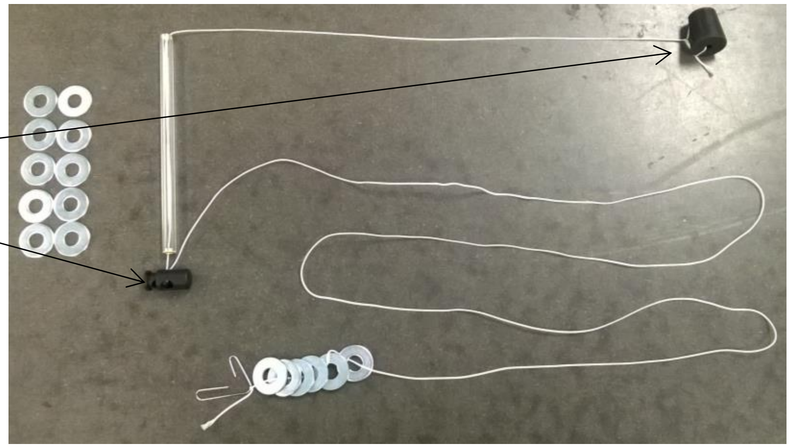
PHY 123 Lab 4 – Centripetal Force

The purpose of this lab is to study uniform circular motion.

Equipment

- Acrylic tube
- Stopper
- Cord clamp
- Paper clip
- Washers
- String
- Pair of goggles



Introduction

Circular motion is motion in two dimensions characterized by a circular path. Since the direction of an object following uniform circular motion is changing, then the linear velocity vector also changes its direction, but not its magnitude (remember that a vector has magnitude and direction). Therefore, the object has an acceleration. This type of acceleration is called *centripetal acceleration (a_c)* and is directed toward the center of the circle (perpendicular to the linear velocity), and its magnitude is:

$$a_c = \frac{v^2}{r} \qquad (1)$$

where r is the radius of the circular motion and v is the linear, or tangential, velocity.

Applying Newton's second law in the radial direction we can evaluate the net force that causes the centripetal acceleration:

$$F_c = ma_c = \frac{mv^2}{r} \qquad (2)$$

This force is called *centripetal force* and acts toward the center of the motion (same direction as a_c). A centripetal force is not a new force that exists by itself, it must **provided** by some other force to keep an object moving in a circular path. Examples of forces which can provide the centripetal force include gravitation, friction, normal force, or, in this lab, tension in a string. Centripetal force is essentially the net force acting on an object moving in a circular path.

Since the object is moving in circles around its axis of rotation we can calculate its average angular velocity ($\overline{\omega}$) dividing the total angular displacement ($\Delta\theta$) by the total time:

$$\overline{\omega} = \frac{d\theta}{dt} \qquad (3)$$

Or using full rotations:

$$\overline{\omega} = \frac{2\pi}{T} = 2\pi f \qquad (4)$$

Where T is the period of the oscillations, or the time for one complete rotation (2π radians), and f is the number of rotations per seconds (measured in sec^{-1} or Hz).

The relationship between linear velocity and angular velocity is:

$$v = r\omega \qquad (5)$$

Experimental method

First steps to prepare the apparatus

- Weigh and record the mass of the stopper (m in the equations above).
- Weigh 16 washers together and then divide it by 16 to get the average value of the mass of the washers (M in the equations below). Record this value
- Tie the stopper to one end of the string.
- Thread the free end of the string through the acrylic tube.
- Bend the paper clip and tie the loose end of the string to the center of the paper clip.

Preparing for a measurement

Each time you swing the apparatus you will want to know the radius of the motion r and the tension in the string

- The radius r can be found by measuring the distance of the string between the midpoint of the stopper and the closest end of the acrylic tube. To help keep this constant during the experiment, fasten the cord clamp on to the string one centimeter from the other end of the tube. Your goal is to keep this distance constant while you are swinging the string, i.e. when the string is swinging the distance of the cord clamp from the tube should be one centimeter (**not** zero centimeters!) When you are performing the experiment correctly your radius is constant, but the centripetal force is provided by the tension in the string which is equal to the weight of the washers**.** This will not be the case if the cord clamp is touching the tube.
- You can place or remove washers on the string by passing them over the paper clip. The tension force in the string when you are swinging it (which is the same as the centripetal force) will be $F = NMg$, where N is the total number of washers at the end of the string, M is the average mass of the washers, and g is the acceleration due to gravity.

Performing a measurement

- Hold the acrylic tube so that the washers are down, and carefully swing the stopper overhead. At high speed the spring will be pulled up, regulate the speed so the distance between the cord clamp and the tube remains always the same. ***Make sure the cord clamp is not touching the tube. You must wear safety glasses while the stopper is swinging.***
- In order to measure the period, T, measure the time that the stopper takes for 10 revolutions. Then divide this time by the number of revolutions to get T and record this value. The goal of this procedure is to minimize the uncertainty in the period, which is the largest source of error. From the measured period, T, you should be able to obtain the tangential velocity v. (You will need to use your measurement of the radius of the circular path r for this).

Experiments to perform

You should investigate two effects.

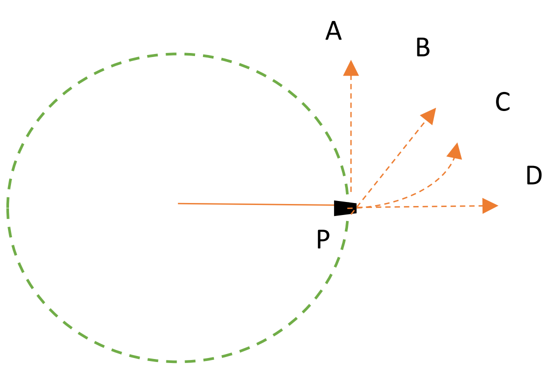
1. For a fixed radius measure the velocity for several different values of the centripetal force (by changing the number of washers on the string). Plot a graph of v^2 vs F_C. Does the dependence of v on F_C when r is fixed match your expectation based on equation 2? Does the slope of the graph match your expectation based on equation 2?

2. For a fixed centripetal force measure the velocity for several different values of the radii. Plot a graph of v^2 vs r. Does the dependence of v on r when F_C is fixed match your expectation based on equation 2? Does the slope of the graph match your expectation based on equation 2?

You can use the web based plotting tool for your graphs using either the iPads on your tables or your own devices.
(http://www.ic.sunysb.edu/class/phy141md/doku.php?id=phy131studio:labs:plottingtool)

Answer the following questions in your lab notebook:

1. **Assume you are swinging the stopper in the counter-clockwise direction as show in figure. Suddenly, the string breaks at the point P, which path would the stopper follow? Why?**



2. **Why is it not possible to have a 90° angle between the vertical string and the portion of the string attached to the stopper?**