Smartphones as Data Collection Tools for Science Education

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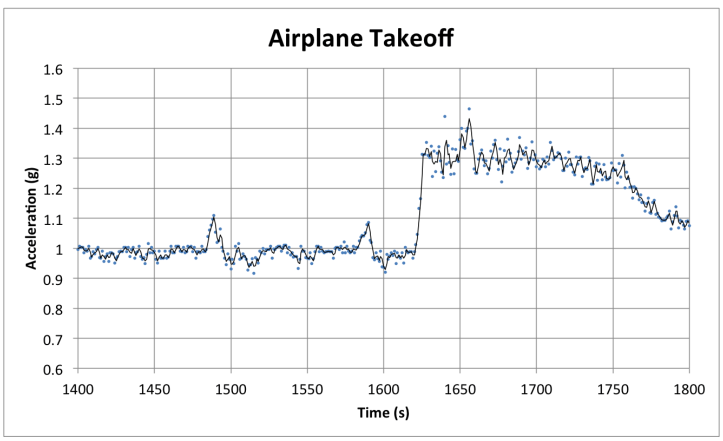
The cell phone manufacturer Nokia recently announced a low-end smartphone for under $100 without a contract[1] while Chinese manufacturers are poised to capture emerging markets in China, India and Africa by offering even lower cost smartphones. Soon all new phones will be smart. Even these low-end smartphones possess computing power comparable to personal computers and are superior to ordinary phones in their remarkable variety of built-in sensors and communications capability. The potential impact on science education could be huge. Science is built on the gathering and analyzing empirical data and the mobility, built-in sensors, and computing power of smartphones provides the key ingredients for creating a powerful data collection tool. In this article we offer a few examples and suggestions for smartphones as real time, data collection and analysis instruments in science education.



Current smartphones have accelerometers to correctly orient the screen display. Figure 1 details data collected while taking off in an airplane using a free app [software application] that we wrote[2] to read the internal accelerometer, and display or send the data in spreadsheet form to an email address.

Figure 1. While taxiing down the runway the acceleration is close to the expected 9.8 m/s^2. On takeoff the acceleration rises to 1.3g for about 125 seconds before beginning to taper off back to 9.8 m/s^2.

While collecting data on an airplane illustrates the mobility of the smartphone, a student laboratory acceleration exercise need not be as dramatic. Common lab experiments such as circular acceleration are possible by tying the phone to a string and swinging it in a circle or securing it to a bicycle wheel as well as the measurement of linear accelerations from bicycles and elevators. Acceleration due to gravity can be determined by just dropping the phone[3].

Significantly, smartphones have the computing capacity to perform complex data analyses such as the Fast Fourier Transform (FFT) of sound arriving at the phone's microphone. We originally wrote such an FFT app for a Nokia phone in 2008[4]. Figure 2 shows a screen shot from a more up-to-date iPhone app[5] of the FFT of a triangle wave of 750 Hz.

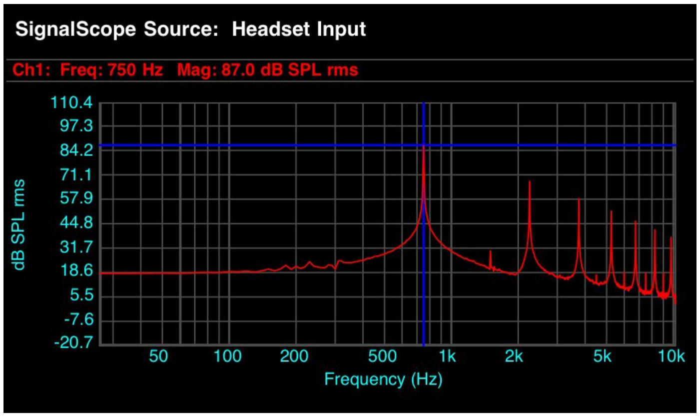


Figure 2.

Plugging an oscilloscope probe, offered by the German company HMB-TEC[6], into the headphone and downloading software available from several sources[7], turns an iPhone or iPod into an oscilloscope. Cellphone oscilloscopes are more limited than laboratory models but are also mobile and far cheaper[8].

The American Physical Society has recently made a spectrometer app available for the iPhone[9]. After building a spectrometer using a grating from a pair of cardboard toy glasses costing less than a dollar and black construction paper students can use the app to capture and analyze spectrums from various light sources and compare them to known sources. Figure 3 shows a screen shot of the spectrum of a compact florescent lamp.

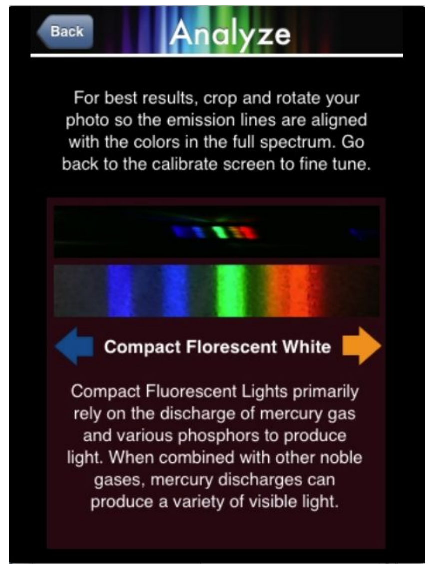


Figure 3. The top spectrum was collected by the app from a real lamp, the lower spectrum is included in the app for comparison purposes.

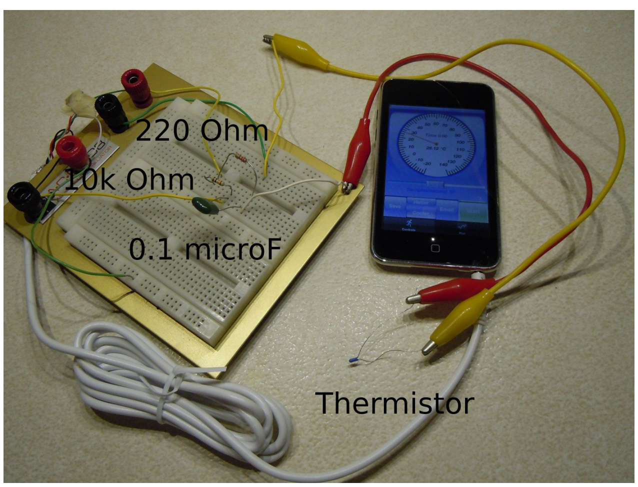


Figure 4. Measuring temperature using an external circuit and an iPod.

Data collection is not limited only to the phone's internal sensors. Most offer USB and Bluetooth connections to local external devices. All have a headphone port for connecting an external microphone and speakers, providing a connection to external equipment in much the same way as the game port on the early Apple II computer was first used in school labs to take data from external experiments.

Using our free temperature app[10] and the external circuit shown Figure 4 a student can measure temperature changes, plot or email the results to a computer to be further analyzed. The headphone volume control serves to calibrate for individual circuit differences. Details are given in Reference 11. Advantages the phone thermometer shares with other potential phone data collection scenarios are mobility and the ability to collect data changing over an extended period of hours or days.

The same thermistor circuit and app can also be used with other measurement sensors that have similar resistance change characteristics. Ambient light levels can be measured by replacing the thermistor with a light activated photo resistor. Some water vapor sensors act as variable resistors that are sensitive to humidity. Strain gauges used in force probes and elsewhere, change resistance when subjected to stress. Basically, the circuit, headphone port and app turn a phone into a measurement tool that can be used for a wide range of experiments with a variety of sensors[12].

Although most of the above examples are for an iPhone, iPad or iPod the concepts are applicable to nearly all smartphones, including Android based phones. Data collection with mobile devices, both from internal sensors and external circuits offer remarkable opportunities for creative new science experiments. Although not every student in every classroom can afford a smartphone at present, all phones will likely be smartphones in the near future. Even now, while prices are dropping, a few students, their teacher or parent could share one to provide new and unique laboratory experiences. Using a smartphone as an instrument for data collection will bring empirical science to a higher level for many students both in a laboratory setting and outside the classroom.

1. Reported in *Wired* magazine, Feb. 22, 2013; http://www.wired.com/gadgetlab/2013/02/nokia-low-end/
2. K. Forinash, R. Wisman, 'Mobile Science – Acceleration', Apple App Store; (https://itunes.apple.com/us/app/mobile-science-acceleration/id389821809?mt=8).
3. P. Vogt, and J. Kuhn, "Experiments Analyzing Free-Fall with a Smartphone Acceleration Sensor," *Physics Teacher* Sept. Vol. 49, 6, (2011) pp. 383.
4. R. Wisman, K. Forinash; 'Science in Your Pocket', *International Journal on Hands-on Science* (IJHSCI) Vol. 1, No. 1, September (2008) p7-15.
5. SignalScope by Farber Acoustical; (http://www.faberacoustical.com/products/iphone/signalscope_pro/).
6. HMB-TEC; http://hmb-tec.de/iPhoneApps/iPhone_Apps.html .
7. We tested: SignalScope, (http://www.faberacoustical.com/products/iphone/signalscope_pro/; AudioScope (http://www.hensleyindustriesllc.com/iphone/audioscope/audioscope.html); and oScope (http://itunes.apple.com/us/app/oscope/id344345859?mt=8).
8. R. Wisman and K. Forinash, 'Smartphones as portable oscilloscopes for physics labs', *The Physics Teacher*, Vol. 50 No. 4 (2012) p242.
9. SpectraSnapp, Apple App Store; (https://itunes.apple.com/us/app/id582838193?mt=8&ign-mpt=uo%3D4).
10. K. Forinash, R. Wisman, 'Mobile Science – Temperature' , Apple App Store; (http://itunes.apple.com/us/app/mobile-science-temperature/id467423322?mt=8). Source code is available to modify for sensors that do not have an exponential response.
11. K. Forinash and R. Wisman, 'Smartphones- Experiments with an External Thermistor Circuit', *The Physics Teacher*, Vol. 50 No. 9 (2012) p566.
12. A list of sensors and how they function can be found at: http://www.sensorland.com/ .