I. Introduction

A. Uniform circular motion occurs when an object goes around in a circle at constant speed.

i. Note that although the object’s velocity is constant in magnitude, it is not constant in direction, and thus the object is accelerating even though its speed is constant! Since the object is accelerating, there must be a net force on it. For example, it is evident that it requires an external force to get a car to go around a corner. On level ground, that force is provided by friction between the car wheels and the ground. If we turn off the frictional force (by coating the ground with ice), the car will no longer be able to negotiate the turn, but will instead travel in a straight line at constant speed, as Newton’s first law implies.

ii. There are several widely held misconceptions concerning the forces required to make an object move in this manner. For example, it is often difficult to discard the incorrect ideas that the force on an object moving in a circle is outward or that there exists a centripetal force that is a separate kind of force. One of our goals for this laboratory is to remind ourselves that the force on and acceleration of an object traveling in a circle with a constant speed are inward, i.e., toward the center of the circle. We will determine the magnitude of the inward (centripetal) acceleration experimentally and then multiply it by the mass to calculate the magnitude of the required centripetal force. We will then attempt to show that, for this experiment, the force responsible for centripetal acceleration is provided by a spring.

The goal of this experiment is to find the force responsible for the centripetal (center seeking) acceleration and compare its value to the predicted. We will use a spring so that we reinforce Hook’s Law too.
II. Objectives

At the end of this activity, you should:

1. Be able to see that \( F_c = m(a_c) = m\left(\frac{v^2}{R}\right) \).

2. Be able to see that \( F_{\text{spring}} = -kx \).

3. Be able to compare \( F_{\text{spring}} \) to \( m(a_c) \) and see if they agree within uncertainty. For this experiment, the spring force on the bob is responsible for the centripetal acceleration.

III. Needed Equipment

A schematic of the equipment that we will use is shown in the diagram below. The shaft has the ability to rotate freely. The crossbar is rigidly attached to the shaft and the bob is attached to the crossbar and shaft by a string and spring, respectively. All of these rotate with the shaft. There is also a "flag" (a bent piece of metal) that rotates with the shaft and interrupts a light beam each time that it passes through the photogate. We will not be using the photogate in this version. Instead we will measure the time for 10 complete revolutions and extract the rotational period from that.
IV. Procedure

A. Preliminary Data:

A.1. Measure the mass of the rotating bob using an electronic balance.

A.2. As always, \( g = 9.810 \text{ m/s}^2 \).

A.3 Measure your spring’s spring constant. Do this by measuring the amount the spring is stretched when a given mass is hanging from it straight down. Use Newton’s second law to find the force exerted by the spring, then Hooke’s law to extract the spring constant.

A.4. Record these numbers for later use.

B. Make two separate runs using two different orbital radii.

B.1. Measure the radius, of your orbit and then measure the time for 10 revolutions. Do this 3 for each orbital radius and take an average to find your orbital period.

B.2.

B.3. Calculate the force exerted by your spring using your spring constant and the amount the spring stretched for the mass to orbit at the give radius. This spring force is your measured value for the tension that bends the bob’s trajectory into a circle of radius \( R \). In other words, this is the left-hand member of the NSL-Radial equation, \( F_c = m(a_c) \).

B.4. To calculate the right-hand side of Newton's second law, calculate the orbital period, the tangential speed, and the centripetal acceleration. Finally, calculate the net force as the product of the mass and the centripetal acceleration.
V. Clean-Up

A. Golden Rule: “Do unto others as you desire them to do unto you.”

This applies as much here in the lab as it does in the Fleet. As future Naval Officers, how can you expect your enlisted sailors to maintain a clean work area if your stateroom, work areas, mess area, etc is a “pig sty?” So as officers it is imperative that we clean up after ourselves not only to follow the Golden Rule, but also to lead by example for the enlisted personnel under our charge.

1. End of Lab Checkout: Before leaving the laboratory, please tidy up the equipment at the workstation and quit all running software.

2. The lab station should be in better condition than when you arrived and more importantly, should be of an appearance that you would be PROUD to show to your legal guardians during a “Parents Weekend.”

3. Have your instructor inspect your lab station and receive their permission to leave the Lab Room.

4. You SHALL follow this procedure doing every lab for BOTH SP211 and SP212!

Many thanks to Dr. Huddle and Dr. McIlhany for their assistance in producing this Laboratory procedure; specific references can be supplied on request. LCDR Timothy Shivok