My Favorite Cell Phone Experiments

Most of our students carry cell phones with them, either in their purses or backpacks. Since the cell phone is a central feature in the lives of our students, in this paper we will look at ways in which the cell phone can be used to arouse the mathematical and scientific curiosity of students.

Activity #1: The cell phone lights up
My cell phone has a display on the front that lights up when I get a call or press a button on the side. But exactly how does it light up? I taped a light intensity sensor to the display and collected data as the display started to light up. The setup is shown in Figure 1. The Fourier light intensity sensor is taped to the cell phone and connected to the HP StreamSmart 400 data streamer. The HP StreamSmart 400 is in turn connected to the HP 39gs graphing calculator, which is used to display and analyze the incoming data.

![Figure 1: The setup for Activity #1](image_url)
To start the experiment, launch the StreamSmart Aplet. The sensor is automatically identified and data starts streaming in, as in Figure 2. I then press the button on the side of the cell phone and see the slight rise in the light intensity register in the stream. I press the STOP menu key to stop the stream (see Figure 3).

The change in light intensity does not look particularly interesting and it is a good time to ask the students whether they think the light intensity increases at a constant rate, an increasing rate, or a decreasing rate. How do LED’s light up and how long does it take them to turn on fully?

To see more detail, I trace to a point in the area of interest and zoom in. Figure 4 shows the data after zooming in 100x (Figure 3 shows the time interval as 5 sec and Figure 4 shows approximately 0.05 sec). In Figure 5, we have zoomed in all the way (the display represents 1/40th of a second’s worth of data) and scrolled to get the best view of our data.

I set a mark at the data point before the first positive change in light intensity (2.128s, 3.017lx) and another at the first point that showed the maximum intensity (2.134s, 54.64lx), as in Figure 6. These results indicate that the light intensity increased a total of 51.62 lux in 0.006 seconds. That is less than 1/150th of a second! To us, the display just comes on instantly; that is, we do not perceive the display growing brighter.

But how does this change in light intensity occur? When I first did this experiment, I did not know what to expect – I was just curious. I do not know enough about electronics to know what to expect in advance; I just figured that whatever happened, there would some good opportunities to discuss both science and mathematics.

I cropped off the unwanted data (Figure 7) and went for a closer look.
Figure 8 shows the scatter plot of light intensity vs. time, while Figure 9 shows the data in a table. The last column shows the delta in light intensity from reading to reading.

From here, I would expect to compare LED, incandescent, and florescent lights to see how they compare. All 3 types of lights have both a minimum and maximum light intensity that correspond to starting and ending states, so a logistic function makes sense for a mathematical model. I would expect the incandescent light to take longer and have a scatter plot that resembles a logistic function the best (smoothest). The LED is probably the quickest, with florescent somewhere in the middle.

I ran the experiment again and kept more of the tail-end of the data and asked the HP 39gs for a logistic fit, shown in Figure 10 below. I subtracted a constant from all the time values so that the first data point had time $t=0$. The relative error of the fit is 0.0023541.
Activity #2: The cell phone rings

I placed a microphone next to the speaker on my cell phone and chose a fairly monotonic ring tone. I played the ring tone and captured the data using the StreamSmart 400 and my HP 39gs graphing calculator. I captured less than a second’s worth of data (Figure 11). I zoomed in all the way on a portion of the data and decided to estimate the frequency of the sound. Since the HP 39gs can play a beep at a given frequency, I will be able to compare my estimate of the frequency with the true frequency of my ringtone by playing a beep with the estimated frequency.

I chose a set of the waves and set a mark at the top of the first wave. I then traced to the top of the next wave and saw the change in time was ~0.002 seconds (Figure 13). I then traced to the top of the fifth wave out and found the time for each wave was fairly regular (Figure 14). From this, I inferred that the frequency of the waves was near $1/0.002$ or 500 Hz.

Finally, I sent a sample of four of the waves to the Statistics Aplet and performed a sinusoidal fit (Figure 15). I examined the fit and found it to be approximately $y = 0.16\sin(3161.89x + 96.04) - 0.05$. Since $\frac{3161.89}{2\pi} \approx 503$, I had confirmation of my estimate of the frequency. Using my HP 39gs, I entered the command BEEP 503; 1 to hear it play a note at 503 Hz for 1 second and found the tone (to my own ears) to be quite similar to the ringtone.
Activity #3: The cell phone has a battery

I taped a magnetic field sensor to the back of my cell phone and called it from another phone. I cannot say I dialed the number anymore, can I? Figure 16 shows the result. I was surprised to see the spike because it led the first ring by at least a second. Without even knowing what it meant, I was intrigued by the shape of the spike.

I zoomed in on the spike to see Figure 17. There seems to be an exponential drop, followed by a logarithmic recovery. I may not know why it is so, but I know I can expect my students to make conjectures about:

- Why the change in the magnetic field surrounding the cell phone changes exponentially at a point near the phone when it is called
- Why the change and recovery from that change might have the sort of symmetry shown
- The relative strength of the EMR from a cell phone and the consequences for any health concerns related to cell phone use

In the cell phone activities presented here, the author was certainly no expert in the phenomena under scrutiny. In fact, it was only the ringtone experiment that represented familiar territory. The point of the paper was more to encourage teachers to use technology to challenge themselves as well as their students to examine the everyday world around them and to use both scientific inquiry and mathematical models to make some sense of what they observe. In this way, we may encourage the curiosity of our students and they may continue both their scientific and mathematical journeys with a sense of wonder as well as a discipline!