

A Voyager/Phyphox Magnetic Dipole Experiment: The Inverse Cube Law

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Introduction

Magnets, from the traditional alnico bar magnets to the modern neodymium magnets, have been of interest to most everyone for decades. The attraction or repulsion of two such magnets when brought close together is particularly interesting due to its intense strength. This strength can be expressed by observing the relationship between magnetic field strength measured in micro-Tesla and distance from the magnet.

This lesson makes use of Voyager to measure both distance and magnetic field strength. Distance is measured by Voyager's rangefinder, and magnetic field strength is measured by Voyager's magnetometer. Data is plotted in real-time using Phyphox software. The advantage of Phyphox over the PocketLab app is that it can *directly* plot magnetic field strength versus distance and can export this data without reference to the time variable.

Phyphox (*physical phone experiments*) is 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.

Figure 1 shows the setup used in this experiment. Voyager has been mounted to a PocketLab HotRod. The rangefinder points toward a piece of white foamboard to which the magnet has been attached with its south pole facing Voyager. Balsa wood sticks have been taped to the table, providing a track to keep Voyager on the straight and narrow. The cart is initially placed with Voyager approximately 5 cm from the foamboard and is then given an easy push toward the left, during which time Phyphox records distance and magnetic field data as the cart slows down to a stop.

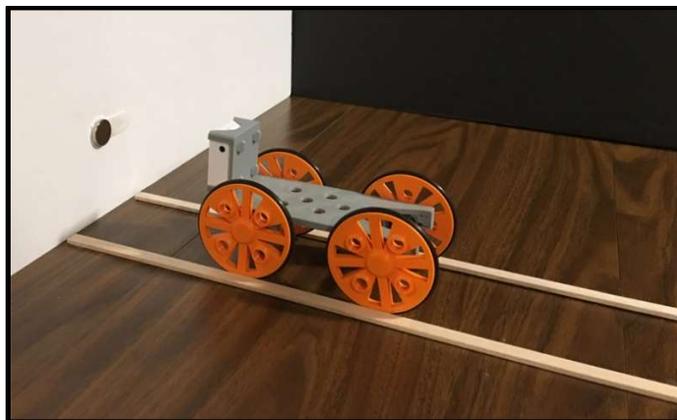


Figure 1

The experiment of this lesson is in a file named *InverseCubeMagField.phyphox* and will be made available from the author when the Phyphox beta is released. This file can then be opened in Phyphox and will appear in the Phyphox main menu in the *PocketLab Voyager* category of the main screen, similar to that in Figure 2.

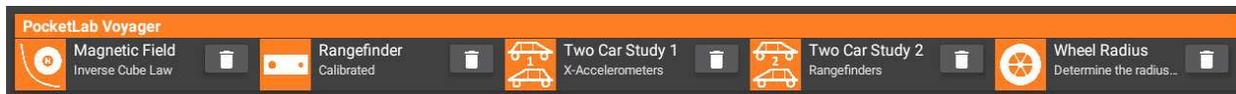


Figure 2

Performing the Experiment

The first screen that you will see after selecting the *Magnetic Field—Inverse Cube Law* experiment from the main menu is shown in Figure 3. The graph axes indicate that a graph of Magnetic Field vs Position will be created when data collection begins. A message in the center of the screen tells you that it is scanning for a Bluetooth device with the name “PL Voyager” and asks you to pick a device. At this point you should turn Voyager on. “PL Voyager” will appear in the message. Click on “PL Voyager” and a message will tell you that Bluetooth is connecting to the device. When the connection is complete, you can start data collection with the pulsating triangle in the upper right corner of the screen. You would then give the cart a little push and stop data collection when the cart comes to a rest. A one-minute YouTube [video](#) clarifies the entire process that was just described.

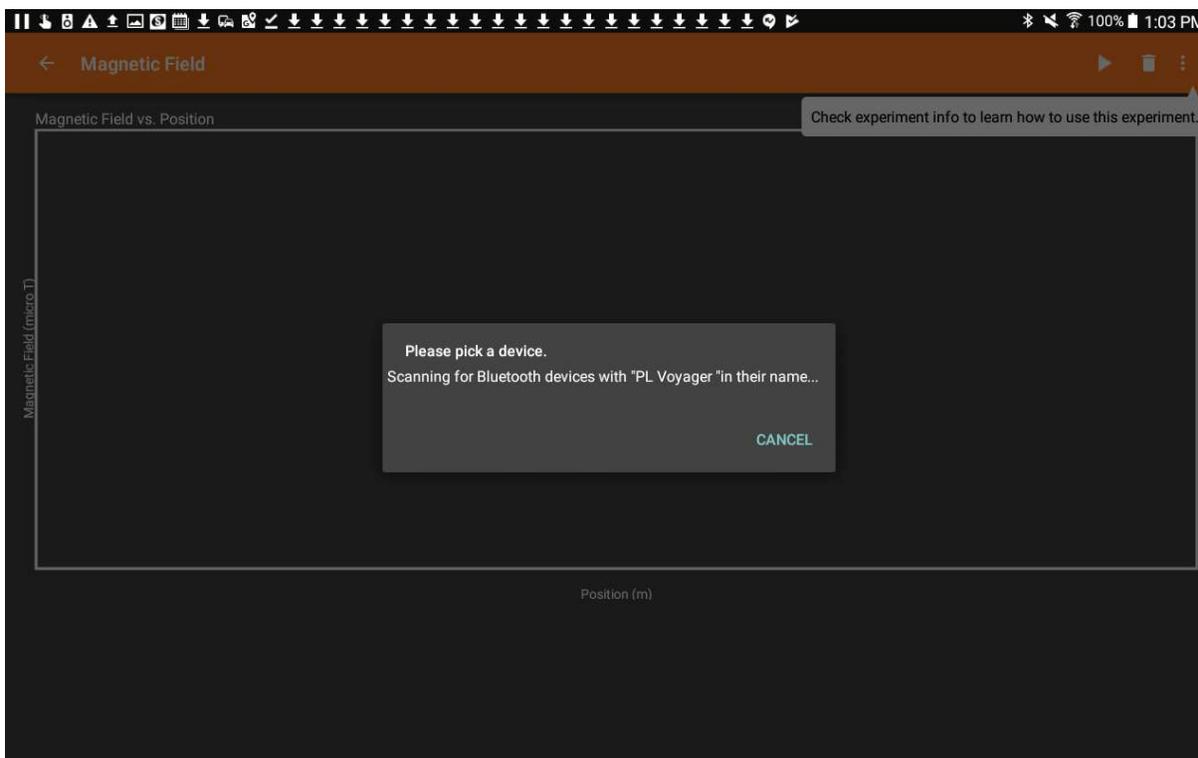


Figure 3

Figure 4 shows what the graph may look similar to once data collection is complete.

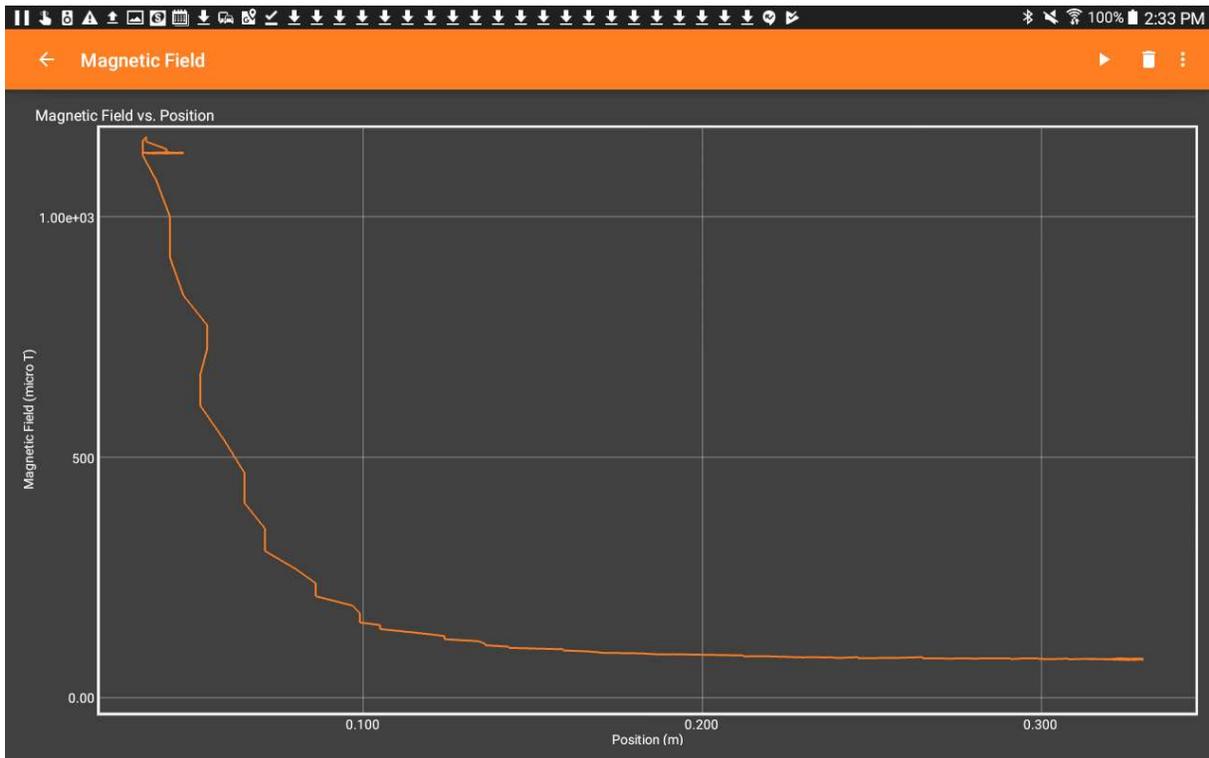


Figure 4

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.

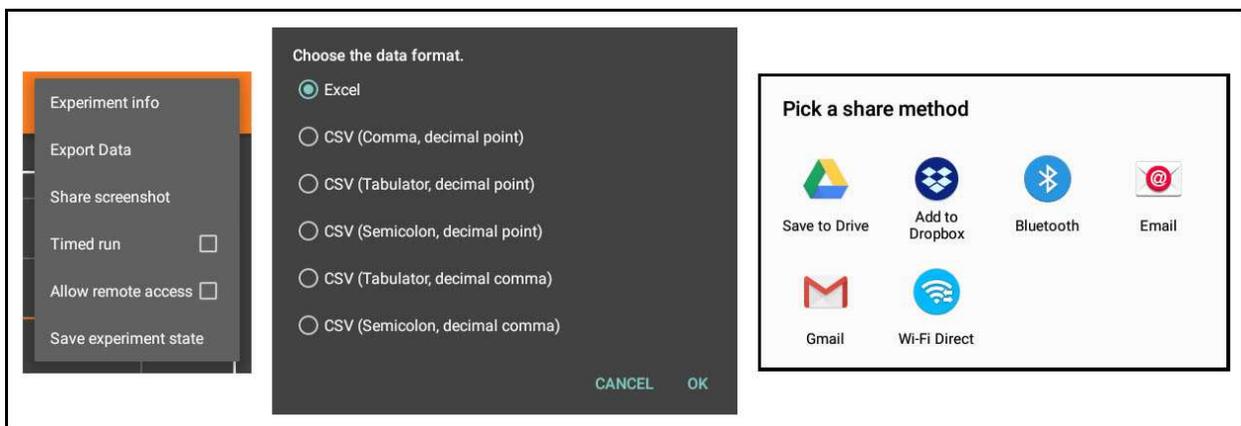


Figure 5

Analysis

The author's approach to the analysis was to export the data from Phyphox as an Excel file. Two graphs were then constructed as shown in Figure 6.

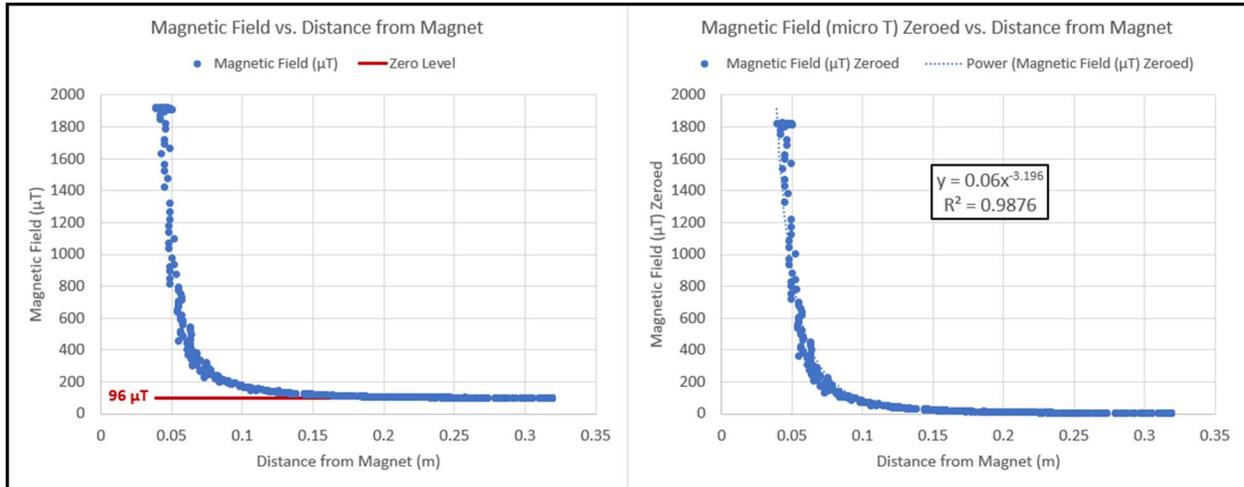


Figure 6

The graph on the left, of magnetic field vs. distance from the magnet, indicates some kind of an inverse relationship between these variables. The graph further shows that the magnetic field strength tends to level out at about 96 micro-Tesla when the distance gets large. However, we would expect it to trend toward 0 as distance gets large. The fact that it doesn't indicates that the "background" magnetic field from the earth's magnetic field and surroundings is about 96 micro-T for the particular orientation of our apparatus. The apparatus was oriented with the track running east-west. Background would likely change if the orientation were changed. In any case, before we can apply a power trendline to the data, it is necessary to subtract the 96 micro-T background from all of the magnetic field strength data.

The graph on the right shows the situation after removing the background, in effect zeroing the magnetic field strength for large distances from the magnet. This zeroing is critical for successfully determining the power relationship between magnetic field strength and distance from the magnet.

The tiny dotted blue trend line was obtained by selecting a power curve in the Excel trendline analysis. It follows the actual data points quite well, as indicated by the R^2 value of 0.9876. The equation of best fit shows that the power is -3.196, which is close to the well-known inverse cube law relating magnetic field strength to distance from a magnet.

It should be noted that a small diameter neodymium magnet works best, as it acts more like a point source. A large magnet is likely to provide readings that violate the inverse cube law when the sensor is close to the magnet. A similar effect exists in the study of the inverse square law of light intensity when the sensor is close to a large source of light.