What follows is a brief review of electric fields, electric potential, and electrically charged conductors for electrostatic situations. You should refer to your lectures notes and textbook for a more complete treatment.

The electric field (E) is a vector quantity. The magnitude of the electric field at a given point in space is defined as the force per unit charge. Therefore if you want to find the magnitude of the force that a charge would experience, you would simply multiply the magnitude of the electric field by the magnitude of the charge. The direction of the electric field at a given point in space is the direction that a positive charge would experience the force. Therefore if the charge is positive, it will experience a force in the same direction as the electric field, and if the charge is negative it will experience a force in the opposite direction. Instead of drawing a vector at every point in space to represent the electric field (that would be impossible!), it's easier to draw electric field lines; electric field lines are a pictorial way of visualizing the electric field. Here's how the electric field and electric field lines are related: In a region of space where the density of electric field lines is large, that means the electric field is strong in that region (and vice versa). The direction of the electric field at a given point in space is the direction tangent to the electric field line at that same location.

The electric potential (V) is a scalar quantity: The electric potential is the potential energy per unit charge. Therefore, the potential energy of a charge is found by multiplying the value of that charge by the value of the electric potential at its location. (Notice the similarities and differences between the electric field and electric potential definitions.) Locations in space with the same value of electric potential are referred to as
**equipotentials** or equivalently **equipotential lines** (even though their shapes may not be geometric lines, i.e. the equipotential lines may be “curved”).

Not surprisingly, the electric field and electric potential are related to each other. In fact, there is a precise mathematical relationship between them that you may have learned in lecture. For the purposes of this lab, however, we’ll only be interested in the understanding the qualitative relationships between the electric field (more specifically the electric field lines) and the electric potential. The relationships are:

- Electric field lines are always perpendicular to the equipotential lines.
- Electric field lines point from regions of high electric potential to low electric potential (or equivalently, from positive charges to negative charges).

Some properties of electrically charged conductors in electrostatic equilibrium:

- All points on the conductor’s surface are at the same potential. That is, the conductor’s surface is itself an equipotential.
- The net electric charge on the conductor resides on the conductor’s outer surface.
- The electric field lines at a conductor’s surface are perpendicular to the conductor’s surface at every point. (since the entire conductor surface is at the same potential).
- If a conductor has a sharp point (a convex region with small radius of curvature) the magnitude of the electric field will be large there.

Consider the point P near the positive source charge in Figure 1. The electric field lines and the associated equipotential lines are shown. At point P you measure \( \mathbf{E} = 40 \text{ N/C} \) pointing to the right and \( V = +200 \text{V} \). What do these quantities mean? If a charge of \(+1.0 \text{ nanocoulomb} (1 \text{ nC} = 10^{-9} \text{ C})\) is brought to this point, the electric force on the charge is \( \mathbf{F}_e = q \mathbf{E} = [10^{-9} \text{ C}] \times [40 \text{N/C}] = 4 \times 10^{-8} \text{ N} \) to the right.

**FIGURE 1**
The value of the electric potential, $V = +200 \text{ V}$, means that the work required to bring a charge of $+1 \times 10^{-9} \text{ C}$ from the location where the electric potential is zero (really far away) up to the $200 \text{ V}$ equipotential surface is $W = qV = [1 \times 10^{-9}] \times [200 \text{ J/C}] = +2.0 \times 10^{-7} \text{ J}$.

The units of electric field can be expressed as volts per meter (V/m), or equivalently in units of Newtons per Coulomb (N/C). The electric field can be written as $E = 40 \text{ V/m} = 40 \text{ N/C}$ to the right. This means that if you make a small 1 cm displacement along the direction of $E$, the electric potential drops by 0.40 volt, from 200.0 V to 199.6 V. In general, $E = -\Delta V/\Delta s$, where $\Delta s$ is a small displacement along the direction of $E$ and $\Delta V$ is the corresponding change in electric potential; the minus sign says that $V$ drops along the direction of $E$.

**THE SETUP**

You will measure electric potential and draw equipotential lines for three different configurations of oppositely charged conductors:

1. Two points (a dipole)
2. Two parallel plates (a capacitor)
3. A hollow circular conductor between oppositely charged parallel plates.

Figure 2 below shows the experimental arrangement for simulating the electric field between two point charges. A DC power supply set just under 20 volts is connected across the two conductors. The exact value of the power supply voltage not important. Simply set it to the maximum power supply voltage which should be below 20 V. A digital multimeter set to read DC voltage on the 20V scale has its negative lead fixed to the negative electrode; the positive meter lead may be touched to any point on the high-resistance conducting sheet (centimeter grid) to measure the electric potential at that point.
The experimental situation just described simulates two “point charges” in electrostatic equilibrium.

PROCEDURE

1. Each group should print out the last three pages of this write-up: graph grids for Dipole, Parallel Plates, Ring & Plates. Every time you identify an equipotential point (you will seek out the 4V points, then the 8V points, etc.), you will mark it with pencil on the graph grid (not the conducting paper).

2. For each configuration (Dipole, Parallel Plates, Ring & Plates) locate and plot four equipotential lines, at 4V, 8V, 12V, and 16V. (All points of the negative conductor are at 0V; all points of the positive conductor are at the power supply voltage. You should verify this.) Indicate on your graph grid the polarity of each electrode, (+ or -). The potential is measured on the black conducting sheet; the equipotential points are to be plotted directly on the last three pages of this write-up, after they are printed out. The plot need not necessarily be to scale; we are interested in shapes.

Some Tips: Take enough points so that you can draw fairly accurate equipotential lines, but not so many as to make it needlessly tiresome. Typically, you should be taking 6-8 points near the electrode, and 10-12 otherwise. For the two point electrode configuration, measure behind the points as well as between, to map the dipole (two-pole) shape. For the parallel strip electrodes you should measure the potential beyond and to the sides of the electrode region. For the circular electrode between parallel strips make measurements inside the ring to test electrical shielding. Electrical shielding, you may recall from lecture, is absence of an electric field inside a conducting material because any excess charge resides on the surface of the conductor. In all cases be careful to take sufficient additional data to define the shape of the equipotential lines and corresponding electric field lines close to the conducting electrodes.

You may also want to use the symmetry of the setup (the equipotential line shapes should be identical on the left as on the right) to reduce the number of points you are taking. However, keep in mind that the direction of the field lines may be different on each side.

To simplify plotting it is a good idea to scan along grid lines of the conductor. If one scan direction gives slow variation, try the perpendicular direction. Lift the probe to move it; don't gouge the black paper. Please do not write on or scratch the conducting paper. Replacement is very costly.

3. Draw a smooth line among points at the same potential. Make sure you label the values of the equipotential lines after you've sketched them. Then draw the associated electric field lines distinctively (use dashed lines for the electric field lines). Recall that the electric field lines should be everywhere perpendicular to the equipotential lines and should enter (or exit) conductors at right angles. Also recall that the direction of the electric field lines is toward decreasing electric potential. Using arrows, indicate on your plot the direction of the electric field lines.

Based on your experimental results, answer the following questions on the back of the respective printed sheets:
Two Parallel plates
a) Describe your shape of the electric field lines in the region between the two plates (are the electric field lines parallel? radial? curved?).
b) Does the electric field extend beyond the edges of the plates?

Two opposite point charges
a) Where is the electric field most nearly uniform?
b) What is the shape of the equipotential lines in the central region between the two electrodes (parallel, radial, curved, etc.)?
c) What is the shape of the equipotential lines close to one of the "point" electrodes?

Hollow circular conductor
a) What is the experimental value of V on the conductor ring? How does V vary inside?
b) Based on your answer to a) what is the electric field magnitude inside the ring? Is this consistent with electrical shielding?

Staple together and submit your three plots, making sure you have answered the questions above on the back side of the papers. Include Name/Course-section/Date.
Each Square Represents 1 cm x 1 cm
Ring & Plates

Each Square Represents 1cm x 1cm