PHYS 1405 – Conceptual Physics 1
Laboratory # 4
Newton's Second Law

Investigation: What factors influence the acceleration of a cart pulled by a falling mass?

What to measure: Velocities of a cart accelerating on an air track, time between those velocity readings

Measuring devices: Air track with pulley and cart, photogates, mass holder with various masses

Calculations: Acceleration, percentage difference

Introduction

In this experiment, we shall investigate the connection between force and acceleration. As we have discussed in class, accelerations are caused by unbalanced forces. If we are familiar with the unbalanced forces acting on an object, we can calculate its acceleration, and vice versa. In this lab, we will be investigating a situation similar to some of the discussion questions you have worked with:

A cart on a frictionless air track is initially held in place. The cart is attached to a hanging mass by a pulley. When the hanging mass is released, it falls down and the cart accelerates along the frictionless track. We consider the cord and pulley to have no mass and no friction. We also consider the cord connecting them to not stretch. What factors influence the acceleration of the cart?

Part 1: Determining the Acceleration

We will be using a set up similar to the one you used in the previous lab. The air track will stay flat for the entire experiment, so you will first need to make sure it's level. Attach the string to the cart and place the string over the pulley so that the mass holder hangs down. The holder by itself has a mass of 5 grams, so if you add 5 grams for the holder, you will have 10 grams total of mass hanging from the pulley.

Question 1: After you add the 5 grams as described above, what is the total weight of the hanging mass, in Newtons?

This weight is related to the tension in the string, so it is the motivating force that moves the cart. The cart and the hanging mass thus both experience an acceleration if the hanging mass is released.

Question 2: Why doesn't the hanging mass fall with an acceleration equal to the acceleration due to gravity – 10 m/s^2 for our purposes?

Question 3: Will the actual acceleration be less than or greater than 10 m/s^2? Why?

Question 4: Determine the mass of the cart. How many total kilograms of mass is the motivating force (the weight of the hanging mass) trying to move?

Question 5: Use Newton's Second Law to calculate the acceleration of this combined mass – this will be your "expected value" for the acceleration.

Placement of the photogates is important. You need to make sure that when the cart passes through each photogate, the hanging mass has not yet hit the floor. Once the mass hits the floor, the cart is not accelerating any more, and we want it to be accelerating as it passes through the photogates.

Release the hanging mass five times, and let the cart pass through both photogates each time. Record the velocity of the cart through each gate, and the time to pass between the gates. Use this information to calculate 5 measured values for the acceleration of the cart, as you did in the previous lab. Calculate the average value of the five measured accelerations, and find the percentage difference between this average measured acceleration and the expected value of the acceleration from Question 5, using the formula

$$\boldsymbol{percentage\ difference = \frac{expected\ value - measured\ value}{expected\ value}\ x\ 100}$$

Present your findings in a data table.

Gate 1 velocity	Gate 2 velocity	Time between gates	Acceleration
Average Acceleration =		% Difference =	

<u>Part 2: Increasing the Hanging Mass</u>

Now we will change the size of the falling mass that is pulling the cart. First, however, think about what increasing this mass will do to the motion of the cart.

Question 6: If the size of the hanging mass is increased, what will happen to the acceleration of the cart? Justify your prediction using Newton's Second Law.

Repeat your velocity measurements and acceleration calculations for four more values of the hanging mass: 20 grams, 30 grams, 40 grams, and 60 grams. As before, take five measurements of velocity and time for each mass, and average the calculated accelerations for each mass. Do not calculate a percentage difference this time. Summarize your measurements and calculations in a data table.

Question 7: Someone makes the following prediction: "If the hanging mass is doubled, then the force that makes the cart move is doubled. Therefore, the acceleration of the cart should double as well." Either confirm or deny this prediction with your data, and explain why the person is right or wrong.

Part 3: Increasing the Mass of the Cart

Remove mass from the hanging mass until it is back down to 10 grams total. Now take two of the small circular silver weights and put one on each side of the cart. Measure the new mass of the cart.

Question 8: If the mass of the cart is increased, what will happen to the acceleration of the cart? Justify your prediction using Newton's Second Law.

Measure the acceleration of the heavier cart, using the photogates as you have done earlier in the lab. Do five trials, and average your acceleration values.

Now add the other two silver weights to the cart, one on each side, and find the new mass of the cart again. Determine the acceleration of the cart over five trials as you have done. Summarize all of your findings for Part 3 in a data table.

Question 9: Someone makes the following prediction: "If the mass of the cart is doubled, then the cart is twice as hard to move. Therefore, the acceleration of the cart should be exactly half of what it was for the lighter cart." Either confirm or deny this prediction with your data, and explain why the person is right or wrong.

Materials List

Airtrack
Two photogates
Cart with weights
Hanger with weights
Pulley and string