

# Physics 110 Lab 2: Velocity, Acceleration, and Forces

Name \_\_\_\_\_ Section \_\_\_\_\_ Date \_\_\_\_\_

## Introduction

In this experiment we will investigate two rather simple forms of motion (kinematics): motion with uniform (non-changing) velocity, and motion with a changing speed, but uniform acceleration. The primary aims of this experiment are: i) to develop an understanding of graphical presentations of position and velocity changes as a function of time, ii) to investigate the connection between acceleration and speed, and iii) to learn how to calculate values of velocity and acceleration from position and time measurements.

Also, in this experiment we will investigate the motion of a simple object under the influence of a constant force. According to Newton's second law, the effect of a constant force is to create an accelerating motion in one dimension. This is of course the simplest application of Newton's second law. To check the validity of this law we will obtain two separate values for the acceleration. The first is by applying the dynamical relationship that we derive using Newton's second law,  $F = ma$ . For the second value we will collect position measurements as a function of time and use these to obtain the value of acceleration. Finally, we will estimate the uncertainty in our experimental results and compare these two values of acceleration within their respective limits of uncertainty.

## Apparatus

### 1-D Motion

The setup that we will use in this experiment consists of a 2-m long track, a fan-cart, and a sonar motion detector. The fan-cart's wheels fit in the grooves of the track, so it is constrained to move on a straight line. The motion detector emits pulses of sonar, at regular intervals of time, along the direction of the track. Once an obstacle reflects the sonar pulses, the instrument detects the reflected pulses and determines the position of the obstacle. These data are fed to the computer, where they are collected, displayed, and analyzed by a software package called DataStudio.

### 1-D Force

The setup for this experiment is almost identical to the one we used above. It consists of a 2-m long track, a cart, and a sonar motion detector. We tie a light string to the cart, pass it over a pulley that is connected to the end of the track opposite the motion detector, and hang a mass  $m$  from the other end. As before, we will use the DataStudio software to collect position versus time data for the moving cart.

## Procedure

### Part A - 1-D Motion with Constant Velocity

1. Begin by adjusting the legs of your track in order to level it. You can tell whether your track is level or not by noting the motion of the cart. If the cart stays put, then the track is level.
2. To start taking data you need to activate the software:
  - (a) Double-click: **DataStudio**.
  - (b) Click: **Create Experiment** (or click on the Setup button on top).

- (c) Scroll down and double-click on **Motion Sensor** (then close that window).
  - (d) Double-click on **Graph** and then choose **Position**.
  - (e) Change the min and max of the y-axis to 0 and 2, respectively.
  - (f) Before taking data click on **Experiment** and then **Monitor Data**, and adjust the detector head if you find that the data are not correct or consistent.
3. Give the cart a gentle push away from the detector and collect data by clicking on the **Start/Stop** button
  4. Select the data points that seem to follow a straight line and perform a linear fit. You can select the data by bringing the cursor to the first data point and then click-and-drag the mouse over the rest of the data points. The selected points are then highlighted yellow. (To select another group of points click anywhere on the graph and your current selection will erase. Now you can select the desired group.) To fit a line to the data, click on the **Fit** button and select **Linear Fit**.
  5. Repeat steps 3 and 4 for two other cart speeds. For one of these two runs push the cart at the motion sensor instead of away. You should now have three graphs two for the cart moving away from the motion sensor and one toward the motion sensor.
  6. Print a copy of the graph for each lab partner. Write your name and the date of the experiment at the top of the page. Also on this page make a separate table for each of the three runs. In each table record the position and time coordinates for two data points on each straight line. From these data calculate the corresponding velocity values, by hand, and compare these with the slopes given by the linear fits. Explain why the slope of the motion towards the detector is negative.

### **Part B - 1-D Motion with Constant Acceleration**

1. Now turn on the fan on the cart and collect data as the cart speeds away from the detector. Be careful to keep your fingers away from the fans!
2. Select the points, but now choose **Quadratic Fit** from the **Fit** menu. (You should be able to explain the significance of these fits.) Print the graph and write a few sentences describing these resulting motions.
3. Repeat steps 1 and 2 for the fan cart speeding toward the detector. Again fit the data and print out this page and write on it a short summary of the motion, answering the following questions:
  - (a) In the position versus time graph: how does motion with constant speed appear?
  - (b) How do two such graphs, on the same plot, indicate the faster moving object?
  - (c) Which object is moving "forward" and which one "backward"?
  - (d) How does "slowing down" appear?
  - (e) How does "speeding up" appear?

- (f) How does a "stop" appear?
- (g) What is the significance of a parabolic position versus time graph?
- (h) How can you tell the accelerating object is moving forward or backward?
- (i) Finally, what was the maximum speed that your cart could reach with its fan turned on?

**Part C - 1-D Force**

1. Hang a 10-g mass from the free end of the string and collect position versus time data for the accelerating cart (with the fan turned off). Fit the data with a quadratic function as you did in Part B and record the value of the acceleration in Table 1 below.
2. Repeat this four more times and record the values of your acceleration in Table 1.
3. Repeat steps 1 and 2 for 20, 30, 40, and 50-g hanging masses.
4. Weigh the cart and record the mass in the space below. Also, estimate and record the uncertainty in your measured value of the cart's mass.

Table 1: Measured acceleration of the cart for different hanging masses.

Trial	a (m/s <sup>2</sup> ) for m = 10 g	a (m/s <sup>2</sup> ) for m = 20 g	a (m/s <sup>2</sup> ) for m = 30 g	a (m/s <sup>2</sup> ) for m = 40 g	a (m/s <sup>2</sup> ) for m = 50 g
1					
2					
3					
4					
5					
Avg.					
St. Dev.					

Mass of cart, M (kg): \_\_\_\_\_

**Analysis**

1. Use Excel to calculate the average acceleration and standard deviation of the five trials for each of the hanging masses, and record the values in Table 1. (Your instructor will give you a quick introduction to Excel if you need it.)
2. Copy the average acceleration from Table 1 as  $a_{kin}$  in Table 2 and the standard deviation from Table as the uncertainty  $\Delta a_{kin}$  in Table 2 for each value of the hanging mass.

3. Draw a free-body diagram in the space below and use Newton's second law to derive an expression for the acceleration of the cart in terms of the mass of the cart  $M$ , the hanging mass  $m$ , and the acceleration of gravity  $g$ .
  
4. Use this expression to calculate the "dynamically" determined acceleration for each value of hanging mass and record the results in Table 2 as  $a_{dyn}$ . Also, determine the uncertainties in these values and record the results in Table 2 as  $\Delta a_{dyn}$ .
  
5. Answer the following question in the space below: Do the results for  $a_{kin}$  and  $a_{dyn}$  agree within experimental uncertainties?

Table 2: Comparison of the "kinematically" and "dynamically" determined accelerations for each hanging mass.

$m$ (g)	$a_{kin} \pm \Delta a_{kin}$ (m/s <sup>2</sup> )	$a_{dyn} \pm \Delta a_{dyn}$ (m/s <sup>2</sup> )
10		
20		
30		
40		
50		