Exploring Centripetal Force

Student Worksheet

1 Centripetal acceleration

In this activity we will explore the properties of the force F (both magnitude and direction) required to keep an object moving in a circular orbit about a central point as a function of the object's period T, and length of the cord L supporting it.

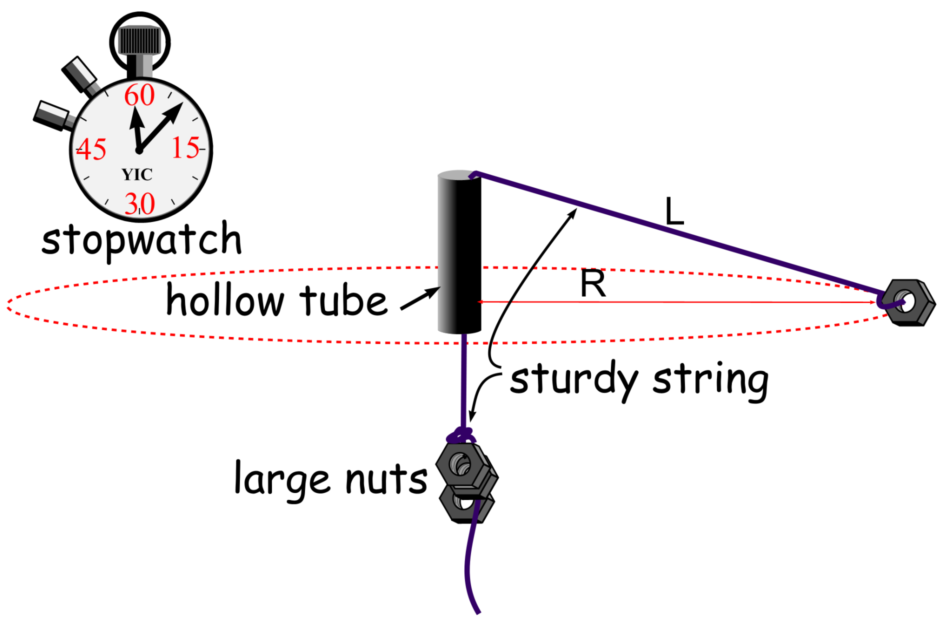

Figure 1: The basic arrangment and equipment needed to investigate the relationship between centripetal force, rotational period and rotational radius.

2 Equipment

You will need the following:

1. a stop watch or watch with a second hand
2. several metres of sturdy nylon cord
3. 30 cm (approx) of 1cm (approx) diameter plastic pipe

4. a metre stick or metric tape measure
5. several large metal nuts

Also needed is a large area (outdoors is best) well away from any obstructions.

3 Hints and Tips:

- Large metal nuts (avaible at most hardware stores), and suspended by a sturdy cord, works well for this experiment.
- Other objects may work equally well, but whatever the case, it is essential that the orbiting object be securely attached to the cord to avoid the hazard of randomly flying projectiles.
- The best results are obtained using cord lengths from 1 to 3 metres, and with each set of experiments having the same period but different rotational radii (cord lengths). Experiment with different cord lengths before collecting data to determine orbital periods that will work for all cord lengths that you will use.

4 The Basics

The weight of the test object (a large single nut) is

$$\mathrm{W} = \mathrm{mg} \tag{1}$$

and in the absence of any other external forces, the centripetal force Fc required to keep the test object in a circular path at constant speed is given by

$$F_c = \frac{4\pi^2 \mathrm{mR}}{\mathrm{T}^2} \tag{2}$$

where m is the combined mass of the nuts in kilograms, T is the observed orbital period of the nut in seconds. The centripetal force is in newtons.

5 Procedure

Thread the cord through the plastic pipe. Attach a nut securely to the cord at one end and two heavy metal nuts to the other end of the cord.

A three metre length of cord will allow for the length to be changed a few times in half metre increments.

Begin with a cord length of one metre from the top of the plastic pipe (the centre of revolution) to the centre of the large nut(s).

Practice revolving the single nut in a circular orbit at constant speed so that the length of the string remains constant and the weight of the nuts exactly balances the centripetal force needed to support the nut as it whorls in a circular path. Do several trials

At a slow speed, record the orbital period T, the length of the cord L and the force F on the force meter.

Repeat for a moderate speed and then for a fast orbital speed. Record your observations.

Repeat the above steps for several different cord lengths. Use increments of 0.5m and use the same periods of rotation as in the 1 metre case.

Table 1: Data Sheet

Trail Number	**Cord Length** metres (m)	**Number of nuts** 1 nut=1 unit of force	**Time for 10 revolutions** seconds (s)	**Period T** seconds (s)	**Comments**
1	1.0	2			
2	1.0	3			
3	1.0	4			
4	1.5	2			
5	1.5	3			
6	1.5	4			
7	2.0	2			
8	2.0	3			
9	2.0	4			

6 Analysis

The following diagram shows the forces acting on the single nut as it orbits the central point on a cord of length L.

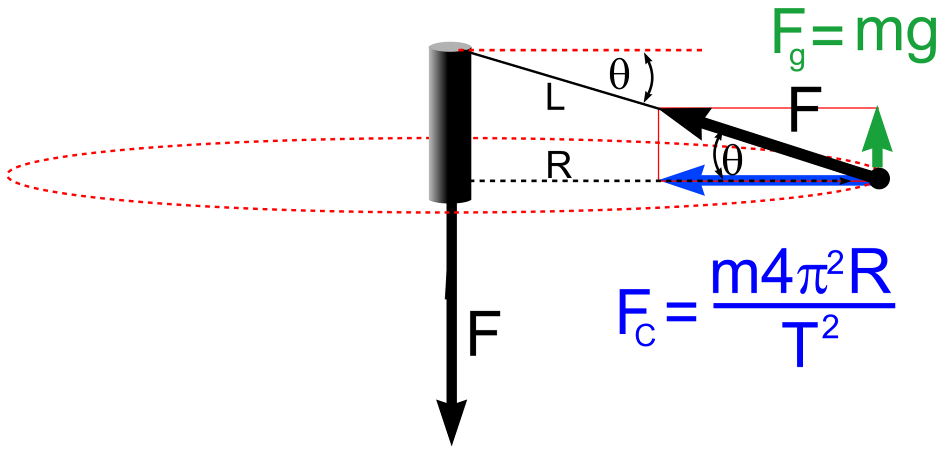

Figure 2: Forces exerted on an object moving in a circular path on the Earth's surface.

From figure 2 we can establish the following identities.

R = L$\cos\theta$

and

F_c=F$\cos\theta$.

Using the form of the centripetal force from equation 2 and substituting the above identities for R and F_c we can write,

$$\mathrm{F}\cos\theta = \frac{4\pi^2 \mathrm{mL}\cos\theta}{\mathrm{T}^2} \tag{3}$$

Simplifying we get

$$\mathrm{F} = \frac{4\pi^2 \mathrm{mL}}{\mathrm{T}^2} \tag{4}$$

Note that the cosine of the angle has dropped out of the equation and only the length of the cord (L) is needed, not the orbital radius R.

1. Plot a graph showing F as a function of T for constant L

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