Centripetal Force

**PHYS 40A: Lab 5**

**Centripetal Force**

*(Includes Pre-Lab Assignment)*

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**Objectives**

These lab activities will focus on the concepts of angular velocity, centripetal force, and the conservation of angular momentum. You should read all the steps in each part before you start. Work in your assigned groups and maintain a collaborative and communicative team.

You will vary the distance a mass is from the center of a circle (radius) and the magnitude of the mass to measure the angular velocity. You will then find the angular velocity at the moment the centripetal force is balanced by the force from the hanging mass, and find relationships between the radius, the mass, and the angular velocity.

For the following activities, you will use a physics simulation program. Visit: [https://uglabs.physics.ucr.edu/](https://uglabs.physics.ucr.edu/) for lab downloads and links.

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**Introduction**

**Centripetal Force:**

We know that in the absence of any outside force, an object will travel at constant speed in a straight path (*Newton’s 2nd Law*). When an object of mass, M, is revolving in a uniform circular motion with a radius of R, the object is in accelerating motion. In a uniform circular motion, the magnitude of the velocity vector is constant, however, the direction is changing inwards towards the center. Therefore, if we observe a change in the direction of motion, we known there must be a force acting upon the object.
**Centripetal Force**

For an object to continue moving in a circle at a constant speed, the force must be equal to the mass, speed, and the radius of the circle. If the force is too small or the object is traveling too fast, the object will move outward from the circular path. If the object is traveling too slowly or the force is too large, the object will move inward towards the center of the circle. Since we know the direction of the force is towards the center of the circle, we describe the force as centripetal, coming from Latin meaning “center seeking”. This leads us to:

\[
\text{Centripetal Force} = F_c = ma = m \frac{v^2}{R}
\]  

(1)

The force is usually written in terms of the angular velocity, \( \omega \), of the object about the center of the circle. This is related to velocity, \( v \), by:

\[
v = \omega R
\]  

(2)

We can then write that the centripetal force is:

\[
F_c = mR\omega^2
\]  

(3)

**Simulated Experimental Apparatus:**

The apparatus provided is a Centripetal Force Accessory with a spinning platter, weights, and force sensor shown in Fig. 1 below.
Centripetal Force

If we vary the speed of the platter until the mass is pushed off the end of the track at the point when the force provided by the mass is exceeded by the centripetal force. At the instant before the mass begins to move it is balanced with the centripetal force.

In this experiment we will vary radius and measure force as the mass begins to be pushed outward. You will then plot your results for $F_C$ vs. $R$.

1. Varying Radius

1.1: Begin an Excel spreadsheet. In these sets of experiments, we will be measuring the force on the mass across varying radius, $R$, with a fixed mass, $M$. Create a table with columns for Radius and Force.

1.2: Drag the Force Sensor to the center of the platter. It should snap to the central axis.

1.3: Increase the Mass Multiplier to 5. Weigh the cylindrical mass D on the digital scale and record the results in your notebook. Hang the mass from the force sensor, which will again snap on automatically.

1.4: Drag the mass to the end of the platter, you will see a string continues the connection to the force sensor. $R$ represents the distance from the rotational axis to the center of the mass. Use the Radius Indicator to measure radius to the center of the mass then record $R$ in your table.

Pro tip: See the User Guide for this app to see the how to fine tune the knobs.
Centripetal Force

1.5: Turn on the rotation and adjust the Speed to 75 rpm. Once the system reaches full speed record the output of the Force Sensor in your spreadsheet.

1.6: Repeat steps 1.4-1.5 for 10 data points choosing different radii, $R$, but keeping the mass and speed the same. Steps should be ~1cm toward the center of the platter.

1.7: Plot this data in your spreadsheet, $F_C$ vs. $R$. We will now analyze this graph.

1.8: We expect the force on the mass to be mathematically related to the radius ($R$) according to equation 3. What graphical fit equation you might use to represent this relation? Explain what the parameters in your fit equation refer to.

1.9: Make a plot of your data in Excel. Use your answers from step 1.8 to choose the appropriate fit equation. Record the fit equation for your plot in your notebook. Sketch the graph by hand in your notebook and discuss the precision of the best-fit model.

1.10: What is the relationship between the fit coefficient, let’s call it “A,” in your equation and the terms for the angular velocity equation?

$$\omega = \sqrt{\frac{F_C}{MR}} \quad \text{(Eq. 1)}$$

1.11: Calculate what you would expect the value of A to be based on the measured values used in your experiment. Determine the percent error between the observed value (from the best-fit line) and the expected value.
2. Centripetal Force

2. F<sub>c</sub> with Varying M

2.1: In this experiment, we will measure the F<sub>c</sub> of the platter for varying mass, M, at a fixed radius, R.

2.2: Start a new tab in your spreadsheet and create columns for Mass and Force. Select a single radius, R, and use the same radius for all trials.

2.3: Weigh another cylindrical mass and connect it again to the force sensor. Drag it to your selected R. Ensure that speed is still 75 rpm then turn on the rotation. Once the system reaches full speed, record the output from the force sensor.

2.4: Without adjusting any other parameters, vary the mass a total of 10 times to values of your choice and repeat step 2.3.

HINT: Use the mass multiplier to change the values of the masses.

2.5: After completing the table of measured F<sub>c</sub> and masses, create a graph of F<sub>c</sub> vs. M and create a fit of the data. Sketch the graph by hand in your notebook and discuss the precision of the best-fit model.

2.6: What is the relationship between the fit coefficient, again let’s call it “A,” and the terms for Eq. 3?

2.7: Calculate the expected value of A and determine the percent error between the measured and the expected value.
1. A 30 kg child sits on the edge of a merry-go-round with a radius 5.0 m. The merry-go-round rotates as shown with a constant speed such that it takes the child 6.0 seconds to make a complete revolution.

   a. What is the child’s angular speed (in rad/s)?

   b. What is the magnitude and direction of the child’s acceleration (in m/s$^2$) at the point in time shown?