# Appendix B

# LabQuest User Guide

*The information used in this guide is derived from Vernier Software & Technology

**Power On**: Press and release the power button located on the top edge of LabQuest to turn on the unit. The LabQuest App will launch automatically.

**Shut Down:** To shut down LabQuest, hold the power button down for about five seconds. LabQuest displays a message indicating it is shutting down. Release the power button, and allow LabQuest to shut down. To cancel the shutdown procedure at this point, tap Cancel. You can also shut down LabQuest from the Home screen. To do this, tap System and then tap Shut Down.

**Data Collection:** To start data collection from any LabQuest App screen, tap "Collect" (shown as a green ➤). During data collection, tap "Stop" to end data collection early. Once data collection is complete, the graph autoscales to the data. Tap the graph to examine a point of interest. The coordinates of the point are shown in the panel to the right of the graph. Tap another point or tap the "Examine" buttons to move the cursor left and right.

**Data-Collection Summary:** A summary of the data-collection settings (Mode, Rate, Duration) is shown in the panel to the right of the Meter screen. For most sensors, the default data collection mode is Time Based. The default collection rate for the connected sensor is automatically set up when LabQuest identifies the sensor.

**Statistics:** To view statistics for the selected data on the Graph screen, choose Statistics from the Analyze menu. Select the check box to select a data column. The statistics information is then displayed in the panel to the right of the graph. To remove the displayed statistics, tap Analyze on the Graph screen, choose Statistics, and then select the checkbox to clear the selection

**Using a Sensor:** After turning on LabQuest, connect an analog sensor to the CH 1 port. The LabQuest App will auto-ID the connected sensor and automatically set the default collection rate for the sensor. You are now ready to collect data. Review the steps below specific to the sensor being used.

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**pH Sensor:**

1. Remove the storage bottle from the electrode by unscrewing the lid, this will loosen the gasket (black ring). Remove the electrode from the bottle and lid. Each probe is stored in an electrode

storage bottle which contains a pH 4/KCl solution. When taking out the probe, leave the black ring and cap on the storage bottle.

2. Using DI water, thoroughly rinse the lower section of the probe, especially around the bulb-shaped glass tip, this is the electrode sensor.Gently dry the glass bulb using a Kimwipe. The shielded glass tip is especially fragile, care must be taken to prevent breakage when using or putting down the sensor. Examine the glass bulb. If it is broken, pH readings will be incorrect.

3. Connect the sensor following the steps listed above. A red box will appear on the screen that will display 'CH#: pH' and display the currently read pH value. Allow the measurement reading to stabilize when inserting the sensor into a solution.

4. Having rinsed and dried the electrode, immerse the electrode in the solution to be tested; the pH will be displayed in the red box on the LabQuest display screen. Wait 5 to 10 seconds before recording pH; wait the same amount of time for each measurement. To measure pH accurately, the solution to be measured must cover the glass bulb on the pH electrode. Remember to rinse with DI water and dry the probe when changing between solutions.

5. When you are finished with measurements, rinse the electrode with DI water. Slide the cap onto the electrode body, and then screw the cap back onto the storage bottle so that only the tip of the electrode is immersed in the storage solution. **Important:** Do not fully submerge the sensor as the handle is not waterproof.

**pH Sensor Calibration:**.

1. Fill two 18 x 150 mm test tubes approximately half-full with pH 4 buffer in one test tube, and pH 10 buffer in the second test tube..
2. Immerse the sensor into the pH 4 solution. Using the stylus, select "Sensors", next select "Calibrate", followed by selecting "CH 1".
3. Click the "Calibrate Now" button.
4. Enter the known value of the buffer solution. Once the reading stabilizes, select "Keep".
5. Remove the sensor, rinse the probe with DI water and gently blot it dry with a Kimwipe before placing it into the next buffer. When the reading stabilizes, enter the known value of the second buffer, then press "OK". The sensor is now calibrated.

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**Voltage Probe:**

To measure a potential difference between two points in a circuit, connect the red and black clips to the two points. A positive reading means the red clip is at a higher potential than the black clip.

The black lead is directly connected to the common ground point of the interface. In some circumstances, this means the black lead is grounded. Because of this connection to the common ground point of the interface, it is easy to unintentionally ground part of your circuit without realizing it. Connect the black lead only to a point in your circuit that can safely be grounded.

To begin data collection, select the collect icon near the bottom of the screen, (shown as a green ➤) or along the right side of the system, shown as a ➤ button. LabQuest will go to the graph screen. You can now measure the potential across the entire circuit. When finished, you can tap on the graph to obtain the potential of any given point.

**Voltage Probe Calibration:**

The Voltage Probe does not require calibration. Zeroing can be helpful in improving the accuracy of measurements. Zero the Voltage Probe by connecting the two leads together. Then, use the stylus and tap on the screen near the current reading. In the pop up, select "zero". A value reading near zero will now display.

The voltage probe may give unexpected non-zero readings when disconnected or open-circuited. If you are getting unexpected or unusual measurements from your Voltage Probe, first check that the red and black leads are properly and securely attached, according to the experimental setup. If you suspect that the readings are not correct, make sure you have zeroed the probe correctly. The reading should go to zero. If it does not, the wires may be damaged.

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**Temperature Probe:**

1. Connect the sensor to LabQuest
2. Start the appropriate data-collection software (Logger Pro, Logger Lite, LabQuest App) if not already running, and choose New from File menu.
3. The software will identify the sensor and load a default data-collection setup. You are now ready to collect data.

**Temperature Probe Calibration:**

In most cases, the Stainless Steel Temperature Probe will not need to be calibrated. It is calibrated before it ships. However, you can calibrate the sensor using Logger Pro 3.3 or newer. **Note:** Calibration can only be done on computers running Logger Pro.

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**Colorimeter: The Laws of Light Absorption**

The Vernier Colorimeter is used to determine the concentration of a solution by analyzing its color intensity. The cuvette slot is designed to accommodate most cuvettes with a 10 millimeter path length. The Colorimeter measures the amount of light transmitted through a sample at a user-selectable wavelength. You may choose from four wavelengths: 430 nm, 470 nm, 565 nm, and 635 nm. Features such as automatic sensor identification and one-step calibration make this sensor easy to use. Light from an LED light source passes through a cuvette containing a solution sample. Some of the incoming light is absorbed by the solution. As a result, light of a lower intensity strikes a photodiode.

The colorimeter allows the selection of a specific wavelength of light with a well-defined color to be used to analyze liquid samples. The beam of light is directed through a sample tube in the sample holder and then onto a photoelectric detector that measures the intensity of the beam. The measured intensity is displayed on the screen of the instrument.

The measurement is started by placing a cuvette containing only solvent in the sample holder. This is called a blank. A blank is a solution containing all absorbing species minus the one you are measuring. The intensity of the light passing through the cuvette and reaching the detector is given the symbol $I_o$. A tube containing the test solution is then placed in the sample holder. If the solute absorbs light of this wavelength, the intensity measured by the detector will be smaller than $I_o$. The new intensity is called I.

The ratio $I/I_o$ is called the transmittance of the sample and is often quoted as a percentage with symbol %T. For our purposes, it is more useful to work with a quantity called the absorbance, represented by A, and defined by

$$A = \log(I_o/I).$$

For example, if the solute absorbs 80% of the light, the transmittance would be 20%. The ratio $I_o/I$ would then be 100/20 or 5, and the absorbance would be 0.7. In most cases, A, or % T, can be read directly from the display of the instrument used in the lab.

The Beer-Lambert law describes the characteristics of light absorption. It states that the absorbance is proportional to the concentration of the absorbing species and to the length of the path of the light beam through the solution. The relationship is commonly written:

$$A = \varepsilon C \ell,$$

where C is the molar concentration of the absorbing species, $\ell$ is the pathlength in cm, and $\varepsilon$ (the Greek letter "epsilon") is the extinction coefficient or molar absorptivity of the absorber. $\varepsilon$ is a characteristic of the absorbing molecules; it generally varies strongly with the wavelength of the measuring light and may vary slightly with temperature, solvent, and other parameters.
A plot of $\varepsilon$ vs. wavelength gives a spectrum of the material. It shows at what wavelengths and how strongly the compound absorbs light. For example, Figure 1 shows the spectrum of $FeNCS^{2+}$. The broad peak extending from 380 to about 600 nm corresponds to a particular electronic excitation in which an electron from the $SCN^-$ ion absorbs a photon and is promoted to a higher-energy 3d orbital on the $Fe^{3+}$ ion. The strongest absorption occurs at about 455 nm. This corresponds to blue light. The spectrum shows that the complex ion also absorbs the violet light around 400 nm and to some extent the green light around 540 nm. The light passing through the solution that is not absorbed still contains the yellow, orange, and red light, so the solution appears reddish to the eye.

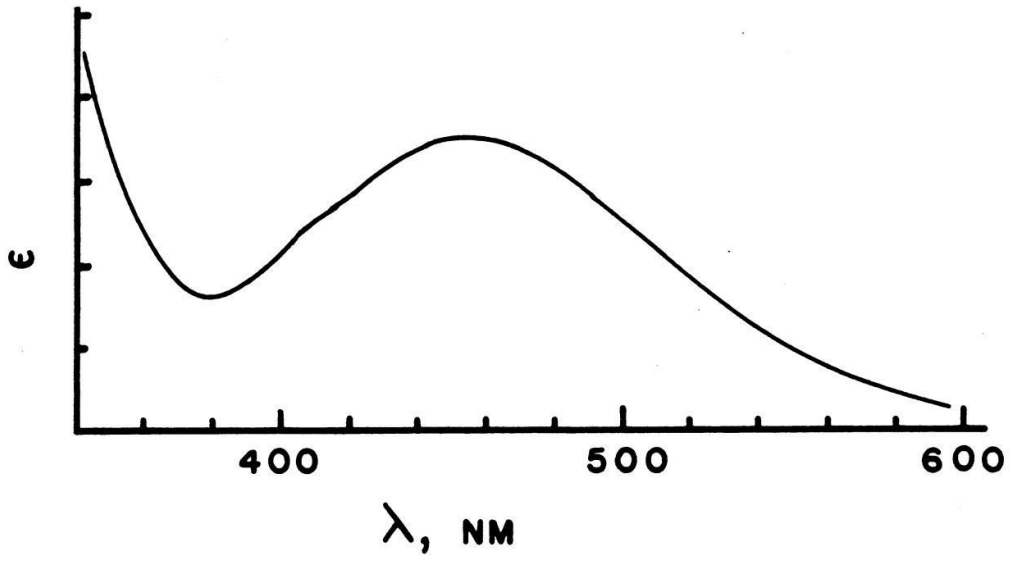


Figure 1: Absorption spectrum of $FeNCS^{2+}$

In using light absorption to determine the concentration of a compound in solution, it is generally best to make the measurements at or close to an absorption maximum; in the case of $FeNCS^{2+}$ this occurs at about 455 nm. Although the colorimeter does not have an option for 455 nm, using 470 nm still allows measurements at a wavelength with a high absorption for this substance. This approach gives the maximum sensitivity for measuring low concentrations. Even more importantly, it assures that the measurements are not strongly affected by small errors in the reading.

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**Using The Colorimeter:**

1. Power on LabQuest.

2. Obtain the appropriate cuvettes for the colorimeter you will be using. Water present on the outside of the cuvette may cause erroneous readings and damage the colorimeter. Always dry the outside of the cuvette with a Kimwipe before inserting it into the colorimeter. Dry Kimwipes can be reused to prevent excess waste.

3. Plug the colorimeter probe into CH: 1. A red box will appear on the screen that will display 'CH#:Absorbance' and will show the currently read absorbance value. Press the < and > buttons on the colorimeter to select the wavelength you will be using for your experiment.

4. Allow the colorimeter to warm up for about 5 minutes before calibrating. **Follow the calibration steps listed below before continuing.**

5. Collect absorbance data for selected samples.

6. Place a cuvette with a sample in the Colorimeter cuvette slot. Make sure to line up the clear sides of the cuvette properly. For best results, use one cuvette to make all your measurements for a given experiment.

7. Tap the green arrow in the lower corner of the LabQuest screen to start data collection.

5. When your measurements are completed, remove the cuvette from the sample holder and close the cover. If you do not need to use the instrument further, remove the colorimeter from the CH:1 port in the LabQuest system. Shut down the LabQuest. Make sure to clean cuvettes and return the LabQuest, colorimeter, cuvettes, and any other glassware and equipment to its appropriate location. Cuvettes can be cleaned using soapy water followed by rinsing with DI water. **Never use a test tube brush to clean cuvettes as it will scratch the cuvette.** Scratches can interfere with light transmission. Invert to drain.

**Colorimeter Calibration:**

A. Slide/Open the lid of the Colorimeter open to reveal the cuvette slot.

B. Insert a cuvette, filled 2/3 to 3/4 full with DI water for your calibration blank (100% transmittance or 0 absorbance). After filling a cuvette with liquid, seal the cuvette with a cap to prevent spills. Make sure to place a cuvette in the Colorimeter so the path of the light source travels through the clear sides of the cuvette.Wipe off the outside of the cuvette with a Kimwipe before inserting it into the sample holder. **Important**: Be sure to orient the cuvette so that the clear sides face forward and back; if all sides are clear, orient one of the clear sides of the cuvette with the arrow at the right side of the cuvette slot. Incorrect positioning of the cuvette leads to errors.

C. Slide/Close the Colorimeter lid. Press the CAL button on the Colorimeter to begin the calibration process. Release the CAL button when the red LED begins to flash.

D. When the red LED stops flashing, the calibration is complete. The absorbance reading of the blank should be very close to 0.000

E. Remove the blank cuvette from the Colorimeter.

You will now have compensated for any absorption due to the solvent so that any additional measured absorption of light by your sample will be due only to solute absorption. This calibration should be checked periodically and must be redone whenever the wavelength is changed.

**Exporting Colorimeter Data:**

1. To export your data to a flash drive or micro SD card: First insert the flash drive or micro SD card. Click the File tab on the top left corner -- Export --- tap on saved file name -- tap the circle with arrow (top left corner) to export the file. At the bottom of the screen it will say "Export to text." Click OK. Remove the flash drive and open the file in Excel. You may need to change the file type to "all files" before you can see the file with your data. Open the file and in the Step 1 box select "delimit", "my data has headers" and click "Next." In Step 2: select "tab", "comma", "space" and "treat all delimiters as one." Click "Next." In Step 3 click "Finish" and save your file as an Excel Workbook. To save multiple data sets, click on SAVE (make sure you do NOT discard your data).

# Useful Information

Strong Acids: HCl, HBr, HI, $HNO_3$, $HClO_4$, $HClO_3$, $H_2SO_4$ (1st proton only)

$M_1V_1 = M_2V_2$ $\quad pH = pK_a + log(\left(\frac{[A^-]}{[HA]}\right)$

$\Delta H^\circ_{rxn} = \Sigma n \times \Delta H^\circ_{f,products} - \Sigma n \times \Delta H^\circ_{f,reactants}$ $\quad \Delta S_{surroundings} = -\frac{\Delta H_{system}}{T}$

$\Delta S^\circ_{rxn} = \Sigma n \times \Delta S^\circ_{products} - \Sigma n \times \Delta S^\circ_{reactants}$ $\quad \Delta S_{universe} = \Delta S_{system} + \Delta S_{surroundings}$

$\Delta G^\circ_{rxn} = \Sigma n \times \Delta G^\circ_{f,products} - \Sigma n \times \Delta G^\circ_{f,reactants}$ $\quad \Delta G^\circ_{system} = \Delta H^\circ_{system} - T\Delta S^\circ_{system}$

$\Delta G = \Delta G^\circ + RTlnQ$ $\quad \Delta G^\circ = -RTlnK$

$E_{cell} = E°_{cell} - \frac{RT}{nF}lnQ$ $\quad E°_{cell} = \frac{RT}{nF}lnK$

At 25°C: $E_{cell} = E°_{cell} - \frac{0.0592}{n}logQ$ $\quad$ At 25°C: $E°_{cell} = \frac{0.0592}{n}logK$

$E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode}$ $\quad V = \frac{J}{C}$

$\Delta G = -nFE$ $\quad \Delta G^\circ = -nFE^\circ$

$F = 96,500 \frac{C}{mol\ e^-}$ $\quad R = 8.314 \frac{J}{mol \bullet K}$

$t_{1/2} = \frac{ln2}{k}$ $\quad k = Ae^{-Ea/RT}$

$\ln ln\left(\frac{k_2}{k_1}\right) = -\left(\frac{E_a}{R}\right)\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$

$\Delta E = \Delta mc^2$ $\quad$ Speed of Light: $c = 2.9979 \times 10^8$ m/s

Spectrochemical Series: $I^- < Br^- < Cl^- < OH^- < F^- < H_2O < SCN^- < NH_3 < en < NO_2^- < CN^- < CO$

**Integrated Rate Laws**

| Order | Integrated Form | Linear Plot |
|---|---|---|
| 0 | $[A]_t = -kt + [A]_0$ | [A] vs t |
| 1 | $\ln[A]_t = -kt + \ln[A]_0$ | ln[A] vs t |
| 2 | $1/[A]_t = kt + 1/[A]_0$ | 1/[A] vs t |