

## Laboratory 1: Motion in One Dimension

Classical physics describes the motion of objects with the fundamental goal of tracking the position of an object as time passes. The simplest example is that of an object that moves backwards and forwards along one line.

One compelling way of envisaging and understanding such motion is to graph the position and velocity versus time. The aim of this laboratory is to acquaint you with computer based methods for acquiring data representing position or velocity versus time and to understand graphical representations of motion.

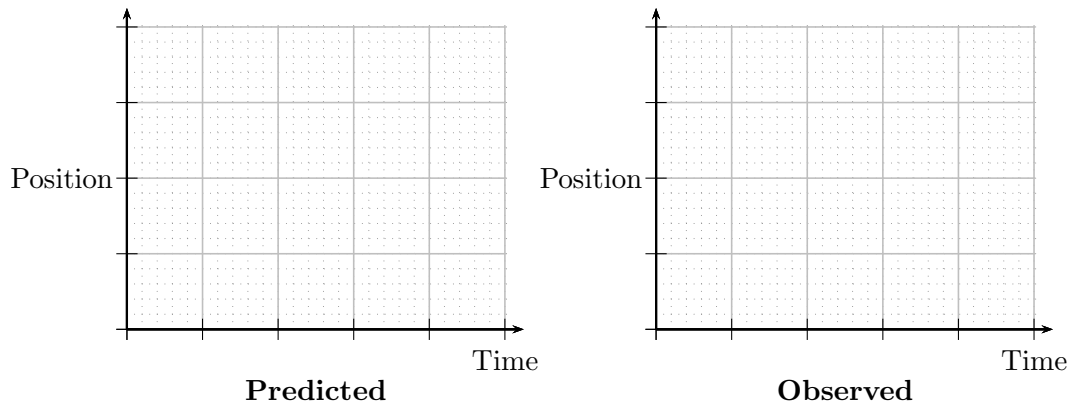
### 1 Setting up Capstone for motion detection.

- a) Set up the interface as described by the instructor. For this experiment, the relevant sensor is called **Motion Sensor**.
- b) The motion detector emits a series of audible clicks and ultrasonic pulses, each of which can be reflected back to a sensor. This measures the time taken for the round trip and uses this to determine the distance from the object which reflected the sound. Start the detector by clicking the **Record** button. Verify that it produces a series of clicks. Stop the sensor by clicking the **Stop** button. Repeat this several times.
- c) Click the **Data Summary** tab in the **Tools** palette. Verify that it lists various data runs.
- d) Follow the instructor's description to configure **Capstone** so that it automatically displays a graph of position vs. time. All of your data will be graphed in this window and any number of plots can be displayed simultaneously.

### 2 Graphical representation of motion.

You will now track and represent graphically the motion of a cart on a track.

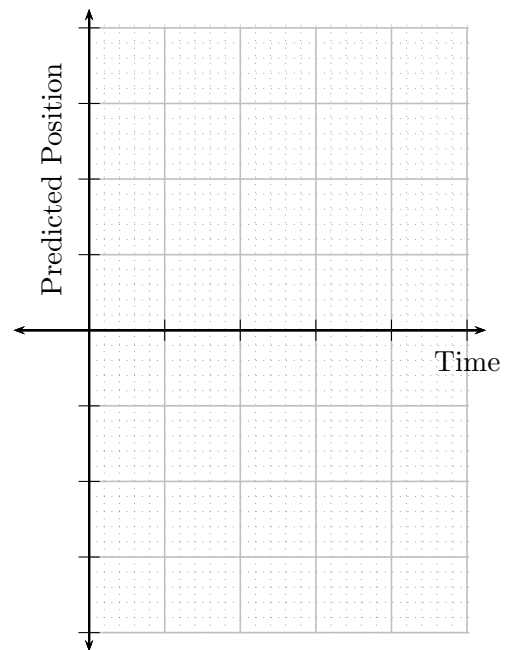
- a) Suppose that the cart is at rest at a location between 0.25 m and 0.50 m from the sensor. In the following figure, draw a **predicted** graph of the cart's position vs. time for this situation.



- b) Place the cart at rest at a location between 0.25 m and 0.50 m from the sensor. Run the motion sensor briefly and observe the graph produced by Capstone. Draw the **observed** graph on the diagram above.
- c) Repeat parts (a) and (b) for a different position between 0.50 m and 1.0 m from the sensor. Ensure that **the data is plotted in the same graph window used in part (b)**. Use the graphs of part (a) to record your results.
- d) Describe the main similarity and the main difference in the appearances of the observed graphs for the previous two situations and comment on whether the data recorded is consistent with what you observed (visually) regarding your position. Do your results indicate that the detector and software are working correctly?

- e) At a later stage, you will move the cart at constant speed in four different combinations of fast vs. slow and toward vs. away from the sensor. Using a single set of axes, **predict** the graphs of position vs. time for motion:

- i) away from the detector at a slower constant speed
- ii) toward the detector at a slower constant speed
- iii) away from the detector at a faster constant speed
- iv) toward the detector at a faster constant speed

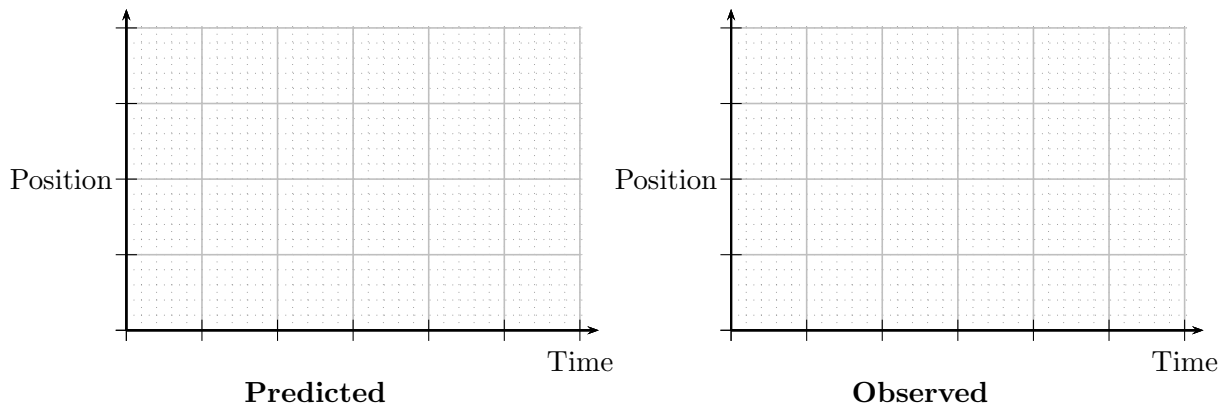


- f) For each situation of part (e), carry out the motion by moving the cart toward or away from the sensor; ensure that it does not approach closer than 10 cm from the sensor. Run the motion sensor, display the four **observed** graphs of position vs. time on the same set of axes, and show it to the instructor.
- g) Describe the main difference between the slope of a graph representing an object moving quickly and a graph representing an object moving slowly.
- h) Describe the main difference between the slope of a graph representing an object moving toward the detector and a graph representing an object moving away from the detector.

If you have successfully noticed the differences between the graphs representing motion above, then you have completed a first step in understanding how graphs can describe the motion of an object.

### 3 Predicting and matching graphs representing motion

- a) Using the figure below, predict the graph of position vs. time for a cart which is at rest for 2 s at 0.25 m from the sensor, then moves 0.50 m further away from the sensor in 4 s at constant rate, then is at rest for 1 s and finally moves 0.25 m toward the detector in 4 s.



b) Carry out the motion as accurately as possible while running the sensor. Draw the observed graph in the diagram above. How do these compare?

c) Close the Capstone window and open the file:

H:\DOWNLOAD\dacollin\CapStone\lab01position.cap.

This will open a new preconfigured Capstone window which displays an ideal position vs. time graph. Capstone will display any new position vs. time data over this. Match this graph as closely as possible by move the cart toward and away from the sensor. Show the graph of your best attempt to the instructor.

#### 4 Velocity versus time: graphical representations

The simplest motion is that with constant velocity. This part of the laboratory involves objects moving toward and away from the motion sensor at constant speeds.

a) Restart Capstone and set up the Motion Sensor as before but allow it to collect velocity data. Configure Capstone so that it automatically displays a graph of velocity vs. time.

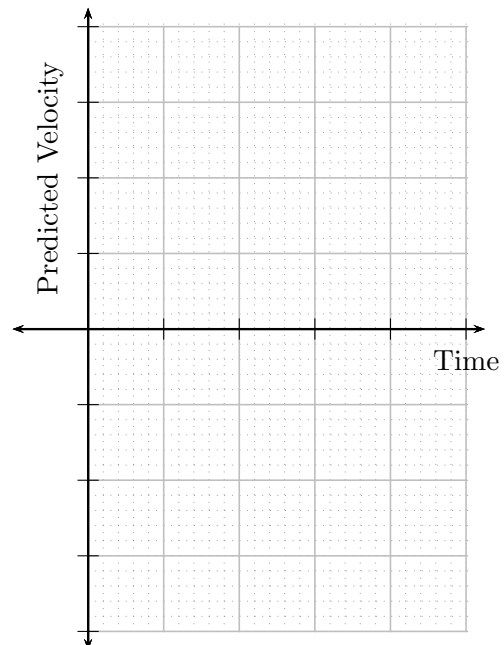
b) At a later stage, you will move the cart at constant speed in four different combinations of fast vs. slow and toward vs. away from the sensor. Using a single set of axes, **predict** the graphs of velocity vs. time for motion:

i) away from the detector at a slower constant speed

ii) toward the detector at a slower constant speed

iii) away from the detector at a faster constant speed

iv) toward the detector at a faster constant speed



c) For each of the predicted situations above, carry out the motion by moving the cart toward or away from the sensor. Run the motion sensor, display the four **observed** graphs of velocity vs. time on the same set of axes, and show it to the instructor.

d) Do your predictions and observations agree? If it does not broadly agree with your prediction, determine what was incorrect with your prediction and correct it.

- e) Describe the main difference between a graph of velocity vs. time for motion toward the detector and one for motion away from the detector.
  
- f) Describe the main difference between a graph of velocity vs. time for motion at a faster speed from one for motion at a slower speed.

### 5 Matching velocity vs. time graphs

Sometimes the motion of an object will be described in terms of its velocity and it will be important to translate this into a description in terms of the object's position.

- a) Close the Capstone window and open the file:  
H:\DOWNLOAD\dacollin\CapStone\lab01velocity.cap.  
An ideal graph of velocity vs. time should appear. Explain in words, using **position and time only**, how the cart will have to move in order to replicate this graph.

- b) While the motion sensor is running, move the cart so as to replicate the illustrated ideal graph (try to match the horizontal parts only). After at least three attempts, show the graph of your best attempt to the instructor. *Note that Capstone has a smoothing function as part of its graph display that could clean up your graph.*

### 6 Graphing with Excel


In many laboratories in this course, you will use the spreadsheet program, Excel, to manipulate data. The aim of this exercise is to introduce you to graphing with Excel.

- a) Restart Capstone and configure it to plot a graph position versus time **and** to display a table of position versus time. Give a motion cart a brief push so that it subsequently moves with constant speed away from the detector.

- b) Highlight data in the table that corresponds to a straight line segment of the graph of position vs. time. Next press **Ctrl + C** to copy the highlighted data. This could also be done by from the graph of the data and performing the same copy technique.
- c) Open **Excel** and paste the data (**Ctrl + V**) into a new blank worksheet.
- d) Using **Excel's** chart wizard, found under the **Insert** tab, produce a **Scatter** plot of the data. The plot should just indicate the data points and not a connecting line. Add axes labels and a title.
- e) Add a trend line and the equation for the trend line and determine the slope of the graph. Use this to record the speed of the cart below.

Show the **Excel** graph to the instructor.

## Using the PASC0 Capstone interface and software

1. To set up the interface and sensor:
  - a) Click on the Capstone desktop icon. This will open a data collection and display window. The window has three “palettes” that surround the central display. The Tools palette is a vertical area on the left; this controls the interface and data. The Display palette is a vertical area on the right; this controls how the data is displayed visually in the central area. The Controls palette is the horizontal area at the bottom and this controls the running of the experiment.
  - b) In the Tools palette, click **Hardware Set Up**. This will open the a window that displays an image of the black Science Workshop 750 interface.
  - c) Observe the port to which the sensor is connected. Click on the same port on the image of the interface. This produces a pull-down menu. Select the relevant sensor. For sensors with two plugs choose the port into which the yellow plug is connected. Note that there is a “settings” icon which provides some controls for how the sensor functions.
2. To manage data:
  - a) Data from each experimental run is saved by Capstone. The data can be manipulated by clicking on the **Data Summary** tab in the Controls palette. The data runs can be manipulated so as to change their names, delete them or change how they may be displayed. This is done via the settings icons.
3. To display data:
  - a) Capstone allows for data to be displayed via graphs, tables, digits, . . . . To select the type of display either choose one of templates or else select the display type from the Display palette. Multiple displays can be placed in the central window. Drag the relevant display type into the central window.
  - b) Click **Select Measurement** on the vertical axis of the graph. This produces a list of the data that the sensor can gather. Choose the relevant item from the menu.
  - c) When using a graph, the data to be displayed can be selected from the **data summary** icon above the graph. To select more than one run left click so that the icon takes a dark shading. Then select from the pull-down menu.
  - d) The origin of the graph can be moved by shifting the cursor so that a “grabbing hand” icon appears. Use this to drag the graph.
  - e) The scale of any axis can be altered by placing the cursor in the vicinity of the axis so that the following icon appears: . Drag this to adjust the scale.
  - f) Capstone typically rescales axes automatically and this can be inconvenient. To fix the axis scaling, click on the axis and options will appear.