LAB 5. FORCE AND ACCELERATION

Introduction

This lab contains two stations, both of which involve one mass accelerated by the weight of anther. One station is a classic Atwood machine with two masses connected by a string over a pulley. The other is a cart equipped with a measuring device that is new to us: a force sensor.

Supplies

Atwood machine: board with two pulleys, two mass hangers with masses, motion detector apparatus, pad for the floor
Rail cart: track with pulley, force sensor, auxiliary cart masses, mass hanger with masses, motion detector apparatus, level, pad for the floor

Data Collection

Atwood machine

One 50-g mass hanger is loaded with one 500-g mass, one 50-g mass, and one 5-g mass for a total mass of 605 g. The other is loaded with one 500-g mass, two 20-g masses, and a 10-g mass, for a total mass of 600 g.

1. Hang the hooks of the mass hangers through the loops at each end of the string, and run the string over the two pulleys.
2. Place the motion sensor on the floor facing up, under the lighter mass. Place the pad under the heavy mass.
3. Lower the lighter mass to the motion sensor.
4. Start data collection.
5. Release the masses so that the lighter mass is pulled upward by the falling heavier mass.
6. Stop data collection after the heavier mass hits the pad or the lighter mass reaches the pulley.
7. Make a velocity-time graph of the run. Fit the linear (constant-acceleration) portion of the graph to a linear fit. The slope of this line is the acceleration of the hanging weight. Record this acceleration.
8. Transfer masses between the hangers to make the next combination of masses.
9. Repeat steps 3-8 until the table below is complete.

m_1 (g)	m_2 (g)	a (m/s^2)	m_1 (g)	m_2 (g)	a (m/s^2)
600	605		570	635	
595	610		565	640	
590	615		560	645	
585	620		555	650	
580	625		550	655	
575	630				

Rail cart with force sensor

You will make measurements with two sensors at once: the motion sensor with which you are already familiar, and the force sensor, which you are using for the first time in this lab.

The force sensor screws into the bed of the dynamics cart. It has a hook on one end that measures small compressional or tensional forces. When the hook is pushed or pulled, the sensor registers a measurement.

You will make the cart as massive as possible. The total cart array will consist of the cart, the force sensor, and two auxiliary masses. Together, these are too massive for our balance to measure, so you must measure them individually and add the masses together.

You also need to calibrate the force sensor before use.

Setting up

1. Use the balance to find the individual masses of the dynamics cart, force sensor, and auxiliary masses.
2. Assemble the cart apparatus.
3. Level the track on the table. Place a barrier and pulley at the end of the track at the edge of the table. Place a motion detector at the other end.
4. Connect the motion sensor and force sensor, and set both to make 40 measurements per second.
5. Place the cart on the track with the hook of the force sensor facing the pulley.
6. Calibrate the force sensor. Use two-point calibration. Make the first point 0 N by placing zero load on its hook. For the second point, connect the string to the hook of the force sensor, run the string over the pulley, hang a known mass from the other end, and hold the cart motionless. The tension of the string is the mass of the hanging weight times g.

Qualitative observations

1. Hold the hook of the force sensor between your thumb and forefinger. Begin data collection.
2. Gently move the cart back and forth by pulling and pushing on the hook.
3. Stop data collection.
4. Make force-time and acceleration-time graphs. Do they correspond to each other?

Hanging mass

1. Connect the string to the hook of the force sensor.
2. Begin with a fairly small hanging mass, perhaps 20 g.
3. Hold the cart steady. Begin data collection.
4. Continue to hold the cart steady for a few seconds, then let it go to be pulled down the track by the falling weight.
5. Catch the cart before it reaches the barrier at the end of the track.
6. Stop data collection.

7. Make a force-time plot. Find and record the average value of the force during two times:
   - f_s, while the cart was held motionless, and
   - f_k, while the cart was freely accelerating along the track.
8. Make a velocity-time plot. Find the portion of the plot where the velocity increases linearly. Fit this portion with a linear fit. Record the slope of this portion: this is the acceleration during this time.
9. Repeat steps 3-8 for increasingly massive hanging weights, up to at least 500 g.

Total cart mass: _________________

m (g)	f_s (N)	f_k (N)	a (m/s^2)	m (g)	f_s (N)	f_k (N)	a (m/s^2)

Data Processing

Atwood machine

1. Find the formula for the expected acceleration of the frictionless Atwood machine.
2. Make a plot of the predicted and measured acceleration vs. the ratio $(m_2 - m_1)/(m_2 + m_1)$.

Rail cart

1. Find the formula for the expected acceleration of the ideal frictionless cart.
2. Find the formula for the expected tension in the string of the ideal frictionless cart.
3. For each hanging mass, calculate what the tension in the string should be when the cart is held motionless and when it is being accelerated by the falling weight.
4. For when the cart is held motionless, make a plot of expected and measured tension vs. hanging mass.
5. For when the cart is accelerating, make a plot of expected and measured tension vs. hanging mass.
6. For when the cart is accelerating, make a plot of acceleration vs. measured tension.

Lab Report

Present your findings in a brief, lucid report. It should contain the following parts.

Data

Show the raw data tables.

Results

Show the graphs that you made: a vs. $(m_2 - m_1)/(m_2 + m_1)$ for the Atwood machine; calculated and measured static T vs. m for the cart; calculated and measured dynamic T vs. m for the cart, and a vs. measured dynamic T for the cart.

Discussion

Atwood machine

Do the calculated and measured accelerations match? What is the relationship between acceleration and $(m_2 - m_1)/(m_2 + m_1)$?

Rail cart

Do the calculated and measured tensions match? What does that mean?

What is the relationship between a and dynamic T? What does that mean?