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 II.

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 your own motion.

a) Set up the motion sensor to reflect off of you as you move through a range of about two meters. Be aware that an older motion sensor does not record correctly when an object is closer than 50cm from it.

b) Suppose that you stand stationary at a location between 0.5m and 1m from the sensor. Without actually standing this way predict a graph of your position vs. time for this situation and draw this in the "Predicted" chart in the following figure.

Predicted   Observed
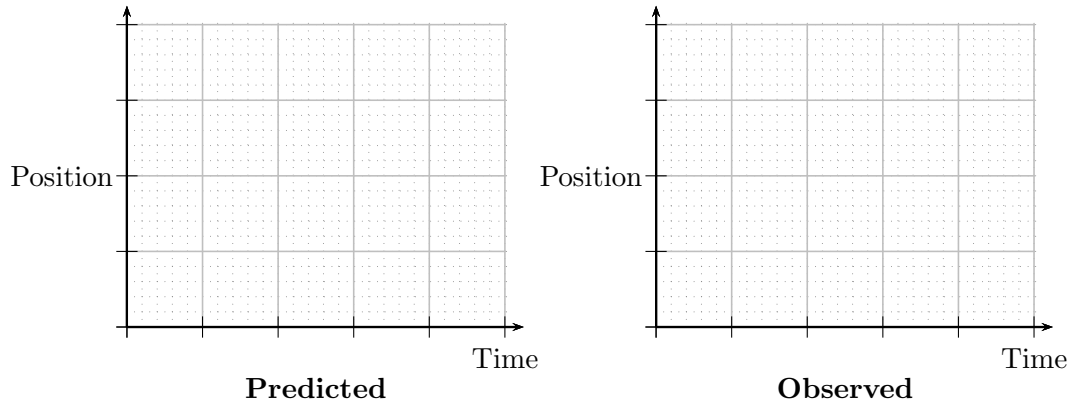
c) Stand stationary at a location between 0.5m and 1m from the sensor. Run the motion sensor briefly and observe the graph produced by Capstone. Draw the graph on the "Observed" chart in the diagram above.

d) Repeat parts (b) and (c) for a stationary position between 1m and 2m from the sensor. Ensure that **the data is plotted in the same graph window used in part (c).** Use the charts of part (b) to record your results.

e) Describe the main similarity and the main difference in the appearances of the observed graphs for the two stationary 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?

f) At a later stage, you will walk 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

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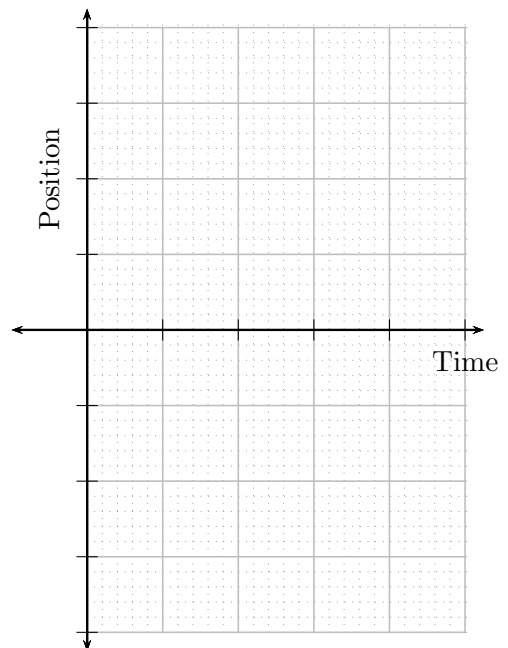
g) For each situation of part (f), carry out the motion by walking toward or away from the sensor; ensure that you do not approach closer than 50cm from the sensor. Run the motion sensor, display the four **observed** graphs of position vs. time on the **same set of axes,** and show it to the instructor.

h) Describe the main qualitative difference between the slope of a graph representing an object moving quickly and a graph representing an object moving slowly.

i) Describe the main qualitative 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 person who stands stationary for 1s at 1m from the sensor, then moves 2m further away from the sensor in 2s at constant rate, then stands stationary for 1s and finally moves 1m toward the detector in 2s.

Position

Time

Predicted

Position

Time
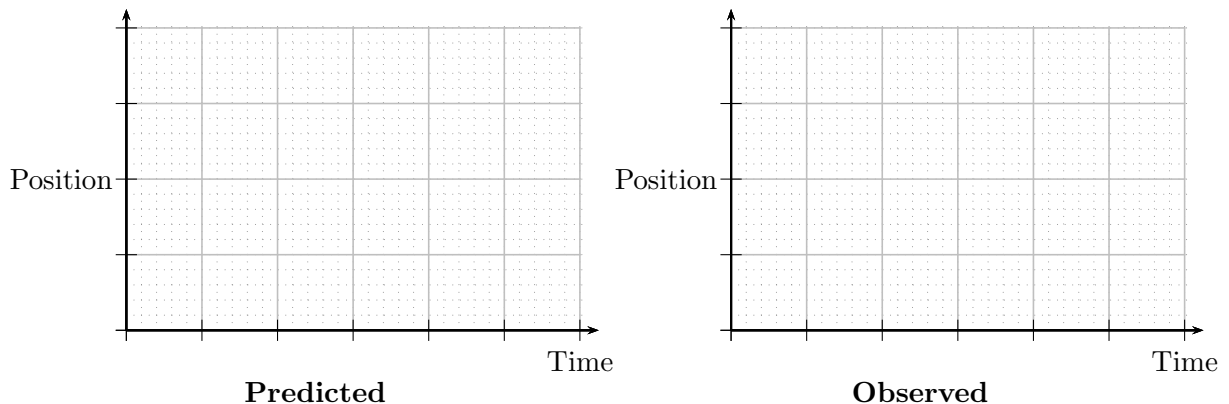
Observed

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\lab01part1.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 walking toward and away from the sensor. Print out your best attempt and attach it to this package.

4 Graphing Motion using 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.

The motion of a walking person is too irregular and this will be replaced by a cart that can slide along a track.

a) Clip the Motion Sensor to the track and ensure that the switch is set to the cart icon.

b) 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 slower constant speed away from the detector.

c) 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.

d) Open Excel and paste the data (Ctrl + V) into a new blank worksheet.

e) 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.

f) Add a trend line and the equation for the trend line and determine the slope of the graph. Use this to write the speed of the cart below.

Print out the Excel graph and attach it to this package.

g) Repeat this entire procedure for a situation where the cart moves with a faster constant speed away from the sensor along the track. Write the speed of the cart below.

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h) Using you results, can you describe a qualitative relationship between the slope of the graph of position versus time and the motion of the cart. If so, what is this relationship?

Using the **PASCO 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 the 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: $\Leftrightarrow$. 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.