Hand Held Centripetal Force Kit

PH110152

Experiment Guide

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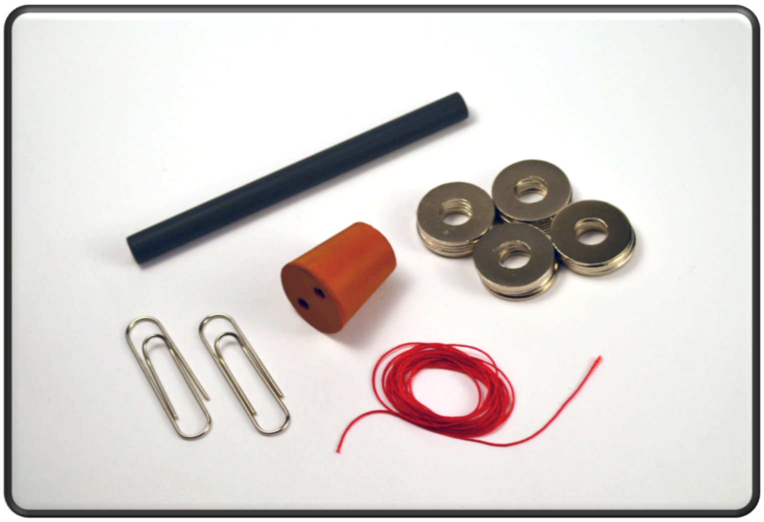

INTRODUCTION:

This elegantly simple kit provides the necessary tools to discover properties of rotational dynamics. A rubber stopper swings around on the end of a string counter balanced by weights, allowing students to see how mass and radius affect centripetal acceleration and rotational velocity.

KIT CONTENTS:

20 metal washers (4.6g each)
1 double holed rubber stopper
2 paper clips
1 string
1 plastic tube

Additional required components:

Scale
Timer
Meter Stick
Masking Tape

GENERAL BACKGROUND:

The centripetal force of an object moving in a circular trajectory is given by:

$$F_c = m_s a = \frac{m_s v^2}{r}$$

Where a is the acceleration (a vector quantity, pointing towards the center of the circle), m_s is the mass of the spinning object, v is the tangential velocity, and r is the radius of the circular trajectory. Even though an object can be travelling with a constant speed, it still can be accelerating as the direction of the velocity is constantly changing as it moves in a circle.

Using the centripetal force kit apparatus set up as shown in the figure below, the centripetal force of the rubber stopper will be equivalent to the weight of the masses pulling down on the string. The weight of the hanging mass is given by:

$$F_w = m_h g$$

where m_h is the total hanging mass (washers and paper clip). Setting the forces equal to one another, one gets:

$$F_c = F_h$$

$$\frac{m_s v^2}{r} = m_h g$$

and solving for tangential velocity:

$$v = \sqrt{\frac{m_h g}{m_s r}}$$

One can see that the velocity necessary to keep the object spinning in a circle is a relation of the hanging mass to the radius of the circle.

We can rewrite the velocity into a quantity easier to measure, the period of one revolution around the circle, using the equation:

$$v = \omega r$$

where ω is the angular velocity given by $\omega = \frac{2\pi}{t}$ and t is the period of one revolution.

Substituting this in for v in the equation above we can rewrite for the period:

$$t = 2\pi \sqrt{\frac{m_s r}{m_h g}}$$

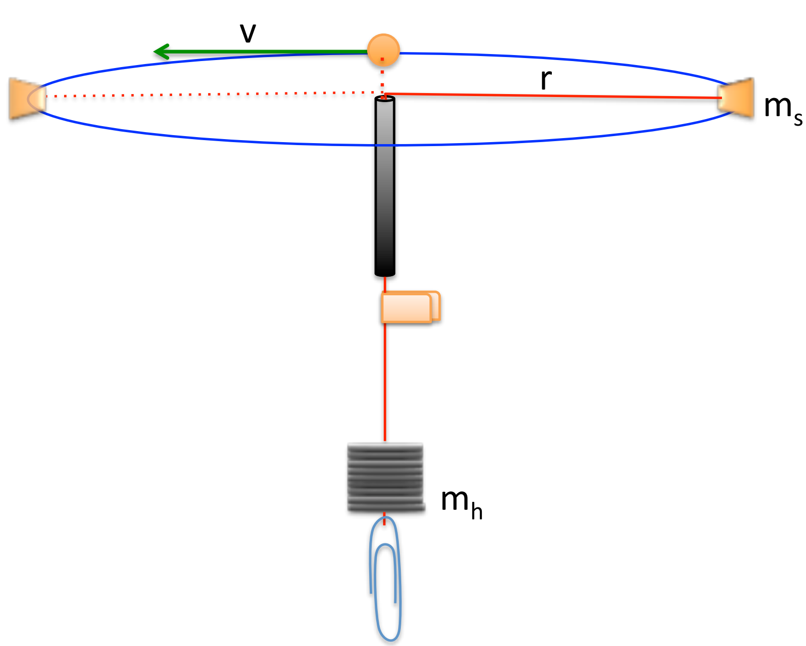

Figure A

Suggested Experiment

1. Assemble the centripetal force kit as shown in Figure A. Thread the string through one hole in the rubber stopper and then back through the second hole. Thread the ends of the string through the plastic tube. Thread the string through 10 washers. Tie the end of the string to one of the paperclips.
2. Lay the apparatus down on a table. Adjust the length of the string such that there is 50 cm of string from the top of the tube to the center of the rubber stopper. Take an inch long piece of masking tape and tape it around the string 1 cm below the tube (in between the tube and the hanging weights).
3. Holding on to the apparatus in one hand by the plastic tube, rotate the rubber stopper in a horizontal circle above your head by making small concentric circle motions. Adjust the rotational velocity of the rubber stopper until the masking tape is situated 1 cm below the plastic tube (so that the radius of the circle is known to be 50 cm).
4. When the rotational velocity and radius is constant, using a digital timer, record the time it takes for the rubber stopper to complete 10 orbits.
5. Repeat steps 3 and 4 for three trials.
6. Slide the remaining 10 washers through the second paperclip. Attach the second paperclip to the paperclip already on the apparatus. Repeat steps 3 and 4 for a total of three more trials with the additional weight.
7. Dissemble the apparatus. Record the mass of the rubber stopper. Record the mass of 10 washers and a paperclip. Record the mass of 20 washers and two paperclips.
8. Fill in the table below. Divide the time it took the rubber stopper to make 10 revolutions by 10 to find the period for each trial. Determine the average period of the three trials. Compute the theoretical value of the period using the equation above for the recorded masses and measured radius.
9. Compare your results by calculating the percent error between the observed period and the theoretical period for each amount of hanging weight.

m_h	10 x t	t_1	10 x t_2	t_2	10 x t_3	t_3	Avg. t	$t = 2\pi\sqrt{\frac{m_s r}{m_h g}}$