17 Circular Motion

Centripetally Speaking

Purpose

To investigate the force required to keep an object moving at constant speed in a circle.

Required Equipment and Supplies

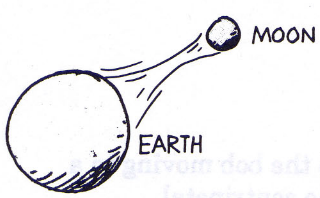
centripetal force apparatus, manual model preferred (Sargent-Welch)
stopwatch (or wrist watch)
hanging or slotted weights

Discussion

Imagine being an astronaut far away from any planets or gravitational effects. If you threw a rock, it would just keep on going—indefinitely in accord with Newton's First Law of inertia. Wouldn't it be surprising if the rock suddenly started moving in a circle? "That can't happen!" you say, it "violates common sense," (actually, Newton's First Law). "Nothing goes in a circle unless *something* causes it to do so." That something is a force called *centripetal force*.

Think of different situations where things are moving in circles—a rock on a string, a child on a merry-go-round, a planet in orbit. In each case something *causes* the circular motion—the string on the rock, the merry-go-round on the child, gravitation on the planet. Even though the *speed* is constant, the object's *direction* is constantly *changing*. The change in direction each instant caused by centripetal force is called *centripetal acceleration* and is equal to v^2/r.

In this experiment, a mass is rotated in a circular path. A spring keeps the mass from flying off at a tangent as the mass is rotated. If the mass is rotated faster, a greater force is required to keep it going in a circle and the spring stretches.



The bob of mass m_b moves in a circle of radius r and makes n revolutions in t seconds. The time, T, for one revolution is t/n. Since the mass goes in a circle, its speed is the circumference, $2\pi r$, divided by the time per revolution, T. Substitute these expressions for v and T to obtain an expression for F_c in terms of mass, radius, number of revolutions, and the time.

$$F_c = \frac{m_b v^2}{r}$$

This value for the centripetal force can then be directly compared to the force, mg, necessary to stretch the spring with hanging weights.

Data Table 17.1

	r (cm)	T (s)	n (rev)	v (m/s)	V_{avg} (m/s)	$a_c = \frac{v^2}{r}$ (m/s²)
1						
2						
3						

Procedure

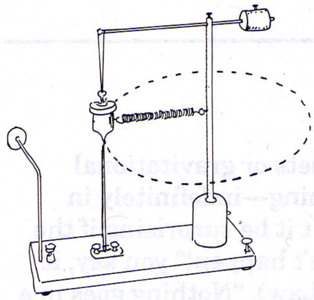


Figure 17.1

CAUTION: Be careful not to allow the rotating bob to hit you (or anyone else) or to get tangled in long hair.

Step 1. With the spring detached, adjust the suspension bar so that the bob (mass) hangs directly above the pointer. Measure the distance from the pointer to the center of the shaft. This will be the radius of the circle that the bob moves in. Measure and record this radius, r, in Table 17.1.

Step 2. Attach the spring between the shaft and the bob. Rotate the shaft so the bob always passes directly over the pointer as shown in Figure 17.1.

Develop your skill at rotating the bob at a constant speed before you make any attempts at timing. Take a few minutes to practice keeping the bob moving in a circle so that it remains over the pointer. Although the bob moves quite effortlessly, you will need to exert just enough torque to compensate for friction. Your efforts will be rewarded with good results.

Step 3. Measure the time it takes for the bob to make 100 revolutions. Repeat your measurement at least once and calculate the average speed. Record your results in Data Table 17.1.

Step 4. Move the pointer to change the radius of the path of the bob and repeat Step 3 for at least two different radii.

Step 5. Calculate the centripetal acceleration, a_c, using the average speed for each radius. Record your data and calculations in Data Table 17.1.

Step 6. Measure the mass of the bob.

m_b = ________

Compute the centripetal force, F_c, required to keep the bob moving in a circle by multiplying the mass of the bob, m_b, by the centripetal acceleration, a_c, at each radius. Record your results in Data Table 17.2.

Data Table 17.2

	$F_c = m_b \frac{v^2}{r}$ (N)	$F_g = mg$ (N)	% DIFFERENCE
r_1			
r_2			
r_3			

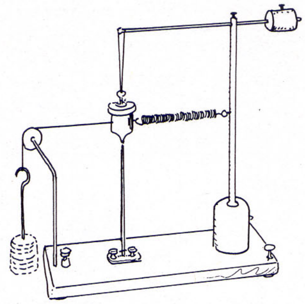


Figure 17.2

Step 7. Now attach the string to the bob and hang it over the pulley as shown in Figure 17.2. Hang just enough weight (remember: $W = mg$) to make the bob line up over the pointer. This hanging weight is the force required to stretch the spring. Record the hanging weights necessary to stretch the spring for each of the three radii. Be sure to include the weight of the weight hanger, if one is used. Record the hanging weights for each radius in Data Table 17.2.

Analysis

1. Calculate the percentage difference between the calculated value of the centripetal force (mv^2/r) and the hanging weights (mg) for each radius. Record your results in Data Table 17.2.

2. How do the forces compare?

3. What are sources of error?

Going Further

The mass of the bob can be varied by unscrewing the nut on top of the bob, attaching a slotted weight, and re-tightening the nut. Devise a method that demonstrates how centripetal force varies with increasing mass. Submit your written plan to your instructor, then try it out.

4. Discuss your results. How does the centripetal force vary with mass? How well do your data support your theory?