LAB 3: Newton's Second Law on an Air Track*

Equipment List:

air track, blower, blower hose and power cord
glider
one digital photogate and one accessory photogate
flat plastic accessory box
string
electronic pan balance

Purpose: To investigate and confirm Newton's Second Law in an environment with nearly zero resistive forces.

Introduction: In this experiment we examine the acceleration of a mass, m (the air track glider), under the influence of a tension force due to the weight of a hanging mass, M_h. We assume that the only horizontal force acting on the glider is the tension force from the string. For this to be true, the track must be level and friction should be negligible. Remember, it is the force from the tension in the string connecting the two masses that accelerates the glider, not the weight of the hanging mass itself.

Theory:

1. Using Newton's Laws, derive an expression for the acceleration of the glider in terms of the mass of the glider and the mass of the hanging weight.
2. Using kinematics, derive an expression for the acceleration given an initial and final velocity, and the distance over which the velocity changes.

Procedure:

1. Following the methods from the "Introduction to the Air Track" document, set up your air track and prepare one glider and two photogates for your experiment. From your accessory box, take the pulley and connect it to the end of the track that does not have the blower hose in it.
2. Set the two photogates apart by a distance of about 60 or 70 centimeters. Measure precisely (interpolating to the hundredth of a centimeter) the distance between the two photogates by using the front edge of the glider as it triggers each photogate as a reference mark. Record your uncertainties and compute the distance between the photogates. By using uncertainty propagation, compute the absolute uncertainty in the distance (the distance is found by a subtraction) between the two photogates.

*Based on the lab by Prof. Newton.

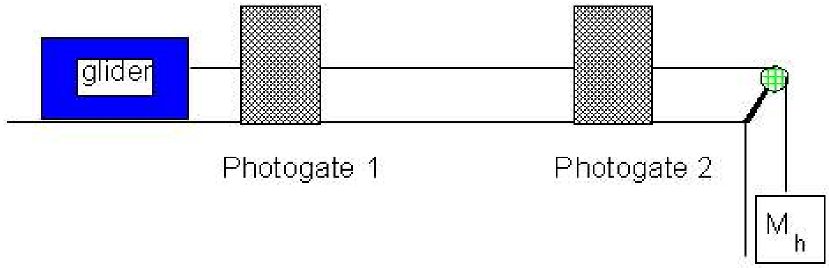

Figure 1: The air track setup with photogates, glider, and pulley.

3. Using the methods detailed in your air track introduction, compute the "effective length" of the flag on your glider. Do this for each photogate. Do not assume the effective length of the flag is the same for the two photogates. Again, by uncertainty propagation, find the absolute uncertainty in the effective length. **Set your timer resolution to 0.1 ms.**

4. Connect the glider to the hanging weight (found in your accessory box) with the string provided.

5. For your first run, use the hanging weight with about seven grams. Confirm the mass of the hanging weight and the mass of the glider (with all attachments in place) on the balance provided. Ignore the mass of the string. Record the absolute uncertainty of each mass using the method of an absolute uncertainty obtained from a digital readout (if you use the electronic pan balance).

6. On the air track with blower on, hold the glider by hand completely clear of the first photogate. Record this initial position for repeat trials. Let the glider go and allow it to accelerate moving through each photogate. Record the two times by using the memory switch and subtracting one displayed time from the other (which time should be bigger?). Record the absolute uncertainty in the time using the digital readout method. Take care not to let you glider bounce back through a photogate as this could change your time readout. Your first run is now complete. Repeat this procedure for a total of five runs. For each run you should let the glider go from the same initial position. You should have five time values for each of the two photogates.

Analysis:

You now have the data to compare your theoretical acceleration, a_t, to the calculated acceleration, a_c. The theoretical value is obtained from the measurement of the two masses and the known value of g (let $g = 9.80$ m/s^2 *exactly* so that $\delta g = 0$). The calculated acceleration is obtained from the distance between the two photogates, the times and effective lengths.

You should derive the absolute uncertainties of each acceleration by the uncertainty propagation methods.

Repeat the above for a different hanging weight value varying the distance between the two photogates. What effect would varying the distance between the photogates have on the absolute uncertainty in the calculated acceleration? State each acceleration with an absolute uncertainty. Do the most probable ranges of the two accelerations (a_t and a_c) overlap? If so, then on the basis of your experiment, the values are equal; if not, speculate as to why this is so. Would you expect a_c to be larger or smaller than a_t based on the presence of systematic uncertainties?

Conclusion:

Discuss the presence of systematic uncertainties and any ways in which these errors may be eliminated. What other experiments could you do with this equipment? What other ways might you experimentally investigate Newton's second law?