

# PLOTTING ELECTRIC FIELDS

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## Background: Electric Fields

An electric field is said to exist in a region if an electric charge placed in this region experiences an electric force. If an electric force  $F$  acts on a charge  $q$  positioned in the electric field, the electric field strength (magnitude)  $E$ , by definition, is the electric force per unit charge or  $E = \frac{F}{q}$ . That is, the magnitude of electric field is the electric force per unit charge. Being that force is a vector quantity and charge is a scalar quantity; since  $E \propto F$  the electric field must be a vector quantity. The direction of an electric field at any point is the direction of the force on a positive test charge placed at a given position in the electric field.

## Lines of Force

Michael Faraday introduced the concept of *lines of force* to visualize the strength and direction of an electric field. A *line of force* is the path that a free test charge would follow while it traversed an electric field. The lines of force or electric field lines (as we now refer to them) are always tangent to the electric field (vector) direction at any point.

Consider a positive charge  $+Q$  as shown in Fig. 1. If a small positive test charge  $+q$  is placed at any point in the field, it will experience a force of repulsion radially away from  $Q$ . The electric field lines are drawn with arrows

to point in such a direction. When  $Q$  is a negative charge, these lines would be

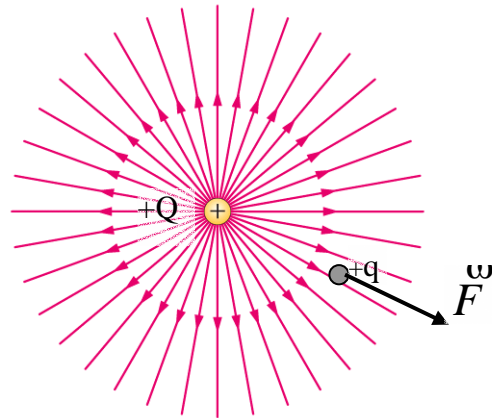


Figure 1.

directed toward  $-Q$  to indicate an attraction of the test charge  $+q$ .

Fig. 2 shows a plane section near a pair of equal charges of opposite sign,

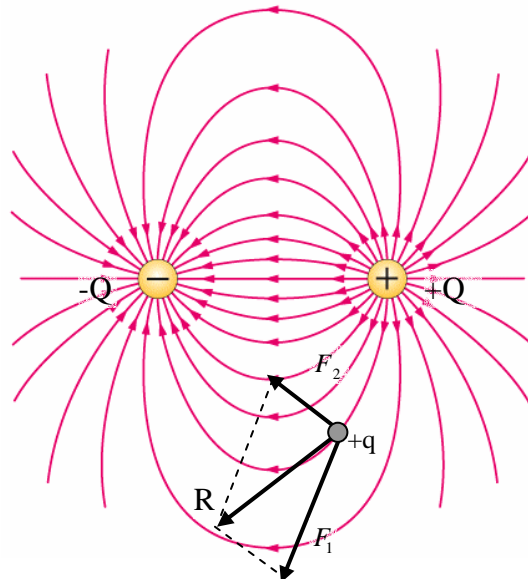


Figure 2.

$+Q$  and  $-Q$ . Each charge exerts a force on a unit test charge,  $+q$ , placed in the

field. The resultant force is the vector sum of the forces. Thus, at the position of  $+q$ ,  $F_1$  is the repulsive force on the test charge due to  $+Q$  and  $F_2$  is the attractive force on the test charge due to  $-Q$ . The resultant force  $R$  is tangent to the electric field line at the point  $b$ .

It is evident that a uniform electric field is represented by a set of parallel electric field lines. A converging set of electric field lines indicate a field of increasing strength; while a field of decreasing strength would be represented by a diverging set of these lines.

### Potential Difference

Two points in an electric field have a difference of (electric) potential if work is required to carry a charge from one point to another. This work is independent of the path between the two points. Consider the simple electric field in Fig. 3. Since the charge  $+Q$  produces an electric field, a force will act upon a test charge  $+q$  at any point in the field.

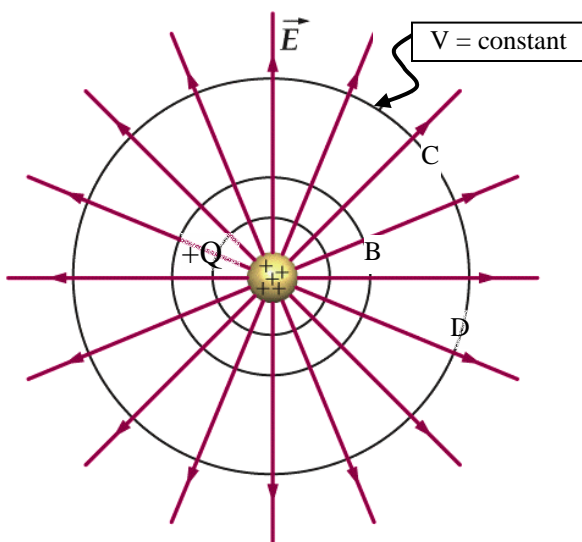


Figure 3.

Hence it will be necessary to do work to move the test charge between any such points as B and C at different distances from the charge  $+Q$ . Notice that B and C lie on two different equipotential (i.e.  $V = \text{constant}$ ) surfaces. The potential difference between two points in an electric field is defined as the ratio of work done in moving a small positive charge between the points considered to the charge moved.  $V = \frac{W}{q}$ , where  $V$  is

the potential difference,  $W$  is the work done and  $q$  is the charge. In mks units,  $V$  is in volts,  $W$  is in Joules, and  $q$  is in Coulombs. The conservation of energy principle requires that the work done must be independent of the path over which the charge is transported.

Otherwise energy could be created or destroyed by moving a charge from one point to another.

### Equipotential Surfaces

It is possible to find a large number of points in an electric field, all of which have the same potential. If a line or a surface is drawn so that it includes all such points, the line or surface is called an equipotential line or surface. The curve CD in Fig 3 is an equipotential line lying on the equipotential surface. A test charge may be moved along an equipotential line or over an equipotential surface without doing any work.

### Interaction of Electric Field Lines and Equipotential Lines

Since no work is done in moving a charge along an Equipotential line it follows that there can be no component

of the electric field along an Equipotential surface. Thus the electric field or lines of force must be perpendicular to the Equipotential lines. *Equipotential lines of an electric field are more readily located experimentally than electric field lines, but if either is known, the other may be constructed.* The set of lines must be normal to one another at all times.

### **Potential of a Conductor**

Electrons in a conductor can move under the action of an electric field. Thus, if an electrical conductor is

placed in an electric field, the electron flow, which constitutes an electric current, will take place until all points in the conductor reach the same potential. There will then be no net electric field inside the conductor, whether solid or hollow, provided that it contains no insulated charge. Thus to screen a region of space from an electric field, the region only needs to be enclosed by a conducting container. Since all parts of the conductor are at the same potential, the electric field lines always leave or enter the conductor perpendicular to the conducting surface.

## **1. Purpose**

To plot the equipotential lines for two different electrode designs and determine the resulting electric field lines.

## **2. Theory**

Along equipotential lines, there is no potential difference. Electric field lines run perpendicular to these equipotential lines at every point.

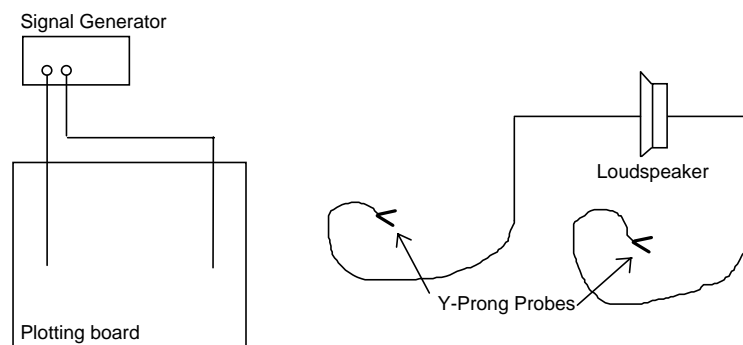
## **3. Equipment**

Mounting Board  
2 different carbonized conducting electrode sheets  
Patch cables  
4 alligator clips  
2 Y prong clips  
Signal Generator  
Loudspeaker

## **4. Procedure**

### **Equipment Setup**

- A. Select one of the conducting sheets and place it on the mounting board with the spring-mounted contacts touching the silver electrode arrangement.
- B. Using mm graph paper, very carefully copy the electrode configuration. You may want to include the numbering system as well.
- C. Connect two patch cables to the loudspeaker and place Y-prong probes on the other end.



## Performing the Experiment

- A. Place one of the Y probes on a point of the electrode graph, preferably near the edge and not on the electrode itself. It is best to use one of the printed points in order to have a good reference. Mark this point on your graph paper.
- B. With the other Y probe, place it about 1 cm away from the probe and slowly move in a circle around the other probe. You should hear the sound in the loudspeaker increase and decrease in intensity. When the sound reaches a minimum, that is the point through which the equipotential line travels. Mark this spot on your graph paper.
- C. Repeat the previous two steps, moving along the line created by the first two points, the line will be approximately straight for the parallel plate electrodes and circular for the point electrodes. You will continue repeating until you have the idea of where that particular equipotential line travels.
- D. Move the fixed probe to another spot and repeat A through C, this will identify a second equipotential line.
- E. Graph at least six equipotential lines between the electrodes, more if you want, just don't make it too crowded. Note: You want to draw nice smooth equipotential lines, so using a ship or French curve might be helpful, but it's not required.
- F. Now use your second electrode configuration and very carefully copy the electrode configuration onto a new piece of graph paper. You may want to include the numbering system as well.
- G. Perform A through F for your second electrode configuration.

## 5. Analysis & Results

The analysis is very simple. Draw lines extending from the electrodes through the equipotential lines making sure that these lines are perpendicular to the conductor's edge as well as at every point to the equipotential lines. These derived lines are the lines of force, or the electric field lines.

## 6. Additional Questions

- A. Is it possible for two different equipotential lines to cross or two lines of force to cross? Explain?
- B. Explain why lines of force must be at right angles to equipotential lines. Use a diagram if necessary.