UNIFORM CIRCULAR MOTION

Objective

To study the relationship between rotational frequency, radius, and centripetal force.

Equipment

Uniform circular motion apparatus, weight holder and weight set, stopwatch, meter stick or metric tape measure, string, triple beam balance.

Introduction

The inward force which causes an object to revolve in a circle with constant speed is called the centripetal force. This centripetal force, **F**, produces an inward radial acceleration, **a**, given by Newton's second law as

$$\mathbf{F} = m\mathbf{a} \tag{1}$$

in which m is the mass of the revolving object.

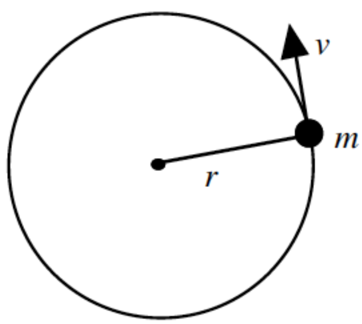

Figure 1: An object of mass m, moving in a circle of radius r, with speed v.

The acceleration, a, can be expressed in terms of the speed, v, and the radius, r, of the circular path as

$$a = \frac{v^2}{r} \tag{2}$$

The speed can be determined from the circumference of the path and the number of revolutions per second, f, as $v = 2\pi rf$. With these two definitions, the magnitude of the centripetal force can be expressed as

$$F = 4\pi^2 mf^2 r \tag{3}$$

In this experiment you will measure the quantities on the right hand side of Equation (3) and use them to calculate F. You will then determine the value of F by an independent method and compare the two values.

Activity 1.

1) Detach the spring from the heavy mass allowing the mass to hang freely (figure 2).

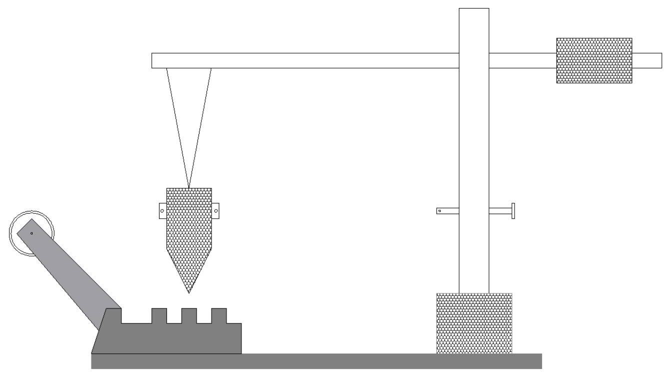

Figure 2: Circular motion apparatus.

2) Adjust the position of the cross-arm so that the heavy mass hangs directly over one of the indicators. Clamp the cross-arm firmly.

3) Remove the mass from the rotating arm. Determine the mass of the revolving heavy mass, m, with the triple beam balance. Record this measurement on your data sheet. Convert this value to kg and record on your data sheet.

Activity 2.

4) Measure the radius of rotation, r, the distance from the center of the radius indicator to the axis of the vertical shaft. To obtain this value, add the radius of the shaft (1.6 cm) to the distance from the exterior of the shaft to the center of the top of the indicator post. Record this value, in cm, on your data sheet. Convert this value to m and record on your data sheet.

5) Reattach the heavy mass to the spring that is connected to the shaft. Rotate the system by turning the knurled portion of the shaft. [The knurled portion of the shaft is the bumpy section.]

6) With a little practice you should be able to keep the mass passing directly over the indicator and determine the frequency f. A piece of white paper located to provide a light background is helpful in seeing that the rotating mass passes exactly over the indicator.

7) Use the stopwatch to time twenty revolutions. The value of f is given by the number of revolutions divided by the time in seconds. What are the units of frequency? Obtain data for 3 trials. Record the time values, calculate the frequency, f, and find the average frequency on your data sheet.

8) Calculate the centripetal force for the rotation using the average value of f. Use equation 3. Record your results on your data sheet.

Activity 3.

9) Measure the force necessary to pull the heavy mass out to the indicator by tying the string to the stationary heavy mass and extending it over the pulley (Figure 3). Apply enough weight to the end of the string to stretch the spring out so that the heavy mass will again be directly over the indicator. What is the necessary weight? Remember that the weight hanger also has mass. Record your answer on your data sheet, in g. Convert this value to kg, and record on your data sheet.

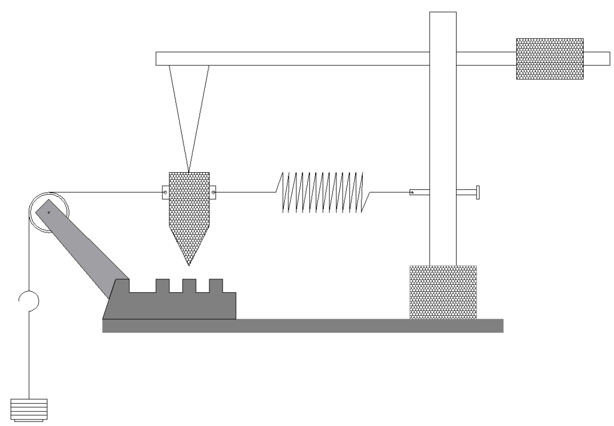

Figure 3: Measuring the force to stretch the spring.

10) Using the weight determined in the previous step, calculate the static force. What is the relationship between the mass and the force? Record your answer on your data sheet.

11) Compare the centripetal force to the static force by computing the percent difference.

$$\text{percent difference} = \frac{|F_{centripetal} - F_{static}|}{\left(\frac{F_{centripetal}+F_{static}}{2}\right)} * 100 \tag{4}$$

Activity 4.

12) Repeat this same procedure at three different radii so you have four radii total with three time measurements and an average for each.

13) In table 3 on the data sheet, convert the mass (g) data to kg.

14) In table 4 on the data sheet, calculate the frequency of rotation (rev/s).

15) In table 5 on the data sheet, calculate F_{static}, $F_{centripetal}$, and the percent difference.

Activity 5.

Answer the following questions and include the answers with your data sheet.

Q1: What happens if you spin the heavy mass faster? How do the measured parameters (radius and frequency) change?

Q2: Does the centripetal force go up or down? How can you tell?

Q3. What happens if you spin the heavy mass slower? How do the measured parameters (radius and frequency) change?

Q4. Does the centripetal force go up or down? How can you tell?

UNIFORM CIRCULAR MOTION
DATA SHEET

Activity 1.

The mass of the revolving heavy mass (g): ________________________________

The mass of the revolving heavy mass (kg): ________________________________

Activity 2.

Radius of rotation (cm): ________________

Radius of rotation (m): ________________

Revolutions per Run: ________________

Table 1: Record the frequency of rotation.

Run	Time (s)	f (rev/s)
1		
2		
3		
4		
5		
	Average Value:	

Centripetal Force (Newtons, N, or $kg(m/s^2)$): ________________

Activity 3.

The static measured mass (g): ____________________

The static measured mass (kg): ____________________

Static Force (N): ____________________

Percent Difference between Forces: ____________________

Activity 4.

Table 2: Table of data.

Radius (m)	Run 1 (s)	Run 2 (s)	Run 3 (s)	Run 4 (s)	Run 5 (s)	Average (s)

Revolutions per Run: ____________

Mass of the revolving heavy mass (kg): ____________________

Table 3: Table of Hanging Mass.

Radius (m)	Hanging Mass (g)	Hanging Mass (kg)

Table 4: Table of Frequency of Rotation.

Radius (m)	Average Time (s)	Frequency (rev/s)

Table 5: Table of Forces.

Radius (m)	F_{static} (N)	$F_{centripetal}$(N)	Percent Difference

Activity 5.

Q1: What happens if you spin the heavy mass faster? How do the measured parameters (radius and frequency) change?

Q2: Does the centripetal force go up or down? How can you tell?

Q3. What happens if you spin the heavy mass slower? How do the measured parameters (radius and frequency) change?

Q4. Does the centripetal force go up or down? How can you tell?