Lab. 7  Circular Motion and the Conical Pendulum

Introduction
In this experiment, you will work with two different types of pendula. The first is an ordinary pendulum like you might expect to find in a clock – the pendulum bob will be moving in a circular arc with a back and forth motion in a plane. The other is a conical pendulum which involves a pendulum bob moving in a horizontal circle.

The “centripetal force” is a special case name for “net force” in Newton’s second law in this particular situation. The centripetal force is still found by considering the sum of all forces acting on an object. The special case here is that we know something about the motion of the object. What we know is that the object is moving along a circular path at a constant speed. This will hold for the vertical circle if we make measurements at the top or bottom of the swing (where the motion is horizontal), and also for the conical pendulum. When we know the motion of an object is along a circular path at constant speed we know the magnitude of “centripetal acceleration” is given by

\[ a_c = \frac{v^2}{r} \]

The centripetal acceleration points inward toward the center of the circle. Once the acceleration of an object is known, we can use Newton’s second law to relate force.

\[ F_c = ma_c \]

Exercise 1: The Vertical Circle and the Pendulum
Here we will measure the centripetal force at the bottom of the pendulum swing using a force sensor. Then you will measure the speed of the pendulum bob at the bottom of the swing and use that speed to determine the theoretical centripetal force at the bottom of the pendulum swing. You will compare the results and see if they agree. If these agree then we have verified our theoretical statement (equation 2) to calculate centripetal force.

1. Mount the force probe on a ringstand and connect the pendulum bob to the force probe’s hook with some massless string. You should use a length of string approximately 1.00m here, and raise the pendulum to a height above the bottom of the swing so that you can repeat the experiment precisely. The height is really how far the mass falls vertically.
2. Carefully select a height. \( h=\)__________________±______________m
3. Measure the force at the bottom of the swing several times, record, average and determine the uncertainty. Note that the Force measured by the force sensor is not the net force. You will need to account for gravitational force in addition to tension.
4. Carefully note the sign indicated by the force sensor on your Labquest 2. You will need to be consistent with all other forces acting and also “ma”. (Direction matters)
5. When you connect your force sensor you will need to go to the sensor settings on the home screen and set the force probe sample rate to 100 samples /sec. The force reading you are interested in is at the bottom of the swing, which should be the maximum magnitude. You can find this by graph or table on the labquest. The tension force is a positive number upward. The weight is down.

<table>
<thead>
<tr>
<th>Force Measured Tension(average)</th>
<th>±</th>
<th>N</th>
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<tbody>
<tr>
<td>F(net)=F_T-mg</td>
<td></td>
<td>±</td>
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It is the net force here that causes centripetal motion as listed in equation 2.
6. You may now use a photogate setup to carefully measure the speed of the pendulum at the bottom of the swing. You should know how to do this by now \((mv^2/r)\). Determine both \(v\), \(r\), \(m\) and with uncertainties, and calculate the theoretical centripetal force (this will have uncertainty that comes from \(v\), \(r\), and \(m\)).

\[
\text{Centripetal Force (}\text{F(centripet)} = m \frac{v^2}{r} = \text{________________________} \pm \text{________________________} \text{N}
\]

Do the net force and centripetal force agree with each other (within uncertainties)?

**Exercise 2: The Conical Pendulum**

A special case of circular motion is the conical pendulum where the pendulum’s “bob” is swung in a horizontal circle of radius \(R\) while attached to a string of length \(L\). Your lab instructor will demonstrate with a sample set up. You also should be able to find setup descriptions/figures in most textbook chapters on centripetal force. The time required for the bob to make one complete revolution or orbit is called the period \(T\). Newton used just such a device to measure the acceleration due to gravity \(g\) (he got to within 4% of the accepted value!). Your job will be to reproduce his work. You will set up your own conical pendulum, being careful to start motion in a circle. Use a good length of string. Your setup may be longer than the demonstration setup since you may go outside, in the atrium, stairs, etc. Long pendulums may work well here.

Measure \(R\), \(T\), \(L\). With uncertainties. Take sufficient number of trials.

\[
\text{R=___________} \pm \text{_______} \text{m} \quad \tan(\theta)=\text{__________} \pm \text{_______}
\]

\[
\text{T=___________} \pm \text{_______} \text{s} \quad \text{v =___________} \pm \text{_______} \text{m/s}
\]

\[
\text{L=___________} \pm \text{_______} \text{m}
\]

Next determine \(\tan(\theta)\) listed in the figure, and also the speed of the pendulum. Refer to the figure you used in your pre-lab. You should have a formula that you can use to determine “\(g\)” in terms of the quantities determined.

Determine “\(g_{\text{measured}}\)” along with an uncertainty, and compare to the accepted value.