Mapping Electric Potentials using IOLab

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As a prequel, watch this brief video.

The version described below expands upon a very similar activity by Mats Selen called equipotential_v2.pdf, for which there is a one-minute video intro

(I) Overview:

Simple 2D geometry: almost rectangular, although not exactly.

Measure V (volts) *vs.* x (m): slope gives the x-component of Electric field, E_x

Measure V (volts) *vs.* y (m) : slope gives the y-component of Electric field, E_y

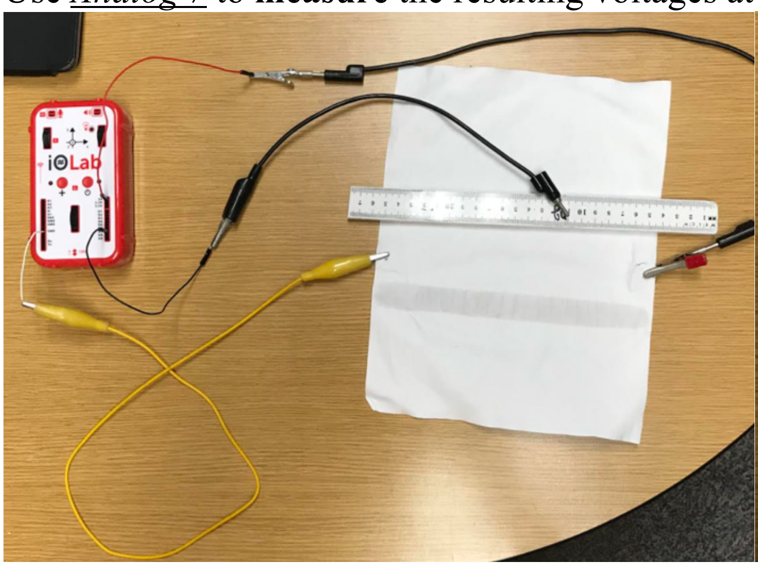
Show that: $E_x >> E_y$

(II) What you'll need:

Wet paper, a few wires, paper clips/alligator clips (improvise)

On the IOLab device: use either *Gnd &* V_0 *(3.0 volts DC)* OR *Gnd & 3.3 volts DC* to **power** the paper-circuit.

Use *Analog 7* to **measure** the resulting voltages at different points on the paper.



Note for TA/Instructor: when ***not connected*** *to anything Analog 7 (or any other analog input on the IOLab device) will drift until saturating at a level between 1.4 and 1.5 V, as is typical of a "floating TTL input." Students can safely ignore that behavior, as they should only* ***record*** *data. when the device when the measurement inputs are properly connected. (As shown below, it is possible to obtain cleaner results with the addition of a "pull-up resistor.")*

(III): Typical Results:

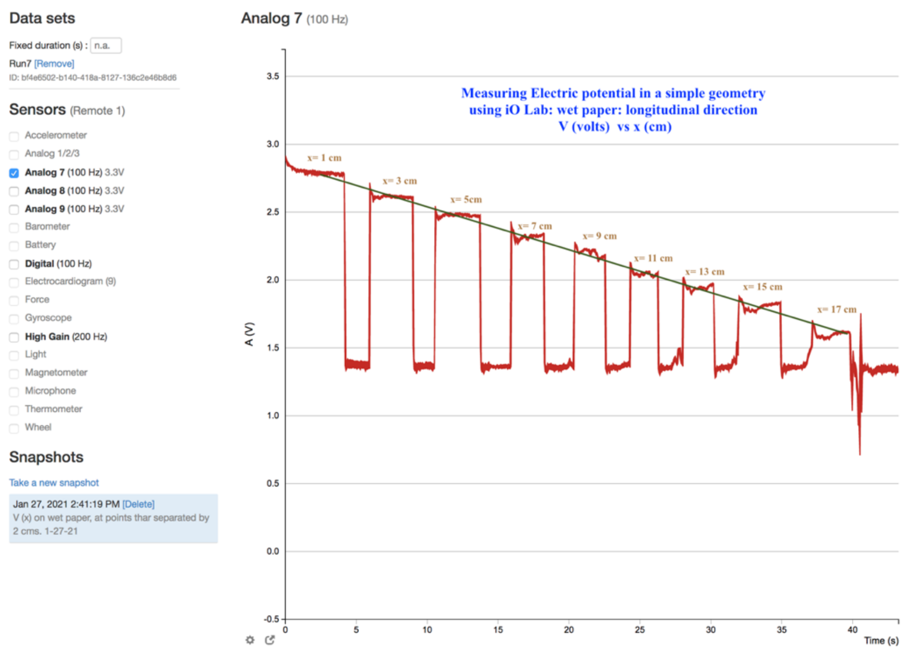


Fig 1: $V(x)$ for various x positions, for a fixed y position.

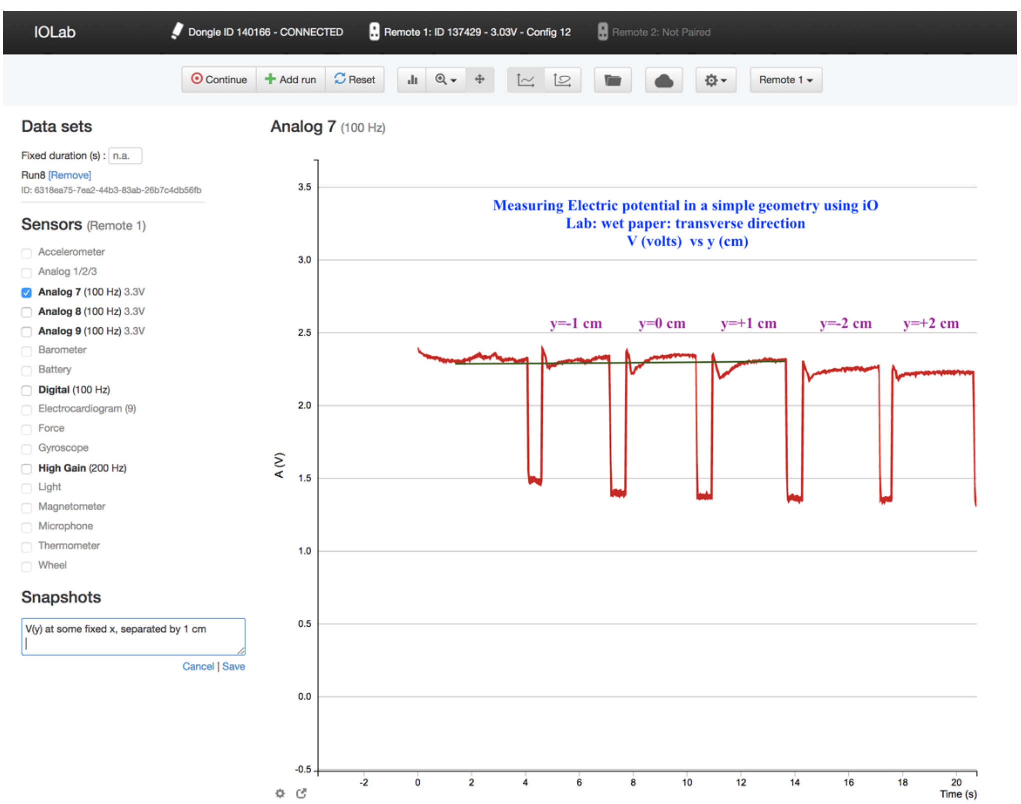
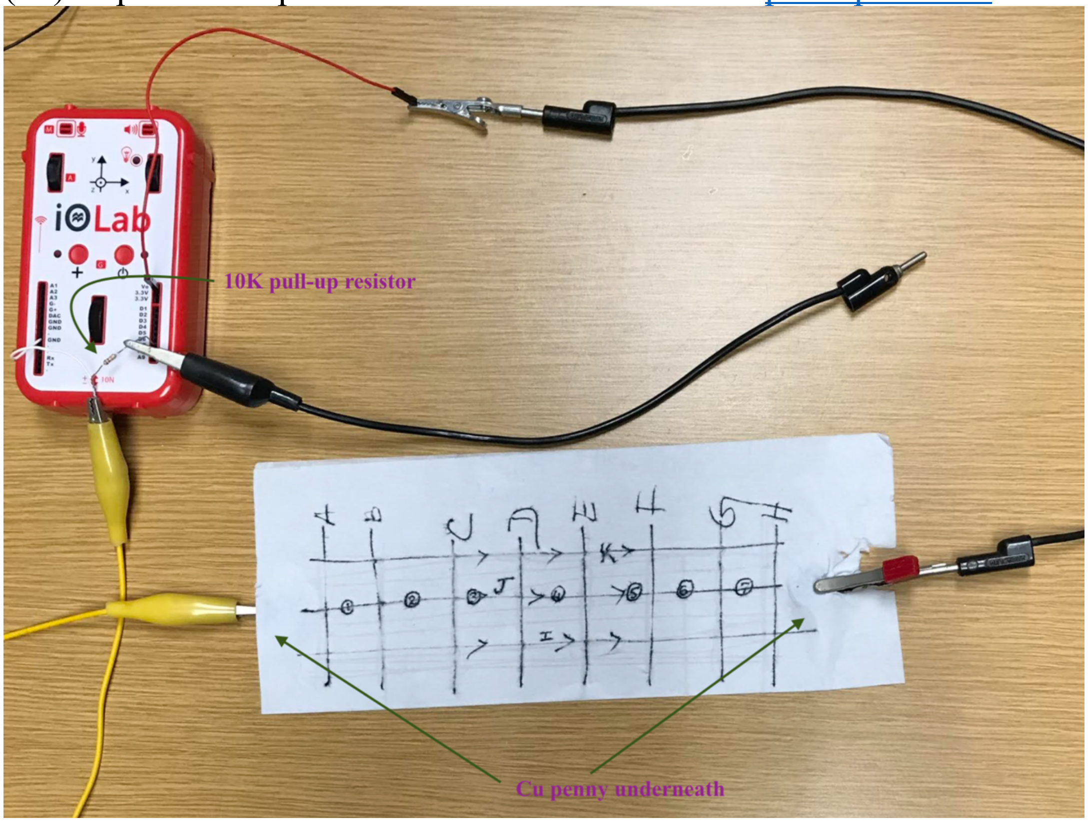


Fig 2: $V(y)$ for various values of y position, for a fixed x position.

(III) Repeat the experiment with the addition of a "pull-up resistor:"



As shown above, connect a resistor between ***Analog 7*** and ***Ground***

- If you don't use any pull-up resistor, your readings will drift towards a number between 1.4 V and 1.5 V whenever your probe is "dangling." (See Fig 1 and 2). You will have to ignore that "dangling" value.
- With an added 10KΩ resistor, the voltage is no longer "dangling," but is fixed to zero (which is nice), but each time you lift the probe and connect it to the paper, you see a time-dependent effect (see fig 3 and 4), because of capacitive effects. The particular value of the resistor added will affect how quickly (or slowly) the system reaches a stable result.
- "Contact Resistance" affects how much of the applied voltage drops across the **contact point** itself, but does NOT affect the *shape* of the $V(x)$ or the $V(y)$ graphs. – To provide an improved contact to the paper, you can use a copper penny on each side, beneath the wet paper. (By the way, leaving a penny in a drop of orange juice will remove the oxide.) I tried with the alligator clip connected to the penny (left), or connected to both penny and paper (right.) Either way seemed to work reasonably well. (I had also tried paper clips, which *could* work, but I found them to provide *unstable* contacts and they ripped the wet paper far too readily. – I also tried crimping some metal foil onto the edge of the paper, which worked.)

- For Fig. 3 (below), I labelled (on the paper) some transverse traces A-H, some longitudinal traces (I-K) along which I simply dragged the probe and measured the voltage (via the wire connected to Analog 7). For Fig. 4, I measured the voltage more carefully at a set of points labelled 1-7, to verify the *linear* dependence of $V(x)$

IV) Results from second attempt:

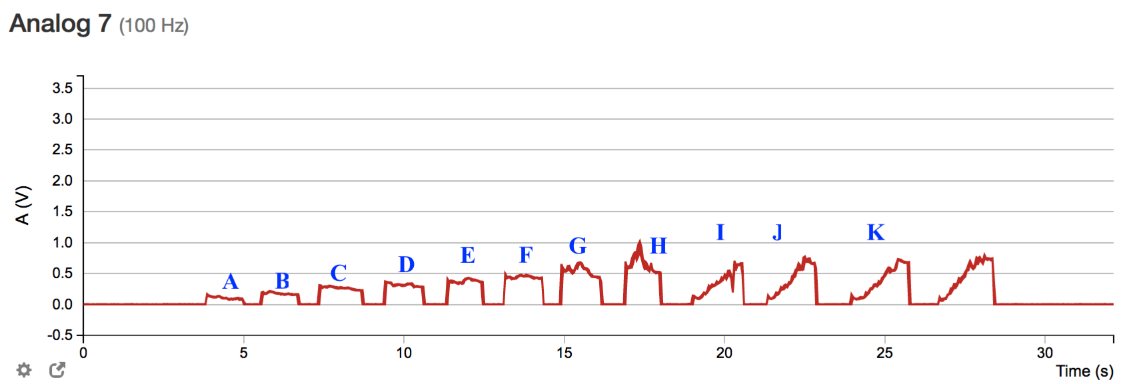


Fig 3: $V(y)$ "traces" for different values of x (traces A,B,C,D,E,F,G,H): all are almost flat. Also shown: $V(x)$ "traces" for a few values of y (traces I,J,K): those are all linear ramps

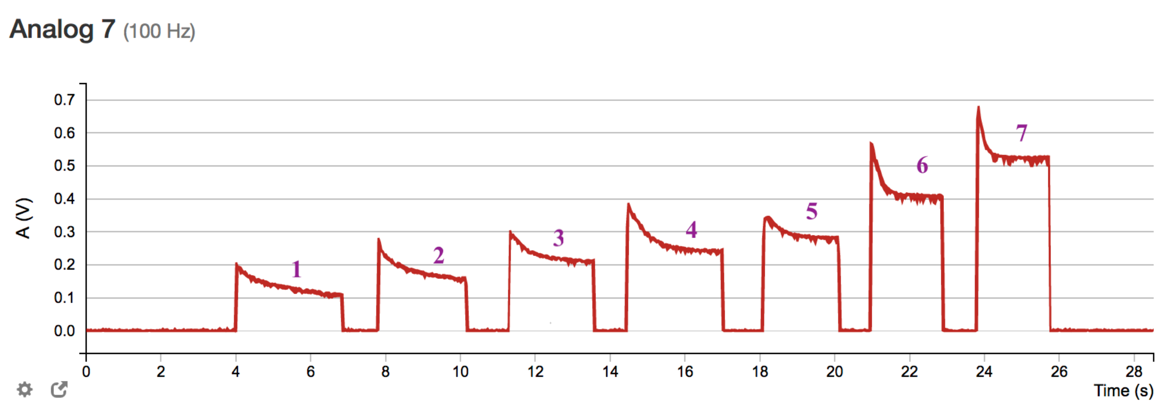


Fig 4: $V(x)$ measured at points 1-7.

Initiative: (a) One can use ***wider*** contacts. (b) If you've had trouble using damp paper, you can try instead using an insulating plate and some salted water, as is described in the original brief video you watched before beginning. (c) Explore other electrode geometries.

(V) **Grading Rubric** (Total 20 points):
10 points: Get it to work and get data. Include initiative.
4 points: Plot V *vs*. x, for fixed y. Is it approximately linear? Extract E_x.
2 points: Plot V *vs*. y for fixed x. Is it approximately linear? Extract E_y.
1 point: Why do you think we choose the convention that the electric field points in the direction of *decreasing* V?
1 point: E_x seems almost the same all along x. (Except near the contacts.) Does that seem reasonable? Why?
1 point: E_y seems to be almost zero in the middle. Does that seem reasonable? Why?
1 point: E_y becomes non-zero if you move too far outside the "channel." Does that seem reasonable? Why?