4.1 Purpose

In this experiment the concepts of electric fields and equipotentials will be explored.

4.2 Introduction

Measurement of electric fields is normally difficult. This experiment will not measure the electric field directly, but will instead measure the applied electric potential between two points. It is possible to simulate electric field patterns using a resistive carbon sheet on which are clamped two electrodes shaped like a desired charge configuration. A voltage applied between the two electrodes sets up a current flow pattern in the carbon sheet. In the carbon sheet the electric potential must remain constant along a line perpendicular to the current flow, or else the current would flow in that direction. Hence, current flows perpendicular to lines of constant voltage, i.e., the equipotential lines. Since electric field lines are also perpendicular to the equipotentials, the current flows along the electric field lines. In this experiment we will map equipotential lines. By constructing lines perpendicular to the equipotential lines, the electric field lines can be mapped. The perpendicular relationship between the equipotentials and electric field lines is shown in Figure 4.1 This figure also shows the basic electrical connections.

Since $\Delta V$ is the electric potential energy per unit charge between two points, the work done by moving a charge $q$ between these points is $W_{AB} = q \Delta V$. This is related to the vector electric field by $\vec{F} \cdot \vec{d} = \Delta W_{\text{elec}} = -q \vec{E} \cdot \vec{d}$, which is just the work done by moving a charge $q$ between two points separated by $\vec{d}$ in an electric field. Here it is assumed the separation is not very large so the field can be considered constant over the distance $\vec{d}$. The finite differences between two potentials may be substituted. This gives:

$$|\vec{E}| = \frac{\Delta V}{\Delta d}$$  \hspace{1cm} (4.1)

where $\Delta V$ is the potential difference between two adjacent equipotential lines that you will measure. $\Delta d$ is the distance between these two points and $|\vec{E}|$ is the magnitude of the
Figure 4.1: Basic electrical connections and the relationship between the equipotential lines and the electric field lines for a dipole configuration

- a) Electric Dipole
- b) Parallel plates
- c) Plate and ‘point charge’

Figure 4.2: a) The electric dipole, two opposite charges of the same magnitude. b) Parallel plates with opposite charge. c) The plate and ‘point charge’.

The electric field. In words, the magnitude of the electric field, $|\vec{E}|$, may be found by dividing the potential difference between two equipotential points by the perpendicular distance between them. The electric field lines are always directed away from positive charges and toward negative charges.

We will study three different configurations. In fact these configurations are two dimensional models that can be intuitively extended to three dimensions. For example, if a slice of the 3-D electric dipole is taken along its z-axis the result is a 2-D model similar to the one found in Figure 4.2 a). The extension of the 3-D models for Figure 4.2 b) and c) should be clear.

### 4.3 Procedure

**Special Cautions:**

- Do not wrinkle the black graphite sheet. Do not write or mark on the black graphite sheets with pens or especially pencils.
- Do not connect both leads from the power supply to the same conductor on the black graphite sheet. Be certain that the voltmeter is set to read volts and not current.

Shown in Figure 4.3 is the field mapping setup. The black graphite sheet is attached to a foam board. The conductors are the white lines on the black graphite sheet. A wire with banana plugs is connected to each of the two ‘conductors’. The wires are connected to the voltage source. A voltmeter is used to measure voltage at points between the conductors.

- Choose one of the three graphite sheet configurations. Turn on the multimeter and set it to voltmeter mode on the 20 volt scale. Connect the negative (black) side of the power supply to the ‘COM’ side of the voltmeter. Connect one of the banana wire leads from the black graphite sheet to the same (black) side of the power supply. Connect the other banana wire lead from the black graphite sheet to the positive (red) side of the power supply. The other wire from the voltmeter (V Ω) will serve as the voltage probe for measurements.

- Turn the voltage supply knob to its lowest setting (fully counterclockwise) and turn on the supply. Touch the free voltmeter probe to the nut on the graphite sheet connected to the positive side of the supply. Turn the voltage supply knob clockwise until you read approximately 10 volts on the voltmeter. Record this voltage.

Supply voltage __________

- The markings on the white Xeroxed sheets correspond to the size and configuration of the black graphite sheet. Use the free voltmeter probe to measure voltages on the black graphite sheet which have the same electrical potential and record them on the white sheets. The spacing between equipotential points should be about 1 cm (the distance between the marks on the graphite sheets). Map out (at least) five approximately evenly spaced equipotential lines and record them on the white Xeroxed paper.
• Sketch (free hand) a smooth curve through the equipotential points in the region between the two conductors on the white sheet.

• Using the fact that the electric field lines are perpendicular to the equipotential lines, sketch (free hand) the electric field lines and indicate their direction on the white sheet.

• Using equation 4.1, calculate $|\vec{E}|$ for each consecutive pair of equipotential lines along the line connecting the centers (symmetry axis) of the two conductors. Record these values of the electric field on the white paper.

• Repeat the procedure and analysis for the other two conductor configurations.

4.3.1 Questions

1. The magnitude of the electric field is calculated along the symmetry axis where the direction of the field is clear. Can the electric field be calculated this way at any arbitrary point? Why?

4.4 Conclusion

Write a detailed conclusion about what you have learned. Include all relevant numbers you have measured with errors. Sources of error should also be included.