Mapping the Electric Field

In this lab, we map the electric field by tracing lines of constant voltage on conductive paper. Using this technique, we can map the electric field near charged and uncharged conductors and uncharged insulators.

I. Step One: the maps

We need to trace the shapes of our conductors in conductive ink. Although the paper is also conductive, the ink is far more conductive and represents near perfect conductors. An insulator is made by cutting out a hole in the paper (although in real life charge can be put on insulators, we cannot reproduce this – the hole will be an uncharged insulator). I have nine sample patterns. Near each conductor (the silver ink spots) is a (+) or (–) sign or a circled zero (0) to indicate if it is to be hooked up to the red (positive) or black (negative) side of the power supply, or if it is not to be connected at all (the zero). You need to make *three* new maps. It is important to do so immediately because they take 20 minuets to dry thoroughly. If you make all three of yours quickly (which is totally possible) you can take one of mine and begin the experiment – simply replace mine with one of yours. Write the *time of completion* on it so that other groups will know if it is dry yet.

Notes on using the pens:

The pens are non-trivial to use. Sorry. Place your paper on a hard surface. Use pens only in well ventilated places; outdoors is ideal. Shake pen vigorously. Grip pen firmly near the center of the pens length – gripping with both hands may be necessary. You're squeezing the ink out and since it is liquid metal, it is highly reticent to flow.

Interesting ideas for shapes to ink onto your paper will be discussed in class. Two parallel lines and two circles are two good, simple, places to start. Note you must have *at least one negative and one positive shape*, but you can have as many as you want!

II. Step Two: the circuit

You have one DC power supply and one Multimeter.

1. Turn on DC power supply adjust voltage to just under 15 volts (say, 13 or 14 is fine). Leave this alone for the rest of the lab.
2. Connect the [COM] on the Multimeter to the negative or black terminal of the power supply. You may use an alligator clip or a banana clip.
3. Point the central rotating knob on the multimeter to the 20 V scale.
4. Turn DC mode on the multimeter.
5. Turn on Multimeter.
6. Plug the red probe into the red Voltage (V) hole on the Multimeter. The probe has one banana end and one pointy end (the probe itself).
7. Place your paper on the corkboard and pin it at the corners. Place one pin into each ink shape on the image.
8. Connect all the shapes marked negative (–) to the negative (or black) terminal of the power supply using alligator clips.
9. Similarly, connect all the shapes marked positive (+) to the positive (or red) terminal of the power supply using alligator clips.

10. Touch red probe to each of your negative pins (you must have at least one negative and one positive) and the voltmeter should read zero.
11. Touch red probe to each positive pin and the meter should read the total voltage (near 20 volts). All should be alike, and should not fluctuate.
12. If either of the two above steps fail, check with the instructor!

III. Step Three: tracing equipotentials.

This should be really easy. Stick the probe onto the paper (don't push through paper!) and it will read a voltage. Pick a series of voltages (say: 5, 10 and 15, for example, you can do more if you like) and *trace lines* of equal potential. Label each curve with the voltage and use *one color for all*. Don't be too concerned about precision; just get it to within, say, ±1 volt. This is just a sketch! Don't be a perfectionist! (You know who you are! I was thinking specifically of you when I wrote this, darn it!) We don't have time.

Note: if you have multiple positive or negative shapes on your paper, you may have disconnected regions of constant voltage (15 volts may circle near each of your two positive circles, for example, if they aren't too close together).

IV. Step Four: constructing the Electric Field Lines

The electric field lines start from your positive shapes and terminate into negative shapes (see why you have to have both?) Further, they intersect the equipotential lines at right angles.

If possible, use a *different color* for your electric field lines. Unlike equipotentials, there is no number (no voltatge) associated with these lines! Put *arrows* →↑↓←on the electric field lines to indicate they point from positive to negative. True electric field lines do not cross one another. If you *think* you have crossing field lines, ask.

Pick a point on the outer edge of one of your positive shapes. One electric field line will begin here. Head toward the nearest 15 V line (or whatever your highest is) and smack into it at a right angle (perpendicular). Head from there to the next lowest, and so on. Try to make these curves smooth – real electric field lines are smooth.

Some of your electric field lines will head off the page, which is fine. Only those which initially sort of "point toward" a negative object will reach one.

V. A Really Weird Analogy: (don't worry you don't have to do anything but read this section. I promise.)

Both the electric field and smoothly flowing fluid obey the same equation (called Laplace's equation). One can think of the positive shapes as sources of water, negative shapes as sinks (places where the water disappears, e.g. like a drain). The electric field lines are the lines the water would follow. All the water starts at a source and eventually goes down one of the sinks (drains). Some bits of water go sort of straight from one to the other, some wander around and head off a long ways first.