Air Resistance

Objectives

We will investigate the effects of air resistance on the motion of an cart on an air-track.

Equipment

- 1 air track
- 1 air track cart with "picket fence" attachment and elastic band "bumper"
- 1 picket fence extender
- Cardboard sail
- Laboratory balance
- Meter stick or tape measure
- 1 Photogate
- LabPro Data Acquisition Interface
- LabPro Digital Adapter for Photogates

Introduction

Your instructor will provide an introduction to this lab.

Procedure

We will be using the same procedure for measuring the speed of the cart as was used in the lab Conservation of Energy and Momentum.

1. The picket fence extender is a piece of cardboard that extends the "picket fence" on the top of the air-track cart so that the cardboard sail doesn't hit the photogate. Attach the picket fence extender to the cart and adjust the photogate height accordingly.

2. Raise one end of the air track by about 2 cm by placing it on a piece of wood, a book or other convenient object. Use trigonometry to calculate and record the angle of incline.

3. Place the photogate about half way down the track and re-adjust the height of the photogate to account for the track incline. Turn on the air track. Release the cart from rest from the raised end of the air track and let it slide through the photogate. Ensure that the LoggerPro recorded the cart's speed as it passed through the photogate. Make a few test measurements to ensure that the speed is roughly consistent between runs, then move the photogate and repeat a few test measurements.

4. Now we will establish the speed of the cart as a function of distance traveled, in the absence of air resistance. This data set can therefore be considered "the control" against which you will compare the speed of the cart once you induce some air resistance. Starting the cart from rest, *and from exactly the same location each time*, measure the speed that the cart reaches at 30 evenly spaced positions along the air track. Make a table of cart speed v_c versus distance traveled x. Leave space for an additional two to three columns of data.

5. Now attach the cardboard sail to the cart and repeat the last step. Make sure that you measure the cart speed at exactly the same 30 locations as you used in the last step. In a new column, record the new speeds v_d into the table you started in the last step.

6. If you have time, make the sail more aerodynamic by building a nose-cone to put on the front of the sail. Repeat the measurements in Part 5 above and record the measured speeds v_{dd} into a new column in your table.

7. Measure the mass of the cart with and without the sail attached.

8. Draw a free body diagram of the forces acting on the cart with the sail attached. Don't forget to include the force due to sliding friction between the cart and the air track itself.

9. Write down an expression for the net acceleration of the cart.

10. Assuming the absence of any friction or drag forces, calculate the expected cart speed v_e at each of the points x in your table. Record these theoretical values into a new column in your table.

11. By hand, and on the same graph, plot your three data sets:

$$v_c \text{ vs. } x,$$
$$v_d \text{ vs. } x,$$
$$v_e \text{ vs. } x.$$

    Use a different symbol for the data points from each set. You may omit uncertainties on this plot but should make a rough "by-eye" estimate your uncertainties from the "spread" of each data set. Your instructor can show you how to do this if you are unsure.

12. Draw a best fit line through each data set. Does one or more data set differ from the other in a way that is not likely to be due to uncertainties?

13. In Microsoft Excel (or similar program), plot $v_d - v_c$ versus v_c. Use Excel to fit a fourth order polynomial to the result. What is the dominant term in the polynomial? If you also completed part 6 above, perform the same procedure for $v_{dd} - v_c$ versus v_c. Is the graph of $v_{dd} - v_c$ versus v_c qualitatively different from that of $v_d - v_c$ versus v_c? Is the dominant term in the polynomial fit still the same? (In other words, has the physical process controlling the drag changed?)