The Magnetic Field Around a Long Current-Carrying Wire

Richard Born
Associate Professor Emeritus
Northern Illinois University

Magnetic Fields from Electric Currents

One of the classes of problems dealing with magnetic fields concerns the production of a magnetic field by a current-carrying conductor or by moving charges. It was Oersted who discovered back in the early 1800's that currents produce magnetic effects. The quantitative relationship between the magnetic field strength and the current was later embodied in Ampere's Law, an extension of which made by Maxwell is one of the four basic equations of electromagnetism.

PocketLab and Phyphox software, used in conjunction with a long, straight current-carrying wire, offer a great opportunity for students to quantitatively study the relationship between magnetic field strength B and the distance r from the wire's center. Students will be able to confirm that B is inversely proportional to the distance r. An alternative version of the experiment using only PocketLab, and not Phyphox, can be found by clicking here.

Experiment Setup

Figure 1 shows the experimental setup for this experiment. A wire is connected to a power supply and is carrying a constant current i of about 8 amps. The right-hand rule applied to the wire tells us that the magnetic field B at locations to the right of the wire is perpendicular to the table top and pointing upward. PocketLab Voyager is placed so that its positive y-axis is in the direction of the magnetic field. A small piece of cardboard is placed alongside the wire so that Voyager's rangefinder can measure distance from the wire. Voyager is initially touching the cardboard and moved away from it to a distance of between 10 and 15 cm. Also, note that Voyager's magnetometer is located below the letter Z on the orange side of Voyager. Phyphox displays a real-time graph of magnetic field strength versus distance from the wire while Voyager is moved. A balsa wood stick perpendicular to the white cardboard has been taped to the tabletop. This serves as a guide when moving Voyager away from the wire. The Samsung tablet shows what the graph may look like after data has been collected.

Phyphox Software

Phyphox (***phy***sical ***pho***ne e***x***periments) is a free 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.

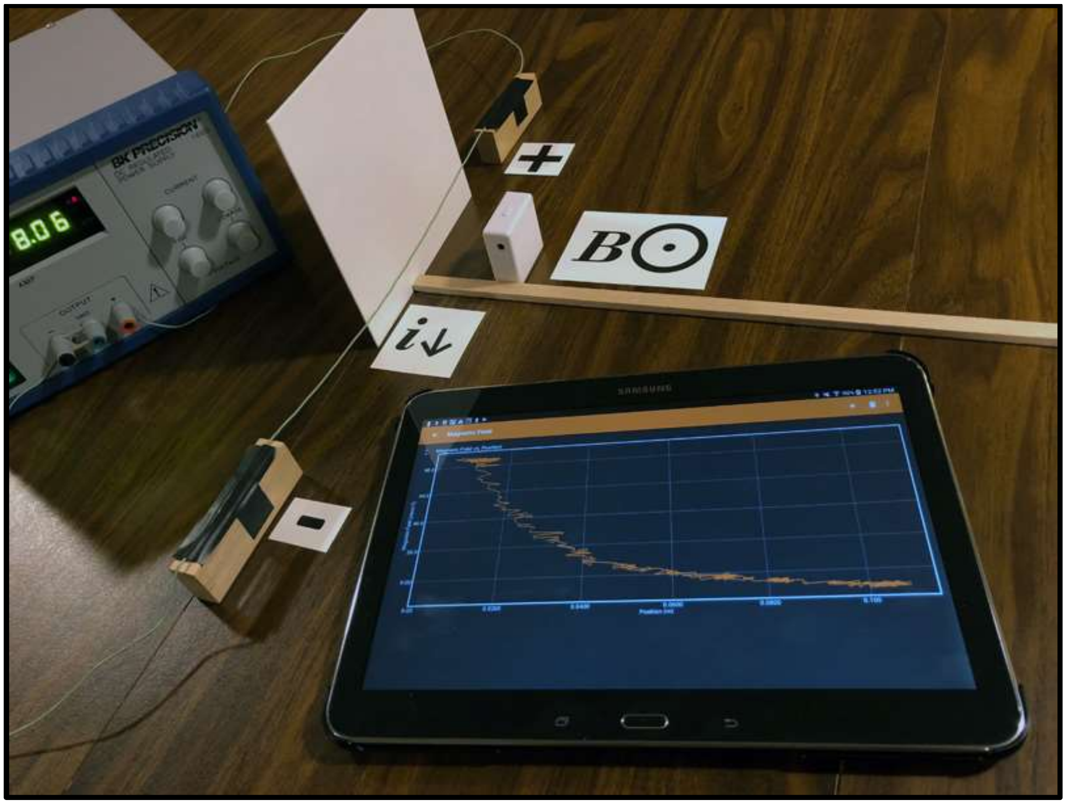

Figure 1

The experiment of this lesson is in a file named *CurrentWire.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 *PocketLab Voyager* category of the main screen, similar to that in Figure 2.

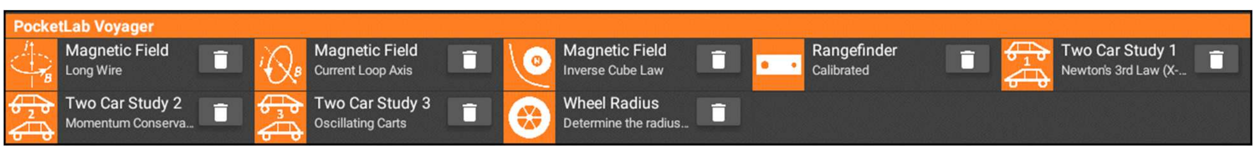

Figure 2

Performing the Experiment

The first screen that you will see after selecting the *Magnetic Field—Long Wire* 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 whenever you are ready with the pulsating triangle in the upper right corner of the screen. Figure 1 shows what the graph may look like after data collection is complete.

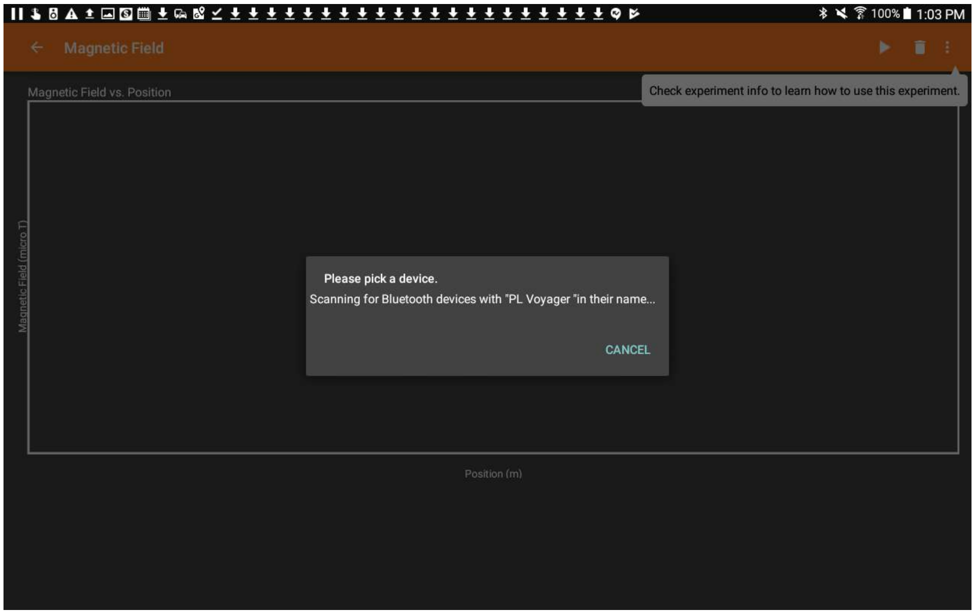

Figure 3

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 4.

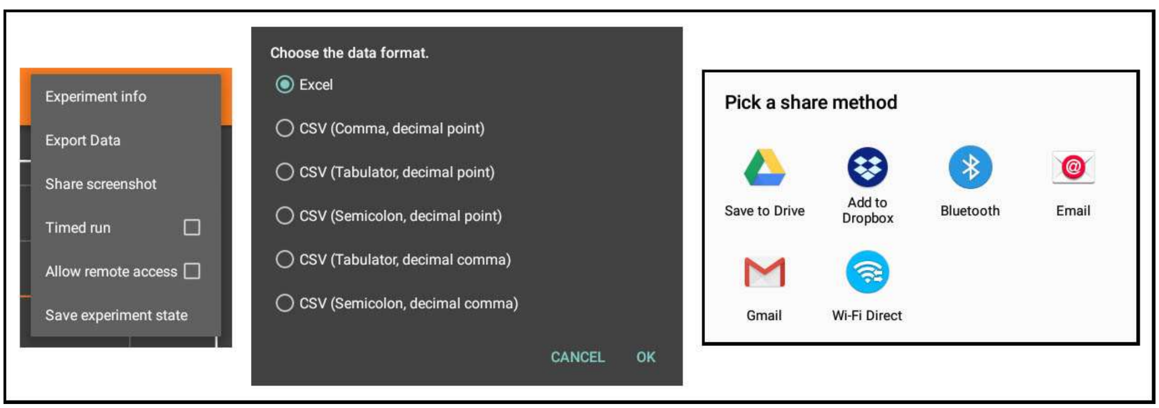

Figure 4

Procedures and Analysis

The author's approach to the analysis was to export the data from Phyphox into Excel. Two procedural steps are suggested:

1. Data was collected for several seconds with Voyager's magnetometer *at rest*, in the same orientation along the balsa wood stick as it will be when collecting actual data, and with the *current turned off*. The purpose of this step is to compute the "zero" for magnetic field. This would allow for adjusting the magnetic field values in step 2 to compensate for the earth's background magnetic field. Figure 5 shows what the raw data looks like for the author's

zeroing. Since the zero visually appears to be about -20.5 micro T, then it would be necessary to add 20.5 micro T to each of the magnetometer values collected in the actual experiment.

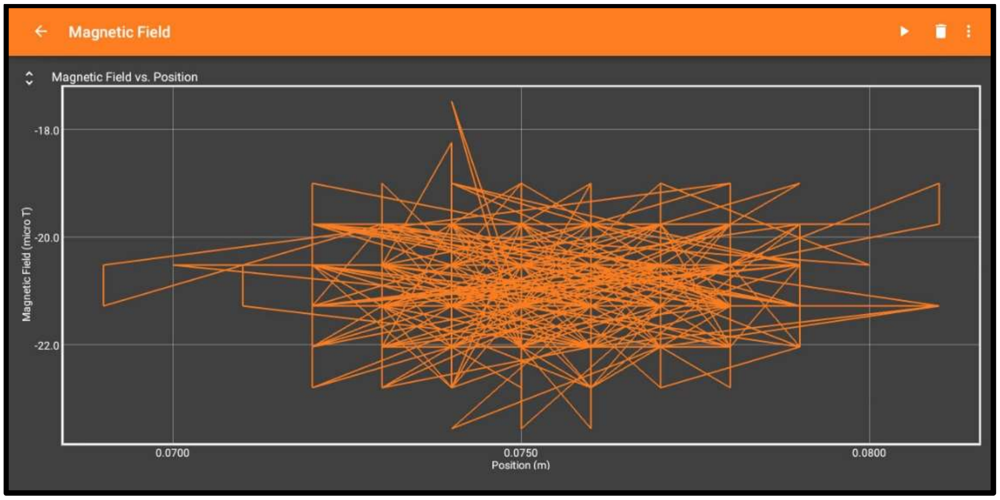

Figure 5

2. With the current turned on and set to about 8-amp, magnetic field strength data was collected while moving Voyager from its initial position touching the wire to a position about 10 to 15 cm to the right of the wire. As mentioned earlier, Figure 1 displays a typical run. Positions are all measured from the white foam board. As discussed in step 1, the magnetometer readings need to be adjusted as well. This is accomplished in our example by adding 20.5 micro Tesla to each magnetometer reading.

   Figure 6 shows the final graph of magnetic field strength vs. distance from the wire. This graph was constructed by exporting the data from Phyphox to Excel. The blue dots show experimental magnetometer data that has been zeroed. The red line was obtained by doing a power curve regression on the data. The power curve of best fit to the data is seen to have a power of -0.998, very close to -1. This gives convincing support that the magnetic field strength is inversely proportional to distance from the current-carrying wire.

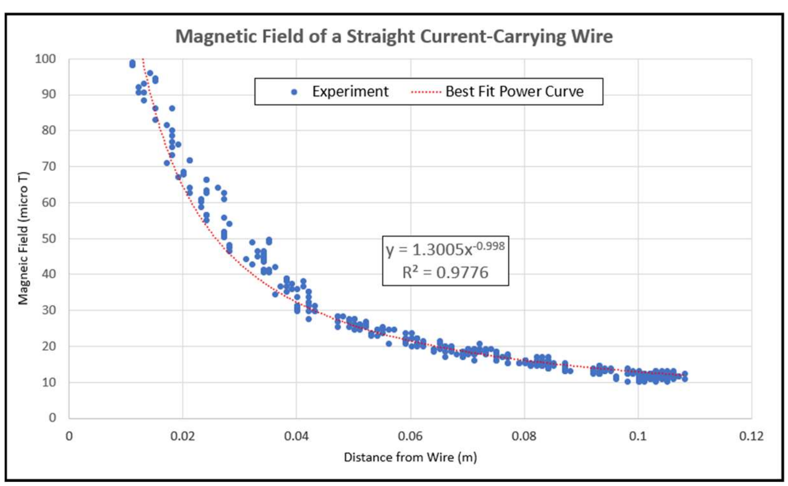

Figure 6