Electric Field Mapping

Objective
To map the equipotential lines and construct electric field line between two charged objects.

Theory
Two like charges repel each other and unlike charges attract each other with a force called Coulomb force. This force is directly proportional to the product of the individual charges and inversely proportional to the square of the distance between these charges.

\[ F = k \frac{q_1 q_2}{r^2} \]  

Where \( k \) is a constant and is equal to \( 8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2 \) in SI units; \( q_1 \) and \( q_2 \) are the two charges, and \( r \) is the distance between them.

An electric field of a charged body is a region in which another charged body feels the force of attraction or repulsion. If a force \( F \) acts on charge \( q \) at a point in the field of another charge then the electric field \( E \) of this charged body is given as:

\[ E = \frac{F}{q} \]

The direction of an electric field is the direction of a force on a positive unit charge placed in the field. We can visualize the direction of an electric field by drawing the path of free motion of a positive charge in the electric field.

The map of isolated positive and negative point charges are shown in the figure above.

If we have two electric charges of opposite polarity lying close to each other then electric field lines emanate from the positive charge and converge onto the negative charge as shown in the figure below:
The solid lines in the above two figures represent the electric field and the dashed lines represent the equipotentials. Equipotential line is such a line that is perpendicular to the electric field and no work is required if a test charge is made to move along this line. Potential difference between any two points on the equipotential line is zero.

The magnitude of the electric field can be calculated from the potential difference as:

\[ E_s = -\frac{\partial V}{\partial s} \approx -\frac{\Delta V}{\Delta s} \]

which tells us that the electric field is directly related to the rate of change of the electric potential from point to point in space. The more drastically the electric potential changes from one point to another, the greater the magnitude of the electric field pointing along that displacement \( s \). Conversely, if the electric potential doesn’t change at all from one point to another (along the equipotential line), then the electric field cannot point in the direction of that displacement at all (we could say that the component of the electric field in that direction must be zero.) Another way of saying this is that the electric field has the opposite direction of the greatest rate of change of potential with distance away from the point in question, and its magnitude is equal to that rate of change.

**Equipment:**

- Field mapping board
- Field plates and the two stencils (template #1 and template#2)
- U-shaped probe
- Galvanometer
• Wires with banana plugs on their ends
• Power supply
• sheets of papers

Procedure

1) Secure one potential source (power supply), one Overbeck electric field apparatus, one galvanometer, several wires, and several pieces of paper.

2) Turn the field mapping board over (under side - see Figure 1) and attach the parallel plate capacitor field plate with silvery side facing, using the two plastic-headed thumb screws.

Figure 1: Under side of the Field Mapping board

3) Connect the potential source (power supply) to the two binding posts on the upper side (see Figure 2) of the mapping board marked "Bat. or Osc.". (DO NOT TURN ON THE
BATTERY UNTILL YOU COMPLETELY WIRE THE CIRCUIT AND YOUR INSTRUCTOR APPROVES THE CIRCUIT). The two conducting (silver paint) parallel plates are now directly connected to each end of the potential source.

Figure 2: Upper side of the field mapping board

4) Fasten a sheet of paper to the upper side of the mapping board. Secure the paper by slipping it under the four rubber bumpers. (If you are using A4 papers, you may slide the paper under only the top two bumpers).

5) Select the right design template (stencil) containing the field plate configuration that you have chosen, place it on the two metal projections, and trace the appropriate design. Remove the template.

6) Connect a wire to the first potential port E1 and connect the other end to one side of a galvanometer. Eight similar resistors are connected in series between the two binding posts on the field-mapping board to eight points separated by the same difference of potential. If the potential at the binding post close to E1 is taken as the reference (V= 0
V) connected to the negative (common – 0 V) of the potential source and the other binding post to +4.0 V, then the potential at E1 is 0.50 V; at E2 is 1.0 V and so on.

7) Connect another wire to the U-shaped probe and the other end to the other terminal of the galvanometer.

8) Carefully slide the U-shaped probe onto the mapping board with the ball end on the underside. You should now have connected your apparatus as shown in the circuit diagram of Figure 3.

Figure 3: Circuit diagram of the Electric field mapping experiment

9) Turn the potential source and set it at 4.0 V. Gently glide the probe over surface until the galvanometer reads 0. Mark this spot on paper through the center of the hole on the top of the probe. This spot you marked is at the same potential as the potential at port E1; this is why the current through the galvanometer is zero.

11) Move probe to another spot where meter reads 0. Mark this spot. Repeat until you have mapped out an equipotential line (about 8-10 points).

12) Connect probe to the other potential ports E2 - E7 and repeat steps 10-11 for all of them.
13) Connect points of equal potential to form equipotential lines. Draw in electric field lines.

14) Repeat this procedure for other two plates (*Point and Plane & Small Circular Plane*) provided to you.

**Questions:**

1) Describe the central electric field \((E)\) shape in the case of two parallel plates.

2) Do the distances between adjacent equipotential lines between the two parallel plates, approximately measure the same? Calculate an average value for the magnitude of the electric field between the plates.

3) Does the electric field extend beyond the edges of the plates in the two parallel plates experiment?

4) Is it possible for two different equipotential lines or two lines of forces to cross each other? Explain.

5) How does the electric field strength vary with the distance from an isolated charged particle?

6) What is the equipotential shape close to "point" electrode?

7) Where is the electric field most nearly uniform in the two opposite point charges experiment?

8) What is the central equipotential shape in the two opposite point charges experiment?