PHYS 1401 – General Physics 1
Laboratory # 4
Newton's Second Law

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 in the lab that is similar to many of your homework problems:

A cart of mass M_1 on a frictionless air track in initially held in place. The cart is attached to a weight by a pulley. The weight (which has a mass M_2) hangs in the air. When the cart is released, the weight 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 is the acceleration of the cart?

There are two ways to find the acceleration of the cart. First, we can calculate the value of the acceleration using forces and Newton's Second Law. However, we can also use the kinematics equations to find the acceleration, if we can measure certain quantities. We can measure all the quantities we need to make these calculations in the lab.

Part 1: Using Newton's Second Law

In order to use Newton's Second Law, we must first draw a diagram of the forces acting on the cart, and a diagram of the forces acting on the weight. Draw both of these diagrams as part of your lab report.

Question 1: Why can we safely eliminate the Normal Force from the diagrams for this situation? What force do we replace it with?

Now write a version of Newton's Second Law for each object, one for the cart and one for the weight. Note that the cart is accelerating in the x-direction, and the weight is accelerating in the y-direction. Remember that the sign of a force or acceleration indicates its direction!

Question 2: Why doesn't the falling weight accelerate at 9.8 m/s^2?

Question 3: What can we say about the relationship between the acceleration of the hanging weight and the acceleration of the cart? Why can you say this?

If the cord does not stretch, and if the cord does not slip on the pulley, we can say that the tension in the cord felt by the cart is the same as the upward tension felt by the weight. This should help you solve the equations from Newton's Second Law for acceleration.

Write out a formula for the acceleration of the cart, based on your solution of the equations from Newton's Second Law. Measure the mass of the cart, and use your equation to calculate the acceleration of the cart for five values of the hanging mass: 5 grams, 10 grams, 25 grams, 30 grams, and 50 grams.

Part 2: Using the kinematics equations

We can also find the acceleration of the cart using the kinematics equations. As the cart moves along the air track, we can measure certain quantities of its motion with our equipment and plug them into one of the kinematics equations to find the acceleration. However, this time we only have one photogate on the air track, and so we can't get two time values like we did in the previous lab.

Question 4: With the limitation on time measurement in mind, which equation must we use to find the acceleration?

Question 5: What things will we need to measure to find the acceleration? What instruments should we use to measure them? Will some of the quantities in the equation you selected be zero?

Question 6: In a brief paragraph, describe how you would set up the air track to measure the quantities you will need to measure.

Once you have things set up (check with me before you start!) take measurements for five different values of the hanging mass: 5, 10, 25, 30, and 50 grams. Note that the weight holder itself has a mass of 5 grams – you must take this into account! Do five trails for each mass and average the results. Create a data table showing your measurements and your calculated values of the acceleration of the cart.

Part 3: Comparing the two methods

Note that we have made a number of simplifying assumptions in Part 1. We assume that the cord does not stretch, so that we can tie the acceleration of the cart to that of the falling weight. We assume that the cord and the pulley are massless, so that we do not have to account for their weights. So that we can eliminate considerations of friction, we assume that the pulley has no friction, and that the air tracks are successful in eliminating friction. If these assumptions are valid, then the acceleration you calculate in Part 1 should be essentially the same as you found in Part 2. You can find the percentage difference between the two using this formula:

$$\text{Percentage Difference} = 100 \text{ x } \frac{(Part1 - Part2)}{Part1}$$

Question 7: Compare the values for acceleration that you calculated in Part 1 using Newton's Second Law to the values you measured in Part 2. Remember that a percentage difference less than about 10% is generally not significant. How good are the simplifying assumptions in Part 1?

Question 8: 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 9: 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. Measure the new mass of the cart. 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.