Name: ______________________________________

LAB 5. BALANCED AND UNBALANCED FORCES

Introduction

This lab comprises two activities. In one, you balance a cart free to roll on a ramp against a hanging mass; in the other, you measure the acceleration of a cart pulled by a hanging weight.

Supplies

Both activities: dynamics cart with a string,
Balance: adjustable ramp with pulley, level, mass hanger and masses
Rail cart: track with pulley, force sensor, auxiliary cart masses, mass hanger with masses, motion detector apparatus, level, pad for the floor

Data Collection

Balance

A string running over the pulley at the end of the ramp connects a mass hanger to a dynamics cart. For a given hanging mass (less than the cart mass), find the inclination angle of the ramp that keeps the cart and hanging weight from accelerating either up or down.

1. Measure and record the mass of the cart. Mass = ________________________.
2. Lower the ramp to the 0° position. Level the ramp.
3. Place the needed mass (50 g, 100 g, 150 g, 200 g, 250 g, or 300 g) on the hanger. Run the string over the pulley at the end of the ramp.
4. Adjust the ramp incline angle so that the cart rolls neither up nor down. Tighten the set screws on the ramp to lock it into place.
5. Check the angle by pushing the cart up the ramp and down the ramp. It should coast to a stop on about the same distance and time in both directions. Loosen the set screws and adjust the incline if necessary. Record the angle.
6. Complete steps 3–5 for each hanging mass.
7. Repeat the measurements (steps 3–6) for all hanging masses three times, by three different experimenters.

	Angle α (degrees)		
Hanging mass m (g)	Trial 1	Trial 2	Trial 3
50			
100			
150			
200			
250			
300			

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.

Set 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.

Hanging mass

1. Connect the string to the hook of the force sensor.
2. Place the pad under the hanging weight so that it does not crash to the floor.
3. Begin with a fairly small hanging mass on the string, perhaps 20 g.
4. Hold the cart steady. Begin data collection.
5. Continue to hold the cart steady for a few seconds, then let it go to be pulled down the track by the falling weight.
6. Catch the cart before it reaches the barrier at the end of the track.
7. Stop data collection.
8. 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.
9. 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.

10. Repeat steps 4-9 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)

Keep your data. You will use them beyond this lab.

Data Processing

Using a spreadsheet will make this easiest.

Balance

1. Average the angle readings for each hanging mass.
2. Calculate $M \sin(\alpha)$, where α is the angle and M is the mass of the cart, for angles α from 0° to 45°.
2. Make a plot of hanging mass m (vertical axis) vs. angle α (horizontal axis). On the same axes, plot the smooth curve of $M \sin(\alpha)$ vs α.

Rail cart

1. Make a plot of measured static tension f_s vs. hanging mass m. Fit it with a straight line and estimate its slope.
2. Make a plot of acceleration a vs. measured dynamic tension f_k. Fit it with a straight line and estimate its slope.

Lab Report

Data

Show the raw data tables. You may simply attach this sheet with the tables completed.

Graphs

Show the graphs that you made: m and $M \sin(\alpha)$ vs. α from the balance activity; f_s vs. m and a vs. f_k from the rail cart activity.

Discussion

Answer these questions thoroughly.

Balance

Do the hanging mass data match the $M \sin(\alpha)$ curve? Should they? Explain.

Rail cart

What is the relationship between f_s and m? What is the meaning of the slope of the line?

What is the relationship between a and f_k? What is the meaning of the slope of the line?