Centripetal Force

Purpose

1. To demonstrate centripetal force acting on an orbiting body.
2. To relate angular motion and linear motion.
3. To relate centipetal force and angular motion.

Introduction

In this lab, you will swing a mass (stopper) in orbit around a center of motion. The stopper will be tied to a string, and the string will run through a vertical glass tube in your hand. The other end of the string will be connected to a hanging mass to produce tension in the string. This tension is the centripetal force keeping the stopper in orbit at a constant speed (see Figure 1).

If the tension produced by the hanging mass draws the stopper inward, decreasing the length of the string (decreasing the radius, r), the hanging mass will drop toward the floor. If the tension allows the stopper to fly outward, increasing the length of the string (increasing the radius, r), the hanging mass will rise. In either case, the stopper's speed would not be constant. Therefore, you will know the stopper is moving at a constant speed when the string does not slide up or down in the tube. As the stopper moves at a constant speed, it experiences centripetal acceleration because it constantly changes direction (recollect the definition of acceleration is not only a change in speed, but a change in direction). At this constant speed, the hanging mass's weight downward and the tension in the string upward must be equal in magnitude. The tension pulling on the stopper must be sufficient to counteract the stopper's inertia. Thus, the centripetal force is due to the tension in the string.

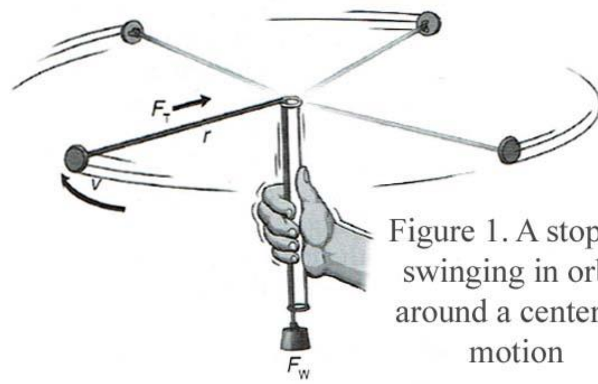

Figure 1. A stopper swinging in orbit around a center of motion

Key Equations

$$C = 2\pi r \qquad a_c = \frac{v^2}{r}$$

$$v = \frac{C}{t} \qquad F_c = ma_c$$

Equipment

1. 2.0 m of heavy string
2. 20 cm glass tube with fire-polished ends
3. Large one-holed stopper
4. Stopwatch
5. Mass balance

Procedure

You will be swinging a stopper in a forced orbit around a glass tube. To reduce the effect of friction and to avoid hitting the ceiling, practice swinging the stopper parallel to the floor (perpendicular to the tube), not at an angle, while holding the tube vertical. When both starting and stopping the motion, slide your thumb over the end of the tube to hold the string. This is especially important when stopping the motion because you will measure the length of the string.

Part I. Timing the revolutions (Table 1)

A. Prepare the centripetal system.
   1. Measure the mass of the stopper, and record in table 1 in kg.
   2. Thread a 2.0 m string through a glass tube.
   3. Firmly tie the top end of the string to a one-holed stopper, and tie a loop in the other end.

B. Measure the aspects of circular motion.
   1. Pull about 1.0 m of the string through the glass tube and hold it against the top of the

tube with your thumb. Hang 200 g from the looped end of the string.
2. Swing the stopper overhead at a comfortable rate and slowly release the string from under your thumb. Now adjust the speed of rotation until the stopper moves fast enough to hold the hanging mass in equilibrium.
3. Once you have the hanging mass in equilibrium, make certain that the stopper is swinging parallel to the floor and that you are holding the tube vertically.
4. When you are ready, have your partner time 50 revolutions, and record the time in Table 1. When you are done timing, slide your thumb back over the string, holding it tight to the top of the tube so that it cannot slide through. Then, stop swinging the stopper and measure the length of the string from the tube to the middle of the stopper, which is the radius, and record in Table 1.
5. Trade responsibilities with your partner, and complete two more trials with the 200 g hanging mass.

C. Replace the 200 g hanging mass with 300 g, but use the same stopper on the other end. Complete three trials following the procedure from Step B above.

Part II. Relating the measured and theoretical centripetal force (Table 2).

A. Determine the measured centripetal force.
1. For each trial, calculate the stopper's linear velocity, using equation $v = C/t$, and record in Table 2.
2. For each trial, calculate the centripetal acceleration, using $a_c = v^2/ r$, and record in Table 2.
3. Determine the centripetal force for each trial, using $F_c = ma_c$, and record in Table 2.

B. When the stopper is orbiting at constant speed, the magnitudes of the mass's weight and the tension acting on the stopper are equal. Therefore, the weight of the hanging mass is equal to the theoretical centripetal force. Calculate the weight of the hanging mass, and record it as the theoretical centripetal forces.

C. Find the percent discrepancy between the measured and theoretical centripetal forces.

Report Sheet – Centripetal Force

Table 1. Circular Motion Values

Trial	Stopper mass (kg)	Hanging mass (kg)	Radius (m)	Revolutions	Time (s)
1		0.200		50	
2				50	
3				50	
4		0.300		50	
5				50	
6				50	

Table 2. Centripetal Values

Trial	Linear velocity (m/s)	Centripetal acceleration (m/s^2)	Calculated centripetal force (N)	Theoretical centripetal force (N)	% discrepancy
1				1.96	
2					
3					
4				2.94	
5					
6					

Questions

1. What is the source of centripetal force in this experiment?

2. A centripetal force is always ______________________ to an objects motion, towards the center of the circle.

3. Your goal in swinging the stopper was to move it at a constant speed. While swinging at a constant speed, is it ever traveling at a constant velocity? Why or why not?

4. When an object is swinging around a center-acting force, what is the direction of the velocity vector in relation to the centripetal force vector?

5. In examining the equation for calculating the centripetal force acting on an object, how is the centripetal force impacted if the object doubles the speed by which it is traveling (while maintaining the same radius)?

$$F_c = \frac{mv^2}{r}$$

6. How is force impacted if the mass of the object is cut in half?

7. What happens to the force needed to keep a stopper in circular motion at the same speed and mass, if the length of the string is doubled? Again, look at the equation for calculating centripetal force.

8. Suppose the string holding the mass slides upward through the tube. What does this tell you about the relationship between the weight of the mass and the tension in the string?

9. A centrifugal force does exist between the string and stopper. Is this what causes the stopper to fly outward? Explain.

10. If a weight is added to the string, will the linear velocity increase or decrease in order to maintain a constant radius? Explain.

11. List several sources of error, describing their effect on the measured linear velocity.