# **Instructions for Vernier Data Analysis Worksheet**

The worksheet has three pages and every page has three data tables. The first table on the top is the same on all three pages (so that you do not have to keep flipping the pages back and forth when filling in tables 2 and 3 on a given page).

**Page 1**

Table 1:

* The emf and the value of the external resistor were measured with the multimeter before the start of each measurement. The values were recorded in the lab notebook. Find them and enter them into the data table.
* We started recording data before connecting the circuit. Thus, our data collection did not start at seconds, but at some later time. Record the time for the first connected voltage measurement.
* seconds. Our initial interest was in determining the changes in the battery performance over a 2-hour time interval. Later, we looked into the performance for an interval given by the external voltage staying above the cut-off voltage of 2.0 V.

Table 2:

* and are read off the data tables as recorded by the Vernier Analysis software. Careful, column zero “counts” data points and is not equal to column one which is the time column. (They are off by one row.)
* The calculation of the percentage is done with a calculator (for bigger data sets this will be done in Excel).
* Remind students that percentages do not have units. Round answer to 3 sig. figs.

Table 3:

* and are read off the data tables as recorded by the Vernier Analysis software. It creates the columns “time”, “potential”, “current” during the measurement. Careful, the current is measured in A, but will be recorded in mA here.
* The calculation of the percentage is again done with a calculator (for bigger data sets this will be done in Excel).
* It is easier to record and at the same time, then find and record and .

**Page 2**

The equations were previously discussed in class. Here, we are just explaining how to “transfer” the equations from paper into the graphical analysis program to calculate new columns. We did not use Excel at this point in the semester. That would be another option. I like the graphing options in Vernier better than in Excel, so we stayed in Vernier.

The free Vernier Graphical Analysis program does not let you divide two columns by each other, and it does not let you subtract two columns from each other. Thus, we defined two “helper” columns (-1\* X) and (1/X) to get around this limitation.

Table 1:

* Copy from page 1 (so that we can see the values of , , and the emf).

Table 2:

* The internal voltage drop of the battery is
* Create the following new “calculated columns” in Vernier:
  + [V] using expression with
  + [V] using expression with
* Students need to be reminded that “emf” is the value they measured for the specific data run with the multimeter. and are constants; and are columns that already exist and are chosen from a pull-down menu.
* Once the columns are defined, they are immediately calculated by the program. Students can then record and .
* As , we did not calculate the percentage increase, but the factor by which the internal voltage drop increased (keep 3 sig. figs.):

Table 3:

* The internal resistance of the battery represents the increasing voltage drop inside the battery:
* Create the following new “calculated columns” in Vernier:
  + [1/A] using expression with
  + [ohm] using expression with ; .
* Once the columns are defined and calculated, the values for and are read from the data table and the factor of increase is calculated by calculator:

**Page 3**

We will need to define two more columns. Again, the relationship between power and energy and between current and battery capacity has been discussed with the students. We are now explaining how to use the “View Integral” option in Vernier and how to correctly set the boundaries of the integral, so that it does not calculate the integral for the whole data set but only for the 2-hour time interval that we are interested in.

Table 1:

* Copy from first page (we again will need to know the values of , , and the emf).

Tables 2 and 3:

* The total power delivered by the battery is current \* emf, the power delivered to the external load is current \* external voltage.
* Create the following new “calculated columns” in Vernier:
  + [W] using with
  + [W] using with
* Students will now use the graphing options to calculate the integrals. While we generally use the term “area under the curve” in the algebra-based physics class, the menu option in Vernier is called “view integral”, so the term “integral” has been explained to mean “area under the curve”. Vernier will highlight the area as it is being calculated, so there is a visual explanation of the calculated quantity.
  + Click on “Graph Options” (bottom left, looks like a “graph”, not a magnifier).
  + Choose “Edit Graph options” (bottom choice, make sure to scroll to it).
  + Enter “X-axis range” values (these are the values of and ).
  + Click outside the menu to exit.
  + Click on “Graph Options” once more and choose “View Integral”.
  + A box appears in the graph that reads “Integral”. It lists the range (confirm that the correct time-interval is displayed), then states the “area” with correct units.
  + Record all digits displayed (you can round later; first record the calculated data).
* In order to calculate the correct integral:
  + Make sure that is chosen for the y-axis to calculate
  + Make sure that is chosen for the y-axis to calculate
  + Make sure that is chosen for the y-axis to calculate
* For Table 2: The % of the converted energy that was delivered to the external load resistor is:
* For Table 3: given battery capacity values in the battery data sheets are in milli-ampere-hours for these small batteries. => Convert value from [A\*s] to [mA\*h].