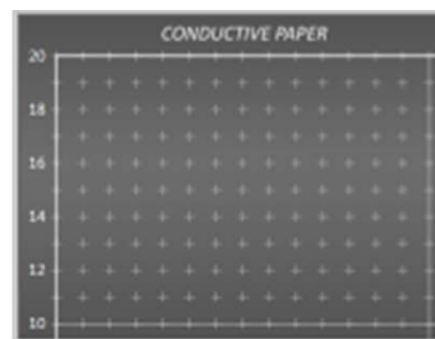**The conductive paper.** This special paper has been coated with a black pigment made of carbon black particles which allows it to be conductive. When electrodes are added, a voltage flows between them through the paper. Tools in this lab will allow the user to draw equipotential lines and electric field lines on this paper. Specifications: 20cm x 28cm.

The Model 359 Power Supply. In the upper right corner of the screen is the power supply. This always-on power supply can be adjusted with two rotating knobs labeled Coarse and Fine. Click and drag a knob clockwise to increase voltage or counterclockwise to decrease voltage. The Coarse knob changes the voltage faster and less accurately than the Fine knob.
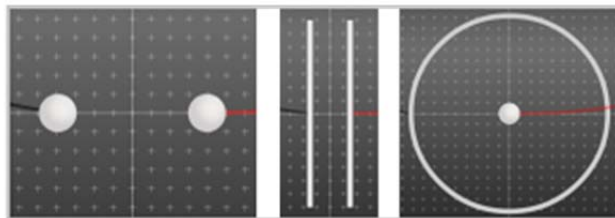

The voltmeter. In order to read voltages on the conductive paper, one must use a voltmeter. The negative input of the voltmeter is permanently attached to the negative terminal of the power supply, making zero volts the frame of reference. The red, positive input probe starts out on the left side of the screen. This can be moved by clicking on the probe itself, the crosshair at the end of the wire. If there are electrodes in place, and a voltage from the power supply, the voltmeter should read a voltage as the probe is moved around on the paper.

The probe can also be moved using the arrow keys on the keyboard. The up, down, left, or right keys will move the probe slowly, while Shift+Up, Shift+Down, Shift+Right, or Shift+Left will move the probe more quickly. To add a marker on the paper where the probe is resting, either hit the "M" key on your keyboard or right-click the probe and select "Add Marker."

The electrodes. Four electrode setups are available for experimentation in this lab, and can be chosen from the drop-down menu that begins with "Dipole." Click this menu to choose between a dipole setup, a ring setup, a parallel plate setup, and a shielded setup. The horizontal position of the dipole and parallel plate electrodes can be adjusted by clicking and dragging on an electrode left or right. The ring electrode and shielded setups cannot be changed.
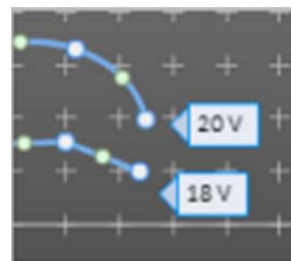

Equipotential markers and lines. Blue equipotential markers can be placed anywhere on the paper while using the voltmeter probe. Either hit the "M" key or right-click the probe and select "Add Marker" to drop a blue dot under the probe onto the paper. *Once placed, markers cannot be moved* but they can be deleted by right-clicking the marker and selecting "Delete Marker."

To draw an equipotential line, <u>click and drag on a marker and release the mouse on a different marker</u>. Once a line is drawn, it can be adjusted by clicking and dragging the newly formed control point that is on the middle of the new line. Clicking and dragging this control point will allow for various curves to be drawn on the paper. Similarly, to remove the new equipotential line or curve, right click the control point and select "Clear this Line."
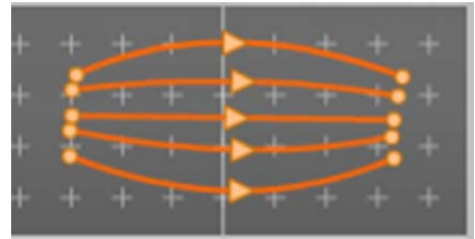

The equipotential labels. For many experiments, several different equipotential lines, bunched tightly together, will be drawn for different voltages. To keep track of which lines correspond to which voltages, labels can be added to the paper by right-clicking on any marker and selecting "Add Label." Once added, the user can click on the label text and modify it to meet their needs. These can also be moved anywhere on the paper by clicking and dragging on the arrow on the left of the label. To delete, right-click on the label and select "Delete Label."

The electric field lines. Clicking and dragging directly on the paper will draw orange electric field lines. These work very similarly to the equipotential lines, except that once drawn the ends can be moved by clicking and dragging. The curvature can be adjusted by clicking and dragging on the control arrow in the middle of the line.
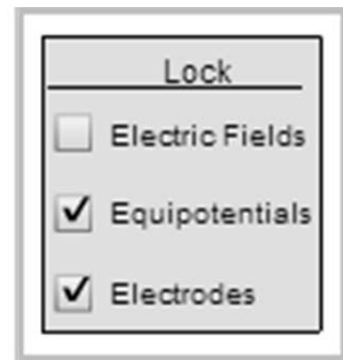
Right-clicking on either end or on the control arrow will give the options for "Reverse Direction" and "Reverse Direction (all)." These options will reverse the direction that the arrow is pointing. The first option only applies to the curve that was clicked, while the second option will flip all arrows on all electric field lines on the screen. Right-clicking also shows a third option, which is to "Clear this Field Line."
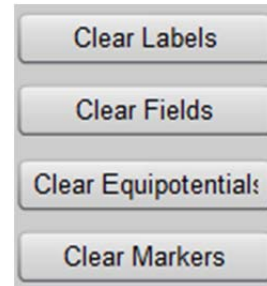
The stations. To allow for multiple electrode configurations at once, there are 5 different experiment stations in this lab. Each station is unique and can be changed however the user sees fit, and will remain unchanged as other stations are modified. Switch between stations by using the Station drop down menu just to the right of the electrode menu.

The locks. To help with overlapping lines and markers, the user has the option to lock the Electric Field markers and lines, the Equipotential markers and lines, and the electrodes. All this means is that when any of these objects are locked, the ability to move them with the mouse is disabled, and any control points are no longer visible. This not only helps simplify the look of many side-by-side lines, but also prevents any stray mouse clicks from moving an object that the user may want to stay in place. All of these locks are on the bottom left of the screen.

Clear. There are 4 buttons on the bottom left of the screen that allow for quick clearance of various components on the screen. These only clear the objects in the active station.	Clear Labels Clear Fields Clear Equipotentials Clear Markers
The ruler. Should the user need to make a distance measurement, a ruler is available by clicking the Ruler checkbox on the left of the screen. Once visible, the ruler can be moved by clicking and dragging near the 5 cm side, or rotated by clicking and dragging on the 20 cm side.	☑ Ruler
Snapshot. As with most of our labs, you can take a screenshot of any portion of the screen by clicking on the Snapshot icon and then clicking and dragging a box around what you want to capture. A dialog will then appear asking you what you want to call the image and where you want to save it. In most labs, a timestamp will be added to the image to keep track of it better.	