MND Physics

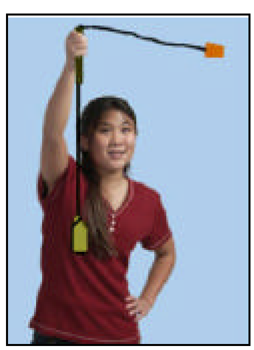
Centripetal Force Lab

When an object is traveling along a circular path and moving at a constant speed it is in a state of uniform circular motion. The magnitude of the force that maintains this circular motion, the centripetal force, can be found by

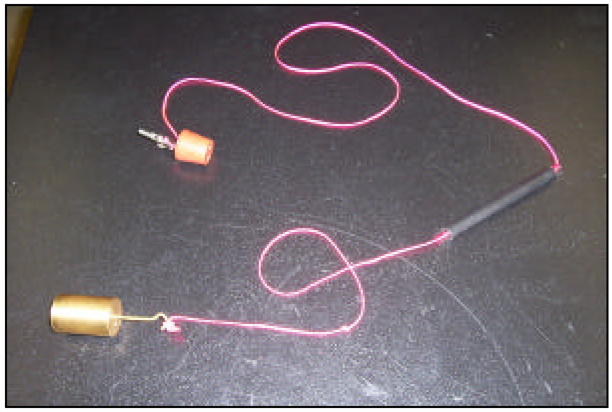
$$F_c = (mv^2) / r$$

where "F_c" is the magnitude of the centripetal force, "m" is the mass of the object in circular motion, "v" is the speed of the object, and "r" is the radius of the circular path in which the object is traveling.

In this lab, you will be twirling a rubber stopper in a circular path overhead. As shown below, a string passes from the stopper freely through a tube (which will be held in your hand allowing you to drive the motion) and then down to a mass hanging at the other end of the string. The centripetal force will be supplied by the mass below the tube (its weight). You will also be measuring the quantities in the centripetal force equation above and calculating the value of the centripetal force.



EQUIPMENT: Glass or plastic rod, string, mass set, rubber stoppers, alligator clip, stopwatch, balance.



Critical considerations for success in this lab:

1) The rubber stopper must swing in a horizontal circle overhead; if the stopper swings at an angle to the horizontal, it will be accelerating on the downhill portion and decelerating on the uphill portion of its path. If this occurs, you do not have uniform circular motion and will incur error!

2) When taking time trials, the radius of the circular path must remain constant. Practice first and redo if the string slips.

3) The apparatus is designed to demonstrate uniform circular motion, not to see haw many people can be hit by rubber stoppers…BE CAREFUL!

4) Speed often implies as fast as humanly possible…NOT IN THIS CASE! If you swing the rubber stopper too fast the mass will pull up against the tube and your readings will not represent the actual forces involved. DO NOT SWING THE STOPPER TOO FAST.

PROCEDURE:

In each part of the lab you will be measuring the following quantities:

1) The MASS of the stopper(s) with alligator clip.

2) The TIME for one complete revolution of the rubber stopper. To reduce error, first get the stopper in uniform circular motion. Once the stopper is in uniform motion, your lab partner will time 25 revolutions. Divide the total time by 25 to obtain the time for one revolution.

3) VELOCITY. Use the definition for velocity, the distance traveled by the stopper in one revolution, and the time for one revolution to calculate the average velocity.

4) CENTRIPETAL FORCE. The accepted value of the centripetal force will be equal to the weight of the hanging mass. The experimental value is calculated using the formula given in the introduction of this lab.

5) RADIUS of the circular path. Once the time trial is completed, the string should be CAREFULLY grasped while the stopper is still in motion. The distance from the top of the tube to the center of the stopper should then be measured. This is the radius.

PART 1

Use the alligator clip to fasten the string to the stopper. Weigh the stopper and clip assembly. A hanging mass of 100 grams should be tied to the opposite end of the string (see illustration on page 1). After assuring that everyone is at a safe distance, swing the stopper in uniform circular motion in a small radius of approximately 30-50 cm and record the values listed in the procedure.

PART 2

Use the same stopper and hanging mass in part 1 except now make the radius as large as you can while maintaining uniform circular motion (try for 2-3 times or more the radius used in part 1). Record the values listed in the procedure.

PART 3

Now using 2 stoppers connected to the same clip and a hanging mass of 200 grams, repeat the process stated in Part 1 above. Record the values listed in the procedure.

PART 4

Using 2 stoppers connected to the same clip and a hanging mass of 200 grams, repeat the process stated in Part 2 above. Record the values listed in the procedure.

PART 5

Using the mass and stopper from parts 3 and 4, swing the stopper in a vertical circle. Explain in your report why this is not uniform circular motion.

PART 6

Swing the stopper in horizontal uniform circular motion. Stop the driving motion supplied by your hand. Observe what happens to the motion and stopper.

DATA:
Create your own data table. You will be measuring and recording all the values listed on page 3 (see first part of procedure) for various trials.

CALCULATIONS:
Calculate the centripetal acceleration for trials 1 thru 4 (4 separate calculations).
Calculate the centripetal force for trials 1 thru 4 (4 separate calculations).
Calculate the percent error for each force calculation. Use the hanging weight as the accepted value of the centripetal force.

QUESTIONS:

1) What are the sources of your error? Include a detailed error analysis (explanation of each source of error and its influence on your results).

2) From Part 5, describe the motion of the stopper. Is it accelerating? Why or why not?

3) From Part 6, describe the motion of the stopper. What happens to the radius of the circular path? What happens to the speed of the stopper? Where does the "speed" go?

4) If the weight of the hanging mass supplies the centripetal force to keep the stopper in circular motion, why is your hand needed to drive the motion?

5) Which of the following would cause the greatest increase of centripetal force… doubling the mass of the stopper (while everything else remains fixed) or doubling the speed of the stopper (while everything else remains fixed)? Justify your answer mathematically.