Two Voyagers Connected to a Single Device via Phyphox: A Conservation of Momentum Experiment

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In the study of collisions between two carts, it is desirable to collect position data for both carts. This can be done with a pair of Voyagers, each connected to separate devices running the PocketLab app. Starting data collection on both Voyagers by *simultaneously* clicking data recording on both PocketLab apps is difficult. One cannot view the data on a single device in real time, and analysis of data requires combining data from two separate devices.

It would be nice if one could connect two (or more!) Voyagers to the same device—say to an Android device or an iOS device running an app that could display concurrent data collection from both Voyagers. Such a capability is possible by the use of *Phyphox (phy*sical *pho*ne experiments), an app developed at the 2nd Institute of Physics of the RWTH Aachen University in Germany. The author of this lesson has been working with a pre-release Android version of this app that supports BLE (Bluetooth Low Energy) technology to transfer data from multiple Voyagers to the Phyphox app. It is important to understand that this capability of Phyphox may not be available to the public until the July 2018 anticipated beta release.

In this lesson, an experiment with a pair of carts is discussed. Figure 1 shows the experiment setup. Two PocketLab 3D printed carts are used for this study. Strips of balsa wood taped to the table provide rails to keep the carts on track. Magnets are attached to the bumpers on each of the carts with like poles facing each other so that the magnets will repel one another. Cart A is given an initial push toward cart B at a speed that allows for a non-contact "magnetic" collision. Cart B is initially at rest. Both have Voyagers attached as shown, with A's rangefinder facing a foamboard "wall" on the left and B's rangefinder facing a foamboard "wall" on the left and B's rangefinder facing a foamboard "wall" on the right. The rangefinders provide position data for each cart and can in turn be used to determine velocities. The two carts with their Voyagers and magnets have nearly the same mass (0.170 kg each). Therefore, conservation of momentum tells us that the velocity of B right after the "collision" should he the same as the velocity of A right before the collision.



Figure 1

The experiment of this lesson is in a file named *TwoCarStudy2.phyphox* and will be made available from the author when the Phyphox beta with BLE is released. This file can then be opened in Phyphox and will appear in the main screen similar to that shown in Figure 2.



Figure 2

Performing the Experiment

The first screen that you will see after selecting the *Two Car Study 2* experiment is shown in Figure 3. The top graph indicates that PocketLab Voyager A will make use of its rangefinder. The bottom graph indicates that PocketLab Voyager B will also make use of its rangefinder. A message in the center of the screen tells you that it is scanning for Bluetooth devices with the name "PL Voyager" and asks you to pick a device. At this point you should turn on PocketLab A, on the cart on the left. "PL Voyager" will appear in the message. Click on "PL Voyager" and a message will tell you that Bluetooth is connecting to the device. You will be asked a second time to pick a device—this time turn on the Voyager mounted on the top of the cart on the right. You can now start data collection with the pulsating start triangle in the upper right corner of the screen. You would then give cart A a little push and stop data collection when cart B comes to a rest following the magnetic collision.



Figure 3

A one-minute YouTube <u>video</u> clarifies the entire process. It is important to remember that rangefinder Voyager A be selected *first*, and rangefinder Voyager B be selected *second*. If they are not selected in the correct order, then the two graphs will be matched to the wrong Voyagers. Figure 4 shows what the graphs may look like after data collection is complete.



Figure 4

In order to export the data, all you need to do is click the ellipsis in the upper right corner of the screen and select *Export Data* from the drop-down menu. You can then choose the desired data format (Excel, CSV) and pick a method for sharing the data (Google Drive, Dropbox, Email, etc.) See Figure 5.



Figure 5

Analysis

There are a variety of ways to approach the analysis of the rangefinder data from this experiment. The author elected to export the data from Phyphox as an Excel file, and then initially construct the two graphs shown in Figure 6.





One thing that complicates the analysis is the fact that we have a "magnetic" collision. It is difficult to know exactly when the "collision" begins and when it ends. We don't want to determine the velocity to close to the time where cart A stops and cart B start moving, as such data might be in the "collision" time zone. The author elected to determine the velocity in the time zones highlighted in red in the graphs of Figure 6. It is these red regions that are of interest for further investigation, so the data for these regions was used to construct a new pair of graphs, as shown in Figure 7. Copying just this data to new graphs allows for easy trendline analysis of these regions in Excel. With these small data ranges, it is reasonable to use a linear trendline, from which the slopes tells us the velocities. We find velocities of 0.2491 m/s and -0.2183 m/s for carts A and B. The fact that B's velocity is negative is due simply to the fact that its positions decrease as cart B moves toward the cardboard wall on the right of the setup. Sine the velocities are within 13% of one another and the cart masses are equal, it is reasonable to say that momentum is conserved.



Figure 7

Suggestion for Further Investigation

- 1. Hold the two carts still with their magnets touching, and then release them. Show that momentum is conserved in this "explosion" of the two carts.
- 2. Add some mass to one of the carts so that its mass is increased by about 50%. Show that momentum is conserved when the two cards "explode".