

Lab A2: CONSTANT-ACCELERATION MOTION IN ONE DIMENSION

8/19/02

GOAL:

A cart will accelerate down a nearly frictionless inclined plane. Electrically generated sparks will mark the instantaneous position of the cart (on a piece of tape) along the incline at intervals of 0.1 second. Measurement of the position of the cart as a function of time will allow the determination of the cart velocity as a function of time and of the cart acceleration. The validity of the d-v-a-t formulae will be tested in the process.

READING: Walker Chapter 2

PROCEDURE:

- 1) Record the letter of the air track & the height of the riser block that you are using.
- 2) Generate your spark tape: Tilt the air track by placing one or more of the provided riser blocks under the single leg of the track; record the total height of the riser blocks to three significant figures. Also record the distance between the single foot of the air track and the center of the double feet. Note the scale on the track !

Tape the spark tape carefully to the track, taking care that it is flush with the lip of the track. The light gray side of the tape should be on top; the red (or black), underneath. Make sure that your tape is flat so that the glider will not rub against it while accelerating down the track.

Place the cart on the uppermost part of the incline. Make sure that the wire attached to the cart touches neither the wire that parallels the track nor the spark paper.

With one person holding the cart in place with a wood pencil, the other person turns on the air supply and then the spark source. (Use a spark rate of 10 Hertz.) After the sparks begin, the cart is released and allowed to accelerate freely down the track. Its position, at 0.1 second intervals, will be marked with sparks.

Stop the sparking slightly before the cart reaches the bottom of the incline.

- 3) Be careful in handling your tape. If you scratch it, you may introduce spurious spark-like marks.

Immediately after generating your tape, inspect it for missing sparks – occasionally sparks may fail to register on the tape. If there are missing sparks, you probably will have to collect a new spark tape.

Circle the legitimate sparks immediately upon generating your tape, and put your names on the tape.

RESULTS:

Construct a data table that has five columns labeled as shown below. Allow space for 20-25 rows in your data table (notice that the n=0 row has been filled in for you).

SPARK n	TIME (sec) t_n	POSITION (m) {relative to n=0 spark} x_n	?POSITION (m) {change in position) $x_{n+1} - x_{n-1}$	VELOCITY (m/s) v_n
0	0	0	-----	-----

1) Determining acceleration -- method one

a) You may want to ignore the first three or four marks on the tape since they are likely not as reliable as the later marks. Why? Keeping this in mind, choose the spark you will use as the position and time origin. Label this spark as spark 0. Obtain accurate position measurements (x_1, x_2, \dots) for each spark relative to spark 0, precise to 3 (or more, if appropriate) significant figures. Measure the positions and record them in your data table. **(Note that you are filling in ONLY the first 3 columns of the table at this point!- leave the last two columns blank for now)**

b) Invent a method of determining the velocity at each of the spark times (except $t = 0$) listed in your data table by using the positions of the immediately preceding and following sparks. (for example, determine the velocity at time t_2 by using the spark positions x_1 and x_3 and the known time interval between the making of these

sparks) Describe your method (including any relevant equations; with symbols NOT numbers!). A labeled diagram (graph sketch) is necessary for any convincing explanation.

Have your instructor approve and initial your method before proceeding.

c) Use the method you described in part b to calculate the velocity of the cart at each spark time (except the first, of course). Fill in the remaining columns of your data table.

d) Use your graphing calculator to make a plot of v vs t for your cart. Apply a linear fit to the plotted data. Devise a way to use your calculator to look at a plot of the residuals vs time for your v vs t graph. Discuss your method in your journal. Sketch the residuals graph and discuss its meaning. Obtain a printed copy of the v - t graph (including the fit equation) by using the Graphical Analysis for Windows software on the NCSSM network. Make sure that the fit parameters are included on the printed graph.

e) Write down the general form of a linear equation using the usual math symbols (i.e., x , y , m , b). Right below the math equation, using the usual physics symbols (i.e., v , t , a , v_i), write the physics equation you suspect describes velocity versus time for the cart. In side-by-side columns, match the math symbols with the corresponding physics symbols; e.g., what symbol does the math "y" correspond to in this physics equation? Finally, add a third column that gives the numerical values (with units and proper significant figures) for the fit variables m and b .

f) In words, what physics quantities do the slope and the v -intercept represent? Discuss why your values make physical sense.

2) Determining acceleration -- method two

a) Let's first try to fit the x - t data set with a straight line. Remember that time t is the independent variable (i.e., horizontal axis) and that position x is the dependent variable.

Look at the residuals plot for this fit. Sketch the plot of residuals-vs-time and explain how you know (from looking at the residuals plot) that a linear fit is not appropriate.

b) We visually observed that the cart accelerated; therefore, a likely candidate for a better fit to the data is a quadratic fit. Why is a quadratic fit appropriate? Apply such a fit to your x - t data and obtain a printed copy of the fitted graph using Graphical Analysis for Windows. Make sure that the fit parameters (a, b, c) are printed on the graph. Again, investigate and discuss the residuals for this fit (but don't print -- only sketch -- residuals).

c) Write down the general form of a quadratic equation using the usual math symbols (i.e., a , b , c , y , x). Right below the math equation, using the usual physics symbols (i.e., x , x_i , t , a , v_i), write the physics equation you suspect describes position versus time for the cart. In side-by-side columns, match the math symbols with the corresponding physics symbols; e.g., what symbol does the math "y" correspond to in this physics equation? Finally, add a third column that gives the numerical values (with units and proper significant figures) for the fit variables a , b and c .

ANALYSIS:

1) Make a table with the following columns: method one, method two, % difference. In two rows, list the values that you determined for the acceleration and initial velocity of the cart, and the % difference between the two values for the cart's acceleration and initial velocity. (You may want to compare your values of acceleration with those from other groups who used the same air track at the same tilt. As long as the tilt remained the same, the results should be the same.)

2) In RESULTS, you actually calculated the average velocity of the cart for each 0.2 second interval [i.e., $v_n = (x_{n+1} - x_{n-1}) / (t_{n+1} - t_{n-1})$]. Under what condition is the average velocity over a time interval equal to the instantaneous velocity at the mid-point of the time interval? Explain why that condition is sufficient.

OPTIONAL: At the beginning of this lab, you measured the height of the riser blocks and the separation between the feet of the air track. Using simple geometry (similar triangles), you could have predicted your acceleration result before taking any data. Specifically how would you make this prediction? Discuss this with your partner. You don't have to write the answer to this one in your lab journal. (Hint: What would the acceleration of a cart on a horizontal track be? ... on a vertical track?)

CONCLUSION (aka SUMMARY): Be sure to include the Conclusion in your lab journal. See the lab guide!