SP211 Lab 3
Newton's Laws

Equipment

You will need the following equipment to complete this lab. Quantities needed are listed inside of the parentheses.

LabQuest Mini (1)
Cart (1)
Motion Sensor (1)
Track (1)
Force Sensor (1)
Pulley Wheel (1)
Hook (1)
Slotted Mass Set (1)
500 g Mass (1)
Small Screwdriver (1)
Table Clamp (1)
Small and Large Rod Holder(1)
Large and Small Rod (1)
String (1 roll per room)
Force Bracket with Springs (1)
Meter stick (1)

You will also need the Vernier Graphical Analysis software and Google Gemini to complete this lab.

Procedure 1: Force Sensor Calibration

1) Every time you plug a force sensor in or restart Vernier Graphical Analysis, you'll need to calibrate the force sensor. To do this, plug the force sensor into the LabQuest Mini and the LabQuest Mini into your computer. Open Vernier Graphical Analysis and click on the Force button in the bottom right corner of the window (Figure 1), then calibrate. Hang the force sensor on a rod and make sure it is set on ± 10 N. In the "Enter first known value" box, type 0, and click keep. Next hang a 500 g mass from the hook of the force sensor, type 4.9 in the "Enter second known value" box, and click keep. Answer Question 1 on the attached worksheet.

2) Now that the force sensor is calibrated, spend a moment pulling and pushing on its hook while collecting data. Answer Question 2 on the attached worksheet.

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Figure 1: The red oval indicates where to click to calibrate the force sensor.

Experiment 1: A Cart On an Inclined Plane

1) In this experiment, we are going to measure the forces on a cart on an inclined plane using the setup shown below (Figure 2). Before we take a measurement, answer Questions 3 and 4 on the attached worksheet.

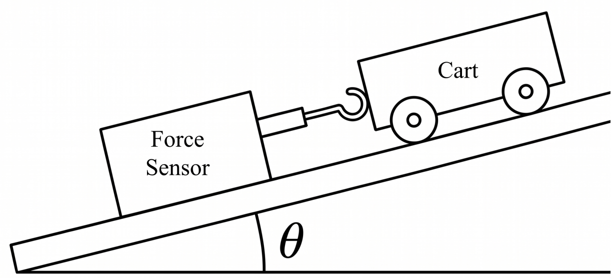

Figure 2: Force sensor orientation with a cart on an inclined plane.

2) It should be clear from your work on the free body diagrams that the component of the force of gravity on the cart that goes down the plane is equal in magnitude to the normal force from the cart on the force sensor. Now we will predict what that is. First, measure the mass of the cart and record it on the attached worksheet (Question 5). Then place your track at an incline between 5° and 10° and take some measurements of it to determine the angle θ at which it is inclined (Question 6 on the attached worksheet). Once you have both of these, answer Question 7 on the attached worksheet.

3) Now let's confirm your prediction from the last step. Set up the force sensor on the track like shown in Figure 2, zero the force sensor by clicking on the force button in the lower right corner (see Figure 1), then place the cart on the track touching the force sensor hook. You will have to hold the force sensor steady on the track (this is a static experiment). Use the Vernier Graphical Analysis software to collect a reading from the force sensor. Record this in Question 8 on the attached worksheet.

4) Prior to the next part of our experiment, answer Question 9 on the attached worksheet.

5) Plug in the motion sensor and place the motion sensor at the top of the track. Change the graph Vernier Graphical Analysis displays to a graph of acceleration (on the y-axis label to do so). Remove the force sensor from the track and assign a lab partner to be prepared to catch the cart at the bottom of the incline (this is a dynamic experiment). Place the cart at the top of the track, click collect, and release the cart. Answer Question 10 on the attached worksheet.

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Experiment 2: A Cart Pulled By a Hanging Mass

1) Next, consider the setup in Figure 3: A cart and force sensor are screwed together so they act like one combined mass. The force sensor has a string tied onto its hook, which passes over a pulley, and has a mass hung from it. Answer Questions 11 and 12 on the attached worksheet about this setup.

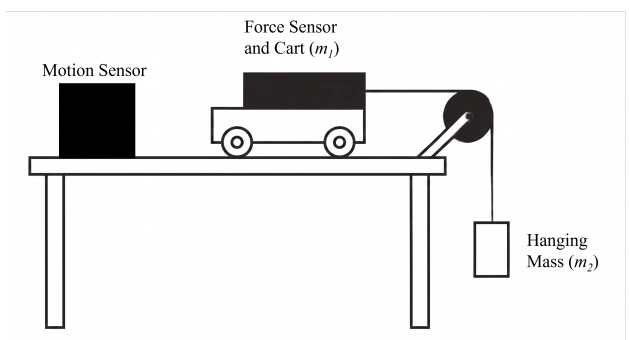

Figure 3: Experiment 2 set up.

2) Attach your force sensor to the cart and measure their combined mass (m_1). Record that on the attached worksheet (Question 13). Using the hook and slotted masses, decide on a mass to hang (m_2) that will not cause damage to the equipment or floor (about $\frac{1}{8}m_1$ works well). Measure and record its mass. Answer Question 14 on the attached worksheet.

3) Set up the experiment shown in Figure 3. You will likely need to level the track as best as possible by turning the track legs. A cart will not roll freely on its own on a level track. Change the graphs displayed by Vernier Graphical Analysis so that one displays force and one displays acceleration (adjust the number of graphs shown via the box in the upper right and what each individual graph is by clicking on their y-axis title). Click collect,

hold the cart in place for approximately 2 seconds, then allow the cart to start accelerating towards the pulley. Catch the cart before it hits the pulley and before the hanging mass crashes into the floor. Answer Questions 15 through 17 on the attached worksheet.

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Clean Up

Please return your lab station and the drawer of equipment to a clean and organized form. Follow any directions your instructor gives you about where to return equipment to when you are finished with the lab.

LAB 3 Worksheet

Name(s) and Alpha(s) Date

Procedure 1: Force Sensor Calibration

Question 1: When the 500 g mass is hanging from the force sensor, what type of force does the 500 g mass exert on the force sensor? Explain clearly why the wrong answer is "weight". Draw a free body diagram of the hanging mass to justify your answer and identify what force is part of a Newton's 3rd Law pair with a force on the force sensor.

Question 2: When does the force sensor record positive forces? When does it record negative forces?

Experiment 1: A Cart On an Inclined Plane

Question 3: Draw a free body diagram for both the force sensor and the cart.

Force Sensor:

Cart:

Question 4: Which of the forces that you drew are Newton's 3rd Law pairs? Why is the component of the force of gravity that goes down the plane *not* a Newton's 3rd Law pair with the normal force on the cart from the force sensor?

Question 5: What is the mass of the cart?

Question 6: What is the angle at which the plane is inclined? You'll need to take some measurements and do some trigonometry to calculate this. Show your work.

Question 7: Calculate the component of the force of gravity on the cart that is down the inclined plane. Show your work.

Question 8: What did the force sensor read for the component of the force of gravity on the cart that is down the inclined plane? What are some sources of error that could account for the difference in your calculated (Question 7) and measured values? “Human error” means you should have been more careful in taking data! Think deeper than that.

Question 9: Draw a free body diagram for just the cart on an inclined plane. Based on your free body diagram write down an equation for the parallel (relative to the incline) and an equation for the perpendicular components of Newton’s 2nd Law. Use these equations to predict what the acceleration of the cart down the inclined plane would be if you allowed it to roll down the track. Show your work.

Question 10: What was the average acceleration of the cart down the track (you could have Google Gemini analyze your data to do this)? Does it match what you predicted in Question 9? If not, what are some sources of error that could account for the difference in your calculated (Question 9) and measured values?

Experiment 2: A Cart Pulled By a Hanging Mass

Question 11: Draw a free body diagram for both masses m_1 and m_2 shown in Figure 3.

Force Sensor and Cart (m_1):

Hanging Mass (m_2):

Question 12: Based on the free body diagrams that you drew in Question 11, write down Newton's 2nd Law for both masses. Make sure they are properly divided up into components and that you have the orientation of the positive direction correct. Use these to derive equations for the acceleration of the cart and the force of tension in the string that connects the force sensor to the hanging mass. Show your work.

Question 13: Record your measured masses here.

Force Sensor and Cart (m_1):

Hanging Mass (m_2):

Question 14: Using your answers to Question 12 and your measured masses (Question 13), calculate the expected acceleration of the cart and the force of tension in the string. Show your work.

Question 15: Using your data and graphs, determine the average values for the acceleration and tension (you could have Google Gemini analyze your data to do this). Record them below.

Acceleration:

Tension:

Question 16: How do your measured acceleration and tension compare to your calculated values (Question 14)? What are some sources of error that could account for the difference in your calculated and measured values? "Human error" means you should have been more careful in taking data! Think deeper than that.

Question 17: When was the tension in the rope equal to the force of gravity on the hanging mass? When and why was it not equal to the force of gravity on the hanging mass? Why is there a drop in the tension measured by the force sensor when you let go of the cart?