

PHYS 1P91 Experiment 02

Kinematics 1 : Motion in a straight line

Notes

- Words in **blue** are links to additional reading or videos.
- Text in **gray** boxes are hints and things to take note of.
- Text in **red** boxes are important instructions or prompts that guide you to DISCUSS some of the key RESULTS and CONCEPTS learned in the lab. These prompts may not be the only items that need to be included in your report.

1 Lab objectives

- Use the iOLab to produce graphs of position, velocity and acceleration as a function of time.
- To explore how position-time graphs relate to actual movement.
- To explore how position-time graphs relate to velocity- and acceleration-time graphs.

2 Introduction

A change in the position of an object is known as *displacement*. *Distance* is defined to be the magnitude or size of displacement between two positions. Note that the distance between two positions is not the same as the **distance traveled** between them, such as in Figure 1.

Position-time graphs are a great way to track the position of an object through time. Consider the simplified graph in Figure 2, where there are three segments of travel that are described by straight lines like

$$x(t) = vt + x_0 \quad (1)$$

An important way to understand this equation is to realize that *velocity* is the slope of a position-time graph as this equation has the same form as $y = mx + b$.

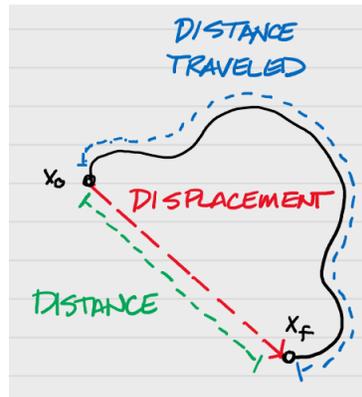


Figure 1: Illustration of distance versus displacement.

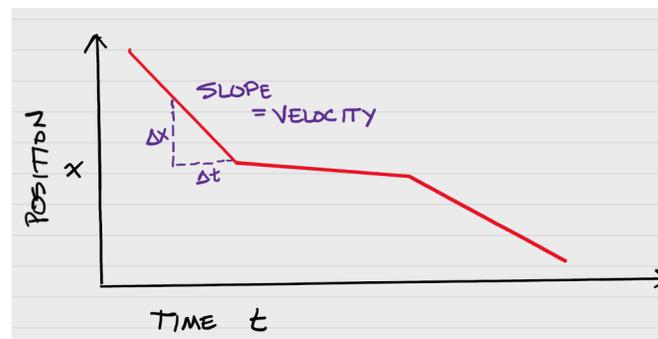


Figure 2: Hypothetical position-time graph. The slope along any segment is the average velocity for that part of the journey.

This fact is true even if the position-time graph is not made of straight lines - because every two points on a graph has a slope to it.

In a similar way, when velocity changes with time, the slope of a [velocity-time graph](#) such as in Figure 3 is the [acceleration](#) of the object.

$$v(t) = at + v_0 \quad (2)$$

The iOLab device contains many sensors that record values of motion, electricity and magnetism, temperature and others as a function of time. In other words, the iOLab records time graphs of various parameters, whose slopes can be measured and analysed!

In this lab we will be using the iOLab to create some one dimensional position-time, velocity-time and even acceleration-time graphs to understand them better.

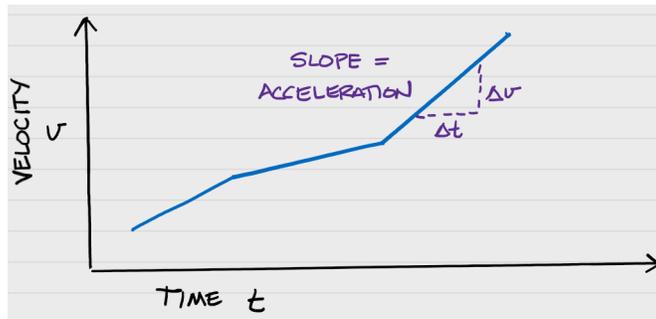


Figure 3: Hypothetical velocity-time graph. The slope along any segment is how the velocity is changing in time, which is known as the acceleration.

3 Procedure

This lab is a qualitative lab, and you will only be providing pictures of the graphs of the data collected by the iOLab. It is for you to gain a better understanding of how to use the software to collect data, and more importantly, of the motion of objects and how that translates to data collected in a graph.

For every lab, please use the lab tables template provided on Sakai.

3.1 Prepare the iOLab.

Insert the iOLab USB dongle into your computer and turn on the iOLab. Connect to the iOLab online software.

You will only need some flat space to roll the iOLab back and forth and the measuring tape provided.

If you quit or restart the software, the iOLab itself will be turned off - it also has an automatic turnoff if it is not used for 15 consecutive minutes. If this happens simply turn the device back on.

It may not be much to look at, but please include a photograph of your iOLab and space where it will roll, with the tape measure placed alongside for reference, as part of your lab report. You can use your laptop or cell-phone camera to take the picture.

3.2 Time-out for learning PhysTks and iOLab Online

Take a moment and review the general features of the iOLab Online software from the [videos on Sakai](#) if you have not done so already. Links to these videos will only work if you are logged into Sakai.

4 Take data

4.1 Free-wheeling (Testing the wheel sensor)

Set the iOLab wheels-down on a table. Select the Wheel sensor. Lay out your tape measure alongside the iOLab.

The length of time needed for these experiments will probably be on the order of 3-10 seconds. The wheel sensor gathers data at a rate of 100 Hz, or at 100 points per second. If your experiment is set to run for 10 seconds, it means that you will collect $10 \text{ sec} \times 100 \text{ Hz}$ data points. If you have a very long data collection time, it might take up to a minute after the collection is done to display the data. Wait until the data changes from red to blue before proceeding to data analysis.

The coordinate system is indicated on both sides of the iOLab device. Note that the iOLab wheels roll in the $\pm y$ direction of the device. In iOLab Online, you can select the desired data from the $y=$ pull-down menu. You will select x, m for position, $V, \text{m/s}$ for velocity, or $a, \text{m/s}^2$ for acceleration.

Try and see how the data shows the forward (positive y) and backward (negative y) motion of the device by rolling the iOLab back and forth and watching the real-time data collection in the graph window.

Next we will check to see if the iOLab wheel sensor is calibrated. To do this you will need the measuring tape provided and you will need to review the videos on [Measurement Uncertainty](#), [Understanding Uncertainties](#) and [Comparing Values](#)

Note: the uncertainty of the position sensor on the iOLab is 0.0005 m

Determine the precision of the measuring tape and record this value in your report

Determine the uncertainty of the measuring tape and record the value in your report.

Use the laid out tape measure to determine if the software is recording accurate distances. *i.e.* compare the movement of the device to the value recorded by the software. Explain how you did this in detail in your report.

Compare the expected value and uncertainty from the measuring tape with the values you obtain from iOLab online (value and uncertainty). Are the values within uncertainty of each other? What is the percent difference between the values?

If you find that the distances do not match reasonably well, you might want to try a different smooth surface, as some might cause the wheels to slip which in turn provides an incorrect measurement.

4.2 Make a position-time graph

Now consider the graph shown in Figure 4. This hypothetical curve traces the motion of the iOLab in time. However, the y-axis could be position, or maybe velocity, or even acceleration.

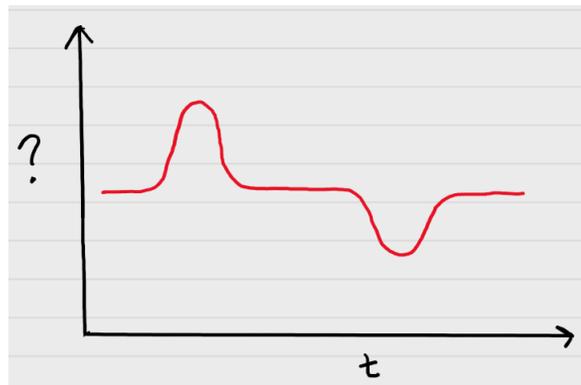


Figure 4: A hypothetical graph of the iOLab motion. The y-axis could represent position, velocity, or even acceleration.

Assume that the y-axis of Figure 4 is position. You can assume that any horizontal part of the red line is zero, or your starting point. To observe the position of the iOLab in real-time, select x, m in iOLab Online. Try to mimic the shape of this curve with your iOLab. You may need to adjust the length of your data collection to give you enough time to complete the curve.

Include a picture of your best attempt in your lab report (properly labeled, of course). A useful caption for this graph might be "Trace of iOLab motion if y-axis is position".

Provide a short (a few sentences) description of how you moved the iOLab to generate that graph.

Intuition Check: If you are having a very challenging time trying to mimic the curve in Figure 4, you may find that drawing out the idealized image with labels on what happens in each section becomes helpful.

Another way to think about this experiment is to review what happens when you toss a ball upwards. Think about what happens to the ball as it is released, hits its peak, begins to fall back down towards and past your hand. What changes in motion are happening? The same things are happening now, but on a horizontal surface with you pushing the iOLab device back and forth along the smooth surface.

From this same data set, include in your report a picture of the iOLab velocity curve. You do this by selecting $y=V(m/s)$, then selecting Draw again. Remember to properly label your graph.

Provide a description of how the velocity changes in relation to the two "humps" seen in the position-time graph in your discussion.

4.3 Make a velocity-time graph

Going back to Figure 4, now assume that the y-axis is *velocity*. You can still assume that any horizontal part of the graph is zero speed, ie. it is not moving. Think about when the iOLab is at rest, and when it has peak speed in the forward or backward directions.

Once again, try to mimic the shape of this curve with your iOLab, this time focusing on the $y=V(m/s)$ velocity data.

Include a graph of your best attempt in your lab report (properly labeled, of course). Provide a short description of how you moved the iOLab to generate that graph.

From this same data set, include in your report a picture of the iOLab acceleration curve. You do this by selecting $y=a$ (m/s²), then selecting Draw again. Remember to properly label your graph.

What did the acceleration data look like, compared to the velocity data?

4.4 Make an acceleration-time graph

This one is considerably harder, and may take some time to get something similar to Figure 4.

Go back to Figure 4 one last time, and assume that the y-axis of Figure 4 is *acceleration*. Once again, try to mimic the shape of this curve with your iOLab.

Intuition Check: Breaking down the idealized curve into its different components may help you map out what you need to do. **For this graph we are not asking for a perfect replica of the ideal curve, but try to give us your best attempt.**

Think about the start of the graph, when $a_y = 0$. That could mean the velocity is constant, and maybe zero. Then we encounter a large positive acceleration, but only for a brief moment. Regardless of what the iOLab was doing before, it's velocity is not zero now!

In the time between the “humps”, $a_y = 0$ is near zero again. Does this mean there are any forces acting on the iOLab; anything pushing or pulling it?

At the end there is a large negative acceleration. What would that do to any positive y velocity the iOLab had received from the first acceleration?

Note: Live-view is a coarse approximation of the final data, and only displays a 2-second wide window. For this reason, relying on live-view for the accelerations graph may prove challenging. You will have to wait until the data turns blue before you can determine if you need to repeat the run.

Include a picture of your best attempt in your lab report (properly labeled, of course). It may not match the idealized curve and that's okay. We will review this again in Experiment 3.

Provide a short description of how you moved the iOLab to generate your graph in your discussion.

You might find that your final acceleration-time curve is a bit jittery or noisy. If you want a smoother graph, you can adjust this data by moving the smooth slider (found under the data window in iOLab Online). You need to click Draw again to see the effect.

From your iOLab acceleration data set, include in your report a picture of the iOLab position curve. You do this by selecting $y=x$ (m) in iOLab Online, then selecting Draw again. Remember to properly label your graph.

What did the position data look like, compared to the acceleration data?

Whether or not you managed to match the appearance of Figure 4 in your acceleration curve, what should the position data look like?

Finally, include a copy of the three ideal curves, broken down into the different labelled sections of motion (*i.e.* recreate Figure 4 with vertical lines separating the different motions, as well as a short description of what is happening in each section).

For the ideal curve (Figure 4), feel free to hand draw it OR create it on the computer. use labels like A,B,C; 1,2,3; I,II,III etc on the graph and refer to these labels while talking about the graph you created. **Do not put your explanation on the image itself either include it in the caption OR the discussion by referring back to your labels.**

Finishing Up

Now that you have completed the lab, be sure you filled out all portions of the data tables (templates found in the Resources Tool on [Sakai](#)), include figures, and develop a robust discussion using prompts found throughout the manual.

Ensure to give yourself enough time to complete the report and to hand it in by the due date as late lab reports will not be accepted! If you have any questions please attend a live lab session to get help from one of the course lab demonstrators, or email Phys1P91@brocku.ca.