615-3195 (10-230) Field Map Kit

Warranty and Parts:

We replace all defective or missing parts free of charge. Additional replacement parts may be ordered**.** We accept Mastercard, Visa, School P.O's. All products warranted to be free from defect for 90 days (**29-3000 Ink Pen** has a shelf life of **6 months**). This warranty does not apply to accident, misuse or normal wear and tear.

About This Kit:

The **Conductive Paper** forms the conducting medium between electrodes. Ordinary paper has a very small electrical conductivity and would not be practical as a conducting medium even if a sensitive electrometer were used to indicate potentials. The conductivity of the paper would vary greatly within the paper, particularly where there are fingerprints. Paper may be made into a lower level conductor by incorporating acetylene black with the paper pulp. The electrical resistance of a square piece of paper is on the order of 100 to 10,000 ohms depending upon thickness and amount of carbon. Conductivity is quite uniform within an individual sheet and in any direction.

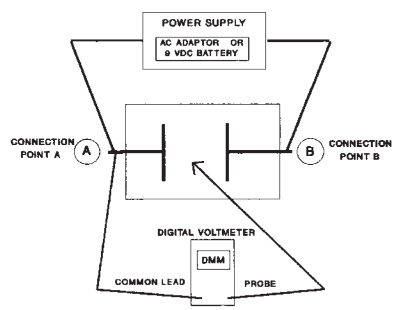
The **Conductive Pen** is used to draw electrodes on the conductive paper. The ink used is a lacquer-based suspension of tiny metal flakes. When ink is applied to the paper, the metal flakes settle out of the lacquer and overlap each other to produce a continuous conductor. The lacquer slowly evaporates and hardens to lock the flakes in place. Depending on width and thickness, a line of dried ink may have resistance of 1 to 10 ohms per centimeter of length. Since this resistance is low compared to the resistance of the paper, electrode resistance causes only minor distortion of the field.

Potential Measurement:

Since resistance of the medium is high, it is desirable to use a high impedance voltmeter. A solid state voltmeter with input impedance of 10 megaohms or more is good, since this is on the order of 100 times that of the paper. Good results may be obtained with a 50,000 ohm impedance meter if the **null method** of measurement is used.

The voltage applied to the electrodes should not exceed the voltage range of the meter, neither should it be less than 50% of full scale. If the meter has a variety of voltage ranges, select one range to accommodate a common battery such as 1.5, 6 or 9 volts. Since the current drain rarely exceeds 1 milliampeter, small batteries will work.

Recommended power source: **615-4065 Battery Kit** from **Science First**.



Setup photo courtesy Bob Cutter, Lynnfield high School, Lynnfield MA

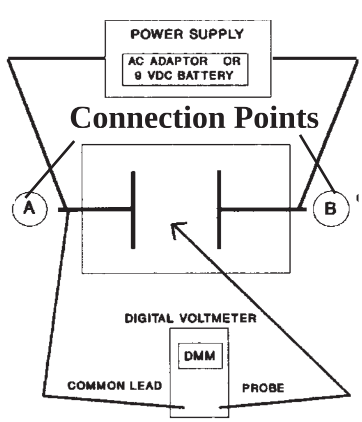


Diagram 1

Collecting and Arranging Data:

Your data will be arranged into a form called an **electric field map.** The data you get from the conductive paper must be transcribed to other paper.

This is a good group project if you follow this procedure:

1. Draw the electrode on conductive paper. The paper itself is marked with lines 1 cm apart on both X and Y coordinates.

2. The electrodes you draw consist of straight lines and/or parts of circles. Record the coordinates of the **ends** of the lines on your data sheet. Record the coordinates of the **centers** and **radii** of any circles used.

3. Now reconstruct the electrode configuration on other graph paper.

Hints

You will need a voltage source to operate this kit. Batteries or a low voltage power supply will be suitable.

The push pins are conductive and should be connected to the voltage source using alligator leads.

The conductive ink is used to draw an electrode on the paper.

A multimeter must be used to measure voltage points on the paper near the electrodes drawn.

Equipotential Lines Using High Impedance Meter

This is illustrated in **Diagram 1,** next paper. If you have a high impedance voltmeter (10 megohms or higher) you can obtain data by direct measurement. Connect one terminal of the meter directly to one of the electrodes. This will be your reference point. Select a voltage between 10 and 20% of the applied voltage and record this on your data sheet. Use the other meter lead as a probe. Locate points on the conductive paper having exactly this voltage. Record the coordinates of 6 or more widely spaced points having this voltage. Repeat for other voltages.

How To Use:

1. Place paper on a hard, flat surface when drawing lines.

2. Choose or assign an electrode configuration (see pages 3, 4.) Consider assigning two students to each configuration. Also consider drawing electrode configurations before the lab to save time both in drawing electrodes and in allowing ink to dry.

3. Draw electrodes in pencil first. See drawing tips, next column.

4. Trace electrode on conductive paper. See tips for using ink, next column

5. Mount conductive paper on cork board using a push pin in each corner. Use 2 more push pins to attach wire leads to the electrodes. Make sure push pins are all the way in and flat. The wire leads must be clean to obtain good contact. If the leads are properly connected, there will be only a very small voltage difference between the push pin and any point on the electrode outline. If the voltage between push pin and inked line exceeds 1% of applied voltage, you may re-ink the line or wider the contact area under the push pin.

6. Plot equipotential lines by connecting one lead (ground or common) of the voltmeter to one electrode using push pins. See *Diagram 1*. This is the reference electrode.

7. Choose a desired potential and move the other electrode about on the conductive paper to locate a set of points all having this same voltage. Use your meter to find an appropriate point.

8. Record the coordinates of these points. Reproduce the coordinates on graph paper. The more data points you have, the more accurate your results will be.

9. Connect each set of points with a smooth continuous line

10. Construct field lines by drawing a single line from one electrode to the other in such a way that it will be perpendicular to each and every equipotential line it intersects. Use pencil instead of conductive ink for this step.

11. Examine electric field gradients. A study of equipotential lines will disclose that distance between the lines is dependent upon electrode shape and distance from the electrode.

Potential gradient is the potential difference between two points divided by the distance between these points. It may be expressed in volts per centimeters. Since electrical insulations fail at high potential gradients, this is an important factor in designing electrical conductors.

These figures illustrate electrical conductors with potential insulation problems: *Two Points; Coaxial Cable; Point and Plate*.

The *Lightning Rod* figure illustrates the effectiveness of two different lightning rods. The center vertical line represents the earth's surface. One side is a long projection, the other side a short one.

Hint

You must use a meter to determine which points on the paper have the same potential when measured against the electrode. They will likely not be at equal distance, because the electrode shapes are not always symmetrical. Both electrodes must be drawn for the experiment to work. One electrode will be energized, and a voltage potential will be selected by the experimenter. It can be whatever you want. You will then use your meter to find points on the graph paper near the that share this potential. You then connect all these points in a single, continuous (possibly curved) line. The final step is to draw line between the two electrodes that intersect the first line at right angles. These secondary lines are the electric field lines, reproduced in a form that can be seen.

Tips for Drawing Electrodes:

- Draw in pencil on scratch paper first using template provided.
- Need not draw electrodes as solid shapes; the outline will work as well as the solid shape it represents.
- When satisfied with your sketch, trace on conductive paper with soft pencil.

Tips for Using Ink:

- Place conductive paper on hard surface with printed side up.
- Recheck your drawing, then trace pencil line with conductive ink. Shake ink thoroughly before using. *Do not use the template with the ink.*
- Ink line must be continuous.
- Let ink dry for 15 to 20 minutes.

Tips for Drawing Field Lines:

- Draw a large number of equipotential lines for best results.
- Draw a representative filed line by selecting a point on one electrode and drawing a light dotted perpendicular line from the electrode toward the closest equipotential line.
- Draw halfway to the equipotential line, pause; continue the line perpendicular to the equipotential line being approached, past this line and halfway to the next closest equipotential line.
- Proceed until dotted line arrives somewhere on the other electrode.
- Redraw line smoothly through the points of intersection of the intervening equipotential lines.
- For appearance sake, choose evenly spaced starting points of field lines. If the drawing is symmetrical, you can find a location where a straight line will intersect each equipotential line perpendicularly.
- Space your other lines regularly about this line.

Suggested Activities:

Compare potential gradients at the trips of each projection. Compare known behavior of lightning with this and other pertinent electrode configurations.

The *Parallel Plate Capacitor, Inserted Insulation in conductor,* and *Inserted Conductor* diagrams represent an electric field undisturbed, a field disturbed by a discontinuity of the conductor, and a field disturbed by another conductor, respectively.

Suggested Questions:

- How could electrical measurements detect internal cracks in metal parts?
- How could electrical measurements locate underground anomalies such as a cave, fault, buried pipe, or vein of minerals?

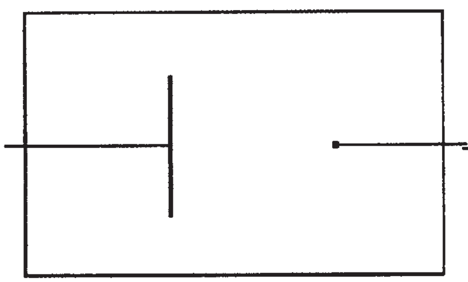
Activity 1

Purpose:

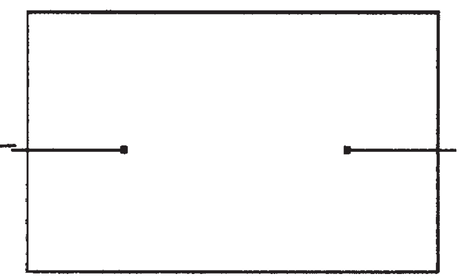
To determine the shape of the electric field about various simple electrode configurations.

Procedure:

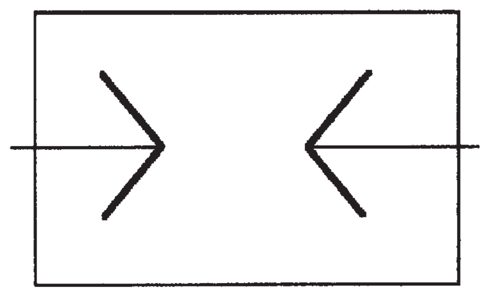
Construct simple electrode configurations of your own or from the list on Page 1 of sample Electrode Configurations.



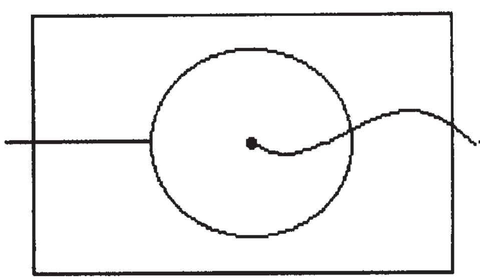
Point and Plate



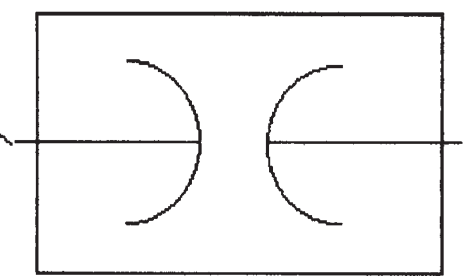
Two Points



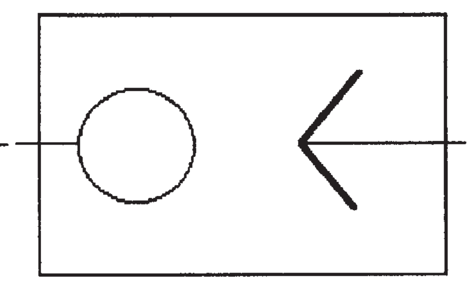
Pointed Electrodes



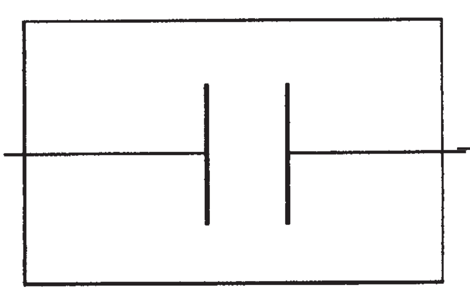
Coaxial Cable



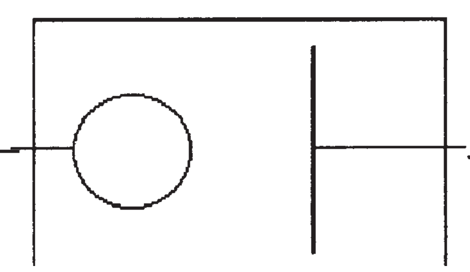
Curved Electrodes



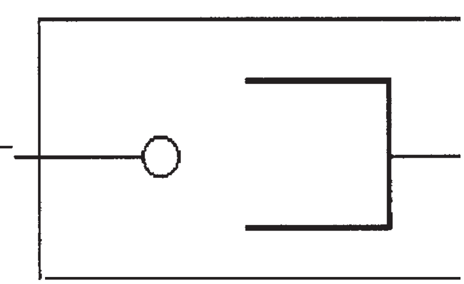
Open Circle and Pointed Electrode



Parallel Plate Capacitor



Open Circles and Plate



Faraday's Ice Pail

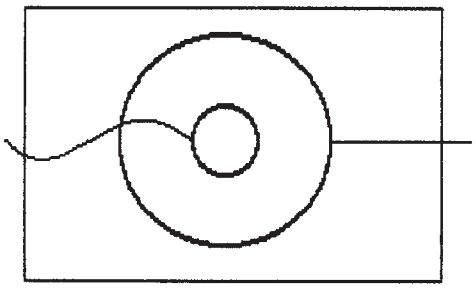
Activity 2

Purpose:

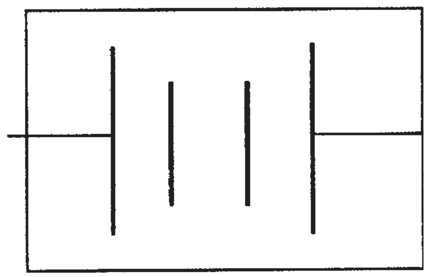
To predict the shape of the electric field for more complex electrode configurations.

Procedure:

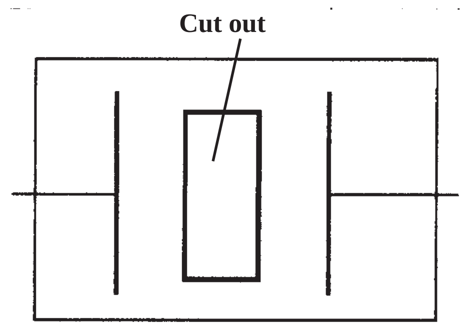
Discuss the results of the first activity noting patterns and similarities about electrodes and their electric field shapes.
Show more complex electrode configurations of your own or from our list.
Predict the shape of the electric fields that will be created. Test your predictions.
Develop your own electrode configurations, making predictions and testing your hypotheses.



Concentric Circles with Hollow Center

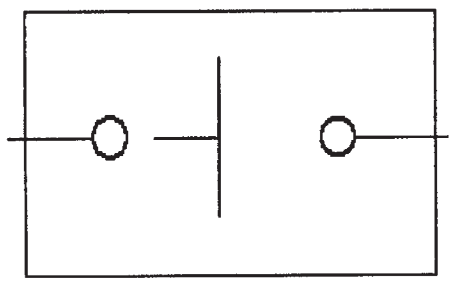


Plates Between a Capacitor

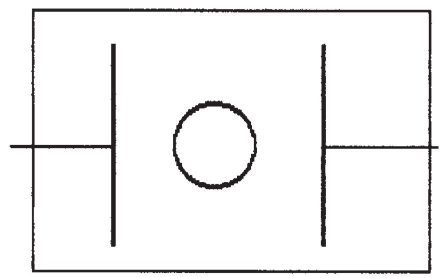


Inserted Insulation or Hole in Conductor

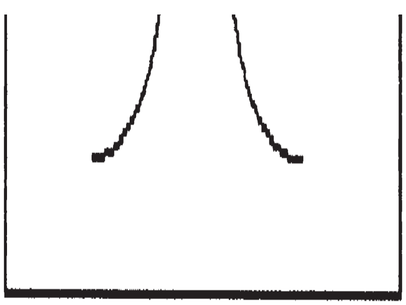
Four Point Charges



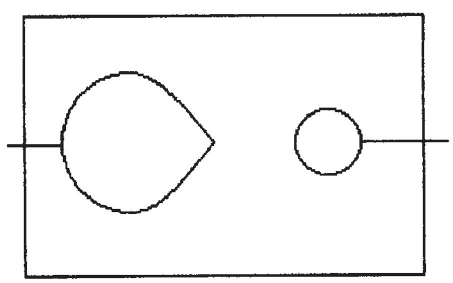
Lightning Rod



Inserted Conductor



Three Point Charges



Charge Concentrator and Sphere

Activity 3

Purpose:

Investigate the relationship between electric field strength and separation distance for parallel plates through use of equipotential gradients.

Procedure:

1. Construct four (or more) sets of parallel plate electrodes at various separation distances.
2. Map several equipotential lines between the parallel plates for each of the plate separation distances.
3. For each equipotential map, calculate several equipotential gradients along the center axis between the parallel plates. (The equipotential gradient is the change in potential difference per unit distance.) Determine average equipotential gradient for each plate separation distance.
4. Plot the parallel plate separation distance vs the average equipotential gradient for at least four separation distances to show the relationship between the two variables. establish a correlation between the equipotential gradient and the electric field gradient. The plot can serve as a calibration curve for the power supply you are using.

Activity 4

Purpose:

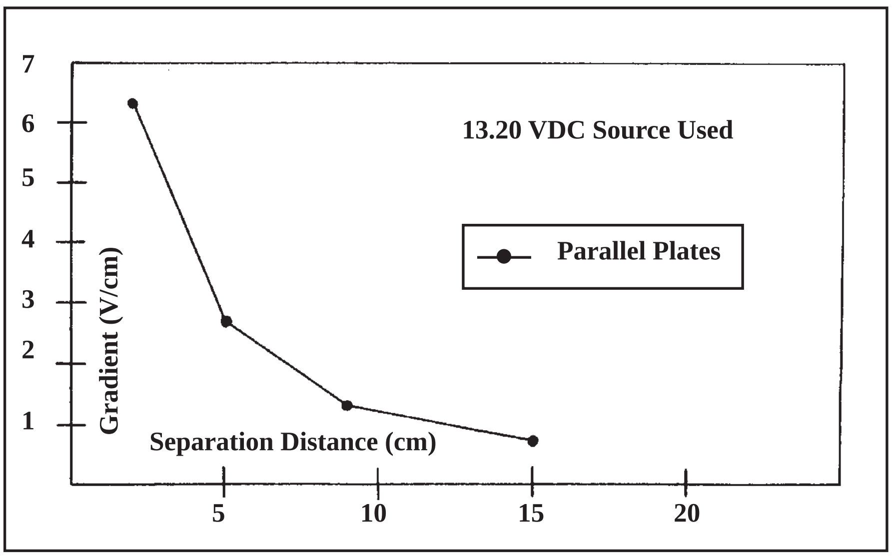
To apply your knowledge of parallel plate separation distance vs equipotential (and electric field) strength along with a calibrated power supply to make and test predictions about a new or untested parallel plate separation distance.

Procedure:

Prepare one or more parallel plate electrodes with separation distances previously unused.

Predict the equipotential gradient and make statements about the relative electric field intensity for the "new" separation distance based on your previous knowledge and calibration curve.

Actually carry out the experiment and test your predictions about the equipotential gradient.



Note: *Both Activity 3 and Activity 4 give best results when gradients are determined as close to the center of the electrodes as possible.*

Teaching Tip:

Make up representative electrode configurations on several sheets of conductive paper before your labs. Hand different sheets to each lab group. Otherwise you might waste valuable lab time drawing configurations and waiting for ink to dry.

Sample Results of Potential Gradient vs Distance

Parallel Plate Separation Distance vs Equipotential Gradient

2.0	6.40
5.0	2.60
9.0	1.46
15.0	0.88