LAB 8, 9 - THE ELECTRIC FIELD I, II

OBJECTIVE  The purpose of this lab is to map the electric field that exists between four different sets of electric charge distributions. They will be constructed using an experimentally derived map of the lines of equipotential that exists about the sets of charges. According to Coulomb’s Law, the electric force (F) that exists between two individual charges q and q₀ is determined from the relationship:

\[ F = k \frac{q \cdot q_0}{r^2} \]

where \( r \) is the distance between the two charges and \( k \) is Coulomb’s constant = \( 9 \times 10^9 \) Nm\(^2\)/C\(^2\). The potential electric force or electric field (E) exerted by charge q at a point r distance away is simply equal to the force (F) on a positive test charge q₀ located at that point divided by the magnitude of q₀ or:

\[ E = \frac{F}{q_0} = \frac{k \frac{q \cdot q_0}{r^2}}{q_0} = k \frac{q}{r^2} \]

The application of the electric field concept allows potential electric forces to be defined for regions surrounding electric charges.
Electric field lines are used to illustrate potential forces in an electric field and are drawn according to the following rules of construction.

1) The electric field vector ($\mathbf{E}$) is tangent to the electric field line at each point on the line.
2) Electric field lines point in the direction of the potential force exerted by a positive test charge $q_0$.
3) The number of electric field lines entering or leaving a charge is indicative of the relative charge magnitude.
4) Electric field lines emerge from positive charges and terminate on negative charges.
5) The number of electric field lines passing through an area is indicative of the electric field strength in that area.
6) Electric field lines do not cross.

An illustration of the electric field lines for two small circular charges is shown in Figure 1 below.

![Electric Field Lines Diagram]

**Figure 1**
The work (W) done in moving a positive test charge $q_0$ through a displacement $\Delta r$ parallel to an existing electric field ($E$) is equal to the loss of electrical potential energy ($-\Delta U$) of the charge or:

$$W = F_s = (E \cdot q_0) \cdot (\Delta r) = -\Delta U$$

Dividing through $-\Delta U$ by the magnitude of the test charge $q_0$ yields $E\Delta r$, the 'potential' potential energy difference between the two points separated by $\Delta r$. This 'potential' potential energy difference is simply termed the potential difference ($\Delta V$) and represents the change in energy levels or electric potential ($V$) between the two points. Lines of equipotential represent individual levels of constant electric potential. The proximity of equipotential lines indicate the electric potential gradient or how rapidly the potential energy state is changing. The lines of equipotential surrounding the circular charges of Figure 1 are shown below in Figure 2. Note that electric field lines are always oriented perpendicular to the lines of equipotential.

![Figure 2](image-url)
**APPARATUS**  Overbeck electric field mapping apparatus, galvanometer, 6 volt dry-cell battery.

**PROCEDURE**
1) Screw the paired circular charge configuration plate shown below in Figure 3A onto the underside of the Overbeck electric field mapping apparatus board.

![Diagram](image)

A  Paired Circular Charges  
B  Parallel Plate Capacitor  
C  Plate and Circular Charge  
D  Faraday "Ice Pail"

*Figure 3: Experimental Charge Configurations*
2) Tape a blank sheet of paper onto the top of the mapping apparatus board and connect the battery terminals as shown in Figure 4.

3) Position the plastic template for the paired circular charge configuration over the blank paper using the pegs at the top of the apparatus board. Trace the outline of the circular charge on the paper and label positive (+) or negative (-) according to their respective battery connections.

Figure 4: Overbeck Electric Field Mapping Apparatus
4) Starting with the **E4** equipotential setting, move the probe around the plate until a zero or 'null' reading is obtained on the galvanometer. Record this point on the paper by marking with a sharp pencil through the hole at the end of the probe. Continue finding and marking 20 to 30 other null points until the trend of the **E4** line of equipotential has been established. Connect the individual data points with a dashed pencil line.

5) Repeat step 4 and map the equipotential lines **E3**, **E5**, **E2**, **E6**, **E1** and **E7** respectively.

6) After all seven lines of equipotential have been mapped, unscrew and remove the paired circular charge configuration plate from the underside of the Overbeck electric field mapping board.

7) Repeat steps 2 through 5 for the parallel plate charge configuration of Figure 3B, the plate and circular charge configuration of Figure 3C, and the Faraday ‘ice pail’ charge configuration of Figure 3D.

**DATA & CALCULATIONS**

After mapping the lines of equipotential for the four electric charge configurations assigned, draw the corresponding electric field lines using the six rules of construction. Remember electric field lines are perpendicular to lines of equipotential. Be sure to label the electric field and equipotential lines and show the direction of the electric field orientation.
QUESTIONS

1. Why is it important to obtain a zero (or null) reading on the galvanometer in order to establish an equipotential point on the paper?

2. What do you consider the most helpful guide when attempting to determine the shape of the electric fields for the different charge configurations?

3. According to theory, the electric field for the parallel plate configuration of figure 3B should be a uniform field. Is this consistent with your experimental result?

   State clearly the evidence for your answer.

4. From your results, which of the six rules of construction is most obvious?

   Which is the least obvious?