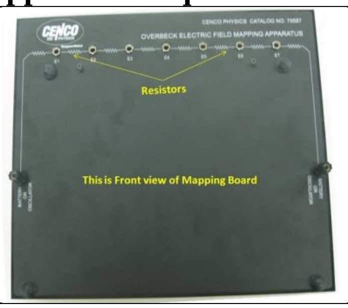
Electric Field Mapping

Objectives

a. To draw equipotential lines
b. To draw electric field lines
c. To calculate electric field intensity

Apparatus Required

<table>
<tr><td>
</td><td></td><td rowspan="3"></td></tr>
<tr><td>Mapping board</td><td>Power Supply</td></tr>
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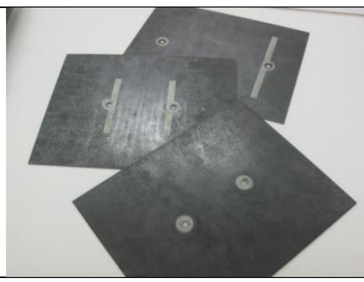
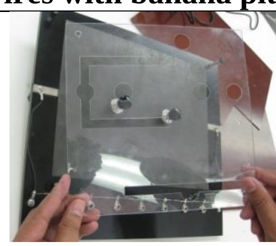
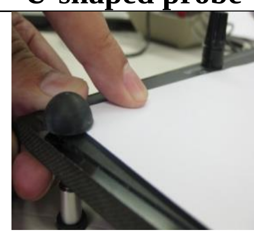
<tr><td>Galvanometer</td><td>Wires with banana plugs</td><td>U-shaped probe</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>3 Field plates</td><td>2 Design Templates</td><td>White Papers</td></tr>
</table>

Introduction

A field is a property of the space in which a material object experiences a force. Just as the gravitational field of Earth applies a force on a mass m near the surface of earth, the electric field applies a force on charged objects. The electric field is produced by a charge or a distribution of charges. Let this charge be Q. If we put another charge q a distance r from Q, the electric field will apply a force on charge q as given by the Coulomb's law

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$$F = k\frac{qQ}{r^2}$$

The electric field is defined as $E = F/q$. Note that both F and E are vector quantities. The units of force is N and the units of E is N/C. The strength of the field and the force fades away at distance away from the charge Q.

Electric field lines are used to visualize the effect of electric field. It is worth mentioning some of the properties of field lines here.

a. Field lines are imaginary.
b. Field lines are converging to negative charges.
c. Field lines are diverging from positive charges.
d. At every point along a field line, the lines direction is the direction of the electric field at that point.
e. The density of the field lines is proportional to the strength of electric field
f. Two field lines never cross each other.

One more very important property of electric field lines is they are always perpendicular to equipotential lines or equipotential surfaces. On these lines and surfaces, the value of the electric potential V is the same. In this experiment we will best utilize equipotential lines to draw electric field lines. However, let us first learn how electric field and electric potentials are related to each other.

The amount of work done to bring a unit positive test charge from infinity to any point P against the electric field is called the potential at the point P. The electric potential is represented by symbol "V". The average electric field in the region of separation Δx is given by,

$$E = -\frac{\Delta V}{\Delta x} \qquad \textbf{(2)}$$

Where, ΔV is the potential difference between two points of separation.

In this experiment you will find the equipotential lines between two charge distributions, using a mapping board. If you look at the figure (1) the series of resistors are parallel to the mapping board. The applied potential will drop from V to zero across resistors as well as across the mapping board from positive electrode to negative electrode. Since there are eight resistors with equal resistance the potential drop across the first resistor is V/8 and we can find the same value of voltage drop at different points in the mapping board (since mapping board is parallel to the resistor). To make this point clear you can see the figure (2) which is schematic of figure (4). Since all these points are at same potential (V/8) the line joining these points is called equipotential line.

To find the equipotential point in the board you will connect one end of the galvanometer to resistor and another end to U-shaped probe. You will move the U-shaped probe in the mapping board until galvanometer reads zero. When galvanometer reads zero the potential at the point in the mapping board is at same potential as the point in the resistor is.

<u>Experiment</u>

Part 1: Drawing electric field lines and equipotential lines between two circular electrodes

In this experiment you will be finding equipotential points in the region between two circular electrodes. Since the circular electrodes behaves like point charges you would be expecting electric field lines as those shown in figure (3).

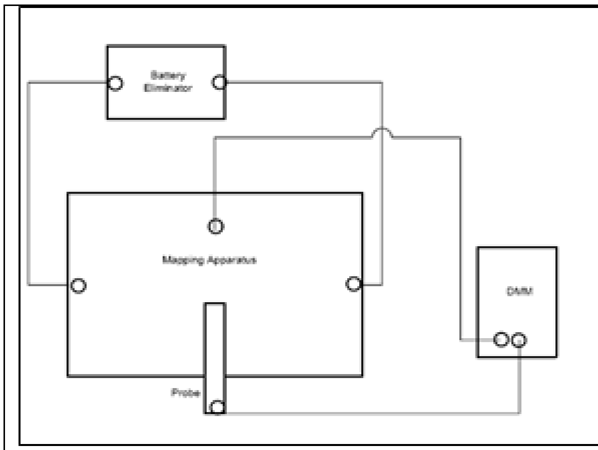

Figure1: Electrical circuit

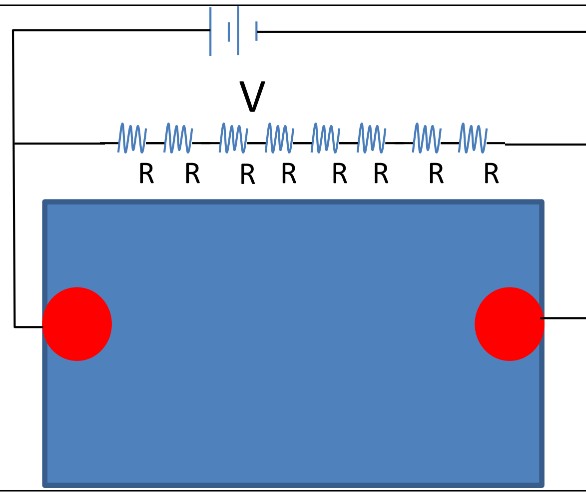

Figure 2: Equivalent circuit where mapping board acts as parallel resistor to the given resistors

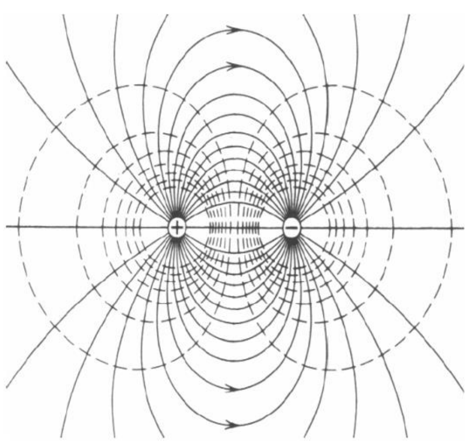

Figure 3: Electric field lines (solid lines) and equipotential lines (dashed) between positive and negative point charges

Figure 4: Mapping board with circular electrodes which are equivalent to point charges

Procedure:

1. Make sure you have all the items shown in Figure.
2. Turn the field mapping board over to the backside (see **Figure 4**). Fix the *plate with circular electrodes* using the two plastic-headed thumb screws (Make sure the silver circles are facing outward). For better electric contact you may use metallic gaskets.
3. Stick a sheet of paper to the upper side of the mapping board. Secure the paper by sliding it under the four rubber bumpers.
4. Select the plastic template (stencil that contains the field plate configuration) that fits in the circular electrodes. Flip the board over to the front side. Fix the template to paper and using a pencil, trace the configuration on the paper. Look back and make sure your drawing and the real shape of the electrode must be identical.
5. Remove the template.
6. Connect the circuit according to **figure 1**. Make sure your power supply is still off.
7. Connect one end of the galvanometer (it measures potential difference) to first potential port E1 and the other end to the U-shaped probe.
8. Carefully slide the U-shaped probe onto the mapping board so that the side with hole lies on the paper and the side with metal touches the electrode plate.
9. **Ask your instructor to check your circuit and template.**
10. Turn on the power supply and set the voltage at 4.0V.
11. Move the probe slowly over surface and close to the electrodes until the galvanometer reads 0. Mark this spot on paper with pencil 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.
12. Move the probe to other points where the galvanometer reads 0. Mark these points on the paper. Repeat until you have mapped out an equipotential line (about 8-10 points). **Make sure your points are well separated. Point may go in circular paths around the electrodes.**
13. Connect probe to the other potential ports E2 - E7 and repeat steps 19-20 for all of them.
14. Connect points of equal potential to form equipotential lines (use free hand for this purpose and don't use a ruler).
15. Draw five symmetric electric field lines. Keep it in your mind that at each point, the electric field lines are perpendicular to the equipotential lines.
16. Draw a straight line joining center to center of two electrodes.
17. Measure the position (x) of the point of intersection between the central line and the equipotential lines. Take the center of the positive electrodes as origin. Use a ruler to find x.
18. Record the value of (x) and voltage (V) on the table 1. You have applied 4.0V across the series of 8 resistors with equal resistance. Hence in each resistor the potential drop will be 0.5V.
19. Use excel to plot V versus x. Find the value of average electric field E from graph by using equation (2)

Table 1

Line Number	Potential Difference (V)	x (m)
1	3.5	
2	3.0	
3	2.5	
4	2.0	
5	1.5	
6	1.0	
7	0.5	

Exercise 2:
Drawing equipotential lines and electric field lines between two parallel plate electrodes

In this exercise you will repeat the procedure in exercise 1 for parallel plate electrodes.

1. Take off the circular electrode plate and replace it with parallel electrode plates.
2. Draw the shapes of the electrodes with the help of right template
3. Draw equipotential lines and electric field lines.
4. Find the electric field at the central line by plotting V versus x

Exercise 3:
Drawing equipotential lines and electric field lines between circular and linear electrodes

In this exercise you will repeat the procedure in exercise 1 for one circular and another linear shaped electrode.

1. Remove the parallel electrode plate and replace it with the circular and linear electrode plate.
2. Draw the shapes of the electrodes with the help of template.
3. Draw equipotential lines and electric field lines.
4. Find the electric field at the central line by plotting V versus x