

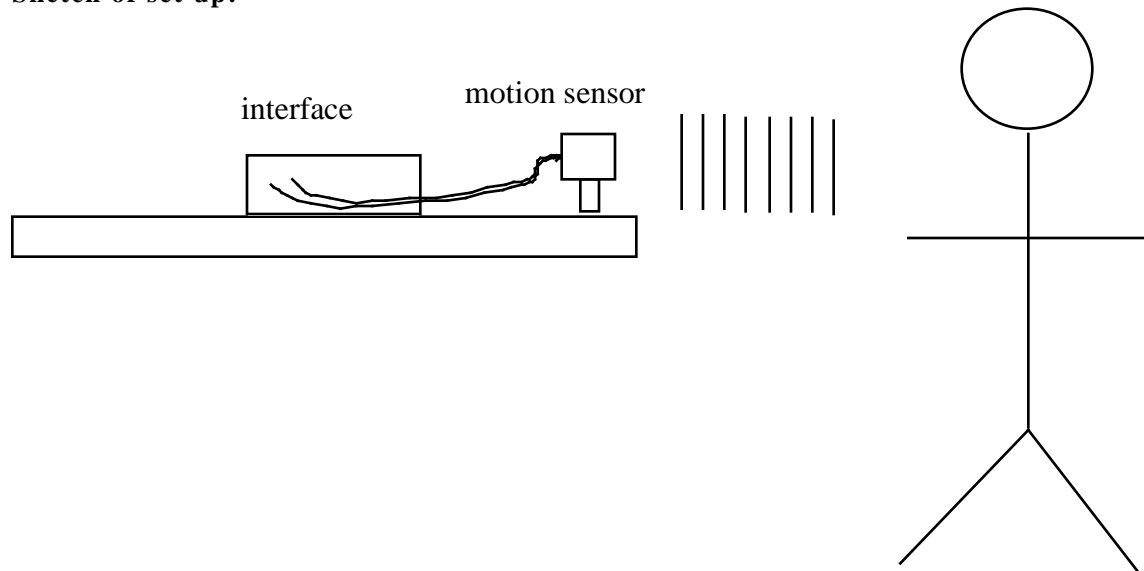
EXPERIMENT 2000.01.1: Motion in 1-Dimension

Topic of investigation: One-dimensional kinematics

Read about this topic in: Serway, Ch. 2; C&J, Ch. 2

Toolkit: Computer
Laboratory interface & software (SW 2.3.2)
Motion sensor
Meter stick

Sketch of set up:



What this lab is about: One purpose of this lab is to let you experience “how motion feels.” An equally important purpose of the lab is to give you some familiarity with computer-based laboratory instrumentation. Presently, computers are used universally in industrial and research laboratory situations to control experimental instruments and to assist in the acquisition of data. They are also used to help the experimenter analyze and visualize data collected.

Preliminary exercises:

0. Getting started with the electronics

0.1 Turn on your interface box. Start your Mac. Launch Science Workshop.

To get the computer to send signals (control) and receive signals (acquire data) via the motion sensor you have to first program the interface box. In Science Workshop, programming of the instrumentation is accomplished iconographically. To do this ...

0.2 “Plug the motion sensor into the interface box” by clicking on the digital (phono) plug icon and dragging it to the first digital channel on the interface box icon in the Set-up window that appears on your screen. (There are two physical plugs coming from the physical motion sensor. The yellow one has to be plugged into the first digital channel port on the interface box.) From the Choose a Digital Sensor window (that comes up immediately) click on Motion Sensor, then click OK. This programs the interface to send out and receive the right kind of signals.

0.3 Immediately after selecting Motion Sensor, your sensor should begin clicking and a Motion Sensor calibration window should appear. If not, double click on the motion sensor icon (below the digital plugs icon). Move a flat surface (like a book or note pad) facing the sensor in and out toward it. The Current Distance reading should change

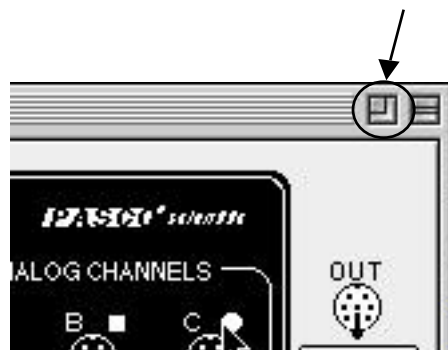
accordingly. Make sure that this reading is about 1.0 m when the reflecting surface is about 1 meter from the sensor. (We won't worry about detailed calibration here.) Note that there is a Max Distance and a Min Distance.

Question: Why do you think the sensor is limited to sensing objects at maximum and minimum distances?

Answer: The sensor works by emitting sonic pulses and receiving their respective echoes. As a pulse travels through the air it fans out. So, one reason there is a maximum distance is that if an object is too far from the sensor the echo that returns is too weak to detect. Another reason is that the sensor times the interval between release of the pulse and return of its echo. If the object is too far away, the echo from one pulse won't return before a second pulse is emitted so the timing will be messed up. There is a minimum distance because each pulse has a finite duration. If the echo comes back before the pulse is fully off the sensor will fail to pick it up.

Note that the trigger rate is set at 20 Hz--20 signals sent per second. Try changing the trigger rate to 5 Hz and to 100 Hz. **What else changes when the trigger rate changes? Does that agree with the above boxed answer?** Reset the trigger rate to 20 Hz and click OK to return to the Set-up window.

0.4 Create a graph by clicking on the graph icon and dragging it on top of the sensor icon. A Display window should appear. Click on Position, x (m), followed by Display. An empty graph (with position and time axes) window will then appear on top of the Set-up window. These two windows will swap being on top if you successively click on one then the other. (Try it.) Having the graph disappear when you are taking data (by using controls on the Set-up window) is a pain, so reduce the Set-up display by clicking on the "zoom box" in the upper right hand corner. See the picture to the right. This should zoom the Set-up window down to just the control panels on the left. Now, by clicking and dragging the graph window you can place the two windows side-by-side and view both at once. Click on the control panel window to bring it to the foreground. Click on the "Mon" (short for "monitor") button and observe that your sensor begins clicking and data begin to appear on your graph. Click on "Stop."

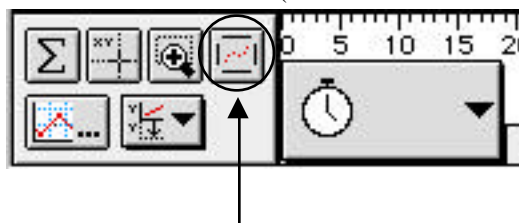


1. Target motion 1

1.1 Monitoring allows you to get a sense of how things are working--where the reflector is, how frequently data appear, and so on. Now, you are going to actually record some data. First, click on the "sampling options" button on the control panel. A Control Options window should appear. Click in the "time" option of "stop condition." Set the stop time to 10 seconds. This will allow you to collect 10 seconds worth of data without having to turn the data collection off. Return to the control panel and monitor to convince yourself that the sensor will record data for ten seconds only.

1.2 One member of your team will start as the controller, another the moving object. The objective of the first exercise is to create a graph of position of the moving object as a function of time that matches the following prescription: Stand for three seconds 0.5 m from the sensor; move as smoothly as possible (that is, with approximately constant velocity) for 4 seconds until you are 1.5 m from the sensor; stand for three seconds. **Before doing anything else, sketch a graph of position versus time for this motion.**

1.3 Now practice matching the prescription with controller starting the sensor and mover moving. Use monitor while you practice. When you think you can do the motion reproducibly make a record by the controller clicking on "Rec" (short for "record"). The resulting data set ("Run # 1") and its graph will be temporarily stored in memory. If the data don't fill up the whole graph, click on the Show All Data button, the rightmost icon of the set of six icons directly below the graph's horizontal axis and immediately to the left of its vertical axis. (The icon looks like a square with its corners removed filled with specks of dust. See the picture to the right. Note: You can delete a stored data set you don't like by clicking on it in the data box of the control panel window (that is, by "selecting" it) and hitting the "delete" key on the keyboard.)



1.4 Switch roles among members of the team until everyone has been a controller and a moving object.

1.5 **For any one of the data sets stored, make a sketch of what you expect a graph of velocity versus time will look like. About what speed should the moving object have in these steps?**

1.6 There is a box to the left of the graph on the graph window that has a sensor icon in it. Place your mouse arrow just above the black inverted triangle, click, and **hold**. A pull down menu with “Digital 1,” “Digital 2,” and “Delete data” will appear. If your arrow is close to “Digital 1” you will see a second pull down menu that has a sensor icon checked next to the position plotting option. Pull your arrow down to the velocity option and unhold (unclick). The result should be a new graph, this time of velocity versus time. **How does it compare with your sketch? How does the speed on the graph compare with what you answered in 1.5?**

Technical point: The Science Workshop software calculates approximate velocity values from the position versus time data by taking differences between successive positions and dividing by an appropriate time interval. If there are small measurement variations in the raw data, there will also be variations in the calculated data--and they will be bigger. For example, suppose one position is 1 mm smaller than it should be while the next is 1 mm bigger; then the difference between the two will be 2 mm larger than the difference should be. This is a general result: Any calculation done with “uncertain” numbers will have a greater uncertainty than the numbers used. Uncertainties are said to “propagate.”

Okay, so some of the unexpected wiggles you see on the velocity versus time graph are due to the above technical point. But, you will probably also observe larger, more pronounced undulations. **What are they due to?** (You could repeat this process to find acceleration versus time, but beware: uncertainty propagation will get even worse when “second differences” are calculated.)

1.7 After concluding this exercise delete all stored data sets.

2. Target motion 2

2.1 Supposedly, “motion is smooth.” To see what this means try matching the following target motion: Starting at 0.5 m from the sensor, walk smoothly for 4 seconds away from the sensor to about 1.5 m, then as abruptly as you can reverse your motion (so that you are returning at the same speed as you went away). Make a sketch of what you expect a position versus time graph should look like if the abrupt turnaround is truly instantaneous (that is, *not* smooth).

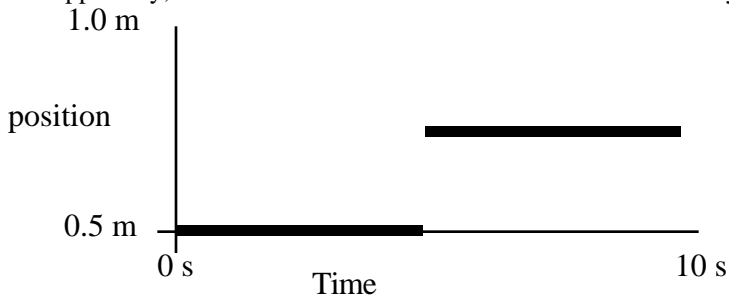
2.2 Now, record data as in exercise 1 for each member of the team.

2.3 **Look carefully at your graphs and describe differences from your expected sketch.**

2.4 As in 1, when finished delete all data sets.

3. Target motion 3

3.1 Supposedly, “motion is continuous.” To see what this means try matching the following graph.



3.2 Repeat steps 2.2-2.4.

4. Target motion 4

4.1 Here's a new prescription: Start at 1.5 m from the sensor; walk toward the sensor as smoothly as possible for two seconds; stop, reverse, and walk to 1.5 m as smoothly as possible for two seconds; repeat again and again, until the sensor stops. **Draw a sketch of the expected motion.**

4.2 Now, when the mover tries this, the mover calls out "NOW" whenever the mover reverses direction. **The mover should note what he or she feels like when "NOW" is called.**

4.3 Sketch a velocity versus time curve for the data recorded. **At what times do you expect the velocity to be zero?**

4.4 On the graph window in the box with the strange icons in the lower left click and hold on the rightmost icon in the second row. (It looks like a set of axes being dragged down.) Drag to "Digital 1" and then to "velocity." A second graph should appear directly below your position versus time graph that is velocity versus time for the same data. Check on this graph where velocity equals zero. **Do these times correspond with your expectation?**

4.5 Repeat the previous step choosing "acceleration" instead of "velocity." Now you should have three simultaneous graphs (position, velocity, and acceleration--note that acceleration has the kind of numerical "shakes" that are described in step 1, above). **What does this graph show for the times where velocity equals zero? At what times is the acceleration greatest (in magnitude)?** Be sure you fully understand how these three graphs are related to each other--including the signs of the various quantities. Also, be sure you connect how the mover felt at the "NOW" spots with the displayed acceleration graph.

4.6 Delete all data sets.

5. Target motion 5

5.1 Stand a few meters from the sensor and walk toward the sensor with constant acceleration. **Sketch graphs of what the position, velocity, and acceleration versus time should look like.** Record data and compare your results with your expectations. **How does this motion feel compared with a constant velocity walk?**

Exploration:

One member of the team can create a target motion another member can try to match. After practicing, record a data set for one mover. Now, on the graph window immediately below the sensor icon are two small boxes--one that says "DATA" and a second that looks like a graph with straight line data. Click on the latter. In the window that appears, click on "show prior runs while recording." Now, using the monitor mode, the second mover tries to match the graph of the first. Delete data, and reverse roles.

Analysis

Before leaving lab review your sketches, observations, and answers to all questions with your instructor.