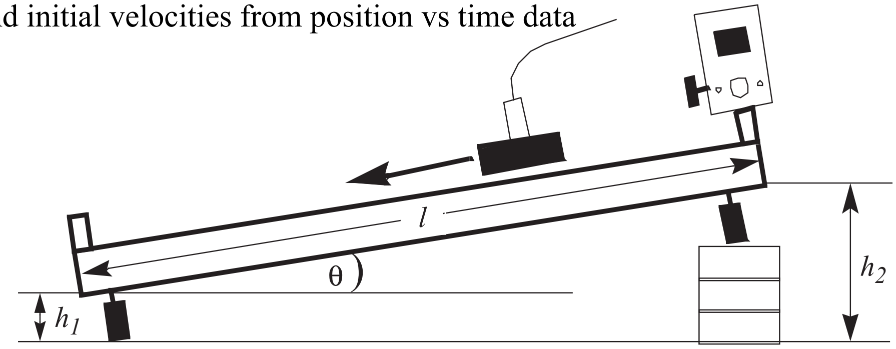
Lab #3
Constant acceleration down an inclined plane

1. Objectives

- To examine the motion of an object undergoing constant acceleration in one dimension.
- To calculate acceleration and initial velocities from position vs time data
- To write a lab report.

2. Material

- Luctor air table
- Heavy steel puck
- Flat wooden blocks
- Meter stick



3. Necessary readings

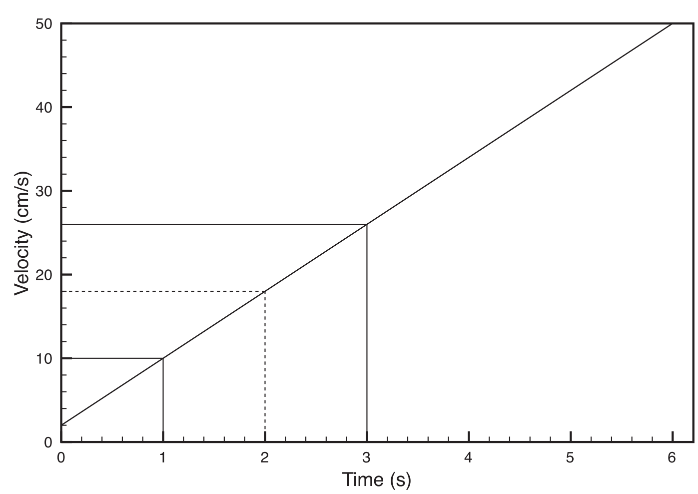
- Textbook: Sections 2.1 to 2.5

4. Theory

If one knows the position of an object as a function of time, it is possible to calculate its velocity as a function of time and its acceleration. In this experiment the acceleration of the puck should be a constant value, $a = g\sin\theta$, where g is 980.6 cm/s^2 is the acceleration due to gravity in Montréal and θ the angle of the incline.

When the acceleration of the object is constant, it means it velocity is steadily increasing. Plotted on a graph, the velocity as a function of time is a straight line which slope is the acceleration and the intercept the initial velocity at t = 0 s. An interesting fact about constant acceleration is that the average velocity between two arbitrary times t_1 and t_2, is exactly equal to the instantaneous velocity in the middle of the interval (at $t = \frac{t_1 + t_2}{2}$).

As an example, the following graph represents the velocity of an object with an initial velocity of 2 cm/s and a constant acceleration of 8 cm/s^2. At t_1 = 1 s, the velocity is 10 cm/s, and at t_2 = 3 s, the velocity is 26 cm/s. The average velocity is $(v_1 + v_2)/2$ = 18 cm/s, which happens to be the instantaneous velocity at t = 2 s, the middle of the interval.



It is therefore easy to calculate the average velocity between two points, and this also gives us the instantaneous velocity in the middle of the interval:

$$v_{av} = v_2 = \frac{x_3 - x_1}{t_3 - t_1}.$$

This process is illustrated below, the velocity highlighted in green is calculated from the two green positions, and the same for the velocity highlighted in red. Of course with this method, the very first and last velocities cannot be calculated. The same process can be performed to calculate the acceleration since it was assumed constant. Remember this method does not work if the acceleration is not constant.

Table 1: The scattered midpoint method

Time (s)	position (cm)	velocity (cm/s)	acceleration (cm/s^2)
0	0	***	***
1	6	10	***
2	20	18	8
3	42	26	8
4	72	34	8
5	110	42	***
6	156	***	***

Because velocity is calculated from the measured positions, its uncertainty will be large, especially if the time interval is very short. Furthermore, the acceleration calculated from the velocities in this method will be very imprecise. A small error on position, results in a bigger error on velocity and a huge one on acceleration. Calculate them using the simplest rules of propagation of uncertainties.

5. Experimental procedure

a) Preliminary adjustments.

The air table must be leveled before being elevated. To do this, put a sheet of “white” paper on top of the black carbon sheet, and carefully smooth out any wrinkle with your hand. Then place the puck on the table and turn on the air pump. When the table is level, the puck will stay in one place. Adjust the legs of the table until this condition is reached (this may take some time). Set the spark-timer interval to 50 ms (same as 20 Hz) before proceeding to step b.

b) First Run (using 3 blocks to elevate the table)

Carefully insert 3 blocks under the “single-leg” end of the table to make an inclined plane. Allow the puck to slide down the incline with the sparking device turned on. Turn it off just as the puck hits the bottom in order to avoid creating a series of “bounce-back” dots. In your logbook, record the measurements for the values of h_1 and h_2 as accurately as possible. The value of l is about 65.0 cm (measure it using the meter stick). Calculate the angle, including uncertainties. An example of this calculation is provided on the website in the chapter on the propagation of uncertainties.

c) Second Run (using 4 blocks)

Add a 4th block to the 3 already under the leg of the table, so as to increase the angle of elevation of the incline. Then repeat the procedure part (2) to obtain another spark-track. Use the same sheet of paper. but make sure the two sets of dots are not on top of each other. Measure the new values of h_1 and h_2, record them in the logbook and calculate the new angle with uncertainty.

6. Analysis

1. For each spark-track, make a composite table giving the position, velocity, and acceleration (x, v, and a) and their respective uncertainties as a function of time (t). Measure the x-values carefully evaluating the uncertainties for each using the rules of propagation. ***Why not use Excel*** to make these calculations for you! If you do, only write the positions and time in your logbook in case the computer crashes.
2. Plot a graph of (x vs t) and a graph of (v vs t) for both spark-tracks, using the information from the tables constructed in the previous point. ***Use a single set of axes for both sets of points*** (two data set for each graph). Ask the professor for help if you are unsure how to do this. Each graph should be presented on one full page. Be sure to include proper titles, identifying labels and units.
3. Plot smooth curves through the points on the x-graphs using a 2nd order polynomial (parabola). Compare the equation found with the kinematics equation
   $$x_f = x_i + v_i t + \frac{at^2}{2}$$
   From this comparison identify the initial velocity and acceleration of the puck. We will not discuss how to evaluate the uncertainty on this evaluation. This evaluation is probably more precise than the values obtained from the velocity vs time graphs.
4. Plot the best straight lines through the points on the v-graphs. From the intercepts and slopes of the v-graphs, determine the values of v_0 (initial velocity) and a (acceleration) for each spark-track.
5. Using the method seen in lab#2 (linest), calculate the uncertainties on v_0 and a extracted from the velocity vs time graph.
6. Use the values of h_1, h_2 and l to obtain the expected values of the acceleration for each track from the formula: $a = g\sin\theta$. In Montreal, the local value of g is 980.6 cm/s^2. Calculate the

uncertainties on the expected accelerations using the uncertainties on the angles calculated in your logbook.

7. Compare the different calculations of the acceleration of the puck using a table like the following:

Table #x: Comparison of the calculated acceleration of the puck, from different methods.

Run	**average from table**	**From *x* vs *t***	**From *v* vs *t***	**expected**
3 blocks				
4 blocks				

8. Use the uncertainties of each result to say if the different calculations agree with each other. If they do not, you must discuss the cause of this discrepancy.

7. Lab Report (practice)

- Follow the instructions found at ***http://www.remi.poirier.com/Labs/Report.html***.
- All the points in the analysis section should be discussed in the final report.
- The graphs must be done using Excel.
- Ask your teacher for help as soon as possible. Do not wait until the day before to start writing your report.