PHYS S123: College Physics I
Lab 4: Circular Motion
9/30/25 (due 10/7/25)

Name:

Topics:

1. Uniform circular motion
2. Centripetal acceleration

Introduction: In this lab you will explore uniform circular motion and centripetal acceleration. The lab consists of several related exercises, each designed to isolate different variables related to circular motion.

Start by assembling an apparatus similar to the one shown in Figures 1 and 2. Mass m_a on the order of 20 grams and a total string length of about 1.5 meters are good starting values. Attach mass m_b, which should be larger than m_a, to the string and tie mass m_a **securely** to the other end of the string; add a little bit of tape to help secure the knot. In order for this to work, m_b should be greater than m_a. Move to an area where there is plenty of room and carefully whirl mass m_a above your head. You will find that mass m_b moves up and down as the speed of rotation is changed. With a little practice you can find a combination of angular speed, mass m_b, and radius of rotation that will place mass m_b in equilibrium. You should find it possible to keep the speed of rotation constant enough to keep mass m_b stationary.

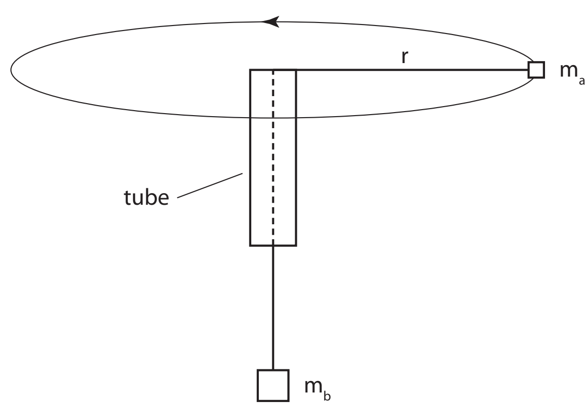

Figure 1: Diagram of a system in which masses m_a and m_b are connected by a string that is fed through a tube. Mass m_a is whirled about the tube with an orbital radius of r. If the speed of rotation is too small, mass m_b moves downward. If the speed of rotation is too great, mass m_b moves upward.

The goals of this lab are (1) to find empirical relationships between the mass, speed, and radius of the whirling mass and the tensional force in the string and (2) to compare the empirical relationship to theory.

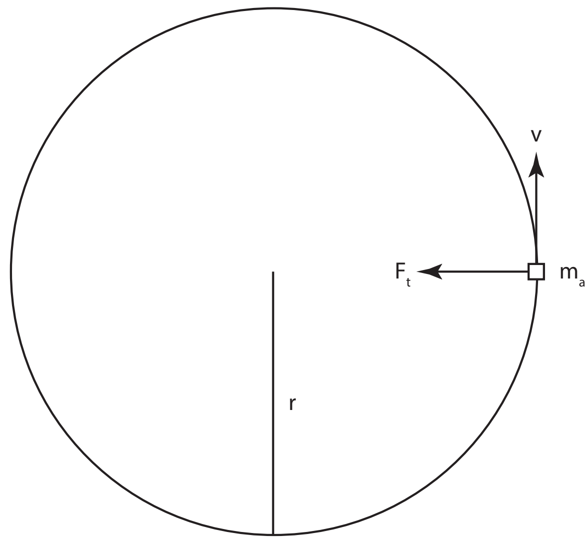

Figure 2: Aerial view of mass m_a moving in a circular path. The variables m_a, r, and F_t can be chosen independently. The remaining variable, v, is measured indirectly. Be careful with units.

What you should turn in: A formal lab report. You are expected to write and submit an individual report, and you should submit it via Blackboard. The lab report should consist of the following parts:

- Introduction: Describe the topic/theory that you are exploring. Provide relevant background material. At the end of the introduction you should indicate in a brief statement or two how you will test that theory. (15 pts)
- Methods: Describe the experimental set-up. Include a diagram if it clarifies your description. [15 pts]
- Results: Present data, including qualitative descriptions, and graphs. Draw the reader's attention to important aspects of the graphs. You should not discuss all of the minutiae of the data. All graphs should serve a purpose. If they aren't referenced in the text, don't include them. Avoid tables whenever possible; graphs are almost always preferred. Please include the graphs within the body of the report, and make sure they are clearly labeled. [30 pts]
- Discussion and Conclusions: Summarize and interpret your results. Discuss whether or not your observations are consistent with theory, and explain why the differences might occur. Do not simply state that there was experimental error. If there was experimental error, describe *how* it affected your calculations. In other words, can the experimental error actually explain the differences between your data and theory? Discuss how your assumptions may have affected your results. This will take some careful analysis of the problem that you are investigating. [25 pts]
- Composition (not a separate section): Be sure that somebody that is unfamiliar with the lab exercise can understand what you've done. [15 pts]

A lab report does not need to be long to be good. You want your report to be thorough yet succinct. This takes practice. For additional tips on writing lab reports, see the information sheet and rubric that I posted to Blackboard.

PART 1: FORCE BALANCE EQUATIONS

Using Figures 1 and 2 as a guide, use Newton's Second Law to write down an expression that relates the tensional force in the string to the mass, speed, and radius of the whirling mass. To perform these experiments, you will also need a couple of equations to calculate the speed of the whirling mass and the tension in the string. Use kinematics to write down an equation for determining the orbital velocity of the whirling mass, and Newton's First Law to determine how you can estimate the tensional force.

Include these equations, and a description of where they came from, in the introduction of your lab report.

PART 2: RELATIONSHIP BETWEEN FORCE AND SPEED

1. Measure the mass m_a, which will be held constant for this part of the lab. $m_a =$

2. For this experiment you will vary m_b and hold r constant. Mark the string with a marker so that you can ensure that r remains relatively constant. $r =$

   Measure the period for each of several values of m_b. Calculate the speed and record your values in Table 1.

m_b	$F = m_b g$	total time	# of revolutions	v

4. Plot a graph of F vs. v (F is on the y-axis and v is on the x-axis). Find a relationship between F and v from your graph.

5. Compare and discuss your experimental results with that predicted from the equation that you derived in Part 1. Plot the theoretical equation for $F(v)$ on the same graph.

PART 3: RELATIONSHIP BETWEEN RADIUS AND SPEED

1. Using the same value for m_a as above, choose one value of F (or m_b) used in part A and find the speed v for a few different values of r.
   $m_a =$

   $m_b =$

   $F = m_b g =$

2. Fill in the table.

r	total time	# of revolutions	v

3. Plot a graph of r vs. v and find a relationship between r and v from your graph. As before, compare the results to the equation that you derived in Part 1 by plotting a theoretical curve of $r(v)$ on the same graph as your data.

PART 4: RELATIONSHIP BETWEEN MASS AND VELOCITY

1. Use a few different values for m_a to find a relationship between m_a and v in a similar manner to what you did in parts 1 and 2. Here, you will want to hold m_b and r constant.
   $m_b =$

   $F = m_b g =$

   $r =$

2. Fill in the table below and plot m_a vs v.

m_a	total time	# of revolutions	v

3. Plot the theoretical relationship for $m_a(v)$ and compare it to your measurements.

PART 5: RELATIONSHIP BETWEEN FORCE, RADIUS, AND VELOCITY

You do NOT need to include anything from this section in your report, but it is useful for helping to understand the centripetal force as well as demonstrating why experimental technique is generally based on the idea of holding as many variables constant as possible.

Using m_a as in part 1, swing m_a in a circle of radius approximately one meter. Hold the tube steady and pull down on the string, in effect increasing F. (Please don't jerk the string or exert too much force; mass m_a can become a dangerous missile!) Do this several times and describe in words the relationship between F, r, and v. The purpose of this section is two-fold. First, it should give you a more literal feel for the centripetal force. Second, you should find it difficult to analyze the situation in which three quantities are simultaneously changing.

PART 6: DISCUSSION OF ERROR

There are at least two important sources of error in this lab. Identify the sources of error and (importantly!) describe in your report how the error affects your experiments. Are the sources of error random or systematic? Do the errors become larger when you change one of the variables? Why?