# Equipotentials
**And**
# Electric Field Lines

## Equipment Needed

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|---|---|
| Battery Eliminator | Digital Multi-Meter |
| Conductor Plates | Lead, Red Banana Jack (3-4) |
| Conductor Probes (4) | Paper, Graph Laminated |
| Cup, Plastic Measuring | Water Tank |

## Introduction

In this lab we will investigate the field lines of a two-dimensional 'parallel plate capacitor.'

We know that the average field between two points separated a distance $\Delta x$ is given by $E_{ave} = \Delta V / \Delta x$ (Equation 1), where $\Delta V$ is the potential difference between the two points. Thus by measuring the distance separating and the potential difference between two points, we can determine the magnitude of the average field. The electric field, however, is a vector quantity, so to completely specify it we must also give the direction. To accomplish this, we first note that the average field between any two points where the potential difference is zero is also zero. An equipotential surface is a surface along which the potential is the same everywhere, and consequently the potential difference between any two points is zero. Thus between any two points on an equipotential surface, the average electric field strength is zero. We define the direction of the average electric field as that in which the potential is changing most rapidly. This direction, it turns out, will always be perpendicular to the equipotential surfaces. Also, the field lines run from a region of higher potential to a region of lower potential. In this lab we will determine the electric field by finding equipotential surfaces. The magnitude of the field will be determined by finding the potential difference between the equipotential surfaces, and the direction of the electric field will be obtained by determining the direction perpendicular to the equipotential surfaces.

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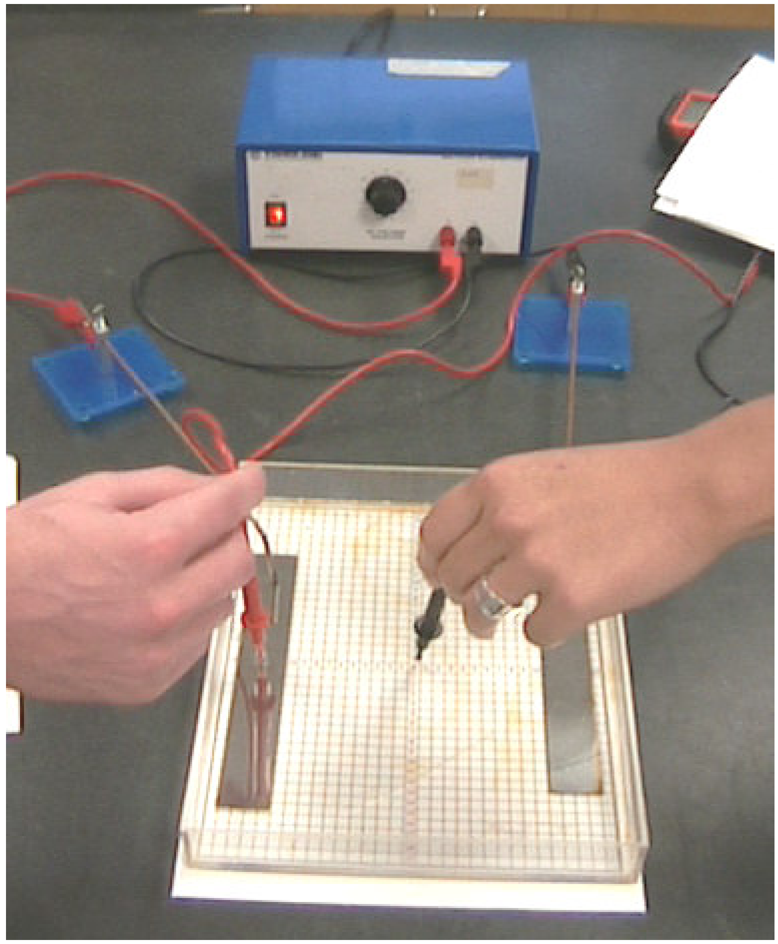
## Typical Setup



To accomplish our goal we will make use of an important property of conductors, namely that a good conductor in electrostatic equilibrium is always an equipotential surface. We can understand this from several points of view. First, we know that the electric field inside a conductor is zero. If we calculate the potential difference between any two points in a conductor using $\Delta V = E_{ave}\Delta x$ (Equation 2), we obtain $\Delta V = 0$ and $\Delta x = 0$. Second, we can understand this physically, since whenever there is a potential difference between two points, work can be done to move a charge. If a potential difference exists inside a conductor, then the charge will move in response to it until the potential difference disappears.

## Procedure

The apparatus for this lab is sketched in Figure 1. It consists of a plastic dish, four probes, several stainless steel metal strips, graph paper, a power supply (battery eliminator), and a digital multimeter. The digital multimeter is an inexpensive and versatile instrument, which can be used to measure resistance, AC and DC current, and AC and DC potential differences.

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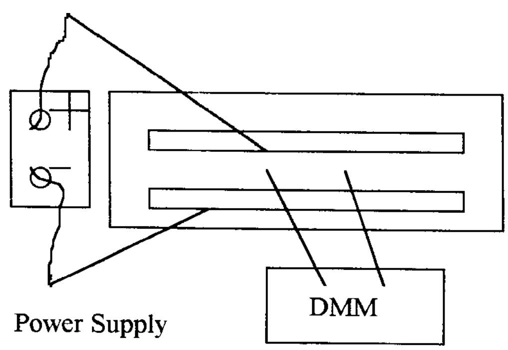
1. Set up the apparatus

To set up the experiment, first determine and record the spacing between the grids on the laminated sheet of graph paper. Next, place the laminated sheet graph paper underneath the dish so that the grid lines run parallel to the edges of the dish. Place the stainless strips with their long edges parallel to the long edges of the dish, so that the *inner edges* of the strips are aligned along grid lines <u>that are separated by 20 grid lines</u>. Place the tip of two of the probes on each of the conductors. Fill the dish with water until the conductors are just covered by the water. Using the provided alligator clips, connect the (+) terminal of the power supply to one of the probes and the (–) terminal to the other probe. It is customary to use a red wire for the connection to the positive side, and the black wire for the connection to the negative side.

**Figure 1** Schematic of experimental apparatus




Set the power supply to 6 V and turn it on.

Connect each of the probes from the digital multimeter (DMM) to one of the remaining two probes. The conductors on the back of the probe will unscrew revealing a hole in the connector that you can put the probe into. Tighten down the connector to hold the probe and make a good contact. Turn the dial on the DMM to the 20 VDC setting. The DC side is indicated by a solid line over several dashed lines. Place the probe connected to the red probe on the DMM on the conductor connected to the plus side of the power supply and the other probe connected to the DMM on the other conductor. The meter should give a reading approximately equal to the setting on the power supply. If it does not, contact your instructor.

2. Data Acquisition

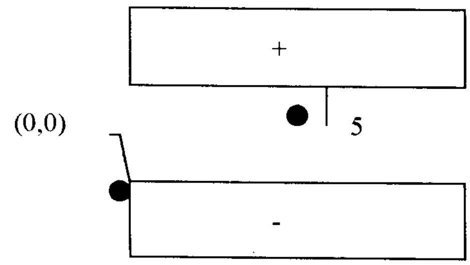
   We will now find several equipotential lines. We will determine these by placing the probe connected tot eh V-Ω terminal of the DMM at a fixed position and then moving the other probe until we find positions where the potential difference between the two probes is zero. We will record these positions quantitatively by using the graph paper located below the dish. Choose and appropriate origin and reference the locations you determine to that origin. One suggestion for your coordinate system is shown in Figure 2. The rest of the procedure will be written with respect to the suggested coordinate system.

   Record the positions of both the inner corners of each of the conductors on your copy of the graph paper.

   Place the probe connected to the (+) side of the DMM (red probe) on the plus conductor. Place the probe connected to the minus side (or common) of the DMM (black probe) at a grid point centered on the conductors and located 5 grid lines below the (+) conductor as indicated in Figure 2. R**ecord the potential difference between these two points in your data table.** (Note: An alternative method is to find the points on the center axis where the voltage is 1vdc, 2vdc, 3vdc, and 4vdc.)

   Place the probe connected to the (+) side of the DMM on the grid centered on the conductors and located 5 grid lines below the (+) conductor as indicated in Figure 2. Record the position of this probe in a data table. Move the other probe to find 7 positions to *each side* of the plus probe where the potential difference between the two probes is as close to zero as you can find. Record each of these points on your graph paper. Find points that are roughly equally spaced horizontally *and include at least three* that extend beyond the region between the two conductors on either side.

**Figure 2** Suggested coordinate system




3. Acquire the next sets of data

   Next move the common probe to the point five grid lines directly below the position of the plus probe and **record the potential difference between these two points**. Replace the common probe with the plus probe at the position that you just placed the common probe and record the position of the plus probe. Find 14 points that are at the same potential as the plus probe in the same way that you just carried out. Record each of these points on your graph paper.

   Now move the common probe five grid lines directly below the current position of the plus probe and record the potential difference. Again replace the common probe with the plus probe, record the position of the plus probe, and find 14 equipotential points in the same manner.

   Finally, place the common probe on the minus conductor and **record the potential difference** between it and the current position of the plus probe.

4. Data Checklist

   At this point your data should consist of 4 measured potential differences and 3 sets of 15 (including the fixed position of the plus probe) equipotential points. We will now use this data to determine what the shape of the field lines for this configuration looks like.

**Data Analysis**

To analyze your data, on graph paper plot your five equipotential surfaces. Draw straight lines indicating the positions of the two conductors between the points you recorded for the inside corners. Next plot the 3 sets of points for the equipotential surfaces you've measured and connect the points with a smooth curve. Describe the shape of the equipotential lines in the interior of the capacitor. How do the shapes of the equipotential lines change in the area exterior to the capacitor? Take the reference of potential to be 0 V on the minus conductor and label each of the equipotential lines (including the conductors) with their respective potentials. Note: you have measured potential differences, not potentials.

Your graph should now have 5 equipotential surfaces with four regions between the equipotential surfaces. Use Equation 1 to find the average field in each of these regions. The correct SI units for the field are V/m but it is quite acceptable and more common to use units of V/cm to indicate the field strength. We argued in class that the field is constant in the interior of a parallel plate capacitor. Do your calculations for the average field in each of the regions support this?
Finally along the equipotential surface for the plus conductor and the three equipotential surfaces that you have measured draw a series of arrows indicating the electric field. Remember the length of the arrows should be proportional to the field strength and the direction should be perpendicular to the equipotential surfaces. Be sure to draw arrows all along the equipotential surfaces to show how the direction changes. Also remember that the field lines point from higher potentials to lower. Label the field lines with the field strength.

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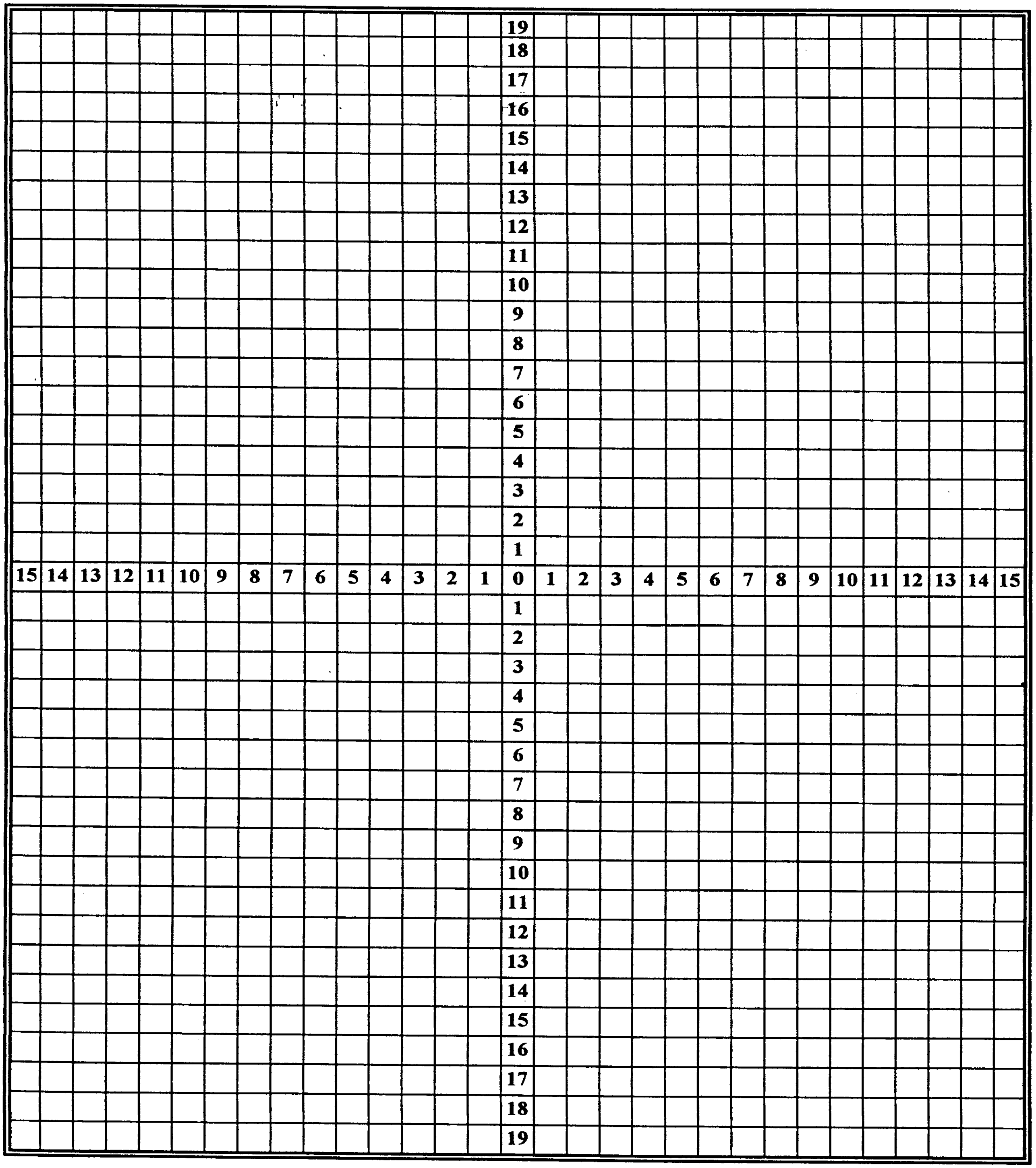
**Report Format**

Your lab report should include the following:

1. A short paragraph describing the objective of the lab
2. A one to two paragraph description of your experiment in your own words
3. A one paragraph description in words of your data
4. The table of data and the graph you've drawn (make sure the graph is properly labeled and includes a descriptive title)
5. A one-paragraph description of the results.
6. Explicitly show all calculations
7. Make a reasonable attempt to account for any discrepancies.
8. Include a one-paragraph summary explaining very plainly the principal results of the lab.

Your report should be written with correct English spelling and grammar, and should be well organized, neat, and legible.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