Newton’s Laws

In-Person | Two Weeks | Draft & Report Submissions

Introduction

This lab is designed to provide students with the opportunity to design and implement an experiment which measures the acceleration of a two-mass system and uses that to obtain the acceleration due to gravity (g). This is a two-week in-person lab. A lab report draft is due after the first week, and a full report is due a week after the final lab class. In this lab students will (a) measure the value of the acceleration “a” of the two-mass system, (b) calculate “a” theoretically for the system, (c) compare the results to the theoretical value of “a”, (d) obtain a measurement for acceleration due to gravity “g” and compare it to the accepted value, and (e) practice identifying and quantifying sources of error.

Theory

Newton’s Laws of motion are the fundamental laws in physics which define the relationship between physical objects and the forces acting upon them. Newton’s Second Law relates the acceleration of an object to the mass of the object and the force applied upon it.

$$F = ma$$

We can use this equation to study a variety of dynamical systems. In this experiment, we will be analyzing a system of pulleys, carts and masses to obtain the acceleration of the two-mass system using Newton’s Laws.

The experimental setup, there are two (variable) masses: one with wheels (cart) and one hanging. They are connected to each other via a taut string going over a pulley. The force of gravity pulls the hanging mass down, which in turn drags the cart mass.

The acceleration of the cart mass is given as:

$$a = g \frac{m_{hanging}}{m_{total}}$$

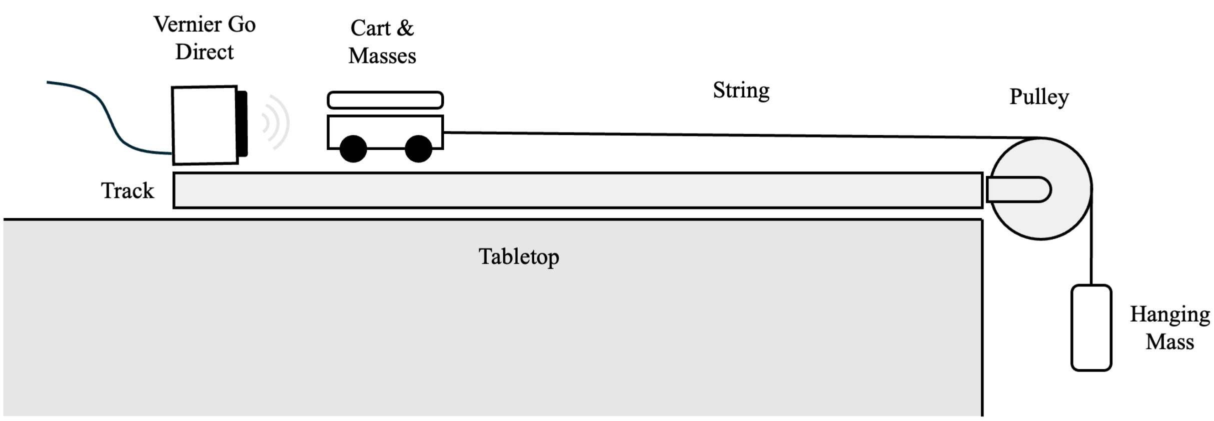
$$m_{total} = m_{hanging} + m_{cart}$$

You are expected to be able to derive these expressions on your own and know how to use them.

Procedure

For this lab, we will utilize the following equipment:

- Vernier Go Direct® Motion Detector – to measure velocity vs time of the cart going down the ramp
- Vernier Graphical Analysis™ Software Package – to obtain slope of the velocity
- A Dynamics Cart
- A Pulley with Clamp
- String
- Paper Clips and a Hook to hang them
- Set of Standard Masses
- Electronic Balance
- Wooden Stop-Block
- A computer – to obtain the data from the Vernier Go Direct® Motion Detector
- Excel (or equivalent) - for data analysis and making graphs
- Word (or equivalent) - for writing the summary



There are three activities to be performed in 2 weeks. The goal is to determine the acceleration due to gravity "g" using the acceleration of a two-mass system. Measuring the velocity vs time data of the cart in the experiment above will provide us with the required acceleration.

Activity 1: Constant Cart Mass, Variable Hanging Mass

The goal of this activity is to measure the acceleration of the two-body system as a function of the variable hanging mass.

1. Setup the pulley with clamp on your table.

2. Attach your string to the cart mass. Add a few standard masses to the cart and measure the total cart mass (along with the string).

3. Select paper clips to attach to your hook. This is your hanging mass. Record its mass.

4. Attach the string to the hanging mass by looping it over the pulley.

5. If the cart does not move, add a few more paperclips to the hanging mass. Keep a record of the mass being added. Record the total "hanging mass".

6. Once the cart starts to move, the system is ready for data collection. Setup the motion detector behind the cart, start the data collection (velocity vs time data), release the cart, then stop the data collection when the cart reaches the end of the track. Your goal is to obtain acceleration from velocity vs time data. (You should be comfortable with obtaining velocity data from the Vernier motion sensor by now.)

7. Store value of measured dynamical acceleration "a".

8. Perform multiple runs for a fixed value of hanging mass.

9. For each value of hanging mass, find the theoretically expected value of dynamical acceleration "a" (using $g=9.8\ m/s^2$). Also record the ratio of hanging mass vs total mass.

10. Change the hanging mass by adding another (or a few more) paperclip(s). Record the new hanging mass. Repeat steps 6 & 7 for the same.

11. Repeat the process for several different values of the hanging mass but keeping the cart mass constant. The more data you collect, the better.

12. Plot "a" measured vs "mass ratio". What does the slope represent?

13. Find the value of acceleration due to gravity "g" from the data collected.

14. Compare the obtained value of acceleration due to gravity "g" and the theoretically accepted value.

15. What are the sources of error in this experiment? What is the standard error in the measurement of dynamical acceleration "a" and acceleration due to gravity "g"? Answer these questions in your report.

Activity 2: Constant Hanging Mass, Variable Cart Mass

The goal of this activity is to measure the acceleration of the two-body system as a function of the variable cart mass.

1. Start with a 100-gram mass on the cart. Record the total mass of the cart. Keep the hanging mass constant throughout the experiment.

2. Measure the hanging mass.

3. Obtain the velocity vs time data and find acceleration.

4. Perform multiple runs for a single cart mass.

5. Find the theoretically expected value of acceleration "a".

6. Repeat the steps for at least a few different values of cart mass.

7. Plot "a" measured vs "mass ratio". Discuss what the slope means.

8. Compare the obtained value of acceleration due to gravity "g" and the theoretically accepted value.

Analysis

In your submission, you will need to include:

- All data tables for both activities with values of "cart mass", "hanging mass", "mass ratio", "acceleration measured", and "theoretical acceleration".

- All plots obtained in both activities.

- Measured value of "g" in both activities.

- Comparison of the measured value of "g" to the standard value.

Discussion

As *parts* of your discussion, please make sure to include:

- Discussion of the graph obtained in Activity 1. Identify any key features and explain how it was used in data analysis. How did you find "g" from this plot?

- Discussion of the graph obtained in Activity 2. Identify any key features and explain how it was used in the data analysis process. Specifically, how did you find "g" from this plot.

- What value of g did you obtain? What is the error?

You must discuss the possible sources of error in your report. You should be considering what could have caused your experimental values to not match up exactly. Why would this happen? Think about systematic vs. random errors and how they could apply in this experiment. This is one of the most important aspects of performing an experiment and is integral to each lab in this course.