5. NEWTON'S SECOND LAW AND THE AIR TRACK

Equipment List:

- One air track, blower, blower hose and power cord
- One digital photogate and one accessory photogate
- One glider
- One flat plastic accessory box
- String
- Electronic Pan Balance

Introduction:

In this experiment the acceleration of a mass, *m*, (the air track glider) is studied, being 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. This will be called the theoretical acceleration.
2. Using uncertainty propagation, derive an expression that yields the uncertainty in the theoretical acceleration in terms of the two masses and their uncertaines from the digital balance (find the uncertainty in a digital readout from the Lab Skills Manual). Let the uncertainty in *g* be zero for simplicity.
2. Using kinematics, derive an expression for the acceleration of the glider given that its initial velocity will be zero, the distance, *d*, over which it accelerates (i.e., the distance between the photgates), and the time interval, t, between the gates. Call this the experimental acceleration.

Procedure:

1. Following the methods from the INTRODUCTION TO THE AIR TRACK section, 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. From this, compute *d* to the one hundredth of a centimeter.

Set your timer resolution to 1 mS.

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

4. For your first run, use the hanging weight with about seven grams. Measure the mass of the hanging weight and the mass of the glider (with all attachments in place) on the digital balance provided. Ignore the mass of the string.

5. On the air track with blower on, hold the glider by hand completely clear of the first photogate such that its velocity will be zero when it trips the first gate. Do at least five runs (for five times) and calculate five accelerations.

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 its uncertainty is zero). The calculated acceleration is obtained from the distance between the two photogates, the initial velocity being zero, and the measured time between the gates.

Use the statistical method for the experimental acceleration (since you can compute five measured accelerations).

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? Perform a descrepancy test between the central values of the two accelerations; you should get less than ten percent. Less than five percent is very good.

Conclusion:

Discuss the presence of systematic uncertainties and any ways in which these errors may be eliminated.

More:

Try calculating the uncertainty in the measured acceleration using uncertainty propagation.