Lab 6

Centripetal Force

Experimental Objectives

- It is our purpose to experimentally verify the equation for centripetal force by
  - measuring the applied force and
  - comparing it to the specific combination of variables expressed as either $\dfrac{mv^2}{r}$ or $m\omega^2 r$.

Introduction

We will be investigating the force which is necessary to maintain the circular motion of an object. The apparatus used will allow you to spin an F-shaped arm which has a mass suspended from the top arm. This mass will be held in place by a spring which makes up the lower arm. The spring will provide the centripetal force. You will need to be familiar with the ideas of circular motion, centripetal versus centrifugal force, centripetal acceleration, and angular velocity. In addition to these concepts, try to understand how we will measure the angular speed in lab.

The centripetal acceleration a_c is calculated from the following equation written either $a_c = \dfrac{v^2}{r}$ or $a_c = \omega^2 r$ where v is the linear velocity of the particle, ω is the angular velocity, and r is the radius of the circle. Note that angular velocity is measured in radians per second.

From Newton's second law, $\vec{F} = m\vec{a}$. Therefore, the force required to keep the particle of mass m moving in a circle with constant speed is

$$F = ma_c = \frac{mv^2}{r} = m\omega^2 r \tag{6.0.1}$$

Recall that the centripetal force is not a force applied *in addition* to other existing forces. The centripetal force is *whatever combination* of existing force act to maintain circular motion.

6.1 Pre-Lab Considerations

1. Why do we say that an object moving with *constant speed* in a circular path is being accelerated?
2. In which direction is that acceleration? How do you know?
3. Is this a_c "centripetal" or "centrifugal?"

6.2 Student Outcomes

Knowledge Developed: In this exercise, students should learn how the forces required to hold spinning objects in place changes with the speed.

Skills Developed:

- Evaluating and propagating uncertainties from the source of uncertainty to the result

6.3 Procedure

The centripetal force is supplied by a spring. Since we cannot directly measure "the force exerted by the spring while it is rotating" while it is rotating, determine how we can measure "the force exerted by the spring during the rotation" when the spring is not rotating.

- By means of the lab apparatus, a mass m can be made to rotate with a constant (and measurable) angular speed ω. With some practice, it is possible to adjust the speed so that the radius of the path remains constant. The value of the radius, r, is marked on the apparatus and so can be measured easily.
- Measuring the mass should be an obvious task.
- Measuring the angular speed ω is straightforward, but may not be obvious. To do so, consider the following:
  - Angular speed (ω) is measured in $\frac{\text{rad}}{\text{s}}$.
  - ω is related to the rotational speed which is measured in $\frac{\text{rev}}{\text{s}}$.
  - There are 2π radians in 1 revolution.
  - We can count the number of revolutions.
  - The "period of rotation," T, is defined as the number of seconds per revolution.
  - We measure the period not by timing a single revolution, but by measuring the time for multiple (20) revolutions divided by the number of revolutions. (This averages out any uncertainty due to reaction-time.)

  As the mass rotates, its period of rotation can be measured. This allows you to calculate the angular speed using the hints above.
- Repeat the entire procedure for a second value of F.
  - To change the force used, you have to adjust the spring as follows.
  - There is a small dial at the end of the spring away from the mass. If you turn it one way, it tightens the spring (increasing the force). If you turn it the other way, it loosens the spring (decreasing the force).
  - When you change this dial, it is unlikely that you will be able to put it back to where you originally had it, so you should be certain that you have all the information you need from the first measurements before you turn this dial!

6.4 Analysis

From measurements of m, ω, and r, calculate the theoretical centripetal force on the mass (which experimentally is supplied by the spring). You can, of course use Rule 2 to determine the uncertainty of this centripetal force (as expected from the theory).

The (unmeasurable) amount of force exerted by the spring to hold the spinning mass at a particular radius is equal to the (measurable) force required to stretch the spring to that radius. Experimentally determine the force necessary to stretch the spring to a specific radius. You should, of course, find the uncertainty in this value as well.

In order to verify the theory of centripetal force, and Equation (6.0.1) in particular, compare the force needed to stretch the spring with the amount of theoretical centripetal force calculated above.

(Revised: Oct 11, 2017)
A PDF version might be found at centripetal.pdf (83 kB)