Electric Fields and Electric Potential.

An electric field is said to exist at a point in space if a force acts on a charged particle placed at that point. The electric field E at a point is defined to be the force per unit charge acting on a small positive test charge which has been placed at that point. Algebraically this is written as

$$\vec{E} = \frac{\vec{F}}{q_o}$$

where q_o is a small positive test charge. The magnitude of the electric field is measured in newtons/coulomb.

The electric potential difference, ΔV, between two points is defined to be the work done per unit charge (against electrical forces) in moving a small positive test charge slowly between two points. If one of the points is taken to be a reference point with zero potential, then the electric potential at any point can be defined in terms of the work done per unit charge in moving a small positive test charge from that reference point to the point at which the potential is to be determined. For isolated charges, the reference point is usually taken to be infinity. The potential is measured in volts. (1 volt = 1 joule/coulomb)

Of the two quantities that have been defined, it is the electric potential difference that is the easiest to measure. If one knows the electric potential at every point in space, it is possible to obtain the electric field. The rate of change of electrical potential in any direction is equal to the negative of the component of the electric field in that direction. For example, the x component of the electric field is equal to the negative of the rate of change of the electric potential in the x direction. Algebraically this would be expressed as

$$E_x = -\frac{\Delta V}{\Delta x}$$

Comparing equation 1 and equation 2 we can see that a newton/coulomb is equivalent to a volt/meter.

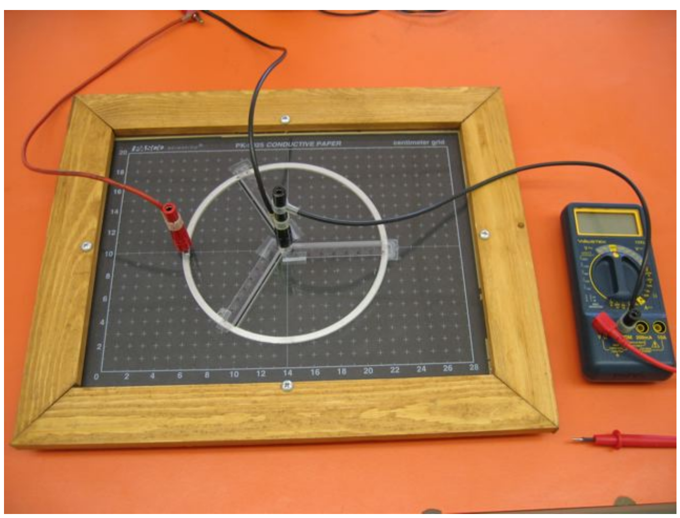

Figure 1: Apparatus.

Procedure

1. In this experiment, you are to quantitatively determine the dependence of the electric field to the radius between two concentric circles of aluminum on a piece of low-conductivity paper. The potential difference between the circles, set up by connecting a D.C. power supply directly to the aluminum, establishes an electric field within the circles and in the plane of the paper that depends on the distance from the center of the circles, r. The

r-dependence of the electric field can be determined by measuring the potential at a number of points between the two circles and then using the rate of change of the electrical potential in the r direction to get a numerical value for the r component of the electric field. A positive value of E indicates that the electric field will be radially outward.

2. Before connecting to the source of D.C. power make sure to connect the positive terminal to the outer circle and the negative terminal to the inner circle. The ground lead on the digital voltmeter (COM port) should be connected to the point holding the negative lead to the inner circle. The probe is used to measure the potential at various points on the paper. Make certain that the digital voltmeter is set to measure DC voltages (20V scale). Once this set up is verified (you may want to check with your lab TA), plug in the leads to the D.C. power supply.

3. Check to make sure there is contact between the aluminum and the banana jack by placing the probe on the outer ring and verifying its potential difference is 12V. If you get some other voltage please see your lab TA. Confirm the zero of the centimeter scale along the measurement channels is placed at the center of the two circles. Starting at the outer ring, measure and record the potential as a function of radius at intervals of 0.50cm for points between the two rings, do not include the inner ring or outer ring. The potential should depend only upon r. Check this by taking two more sets of measurements along the remaining measurement channels. Average the three values of $V(r)$ which you have obtained for each r.

4. The average value of the electric field over each 0.50cm interval can be found by evaluating the quantity

$$E_{avg} = -\frac{\Delta V}{\Delta r}$$

Where ΔV is the potential difference between consecutive measurements of $V(r)_{avg}$ and Δr is the distance between consecutive measurement, 0.50cm.

$$\Delta V = V(r)_j - V(r)_i$$

5. It is reasonable to assume that this value of E is at the midpoint of the interval, so we must calculate that value which is just the average radius of two consecutive measurements.

$$r_{mid} = \frac{r_i + r_j}{2}$$

Use this value of r_{mid} to determine $r_{mid}E$ and $r^2_{mid}E$.

6. Plot E, $r_{mid}E$, and $r^2_{mid}E$ (y-axis values) as a function of r_{mid} (x-axis value). All three curves should be plotted separately. Use these plots to determine the nature of the electric field. If E is a constant then the plot of E as a function of r_{mid} should be best fit by a horizontal line. If E has a $1/r$ dependence then $r_{mid}E$ should be constant and the plot a horizontal line. Likewise if E has a $1/r^2$ dependence, then $r^2_{mid}E$ should be a constant and the plot a horizontal line.

7. It is always suggested you draw or sketch a diagram of your apparatus with some corresponding measurements in your lab notebook. You may also want to keep a copy of these lab instructions in a binder/notebook.