PHYSICS LAB EXPERIMENT – 10

UNIFORM CIRCULAR MOTION

OBJECTIVE: In this lab you will be investigating circular and rotational motion and verifying the form of the centripetal force.

APPARATUS: Plastic tube, string, rubber stopper, hanging weights, stop watch, and meter stick or ruler.

THEORY: In class, we showed that the radial acceleration of an object undergoing circular motion can be written as

$$a_{rad} = \omega^2 r \tag{1}$$

where r is the radius of the circular path and ω is the angular speed that the object is rotating about the center of the circle. In the case that the objects mass, m, is not changing with time it follows that the centripetal force F_c associated with the object's circular motion can be written as

$$F_c = m\omega^2 r \tag{2}$$

For the first part of the lab, you will be verifying experimentally that F_c of an object undergoing circular motion is indeed the quantity $m\omega^2 r$ given in Equation 2. You will do this by twirling a rubber stopper of mass m attached to a string. In order to ensure a constant tension in the string, the string will be run thru a plastic tube (which you will hold) and have another mass, mass M, attached to the other end, as shown in Figure 1. If the stopper is twirled at a constant rate such that the position of the hanging mass M is constant, then the tension in the string F_T is equal to the force responsible for the circular motion of the stopper.

$$T = F_c \tag{3}$$

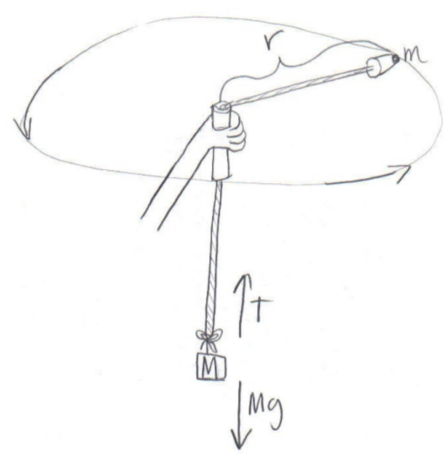


Figure 1: The twirling stopper set-up.

PROCEDURE:

You will experimentally measure the centripetal force on the stopper in two ways and compare them. The first way you will measure F_c is by measuring the tension in the string due to the hanging mass M and using Equation 3. The second way you will measure it is with the use of Equation 2, in which case you will measure m, ω, and r for the stopper undergoing circular motion when the hanging mass is stationary. You will then compare the two quantities, which within experimental uncertainty, should agree.

1) Obtain a string with stopper and tube along with a hanging mass, a stopwatch and meter stick.
2) Set it up and give it a test twirl. You will need someone in the group who is capable of twirling it for 30 seconds at a constant rate. Hint: *it is easier to grip the tube near to the top, holding it near the bottom can make it harder to keep it spinning at the same speed for the full 30 seconds.*
3) Once you are a practiced twirler, **perform 3 trials** in which you measure the radius and angular speed of the stopper as it twirls. Record your data in Table 1. Hints: *to measure ω, count the number of revolutions the stopper makes in 30 seconds and then use this to find ω (make sure this value is converted to rad/s before using it in calculations). Also, it may be easier to measure the radius of the circular motion indirectly, i.e. measure how much string is hanging below the tube when the stopper is in uniform motion and deduce the radius from that length.*
4) Also record the uncertainties for each of your measured values in Table 1.
5) Now calculate F_c for all three trials using Equation 2 and record these values in Table 1 under the column labeled F_c from Equation 2.
6) Next, calculate the tension from the mass of the hanging mass M and record the F_c derived from Equation 3 in the table.
7) Find the percent difference between the averages of the two values.

DATA & ANALYSIS:

Mass of stopper:__________ Mass of hanging mass: ______________

Table 1: Twirling the stopper data

Trial #	Δt (s)	# revs	ω ( )	$\Delta\omega$( )	r ( )	Δr ( )	F_c( ) Eq. 2	F_c( ) Eq. 3

Average F_c from Eq. 2: ________________________

Average F_c from Eq. 3: ________________________

Percent difference F_c: ________________________

QUESTIONS:

1. How does the centripetal force on an object vary with the tangential speed of rotation (v) for a constant radius path? In other words, what must happen to the centripetal force as the velocity is raised or lowered?

2. How does the centripetal force vary with the radius of the path for a constant tangential speed of rotation?

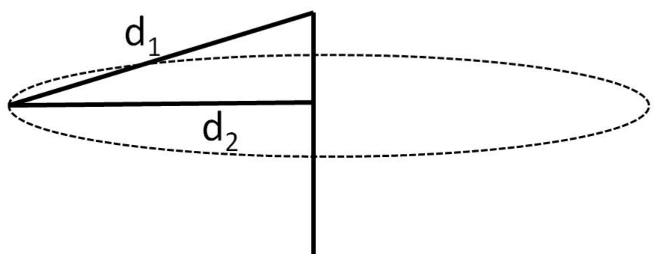
3. The blades of a windshield wiper move through an angle of 120° in 0.34 s. The tips of the blades move on the arc of a circle that has a radius of 0.76 m.
   (a) What is the magnitude of the centripetal acceleration of the tip of the blade?

   (b) If a bug of mass 15.0 g is sitting on the tip of the blade, how much centripetal force is it experiencing?

4. Calculate at what speed the earth would have to rotate in order that an object at the equator would have no measured weight. Radius of the earth is about 6400 km.
   (a) What would be the tangential speed of a point at the equator?

   (b) What would be the length of the day (from sunrise to sunset) in hours?

5. How is the effective value of *g* affected due to the rotation of the Earth, (a) at the equator, and (b) at the poles? Explain briefly.



6. Gravity is also acting on the stopper pulling it downward as it revolves, shown in the figure above (somewhat exaggerated). Which of the two lengths, d_1 or d_2, is the correct one to use in this experiment? Which did you use?

7. What size error did you introduce if you used the wrong one? Quantitatively discuss how this may have affected your results?