Laboratory 8: Conical Pendulum – Prelab

1 Conical pendulum

A conical pendulum consists of a ball at the end of a string, which traces out a circular path as illustrated in Fig. 1. Suppose that the mass of the ball is 0.040 kg, the length of the string is 80 cm and the radius of orbit is 35 cm.

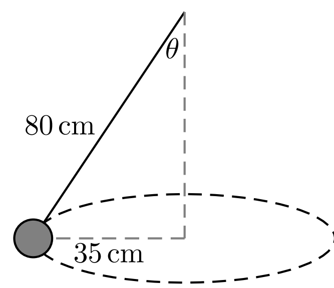

Figure 1: Conical pendulum

a) Apply Newton's second law (vertical component) to determine the tension in the string.

b) Apply Newton's second law (horizontal component) to determine the time taken by the ball to complete one circular orbit.

Laboratory 8: Conical Pendulum – Activity

The conical pendulum, shown in Figure 2, consists of a mass m at the end of a string of length L that moves at a constant speed around a horizontal circle of radius r. A component of the tension in the string provides the necessary force to provide the circular motion of the mass. Newton's laws, along with the concept of centripetal acceleration, can be used to predict an expression for the tension necessary to move the mass in a horizontal circle at any given radius. The goal of this experiment is to verify that this prediction is correct.

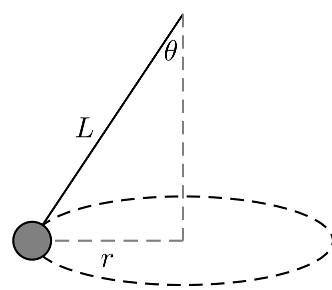

Figure 2: Conical pendulum

1 Theory and experimental design

A force sensor, to which the pendulum will be attached, will measure the tension in the string. You will use Newton's laws and the concept of centripetal acceleration to derive an expression for the tension in terms of experimentally measurable quantities.

a) The angle that the string makes with the vertical axis, θ, will be difficult to measure and too inaccurate to obtain useful results. Express $\sin\theta$ and $\cos\theta$ in terms of r and L.

b) Draw a free-body diagram for the mass and apply Newton's 2nd law in both the horizontal and vertical directions. Use the equation you obtain for the horizontal direction to derive an equation for the tension T in terms of only m, v, L, and r.

c) Unfortunately, we will also not be able to accurately measure r and v. Develop and explain a method to experimentally measure the period of rotation t_p of the mass as it rotates in a horizontal circle. Rewrite your expression for tension T in terms of only m, L, and t_p. Check this expression with the instructor.

2 Experiment

The pivot point of the conical pendulum is attached to a force sensor, which will measure the tension in the string.

a) Measure and record the mass m of your object that will be oscillating and the length L of your pendulum.

b) Open Capstone and configure the Force Sensor to a sampling rate of 50 Hz. With zero mass suspended from the Force Sensor, press the tare button on the side of Force Sensor to zero the instrument. Display the force measurements in a graph to obtain the measured force as a function of time.

c) Set the mass spinning around the vertical axis using your hands and start recording data after releasing your hand (so that the system is spinning without influence from any outside force other than gravity and the tension).

d) While the system is spinning, obtain the elapsed time for ten rotations using a stopwatch. Calculate the period of rotation t_p from this measurement.

e) Calculate an experimental value for the tension in the string T using your measured values of m, L, and t_p. Record this value as T_{calc}.

f) From the measurements of tension acquired with Capstone, select an appropriate range of data to calculate an average value for the actual tension in the string. *Note that* Capstone *can be used to quickly calculate a mean value of selected data on your graph.* Record this value as T_{meas}.

g) Determine the percent difference between the values you calculated in parts e) and f) using

$$\% \text{ Difference} = \frac{|T_{\text{meas}} - T_{\text{calc}}|}{(T_{\text{meas}} + T_{\text{calc}})/2} \times 100 \ \% \tag{1}$$

h) Repeat this experiment two more times with strings of different lengths.

3 Report

The lab exercise that you have done was broken down into many small steps, whose relationship to one another may not be obvious. In order to make sense of the entire exercise, compile a brief, informal report describing the aims, methods and results; excluding the data, a page should be enough. This may be written in *bullet point form.* A *guideline* of what this might contain is:

- *Introduction*
  - Describe the aim of the experiment. What is the question that it addresses?
- *Set up and Theory*
  - Briefly describe/sketch the set up that can be used to meet the aim of the experiment.
  - Briefly describe what theory is useful for understanding the situation and what it eventually predicts (include equations that form predictions). Include derivations that were essential.
- *Experiment*
  - Provide details of the experimental set up.
  - Provide the experimental data and associated calculated quantities.
  - Provide the data analysis.
- *Conclusion and discussion*
  - Describe what the experiment showed. Did it verify something? If so, what? Did it answer a question that was posed earlier? If so, how?

- Describe possible sources of error in this experiment. Be specific (stating that "human error" is an issue without describing what human error and how it entered is not acceptable). Describe, if possible, how such errors may be reduced.
- Describe the main conclusion of this experiment. What answer does it give?