LAB 6: Centripetal Acceleration*

Equipment List:
centripetal force apparatus
stop watch
level
masses and hanger
string

Purpose: To explore the force on an object in uniform circular motion. You will calculate the net force on an object moving in uniform circular motion (provided by a spring) and compare with the expected value, which is the amounf of force needed to stretch the spring by the same amount.

Theory: In this experiment a bob of mass M_{bob} will be rotated in a circle. You will measure the time period of rotation, T, at a given radius R. An object in uniform circular motion has an acceleration

$$a_r = \frac{v^2}{R}$$

Noting that the speed of the bob, v, can be calculated by $v = \frac{2\pi R}{T}$,

$$a_r = \frac{4\pi^2 R}{T^2}$$

From Newton's second law, we know the magnitude of the net force on the rotating bob must be $F_{\text{net}} = M_{\text{bob}} a_r$, so

$$\boxed{F_{\text{net}} = M_{\text{bob}} \frac{4\pi^2 R}{T^2}}$$

This force is provided by a stretched spring, so $F_s = F_{\text{net}}$.

When the bob is at rest (not rotating) we can set it up so that it is in equilibrium with the spring extended to give the same radius as before when the bob was rotating by adding a force to the opposite side of the bob. If the force supplied by the weight W_h of a mass hanging over a pulley is the same as the force needed to stretch the spring, the bob can sit in equilibrium, $W_h = F_s$. Then we expect:

$$F_{\text{net}} = W_h$$

*Based on the lab by Prof. Luna.

Procedure:

1. Remove mass M_{bob} from the centripetal force apparatus and measure the mass with triple-beam balance. Place mass M_{bob} back on the apparatus but do not attach the spring yet.
2. With the spring not attached, level the platform with the level and align the mass pointer with the vertical tooth labeled "15", which refers to a radius of 15 cm.
3. Attach spring to mass M_{bob}.
4. Rotate the central column of the centripetal force apparatus by hand using the grip at the top. Rotate so that M_{bob} moves at a constant speed and the bob pointer is aligned with the 15 cm vertical tooth.
5. Once the rotation is steady, measure the time for 20 revolutions 3 times, find the average of the three runs, then calculate the average period of rotation, T.
6. Calculate the radial acceleration a_r using the average period.
7. Calculate the magnitude of the net force F_{net} in the radial direction.
8. Stop the rotation and leave the spring attached to mass M_{bob}.
9. Attach string with hanger to the other side of mass M_{bob} and run the string over the pulley and off the edge of you bench, letting the hanger hang freely.
10. Add mass to hanger until the mass pointer and the 15 cm vertical tooth are aligned just as it was when M_{bob} was rotating in uniform circular motion. Make sure that the any knots on the string are not getting caught on the pulley!
11. Use the triple beam balance to find the total mass of the hanger and all the masses on it.
12. Calculate weight W_h of the hanging mass, using $g = 9.8$ m/s^2.
13. Find the percentage error between W_h and F_{net}, taking F_{net} to be the "theoretical" or "accepted" value.
14. Repeat steps (2) to (13) for radii of 18 cm and 21 cm.