

PHYSICS LAB, WEEKS 3 AND 4: ELECTRIC FIELD LINES

In this lab we will examine the equipotential lines and electric field lines for some conductor configurations in two dimensions.

Objectives:

- 1) To understand how contour lines of equal voltage, which are quite easily measured, relate to the electric field produced by electrical charges.
- 2) To understand how electric field line maps show us where electric fields are strong or weak.
- 3) To draw some electric field lines from the experimental data.

The basic technique is to use silver ink to draw conducting surfaces on conductive paper, hook up a voltage source to the conducting surfaces, and then measure the voltage at various points on the paper. Review sections 18.6 and 18.7 of the Physics textbook.

The concept of the electric field is useful in determining the force on a charged object due to the presence of other charges. The purpose of this laboratory is to use a voltmeter to map out, but only in two dimensions, a set of equipotential lines for different charge distributions using a voltmeter. An equipotential line connects the set of points for which the potential difference or voltage is a constant value. The two-dimensional charge distributions will be set up by applying a potential difference to a pair of conductors placed in contact with conducting paper. From these equipotential lines the electric field can be determined. Electric field lines ALWAYS cross equipotential lines perpendicularly based on the definition of electric potential. Also electric field lines by convention start on positive charges and end on negative charges.

This lab is based on several theoretical principles:

- 1) The electric field inside a conductor is everywhere zero. If it were not, free electrons inside the conductor would feel this field and flow in such a way as to reduce it, soon to zero.
- 2) The potential is the same everywhere inside a conductor. This follows immediately from 1.
- 3) A point where the electric field is not zero has a variable potential around it. The potential increases going out in some direction and decreases in others. The boundary between regions of increasing and decreasing potential will be a curve along which the potential neither increases nor decreases. Such a curve is called an equipotential line. Electric field lines are everywhere perpendicular to equipotential lines. This is easy to see since no work is done on moving at constant potential. Hence, there may be no component of the electric field in the direction of equipotential lines. Electric field lines run in the direction of decreasing potential “downhill.”

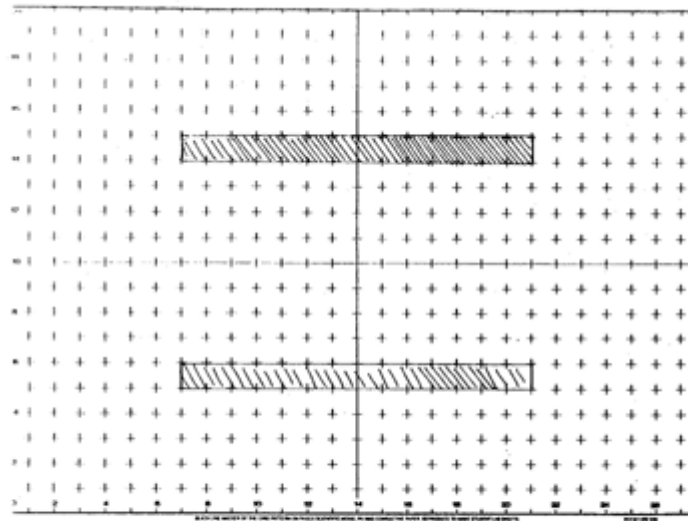
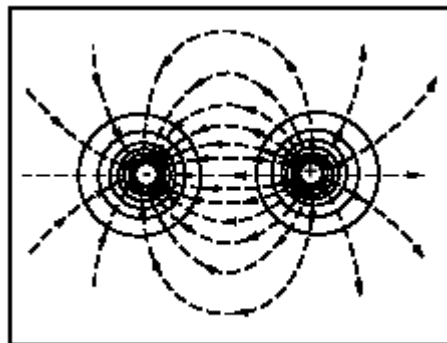


Fig. 1 Parallel Plates



Equipotential and Field Lines

Fig 2. Electric dipole

Distributions of potential and electric fields around complicated charged objects can be difficult to calculate. It is possible to get a good visual representation by making an experimental potential field "plot" around a model of the distribution drawn on conducting paper. We will do this for four situations:

- a) an electric dipole (see figure above)
- b) three point charges
- c) a point and a line
- d) a thunderstorm (cloud over the city or a pair of parallel plates, as a capacitor)

The four situations must be "painted" onto the conducting paper before you start and it takes 20 minutes or so for the paint to dry. So as a preliminary step you should either

prepare the drawings or at least make sure that the kit on your bench contains drawings which are good enough to use.

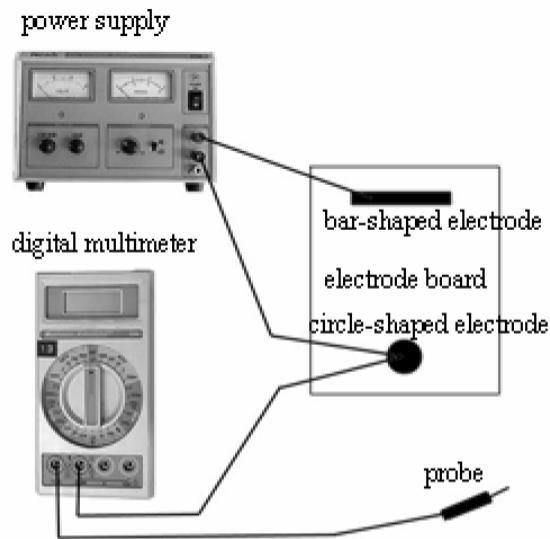


Fig 3. Plotter arrangement

Once the paint is dry, place the conductive paper on a corkboard. Hook up the electrodes using magnets to keep them in place. See Fig. 3.

Apply a voltage of 2 – 10 V to the electrodes. This configuration will simulate the electric field between a positive charge and a negative charge of equal magnitude on each electrode.

Begin mapping your equipotential field lines close to the negative terminal in intervals of 0.5 volt. Using the probe find a point on the conducting paper that gives a voltage of 0.50 ± 0.01 V. Record this point on the grid paper. Now move the probe 1-2 cm away from the point you just located and search for another point or points on the conducting paper giving a reading of 0.50 ± 0.01 V. Continue this process until you reach the edge of the conducting paper or you run into points already located. A suggestion is to use small x's as plot symbols for all these 0.50 V points on the grid paper. Now connect these points with a smooth line (Don't just connect the dots with straight line segments!), and label this line as 0.50 V.

CAUTION: PLEASE DON'T MARK WITH PENCIL OR PENS ON THE CONDUCTIVE PAPER OR POKE HOLES IN IT WITH THE POINTED PROBE.

Repeat the process outlined above for points with a voltage of 1.00 ± 0.01 V. A suggestion is to use small o's as plot symbols this time. (Alternating the plot symbols will distinguish more clearly between the various lines of equal

potential or voltage.) Continue repeating this process for the other voltage values.

Since the equipotential field lines are perpendicular to the electric field lines, draw in the electric field line using a different marker or chalk.

Questions to consider:

- a) Can electric field lines cross? Explain.
- b) Would the maps look different if you use different voltages? Explain.
- c) For the different configurations: Where is the magnitude of the electric field the strongest? The weakest? Explain your reasoning.
- d) What happens to the electric field at the edge of the plate region (at the fringes)?