Laboratory 2: Velocity in One Dimension – Prelab

1 Moving Cart

Figure 1 illustrates a graph of velocity versus time for a cart that moves along a linear track. How far does the cart move in the period from 1 s to 2 s? How far in the period from 1 s to 5 s? Explain your answers.
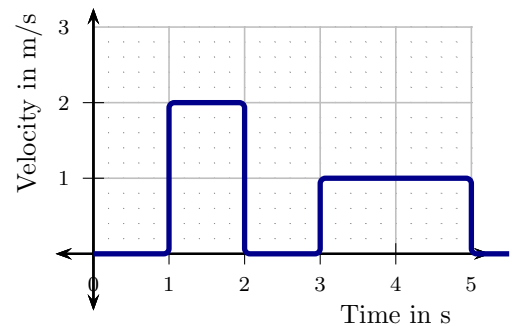

Figure 1: Position versus time for a moving cart.

2 Swimmer Versus Runner

A world-class swimmer can swim 100m in 50 s and a world-class runner can run 100m in 10 s. Figure 2 illustrates idealized graphs of position versus time for an initial portion of the motion for both. Which graph better represents the swimmer? Explain your answer.
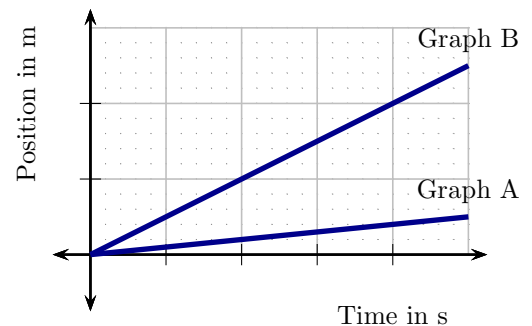

Figure 2: Position versus time for a runner and a swimmer.

Laboratory 2: Velocity in One Dimension – Activity

One of the goals of classical mechanics is to determine the position of an object as time passes. A useful quantity in this context is the object's velocity, that is, its speed together with information about the direction of its motion. Provided that the initial position of the object is known, the position at subsequent times can be determined from its velocity. The purpose of this set of experiments is to acquaint you with the concept of velocity and the relationship between it and position.

1 Velocity versus time: graphical representations

a) Open Capstone. Configure it to read and display position and velocity data from the Motion Sensor II. ConfigureCapstone so that it automatically displays a graph of velocity vs. time.

b) In a while, you will walk at constant speed in four different combinations of fast vs. slow and toward vs. away from the sensor. Before doing this, **predict on a single set of axes** 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, and

   iv) toward the detector at a faster constant speed.
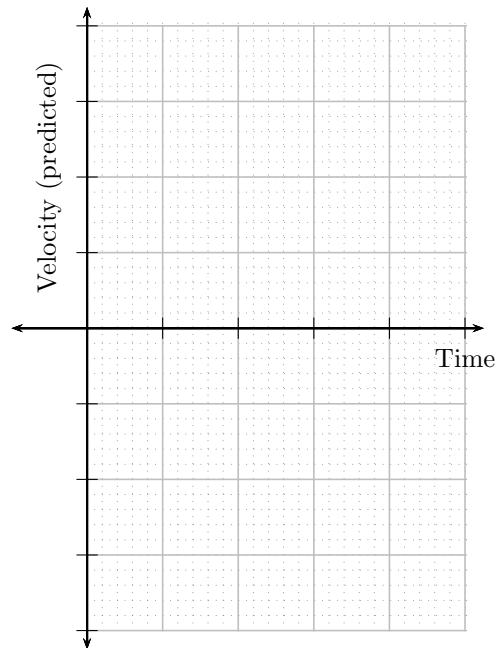
c) For each of the predicted situations above, carry out the motion by walking toward or away from the sensor. Run the motion sensor, display the four **observed** graphs of velocity vs. time on the same set of axes, and show it to the instructor.

d) Do your predictions and observations agree? Explain any major discrepancies that

you may have noticed.

e) What is the main distinction between a graph of velocity vs. time for motion toward the detector and one for motion away from the detector?

f) What is the main distinction between a graph of velocity vs. time for motion at a faster speed from one for motion at a slower speed?

2 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\lab02walk.cap.
An ideal graph of velocity vs. time should appear. Explain in words, using **position and time only,** how you will have to walk in order to replicate this graph.

b) While the motion sensor is running, walk so as to replicate the illustrated ideal graph. Concentrate on replicating the horizontal parts and not the vertical parts of the graph. There is a smoothing function that can improve the appearance of the graph. After at least three attempts, print out your best match and attach it to the worksheet.

c) Close the Capstone window and open the file:

H:\DOWNLOAD\dacollin\Capstone\lab02cart.cap.

An ideal graph of velocity vs. time should appear. Explain in words, using **position and time only,** how you will have to move the **cart** along the track in order to replicate this graph.

d) While the motion sensor is running, maneuver the cart so as to replicate the illustrated ideal graph. After at least three attempts, print out your best match and attach it to the worksheet.

e) Explain any noticeable discrepancies between the graphs for both cases.

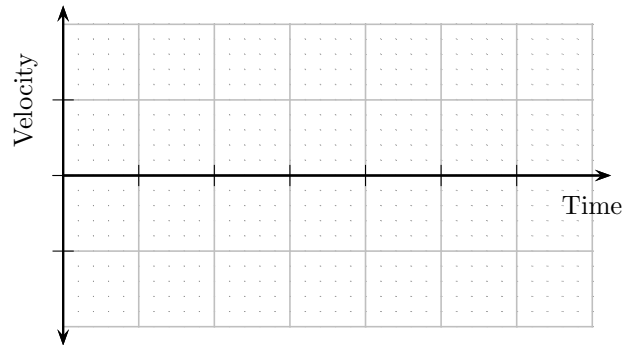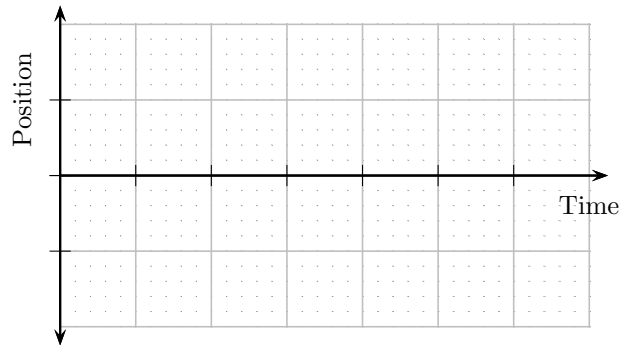### 3 Relating velocity vs. time and position vs. time graphs.

The following exercise explores the relationship between velocity vs. time and position vs. time graphs.

a) Restart Capstone and set up the Motion Sensor as before. Configure Capstone so as to display graphs of position vs. time and velocity vs. time **in the same graph window.**

b) Place a cart on the track, give it a short moderately strong push, and start the Motion Sensor shortly after the cart leaves the hand. Do this in such a way that it takes the cart about 2 s to traverse the length of the track. A graph of position vs. time and of velocity vs. time should have been produced. Print the graph of position vs. time.

The following all refer to the graph of **position vs. time.**

c) Focus on the period after which the motion of the cart has become steady. Pick a portion of this period of duration 1.0 s, indicate it on the printout of your graph, and use the graph to determine the displacement during this interval. Use this to determine the average velocity of the cart during this period.

d) Now divide the 1.0 s period into two subintervals, each of duration 0.5 s and indicate these on the printout of your graph. Determine the displacement during each of these intervals and the average velocity of the cart during each of these intervals. How do these compare to the average velocity of the cart as determined using the entire 1.0 s period (choose one of the following: approximately the same, significantly larger or significantly smaller)?

e) In terms of the graph of position vs. time, does the displacement in any time period correspond to a vertical "rise" or horizontal "run?" Does the time elapsed correspond to a vertical "rise" or horizontal "run?" Indicate each of these on the graph of position vs. time for one of the periods which you used above.

f) To what quantity associated with a straight line graph does average velocity correspond?

g) For the straight section of the graph above, determine the slope using the Capstone fit feature. Use this to determine the average velocity of the cart during this time and compare this to the velocities that you calculated previously (i.e. are they approximately the same, significantly different or slightly different?).

The following refers to the graph of **velocity vs. time.**

h) Observe the graph of **velocity vs. time** during the period when the cart moves at a steady rate. What should this graph look like? How does the value of velocity as calculated in the previous part relate to the graph of **velocity vs. time?**

i) Consider the motion of the cart along the track. Suppose that the cart is held fixed for 3 s after timing commences, then is made to move at a constant velocity away from the sensor, is held fixed for 2 s and finally made to move at a constant slower velocity toward the sensor. Using the diagram below sketch a predicted graph of position vs. time and use this to infer a predicted graph of velocity vs. time.

j) Maneuver the cart so that it replicates the motion above. Have the instructor check the graphs produced by Capstone.

k) At any instant during the observed motion, how is the graph of velocity vs. time related to that of position vs. time?

4 Exercises

a) An object moves at constant speed toward the motion sensor and then suddenly stops. Which of the following best represents a graph of velocity vs. time for this object? Explain your answer.

A

B

C

D
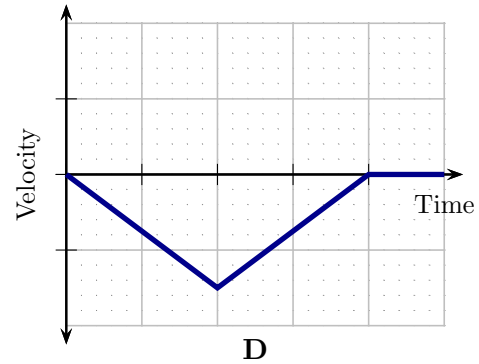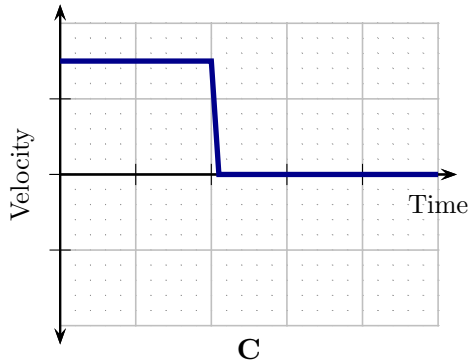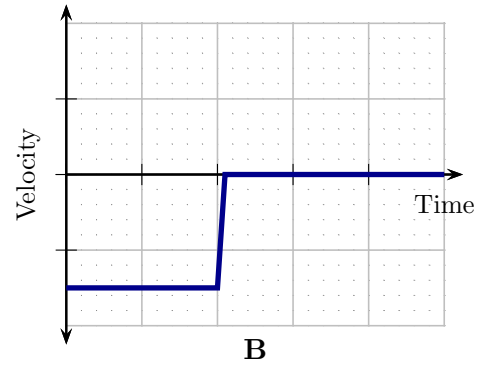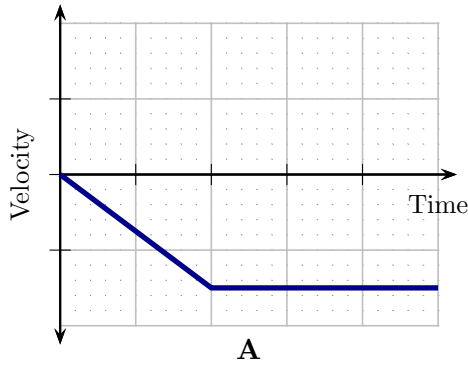
b) A cart moves along a track. A graph of the cart's position vs. time is as illustrated. Describe, qualitatively, the cart's speed and direction of motion from 0 s to 6 s. Graph the cart's velocity vs. time accurately.

Position vs time
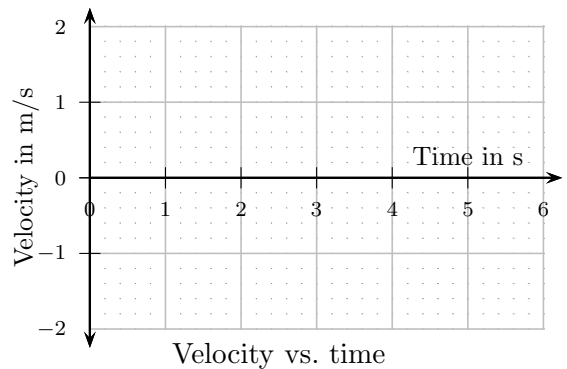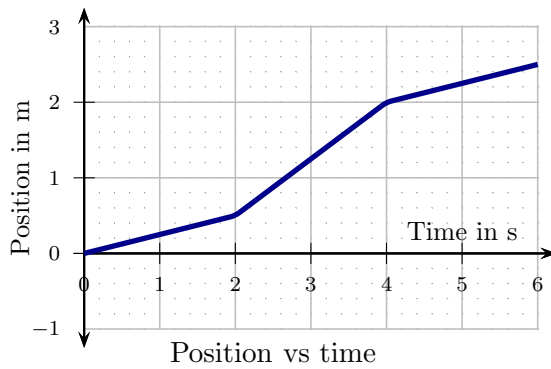
Velocity vs. time

c) An object moves in such a way that a graph of its velocity vs. time is as illustrated. The object is initially 1 m from the motion sensor. Graph, as accurately as possible, the object's position vs. time.

Velocity vs time

Position vs. time
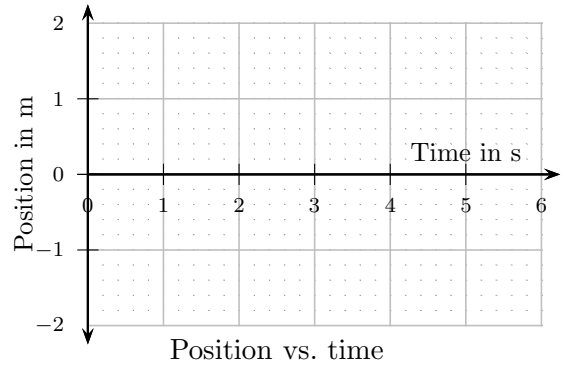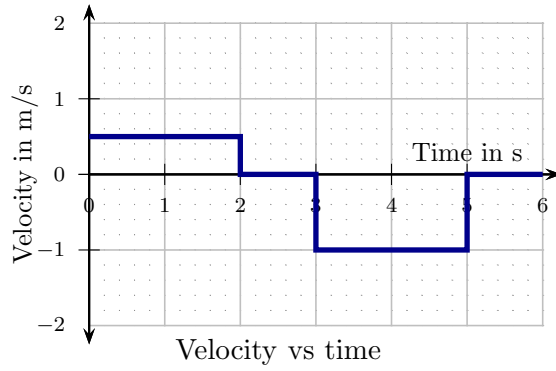
Using the **PASCO Capstone** interface and software

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: ⇔. 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.