Uniform Circular Motion

In lab, youll be able to explore two dimensional motion using the twirl-a-bob. Caution: **Please be careful when you swing the nut around in a circle! Make sure you dont hit your fellow students!**

1. To learn how to use the twirl-a-bob takes a little practice. Start by putting about 40 g of weight into the basket attached to the string. Hold the white PVC pipe vertically and get the nut to swing in a circle. Observe what happens when you twirl the nut faster or more slowly, and write your observation down.

2. Your first task is to understand the relationship between the total weight hanging from the string (basket plus weights in it) and the period of rotation of the nut. See the discussion below. Devise an experimental procedure: that allows you to figure out this relationship. Remember that while you change one variable, you'll have to keep all other parameters constant. You should keep the **length of the string from the nut to the top of the PVC pipe to 60 cm**, by making a mark on the string. We recommend that you adjust the speed at which you whirl the nut, such that the basket rises up until this mark is at the bottom of the PVC pipe and stays there. Vary the mass from about 35 g to about 110 g.

3. Make a data table, and have the instructor approve it before you start taking data.

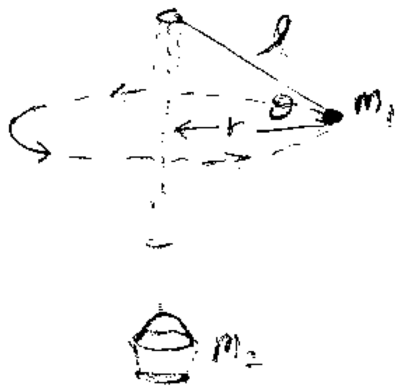
4. Put your data on the board for comparison with the other groups.

5. We will work out the theory together on the board.

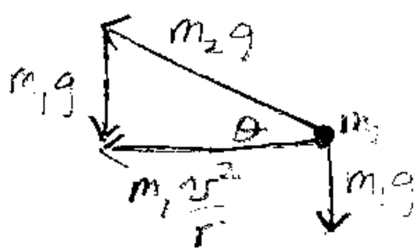
6. Plot your data in such a way that you are getting a straight line. What is the meaning of the slope of the line? From your value for the slope of the line, what do you obtain for g?

7. What (if any) principle(s) of physics does your data support?

8. If you get the nut spinning and hold the PVC pipe stationary, the spinning nut will lose energy (due to friction) and spin slower. The lengths l and r will decrease. What will the angle θ do? Will it increase, decrease, or stay the same as the nut slows down. Predict what might happen, then check out your prediction.



$$\cos\theta = \frac{r}{\ell}$$



$$\cos\theta = \frac{m_1 v^2/r}{m_2 g}$$

Equations of Motion

From the figure we see that the string length l and the radius of the circular motion r are related by:

$$cos(\theta) = \frac{r}{l} \tag{1}$$

The net force on the nut must have a magnitude equal to mv^2/r and be directed towards the center of the circle of motion. The net force is the vector sum of the string tension (m_2g) and the weight of the nut (m_1g). The vector addition of these two forces results in the triangle shown in the figure. From the "force diagram" we see that

$$cos(\theta) = \frac{m_1v^2/r}{m_2g} \tag{2}$$

Equating the $cos(\theta)$ from the setup and the force diagram yields

$$\begin{aligned} \frac{r}{l} = \quad cos(\theta) \quad &= \frac{m_1v^2/r}{m_2g} \\ \frac{r^2}{l} \quad &= \quad \frac{m_1v^2}{m_2g} \end{aligned}$$

Relating v to the time for one revolution T, we have $v = 2\pi r/T$. Substituting this expression for v gives:

$$\frac{r^2}{l} = \frac{m_1(2\pi r/T)^2}{m_2g} \tag{3}$$

Note that r cancels out and the equation reduces to

$$T^2m_2 = \frac{4\pi^2lm_1}{g} \tag{4}$$

All quantites on the right side of the equation are held constant during the experiment, because you spun the nut keeping $l = 60\ cm$ each time.

It is also interesting to note that the angle θ only depends on the masses m_1 and m_2. From the force diagram one can see that $sin(\theta) = m_1/m_2$.