Experiment

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Centripetal Force

Introduction

The application of Newton's 2nd law to uniform circular motion is a logical extension of the physics developed so far. The result is an important equation that explains circular motion, and is therefore essential to problems involving this very common behavior. In this laboratory exercise, you will verify the validity of this equation, study the effects of varying the radius of the circle and the centripetal force on an object rotating in a circular path, and thus become more familiar with uniform circular motion.

Theory

In your text, the author derived an equation for centripetal acceleration starting with a particle moving with constant speed in a circle of radius r. In the space provided utilize vector calculus to derive this expression in detail. In addition, apply Newton's 2nd law to this particle to show that the magnitude of the net force responsible for the motion is given by the equation below. This net force , which comes from the sum of the forces acting on a particle, is called the centripetal force. Be sure to include a detailed diagram in your derivation.

$$\vec{F}_C = -\frac{mv^2}{r}\left(\cos\theta\ \hat{i} + \sin\theta\ \hat{j}\right)$$

Setup

1. Adjust the leveling screw to level the "A" base and rotating platform.
2. Connect Rotational Motor Drive to 12-Volts DC Power Supply.
3. Connect Photo gate to the Smart timer and set the Timer measuring Angular Speed.
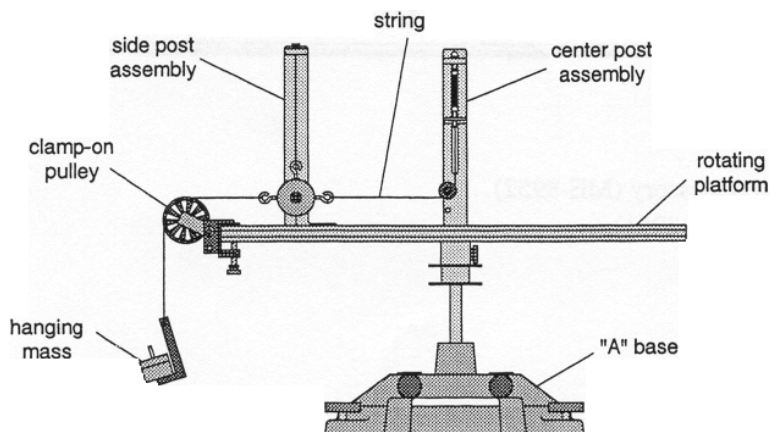
Part I: Vary Radius (constant force)

The centripetal force will be held constant for this part of the experiment.

Procedure

1. Weigh the object and record its mass in Table 1.1. Hang the object from the side post and connect it to the first loop of the <u>black</u> string. The string must pass under the pulley on the center post (refer to the figure above).
2. Attach a string to the hanging object and 50-70g on the hanger over the clamp-on pulley. Weigh the mass (including the hanger) and record this mass in Table 1.1. This establishes the constant centripetal force for this part of the lab.
3. Adjust the side post assembly to a position in which the string of the hanging object is aligned with the vertical line on the side post. Then align the indicator bracket on the center post with the orange indicator. Record the radius in Table 1.1.
4. Remove the mass that is hanging over the pulley. Clear the area around the rotating platform apparatus by removing any object that might obstruct its motion.
5. <u>Make sure that the voltage adjust knob on the motor power supply is fully counterclockwise.</u> <u>Failure to do so may result in bodily injury.</u> Turn on the power supply. Rotate the apparatus by <u>slowly</u> turning the voltage adjust knob in the clockwise direction. Adjust the speed until the orange indicator is centered in the indicator bracket on the center post. This indicates that the string supporting the hanging object is once again vertical and thus the hanging object is at the desired radius.
6. Maintaining this speed, push the Start/Stop button on Timer and note the angular speed (pulley rad/s). Repeat five times and record the average of the five measurements in Table 1.1.(**Note: averaging the five values will probably give an extra sig. fig.**) Then turn off the power supply.
7. Attach the object to the second loop in the black string and repeat the procedure. Do this for a total of five radii.

Analysis

1. The weight of the mass hanging over the pulley is equal to the centripetal force applied by the spring. Calculate this force by multiplying the mass hung over the pulley by "g" (g=9.80m/s^2 three significant figures) and record this force at Table 1.2.

2. Calculate the square of the angular speed and the inverse of the radius for each trial and record this in Table 1.1.
3. Plot the square of the angular speed versus the inverse of the radius. This will give a straight line since:

$$F_C = mr\omega^2$$

   Obtain the slope of best-fit line through the data points. Record the slope above **Table 1.1** Calculate the centripetal force from the slope of your graph and record it in Table 1.2 (be careful with sig. figs.). Paste your graph in the **DATA** section before **Table 1.2**.
4. Plot the angular speed versus the radius. Determine the function that relates the angular speed and the radius, and obtain a best fit graph to your plot. Then determine F_C from the curve fit parameters and record your result in Table 1.2 (be careful with sig. figs.). Paste your graph in the **DATA** section before **Table 1.2**.
5. Calculate the percent difference between the two values found for the centripetal force and **m'g**, and record tour result in Table 1.2.

Part II: Vary Force (constant radius)

The radius of rotation will be held constant for this part of the experiment.

Procedure

1. Attach the object to the first loop of the <u>yellow</u> string. Set the side post assembly to between the 15.00cm and 17.00cm mark. This establishes the constant radius for this part of the lab.
2. Hang sufficient weight (including the mass of the hanger) over the clamp-on pulley such that the string of the hanging object is aligned with the vertical line on the side post. Then align the indicator bracket on the center post with the orange indicator. Weigh the mass (including the hanger) and record this mass in Table 2.1.
3. Repeat procedure in Part I from Step #4 through #6, and record data in Table 2.1.
4. To vary the centripetal force, attach the object to the second loop of the <u>yellow</u> string. Keep the radius constant and repeat the Steps #2 and #3. Do this for five different forces.

Analysis

1. The weight of the mass hanging over the pulley is equal to the centripetal force applied by the spring. Calculate this force for each trial by multiplying the mass hung over the pulley by "g" (g=9.80m/s^2 three significant figures) and record the results in Table 2.1.
2. Calculate the square of the angular speed for each trial and record this in Table 2.1.
3. Plot the centripetal force versus the square of the angular speed. This will give a straight line since:

$$F_C = mr\omega^2$$

   Obtain the slope of best-fit line through the data points. Record the slope above **Table 2.1** Calculate the mass of the object from the slope of your graph and record it in **Table 2.2** (be careful with sig. figs.). Paste your graph in the **DATA** section before **Table 2.2**.
4. Plot the centripetal force versus the angular speed. Determine the function that relates the square of the angular speed and the radius, and obtain a best fit (quadratic fit or power fit) graph to your plot. Then determine m from the curve fit parameters, and record your result in **Table 2.2** (be careful with sig. figs.). Paste your graph in the **DATA** section before **Table 2.2**.
5. Calculate the percent difference between the two values found for the mass of the object and **m**, and record your result in Table 2.2.

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Data (*sample calculations not needed for this page*)

Table 1.1: Varying the Radius

Mass of the object, **m** =_____

Mass hanging over the pulley, **m'** = _____

Radius r (cm)	1/r (cm^{-1})	Angular Speed ω (rad/s)	ω^2 (rad^2/s^2)

(Paste graphs here)

Table 1.2: Results (varying radius)

Centripetal Force = m'g	
Slope and Its Uncertainty From ω^2 vs 1/r Graph	$\pm$
Centripetal Force From ω^2 vs 1/r Graph	
Percent Difference with m'g	
Curve Fit Parameter and Its Uncertainty From ω vs r Graph	$\pm$
Centripetal Force From ω vs r Graph	
Percent Difference with m'g	

Table 2.1: Varying the Centripetal Force

Radius = _____

Mass Over Pulley m' (g)	F$_C$ = m'g (N)	Angular Speed ω (rad/s)	ω^2 (rad^2/s^2)

(Paste graphs here)

Table 2.2: Results (varying the centripetal force)

Mass of Object, m (from scale)	
Slope and Its Uncertainty From F_c vs. ω^2 Graph	$\pm$
Mass of Object from F_c vs. ω^2 Graph	
Percent Difference	
Curve Fit Parameter and Its Uncertainty From F_c vs. ω Graph	$\pm$
Mass of Object From F_c vs. ω graph	
Percent Difference	

Conclusion

Your conclusion must include a description of the experiment and its purpose, a discussion and statement of results, a discussion of random errors and systematic errors. In addition, discuss the dominant source of error, the reliability of the curve fits in Parts 1 and 2, and determine whether or not the results agree with existing theory or a stated hypothesis. The conclusion must be in paragraph form; otherwise, two points will be deducted.