EXPERIMENT 5
CENTRIPETAL FORCE

I. THEORY

The purpose of this experiment is to verify the formula for centripetal acceleration and centripetal force. We will also compute the possible relative error in a calculated centripetal force.

When an object is rotated in a circle with a constant speed, the centripetal acceleration of the object is given by:

$$a = \frac{v^2}{r},$$

where v is the speed of the center of mass of the object and r is the radius of the circle the center of mass of the object travels in.

The speed (magnitude of the tangential velocity) of the object can be written in terms of the period, T, and the radius, r,

$$v = \frac{2\pi r}{T}.$$

In this experiment, the period will be equal to the time elapsed, t, divided by the number of revolutions turned, n. This allows the centripetal acceleration to be written

$$a = \frac{4\pi^2 r}{T^2} = \frac{4\pi^2 n^2 r}{t^2}.$$

Using Newton's Second Law, we will then calculate the magnitude of the centripetal force. The centripetal force will be provided by a string attached to a spring.

The apparatus used in this experiment is shown in the figure below. The object to be rotated is the circular mass (the bob) shown on the side post assembly.

For comparison, we will calculate the force required to stretch the spring the desired distance by a second method. To do this, we hang a mass from the string until the spring is stretched by the same amount as while the object is moving in a circle of radius r. The force on the bob can then be determined using Newton's First Law.

II. LABORATORY PROCEDURE

Set up a data table with one row for each of the four set-ups and columns for bob-mass, radius of revolution, hanging mass needed for bob to hang vertically, first time interval, second time interval and additional time interval if needed. Units should be in the column headings and should be those measured (cm, g, s).

1. The apparatus we will use may already be set-up and leveled for your. If not, level the apparatus by following these step: (1) Adjust the leveling screw on one of the legs of the base until the end of the side of the platform with the pulley is over the leveling screw on the other leg of the base. (2) Rotate the platform 90 degrees so it is parallel to one side of the "A" and adjust the other leveling screw until the platform will stay in this position. The platform should now be level and should remain at rest in any position. **If you move the apparatus after leveling, you will need to repeat this step.**

2. The **bob** should be hanging from the side post assembly as shown in the figure. There should be a string attaching the bob to the center post assembly. Pass another string (as shown) over the pulley and attach a 50.0 g weight hanger. Loosen **Thumbscrew A** that attaches the side post assembly and slide the side post until the **bob** hangs vertically. You can see that the **bob** is vertical by lining up the two strings with the center line etched on the side post assembly. The other two strings attached to the **bob** should be perfectly horizontal. DO NOT LOOSEN **Thumbscrew B** THAT ATTACHES THE BOB TO THE POST.
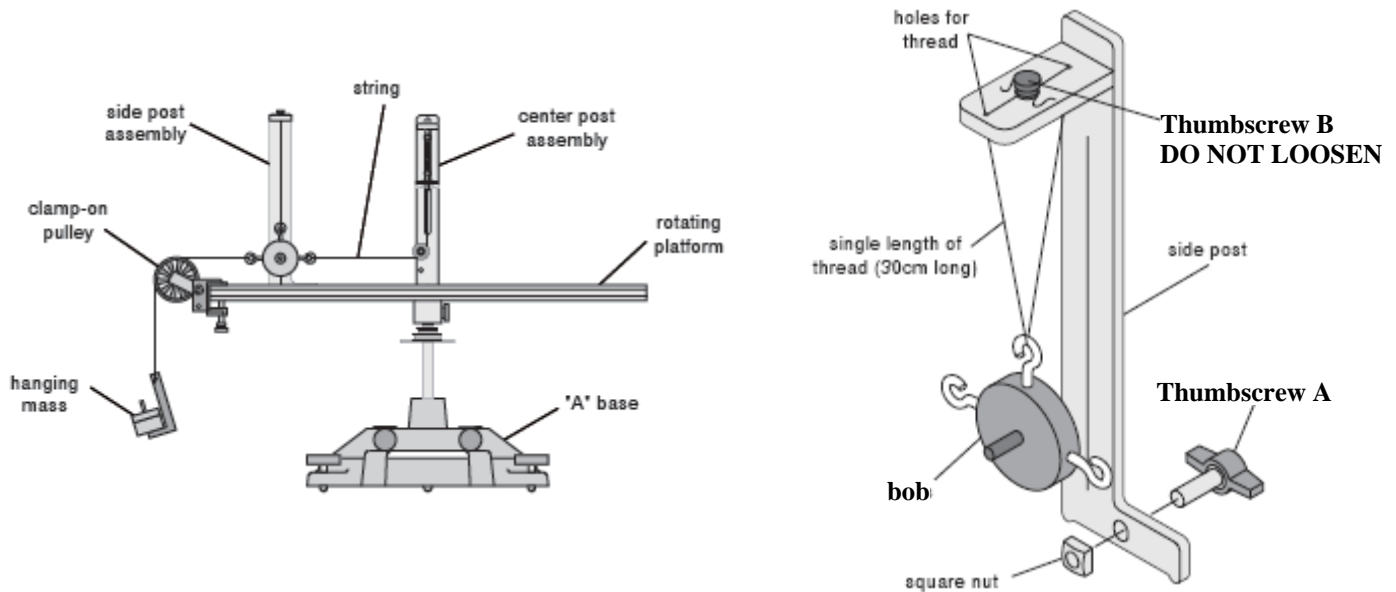
3. Record the radius of the circle that the center of mass of the bob will rotate in. This will be the position of the center line etched on the side post assembly on the rotating platform. To what precision should this be recorded?

4. Loosen the **Thumbscrew C** that secures the indicator bracket on the center post and move the indicator bracket so that it is at the same height as the plastic indicator disk. See figure below.
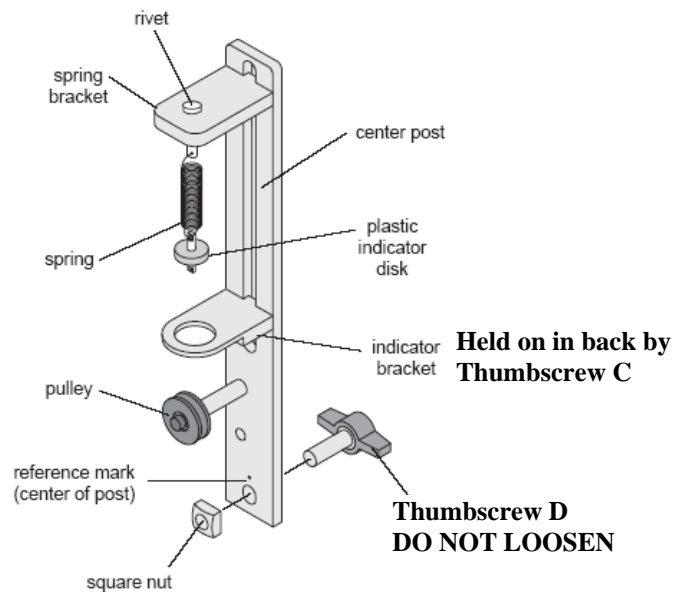
5. Remove the weight hanger.

6. Begin rotating the apparatus slowly by hand by grasping the metal axle below the plastic drum.

7. Gradually increase the speed of rotation until the plastic indicator lines up with the indicator bracket. Once you have a good feel for this rotation speed, measure the time for 2 sets of 10 revolutions. It is not necessary to stop the rotation between sets. If necessary, time a third set of 10 revolutions. What criteria on the times of the first two runs should you require?

8. With the rotations stopped, remove the bob by unhooking it from the strings (DO NOT REMOVE THE STRINGS). Use the triple-beam balance to determine the mass of the bob. Add the two additional masses to the bob. Secure the masses with the thumbscrews. Measure the combined mass of the bob and the additional masses. Reattach the bob to the side post and center post. Repeat steps 6 and 7.

9. Repeat steps 2-7 using the weight hanger plus 20.0 g.

10. Remove the additional masses from the bob and repeat steps 6 and 7.

III. CALCULATIONS AND ANALYSIS

For the first set-up

- Calculate the radial acceleration of the bob while it was spinning. Draw a free-body diagram for the bob while it was spinning, include both the horizontal and vertical forces on the bob. Using Newton's Second Law, determine the tension in the string attaching the bob to the center post assembly.

- Draw another free-body diagram for the bob when the hanging mass was attached and it was not spinning. Determine the tension in the string connecting the bob to the center post assembly. Explain why this tension should be the same as the previous and calculate a percent difference.

For the other three set-ups

- Repeat the above, but do not include detailed calculations. Present the results in a table with one row per set-up.

For the first set-up

- Suppose the absolute uncertainties are as follows ± 0.1 cm for the radius of rotation, ± 0.2 g for the mass of the bob, and ± 0.20 s for the time for 10 revolutions. Determine the possible relative error in the radial acceleration of the bob and the tension in the string determined from it.

General Questions

- Explain why steps 2-5 of the procedure did not need to be repeated when the mass of the bob was changed, but did need to be repeated when the hanging mass was changed.