Discover Centripetal Force Kit

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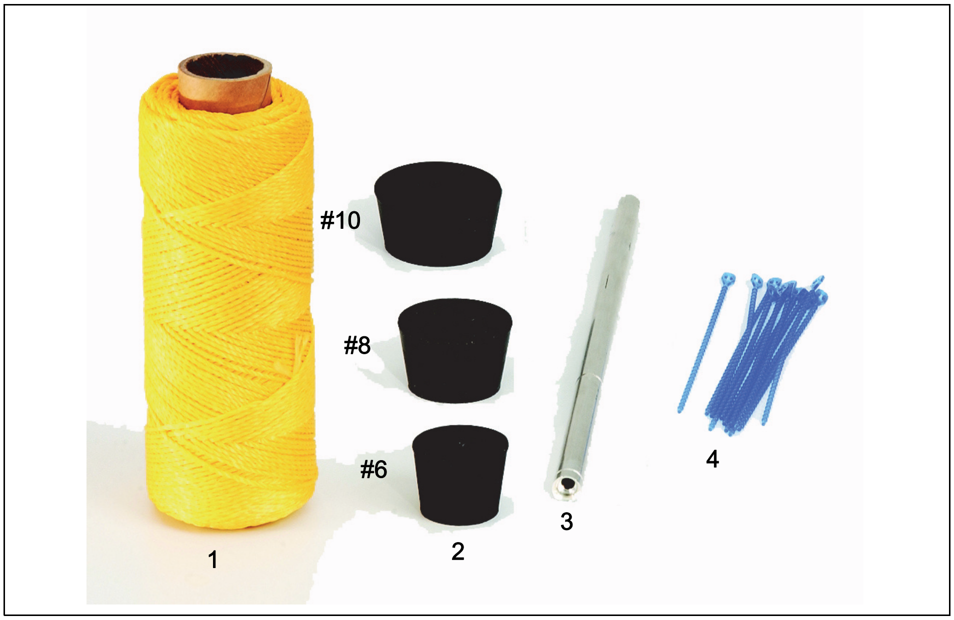


Equipment List

Included Equipment	Model Number
1. Yellow string (73 m)	ME-9876
2. Rubber stoppers (sizes: 6, 8, and 10)	
3. Hollow tube (1)	
4. Plastic ties (10)	

Additional Equipment Recommended	Model Number
Safety goggles	
Marking pen	
Force Sensor	CI-6746, PS-2104, or PS-3202
Hooked Mass Set	SE-8759
Metric Spring Scale 20 N Range	ME-9513

Introduction

The Discover Centripetal Force Kit contains the materials necessary to perform the classical centripetal force lab similar to the first example listed in the table below. In addition, the Discover Centripetal Force Kit can be used in conjunction with Force Sensors or Newton Spring Scales.

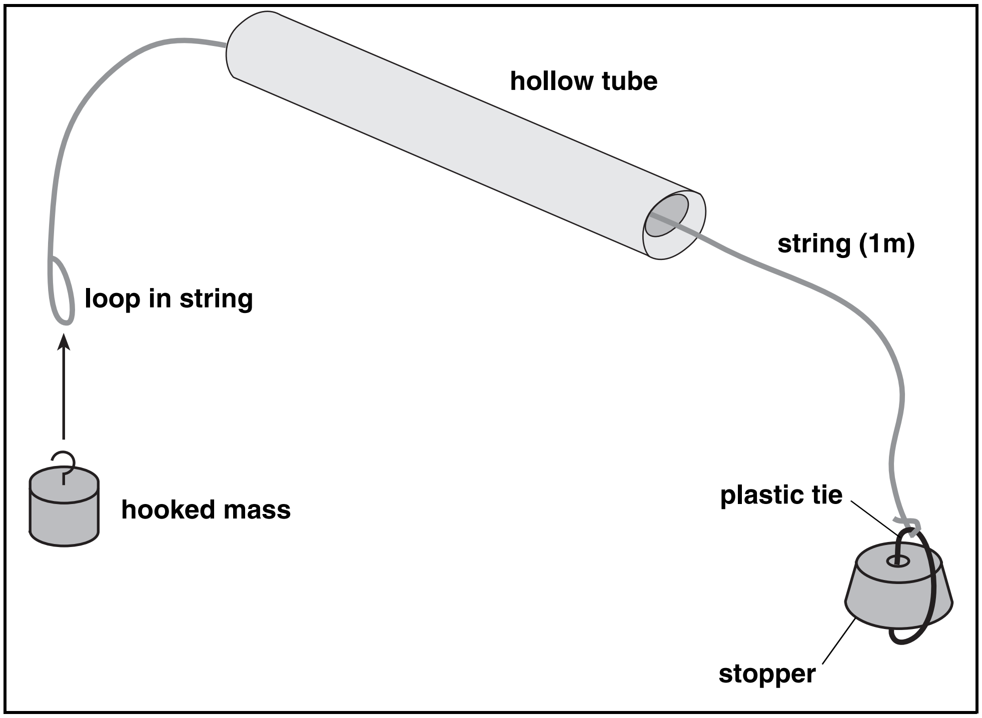
Centripetal Force is an often misunderstood physical concept. Among other things, the popular, yet, misused word "centrifugal" contributes to students' misconceptions. An object moving in uniform circular motion experiences a net inward-pointing force, called the centripetal force. It is important for students to identify the agent for each force that contributes to the centripetal force (net force) for an object moving in uniform circular motion.

The table below gives examples of the centripetal force for certain occurrences:

Situation	Centripetal Force
An object twirled in a horizontal circle.	Tension from the string.
Car driving in a circle.	Static friction on the tires directed toward the center.
A satellite.	Force due to gravity.
A “centrifuge.”	The normal force from the wall of the “centrifuge.”

Included with the Discover Centripetal Force Kit are rubber stoppers of widely varying masses. Convenient blue ties are provided to attach the stoppers easily to the bright, sturdy string. In addition, one tubes is included that is chamfered to decrease friction on the string.

Equipment Setup

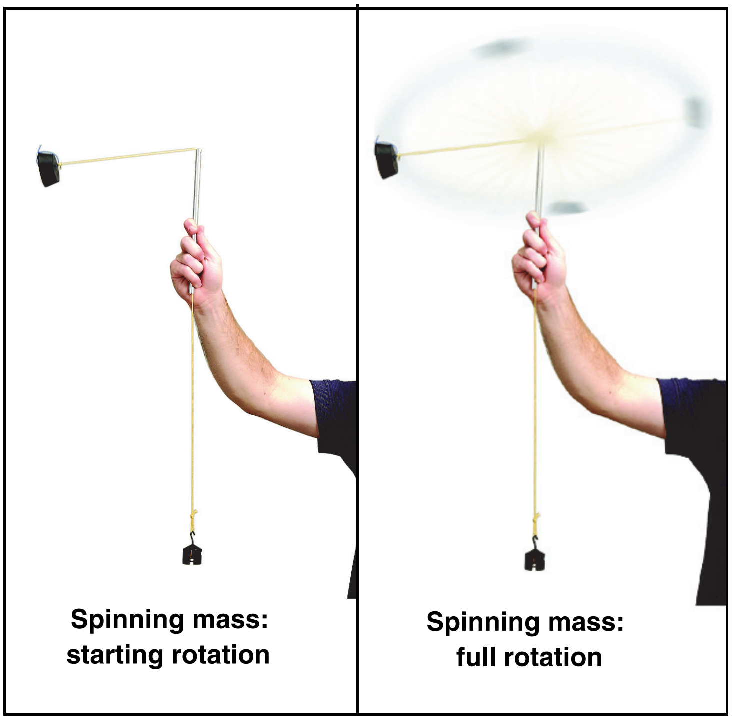


1. Cut a piece of string approximately 1 meter long and feed it through the hollow tube.
2. Secure a plastic tie through the center hole in each stopper.
3. Tie one end of the string to the plastic tie to the stopper that is to be used in the specific experiment.
4. Tie a loop at the other end of the string and hook a mass through the loop.

Important! Please follow these SAFETY guidelines:

- **Put on safety goggles!**
- **Make sure that no one is standing close to avoid hitting others!**
- **Hold the tube far enough away to avoid hitting self.**

5. Firmly hold the tube and start rotating (spinning) the rubber stopper as shown in the following photo (starting rotation). Continue spinning the stopper until it reaches full rotation.



Labs with the Discover Centripetal Force Kit

The Classical Centripetal Force Lab

Set up the lab as shown in the general setup section.

Overview

In this lab, the dependent variable is always the linear velocity (v). The independent variables are the radius (r), the hanging weight - determined by the hanging mass (m_h) - and the spinning mass (m_s). When the velocity is plotted as a function of one of the independent variables, the other two independent variables must be kept constant.

It is important, therefore, to keep track of these values using the following data table for each of the 3 sections of this lab:

radius (m)	m_h (kg)	m_s (kg)	V (m/s)

For each data point collected, students must:

• Select and mark a predetermined radius.

• Select and attach predetermined hanging and swinging masses.

• Adjust the "swing speed" until the predetermined radius is attained.

• Time ten (10) full rotations.

Calculate the Linear Velocity

To determine the linear velocity of the spinning mass, measure the period (T) and the radius (r). To find the period, divide the time of the 10 full rotations by 10. To calculate the linear velocity (v) use the following equation:

$$\nu = \frac{2\pi r}{T}$$

In order to maintain a constant radius, mark the string with a pen. Practice spinning the mass and observing the mark on the string.

Calculate the Force

The centripetal force on the spinning mass is roughly equal to the weight of the hanging mass. Measure the hanging mass and use this value to calculate the centripetal force.

Velocity versus Force

While using the same spinning mass and maintaining the same radius, students find the corresponding velocities for different hanging masses. A graph of Force versus Velocity should yield a square root graph and a relationship of

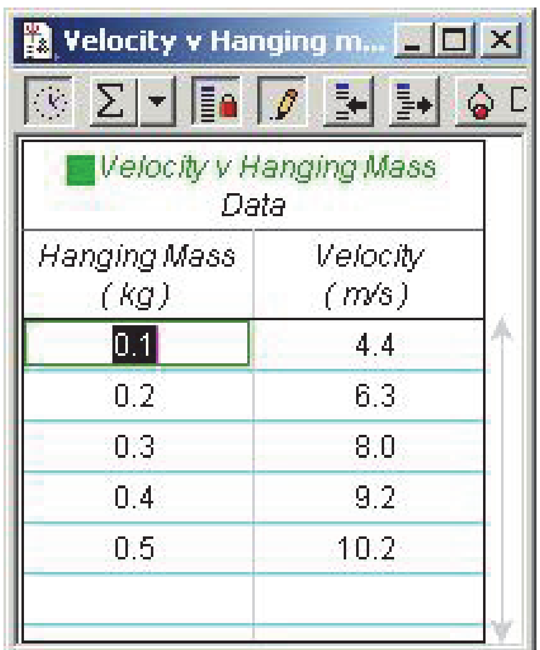
$$v = \sqrt{k_1 F}$$

where k_1 is a constant.

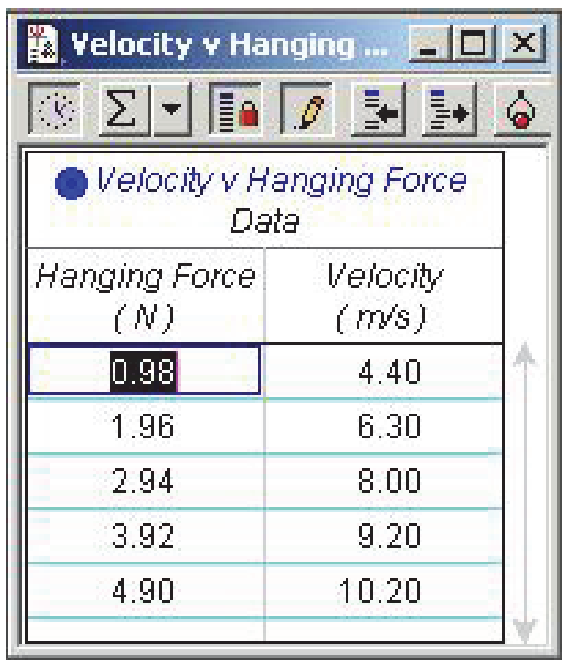
Sample Data:

The following data is for a spinning mass of 22 g (#6 stopper) and a radius of 0.5 m.

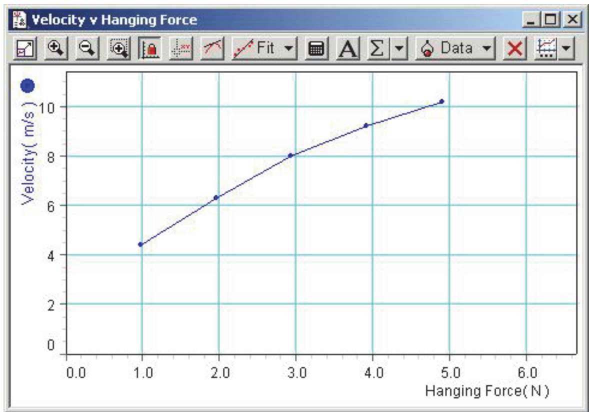
radius (m)	m_h (kg)	m_s (kg)	V (m/s)
.5	.1	.022	4.4
.5	.2	.022	6.3
.5	.3	.022	8.0
.5	.4	.022	9.2
.5	.5	.022	10.2



Hanging Mass (kg)	Velocity (m/s)
0.1	4.4
0.2	6.3
0.3	8.0
0.4	9.2
0.5	10.2



Hanging Force (N)	Velocity (m/s)
0.98	4.40
1.96	6.30
2.94	8.00
3.92	9.20
4.90	10.20



Velocity versus Mass

While maintaining the same hanging mass and radius, students find the corresponding velocity for different spinning masses. A graph of Velocity versus M_s should yield a graph with the relationship of

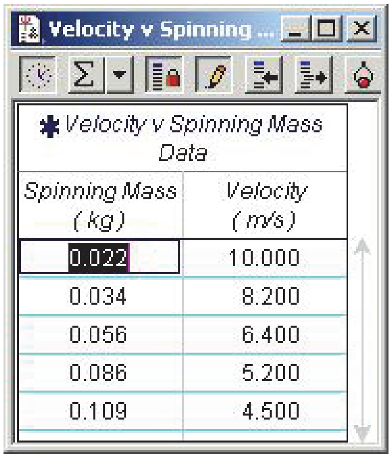
$$v = \sqrt{\frac{k_2}{m_s}}$$

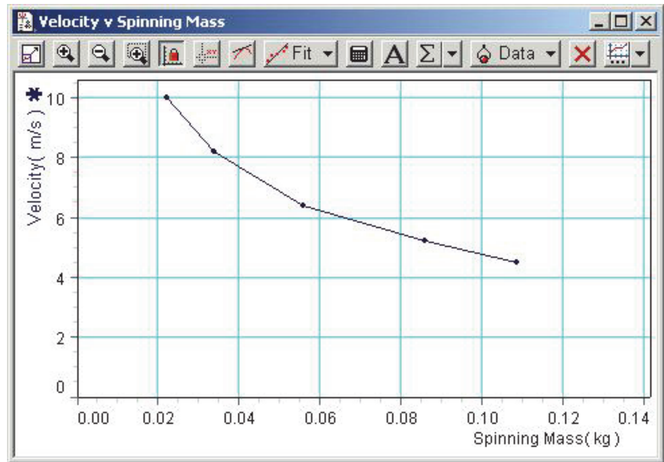
where k_2 is a constant.

Sample Data:

The following data are for a hanging mass of 500 g and a radius of 0.5 m.

radius (m)	m_h (kg)	m_s (kg)	V (m/s)
.5	.5	.022	10.0
.5	.5	.034	8.2
.5	.5	.056	6.4
.5	.5	.086	5.2
.5	.5	.109	4.5





Velocity versus Radius

While maintaining the same hanging mass and spinning mass, students find the corresponding velocity for different radii. A graph of Velocity versus Radius should yield a graph with a relationship of

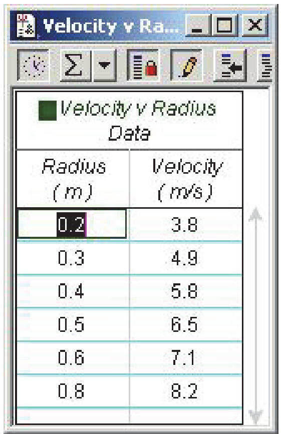
$$v = \sqrt{k_3 r}$$

where k_3 is a constant.

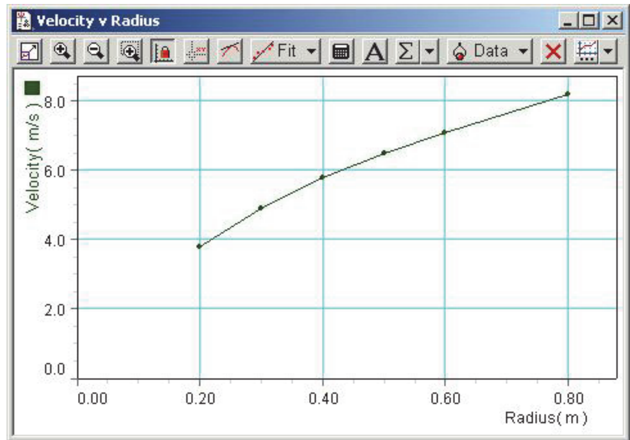
Sample Data:

The following data is for a hanging mass of 500 g and a spinning mass of 56 g (#10 stopper).

radius (m)	m_h (kg)	m_s (kg)	V (m/s)
.2	.5	.056	3.8
.3	.5	.056	4.9
.4	.5	.056	5.8
.5	.5	.056	6.5
.6	.5	.056	7.1
.8	.5	.056	8.2


Velocity v Ra...

Radius (m)	Velocity (m/s)
0.2	3.8
0.3	4.9
0.4	5.8
0.5	6.5
0.6	7.1
0.8	8.2



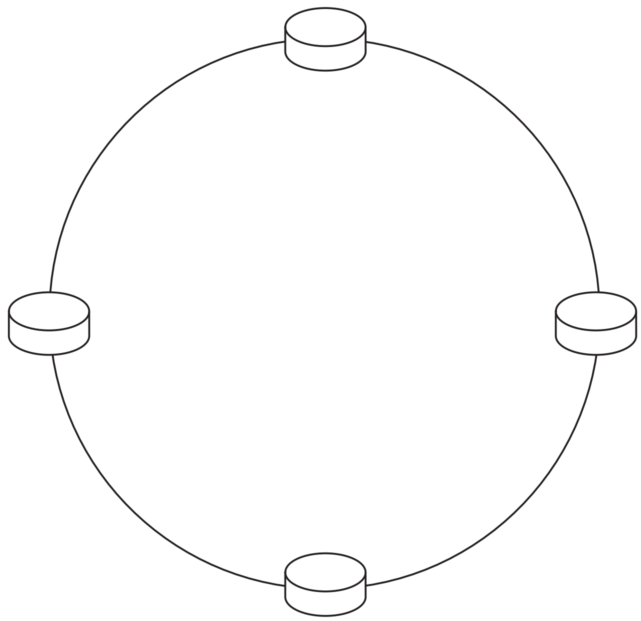
After completing the lab, students should derive the full equation for the centripetal force:

$$\mathbf{F} = \frac{\mathbf{mv^2}}{\mathbf{r}}$$

Questions

1. Using words and a mathematical expression, describe the relationship between force and velocity in uniform circular motion.
2. Using words and a mathematical expression, describe the relationship between mass and velocity in uniform circular motion.
3. Using words and a mathematical expression, describe the relationship between radius and velocity in uniform circular motion.
4. Combine the three relationships above to create one relationship for force, mass, velocity, and radius. Solve it for force.
5. How would you convert this expression into an equation?
6. What is the constant of proportionality for this equation? Explain.
7. How could such an equation be used?

8. The figure below represents an overhead view of the rotating mass. For each of the 4 points, draw the direction and relative magnitude of the force.



Demonstration Using a Force Sensor

Set up the Discover Centripetal Force Kit as instructed. Replace the hanging mass with a Force Sensor. The measurements of the Force Sensor are roughly equal to the centripetal force. Have an assistant hold the sensor. Move it up or down to change the radius.

Demonstration Using a Newton Spring Scale

Set up the Discover Centripetal Force Kit as shown in the Classical Centripetal Force Lab. Replace the hanging mass with a Newton Spring Scale. The measurements of the Newton Spring Scale are roughly equal to the centripetal force. Have an assistant hold the sensor. Move it up or down to change the radius. This method allows the student to "feel" the changing in the centripetal force.

Technical Support

For assistance with any PASCO product, contact PASCO at:

Address:	PASCO scientific 10101 Foothills Blvd. Roseville, CA 95747-7100	Web:	www.pasco.com
Phone:	916-462-8384 (worldwide) 800-772-8700 (U.S.)	Email:	support@pasco.com

Limited Warranty For a description of the product warranty, see the PASCO web site.