Concepts of Physics
Lab 3: Centripetal Force

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In this lab you will measure a force two different ways, and then compare those two results to each other. There is not a "correct" or "accepted" value for the force you will be measuring, so it will not be meaningful to calculate the percent error of your result. It would, however, make sense to calculate the percent difference between the two results. The percent difference between results r_1 and r_2 is:

$$\text{\% difference} = \frac{|r_1 - r_2|}{(r_1 + r_2)/2} \times 100\%$$

Knowing the value of the force in question is not very important, but finding it out will continue developing your experimental technique, and give you some physical experience with rotational motion and centripetal force.

Theory: Centripetal force

When an object of mass M travels in a circle of radius R at constant speed v, there must be a force causing the continual change in direction. That force is called centripetal force, and is directed toward the center of the circle. (Thus, the centripetal force is also always changing its direction!) The magnitude of the centripetal force, F_c, is equal to Mv^2/R. In this part of the lab, you will indirectly find F_c by measuring M, R, and (indirectly) v.

You will find v by measuring the distance traveled, and the time to travel it. Since you can measure the time for many revolutions more precisely than the time for one revolution, that is what you will do. If t_n is the time to make n revolutions, then:

$$v = \frac{\text{(distance traveled)}}{t_n} = \frac{n2\pi R}{t_n}. \tag{1}$$

Thus:

$$F_c = \frac{M\left(\frac{n2\pi R}{t_n}\right)^2}{R} = \frac{Mn^2 4\pi^2 R}{t_n^2}. \tag{2}$$

You will measure M, n, R and t_n directly.

For this rotating object, the centripetal force will be caused by a stretched spring. You can measure this force by hanging masses from a string attached to the spring, and finding out how much mass it takes to stretch it to the appropriate length. If the hanging mass needed is m, then the force exerted by the spring at that length, F_s, must be mg. Here, g is the acceleration due to gravity—assume $g = 9.80$ m/s^2.

According to our theory, if you find F_c and F_s as outlined above, they ought to be the same to within the uncertainties of the experiment.

Activity 1: Practice rotating, counting and timing

Set up the apparatus as shown in Figure 1. Everything should be set up such that when the mass M is directly over the position marker, the spring is stretched.

Now practice spinning the apparatus so that it stays just above the position marker—that is how you keep R constant. When spinning, the mass should be hanging vertically, and the spring should be horizontal—make adjustments if necessary. Practice timing how long it takes for the mass to go around n times (where n is around 50). The person rotating the axle should count the rotations out loud as another person times the n rotations.

To hand in for activity 1

Nothing.

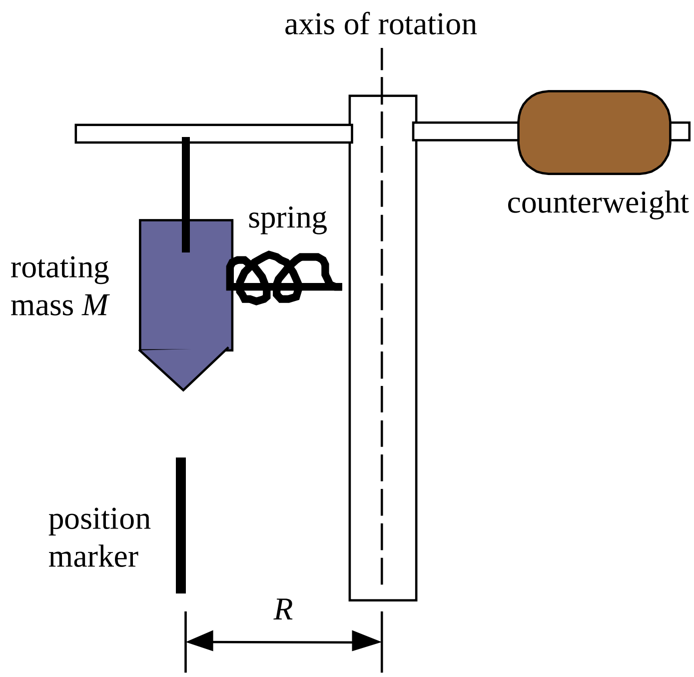

Figure 1: Experimental setup

Activity 2: Finding F_c

Measure R, M, n, and (as outlined in activity 1) t_n; and calculate F_c.

To hand in for activity 2

- Values for R, M, n, and t_n,
- Equation used for F_c,
- Final value for F_c.

Activity 3: Finding $\boldsymbol{F}_s$

Attach a string to the outer edge of the mass M, run it over the pulley, and hang various masses from it until the mass M hangs just over the position marker. Measure m, and calculate F_s.

To hand in for activity 3

- Values for g and m,
- Equation used for F_s,
- Final value for F_s,
- Percent difference between F_c and F_s.