

Experiment: Centripetal Force

Objectives:

- To measure the centripetal acceleration associated with a rotating object using the centripetal force apparatus, for various values of m and r .
- To compare the calculated centripetal force directly with the static force required to pull the object to the same radial position.

Theory:

When a body is caused to revolve in a circle with uniform velocity, the resultant inward force on the body is called *centripetal force*. The centripetal force produces an inward radial acceleration, a , given by Newton's 2nd Law:

$$(1) \qquad \qquad \qquad \mathbf{F = ma}$$

in which m is the mass of the revolving object.

Since $a = v^2 / r$ and $v = 2 \pi n r$, the force can be described by:

$$(2) \qquad \qquad \qquad \mathbf{F = 4 \pi^2 m n^2 r}$$

where r is the radius of the circular path, and n is the number of revolutions per second. It should be noted that $n = 1 / T$, where T is the period.

Equation **(2)** is the working equation for this apparatus. If m is in kilograms and r is in meters, F will be in newtons.

Preliminary Questions:

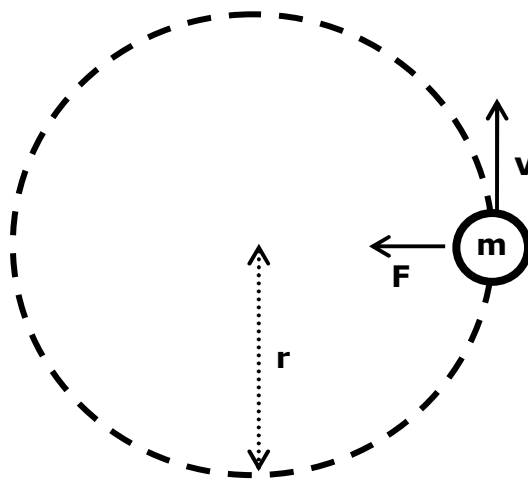
1) A 0.10 kg mass travels in uniform circular motion, at constant speed of 1.5 m/s. The radius of the path traveled by the mass is 0.3 m.

a) What is the centripetal force that keeps the mass traveling in the circular path?

b) What is the centripetal acceleration that keeps the mass traveling in the circular path?

c) How far does the mass travel during one complete revolution?

d) How long does it take for the mass to complete one revolution?



2) A 0.060 kg mass travels in uniform circular motion, where radius of the path traveled is 0.40 m. The mass completes one revolution in 0.25 seconds.

- a) What is the number of revolutions completed per second?

- b) How far does the mass travel during one complete revolution?

- c) How fast (speed) is the mass traveling during this motion?

- d) What is the centripetal acceleration of the mass?

- e) What is the centripetal force acting on the mass?

Procedure:

1. In any given trial, the position of the cross arm and the radial indicator rod must be such that the heavy mass hangs freely exactly over the indicator when the spring is detached. Therefore, when changing the radius of rotation, both the indicator and the cross arm must be moved correspondingly. Note: The location of the counterbalance on the cross arm is not critical.
2. The radius of rotation is the distance from the center of the top of the radius indicator to the axis of the vertical shaft. Measure this value, with a metal ruler or appropriate measuring device.
3. Determine the mass of the revolving object using a digital scale or a dual range force sensor using LoggerPro the software. To change this value, attach slotted weights by placing them on the mass with the open end of the slot outward and secure in place with the knurled nut. Note: *Do not attempt to add more than 100 grams.*
4. A piece of white paper to provide a light background is helpful in seeing that the rotating mass passes exactly over the indicator. Rotate the system by applying torque with the fingers on the knurled portion of the shaft. With a little patience, the rotation rate can be adjusted to keep the mass passing directly over the indicator.
5. For an accurate determination of n (the rate of rotation), the time of 50 or more complete revolutions should be measured with a stopwatch. Record all values and use these values to calculate the centripetal force acting on the object during the uniform circular motion.

6. Using a string tied to the outer end of the object, attach a dual range force sensor and pull the string until the mass is directly over the indicator. Record the force static force required to displace the object using the LoggerPro software. This experiment should be tested for at least two values of the radius of rotation. In addition, trials should be performed for two or more values of the object mass.
7. Once the centripetal force and directly measured force values have been determined, compare these measurements by calculating the % Error between them. To calculate the % Error use the following equation:

$$\% \text{ Error} = \left(\frac{|F_{\text{centripetal}} - F_{\text{measured}}|}{F_{\text{measured}}} \right) \times 100\%$$

8. Your data should be nicely organized in tabular form. The following table is suggested for recording results for comparison (summary):

Table 1:

Trial #	Mass (kg)	Radius, r (m)	n (rev/sec)	Centripetal Force (N)	Measured Force (N)	% Error

Final Questions:

1. When the radius is constant, does the centripetal force vary when the mass of the rotating object is increased? Why or why not?

2. When the mass of the object is same, does the centripetal force vary when the radius of rotation is increased or decreased? Why or why not?

3. Do your calculations for centripetal force agree with your direct measurement of static force? What are possible reasons why the results would disagree?

4. What is responsible for generating the centripetal force experience by the rotating object? Be specific.