Centripetal Force
Fall 2017

Introduction

The purpose of this experiment is to calculate – and then measure – the force a spring exerts on a mass when the mass is hanging vertically while in motion, and at rest.

The Equipment: Meet “Bob”

The apparatus allows you to spin a known mass around in a circle: you can measure the radius of the circle and the speed of the mass and thereby infer the centripetal force from Newton’s second law.

1. Disconnect the spring from “Bob”. Your instructor will show you how to level the base and check the balance between Bob and the counterweight. It is important to check the balance and level carefully.

2. Remove Bob from the supporting string, measure his mass, then reattach it to the string. Adjust the pointer until it is directly under Bob, and if necessary adjust the height of Bob (with the supporting string) to be no more than 1 mm above the pointer.

Calculating the Centripetal Force: Bob in Motion

You will first calculate \( F_{spring} (Rot) \), the centripetal force exerted on Bob by the spring while rotating. Keep linear measurements in cm until you are ready to calculate the force!

3. The radius of Bob’s orbit, \( R_{orbit} \), is the distance from the center of the rotating shaft to the center of the pointer. You will calculate the radius as shown below, measuring the diameters of the rotating shaft and the pointer, \( D_{shaft} \) and \( D_{pointer} \), and the closest distance between them, \( d \) (Figure 1). Use vernier calipers to measure the shaft and pointer diameters, and a meter stick and calipers to measure \( d \) (Figure 2).

\[
R_{orbit} = \frac{D_{shaft}}{2} + \frac{D_{pointer}}{2} + d
\]

- Recall that it is considered bad practice to use the end of a meterstick for measurement. Be sure to record both measurements of \( d_A \) and \( d_B \) in your report. Have your instructor check your radius before continuing; this is frequently where errors are made!

4. Reconnect the spring and set the photogate to “pulse” mode, memory on. Spin Bob at a rate that stretches the spring until Bob is directly above the pointer. Measure the period of one rotation, \( T \) - while doing your best to hold the speed at which the pointer and Bob are aligned (this will take some practice). Collect at least 10 trials, recording the data in a table in your report. Keep Bob spinning during your measurements; don’t stop and restart the rotation!
5. Calculate the average period, \( \langle T \rangle \) and record the minimum and maximum periods. Also calculate the \% difference between the min and max periods; a small difference of only a few percent means your spin rate was fairly well consistent.

6. **Draw an FBD for a rotating Bob.** Call the force of the spring on Bob while he is rotating \( \vec{F}_{spring \text{ (Rot)}} \); this is the force needed to move Bob in a circle at the fixed speed.

7. **Assuming that the motion of Bob is circular**, calculate the average tangential velocity and centripetal acceleration of Bob, and record in your report:

   \[
   v_{\text{tangent}} = R_{\text{orbit}} \omega = R_{\text{orbit}} 2\pi f
   \]

   so, \( v_{\text{tangent}} = \frac{R_{\text{orbit}} 2\pi}{\langle T \rangle} \), and then: \( a_c = \frac{v_{\text{tangent}}^2}{R_{\text{orbit}}} \)

8. Use your minimum and maximum periods to calculate the corresponding tangential velocity and centripetal acceleration.

9. Use your FBD and Newton’s laws to calculate the values of \( \vec{F}_{spring \text{ (Rot)}} \) from your minimum, average and maximum centripetal acceleration.

**Measuring the Centripetal Force: Bob at Rest**

10. Connect the 50-g mass hanger to Bob with the paper clip, and check that the string pulls straight over the pulley. Also check that the pulley rotates freely (if it doesn’t then you’re adding an additional force to the system!).

11. Add masses until the spring is stretched so that Bob is lined up above the pointer (Figure 3).

12. **Draw a second FBD for this system at rest** (Bob and the suspended mass), and use it with the data above and \( g = 9.80 \text{ m/s}^2 \) to find the force of the spring pulling on Bob (when the spring is stretched to the same length as when rotating). Call this force \( \vec{F}_{spring \text{ (Rest)}} \).

**Discussion**

- Restate your value of \( \vec{F}_{spring \text{ (Rest)}} \) and the average of \( \vec{F}_{spring \text{ (Rot)}} \), and calculate the percent difference between them.

- Also restate the minimum and maximum values of \( \vec{F}_{spring \text{ (Rot)}} \). Did \( \vec{F}_{spring \text{ (Rest)}} \) fall within this range of possible values of \( \vec{F}_{spring \text{ (Rot)}} \)? What may have contributed to the error? Be sure to consider how consistently you were able to rotate Bob (step 5), and the assumption made about Bob’s motion in this experiment.

- Which value of the **period** (minimum or maximum) corresponded to the larger value of \( \vec{F}_{spring \text{ (Rot)}} \)?