an object undergoing uniform circular motion is v^2/R, the net force needed to hold a mass in a circular path is $F = m (v^2/R)$. In this lab you will investigate how changes in m, v, and R affect the net force F needed to keep the mass in a circular path.

I. Changing Mass

1. Carefully observe as your instructor or lab technician demonstrates the proper use of the Centripetal Force Apparatus. **Under no circumstances should you supply the motor with more than 12 volts or 0.40A or you will burn out the motor!**

2. Open the file *CentripetalForce***.**

3. Calibrate the force sensor by selecting **Experiment/Calibrate**. On the pop-up menu, select the force sensor and select **Calibrate Now**. You will now perform a two-point calibration of the force sensors:

- For the first calibration point, do not apply any force to the sensor, enter 0 N, and hit **Keep.**
- For the second calibration point, hang a 500 g mass from the sensor. Enter the weight of this mass (4.90 N) and hit **Keep.**

Note: *It is your responsibility to continually check the calibration of the force probe by first removing all mass and seeing if the probe reads 0N and then by hanging 500 grams on the probe and checking to see if it reads 4.9N. If you do not see these values then you either have to re-zero or re-calibrate the probe.*

4. Place a 5 g mass on each side of the apparatus at the 70 mm marks. The movable mass must be located by having one partner hold the center of the mass at 70 mm while a second partner moves the force probe up until the string is taut. The force probe must then be secured in this position.

5. The values of m and R can be directly measured from the Centripetal Force Apparatus (CFA). The tangential velocity is found by using a photo-gate timer and a calculation done in LoggerPro. The photo-gate will measure the time (T) for the mass to complete one complete revolution. The tangential velocity is thus:

$v = 2\pi R/T$

This formula can be found in Logger Pro under **Data/Column Options,** and then select Velocity. By default a radius value of 0.07 m is used. "Pulse Time" is the time for one revolution of the mass.

Note: *This formula only calculates the correct tangential velocity when the radius of the circle is 0.07 m. When other radii are used the user must edit this formula by entering the current radius in place of 0.07.*

6. Set the voltage to 8.0 volts and observe the apparatus to be sure that the string leading to the force probe is vertical and directly aligned with the pulley below it.

7. Click **Collect** and monitor the Velocity and Force for about 10 seconds, then turn off the power supply.

8. Highlight the area of the graph that shows the most constant values of Velocity and Force. Record the mean Velocity and Force in the table below, along with appropriate uncertainties.

9. Repeat the steps above to complete the table. Be certain that the velocity is the same as in the first trial. If not, adjust the voltage on the power supply.

Effect of Changing Mass on Force (R = 0.070 m)

Mass (kg)	***Velocity (m/s)***	***Force (N)***
0.005	±	±
0.010	±	±
0.015	±	±
0.020	±	±
0.025	±	±
0.030	±	±
0.035	±	±

II. Changing Velocity

1. Place a 20 g mass centered at the 70 mm mark on each side of the apparatus.

2. Check your force probe calibration with 0 N and 4.9 N. Re-zero or re-calibrate if necessary.

3. Set the voltage to 4.0 volts and observe the apparatus to be sure that the string leading to the force probe is vertical and directly aligned with the pulley below it.

4. Click **Collect** and monitor the Velocity and Force for about 10 seconds, then turn off the power supply.

5. Highlight the area of the graph that shows the most constant values of Velocity and Force. Record the mean Velocity and Force in the table below, along with appropriate uncertainties.

6. Repeat the steps above to complete the table.

Effect of Changing Velocity on Force (m = .020 kg and R = 0.070 m)

Voltage (V)	***Velocity (m/s)***	***Force (N)***
4.0	±	±
5.0	±	±
6.0	±	±
7.0	±	±
8.0	±	±

9.0	±	±
10.0	±	±
11.0	±	±
12.0	±	±

III. Changing Radius

1. Place a 20 gram mass centered at the 50 mm mark on each side of the apparatus.

2. Click on **Data/Column Options** and then select **Velocity**. Since our radius is now 0.05 m, edit the expression for mass velocity to **2*pi*(0.05)/"Pulse Time".**

3. Check your force probe calibration with 0N and 4.9N. Re-zero or re-calibrate if necessary.

4. Set the voltage to 12.0 volts and observe the apparatus to be sure that the string leading to the force probe is vertical and directly aligned with the pulley below it.

5. Click **Collect** and monitor the Velocity and Force for about 10 seconds, then turn off the power supply.

6. Highlight the area of the graph that shows the most constant values of Velocity and Force. Record the mean Velocity and Force in the table below, along with appropriate uncertainties.

7. Repeat the steps above to complete the table. For each new radius you need to:

a. Edit the Velocity equation by entering the current radius

b. Adjust the voltage in order to maintain a consistent velocity for each trial

Effect of Changing Radius on Force (m = .020 kg)

Radius (m)	***Velocity (m/s)***	***Force (N)***
0.050	±	±
0.060	±	±
0.070	±	±
0.080	±	±
0.090	±	±
0.100	±	±

IV. Analyzing the Data

A. Force vs. Mass

Open the file *Graphing*. This file is set-up to allow you to enter your data and uncertainties and create a best-fit graph.

- Enter your data into the appropriate column. (Force on the y-axis, mass on the x-axis, and the uncertainties in the appropriate columns.)
- Double-click on each column header to change the label and units for each column.
- Select an appropriate best-fit function (in this case **Analyze/Linear Fit**) and display it on your graph. To determine the uncertainties in the linear fit parameters, right-click in the Linear Fit box and select **Linear Fit Options**. This displays the standard deviation of the slope and y-intercept.
- Finish preparing your graph, then print and attach it to the end of this activity.

Question: Compare the generic form of a linear function, **Y =AX + B**, with the theoretical equation **F = m (v^2/R)**. What should the values of A and B equal if the theory is valid? Hint: If a variable is graphed on the x- or y-axis, it can't be part of A or B.

Question: Based on your observation above, calculate the known value of the constants that comprise A in your best-fit function. Does your experimental value of A, with units and uncertainties, agree with this known value?

B. Force vs. Velocity

Create a graph of Force vs. Velocity as described above. Fit your data with a power function and attach it to the end of this activity.

Question: Compare the generic form of a power function, **Y =AX^B**, with the theoretical equation **F = m (v^2/R)**. What should the values of A and B equal if the theory is valid?

Question: Is the power of your best-fit function equal to 2 within your uncertainty? If not, speculate on *specific* sources of possible error and how you would correct these errors if you repeated the experiment.

Question: Calculate the known value of the constants that comprise A in your best-fit function. Does your experimental value of A, with units and uncertainties, agree with this known value?

C. Force vs. Radius

Create a graph of Force vs. Radius as described above. Fit your data with a power function and attach it to the end of this activity.

Question: Compare the generic form of a power function, **Y =AX^B**, with the theoretical equation **F = m (v^2/R)**. What should the values of A and B equal if the theory is valid?

Question: Is the power of your best-fit function equal to -1 within your uncertainty? If not, speculate on *specific* sources of possible error and how you would correct these errors if you repeated the experiment.

Question: Calculate the known value of the constants that comprise A in your best-fit function. Does your experimental value of A, with units and uncertainties, agree with this known value?