THE UNIVERSITY OF TEXAS-PAN AMERICAN
Department of Physics and Geology

Electric Fields and Potentials

Purpose:
1. To understand the relation between the **electric field vector** and the **electric potential**.

2. To understand the relation between the **electric field lines** and the **equipotential lines**.

Materials:

- Frederiksen Power Supply 0-24V AC/DC 3630.00
- Extech Instruments AC/DC Clamp Meter 380950
- Cenco Overbeck Electric Field Mapping Apparatus catalog no. 79585
- Cenco Overbeck Electric Field Mapping U-Shaped Probe
- Cenco Overbeck Electric Field Mapping Parallel Plate
- Cenco Overbeck Electric Field Mapping Parallel Plate Stencil
- Cenco Overbeck Electric Field Mapping Dipole Plate
- Cenco Overbeck Electric Field Mapping Dipole Plate Stencil
- Assorted connecting wires
- Connecting wire alligator clips
- 2 Blank sheets of paper
- Tape
- Pencil
- Protractor

Theory:
The magnitude of the electrostatic force between two point charges q1 and q2 is given by Coulomb's law

$$\vec{F} = k \frac{q_1 \quad q_2}{r^2} \hat{r}_{12}$$

(*r is the distance between the two charges*). The constant **k** is equal to 8.99 x10^9N m^2/C^2. The direction of this force is determined by the sign of the charges: like charges repel and unlike charges attract.

The magnitude of the electric field is *defined* as the electric force per charge:

$$E = \frac{\vec{F}}{q}$$

In the case of a single point charge q generating the field, we find that

$$E = k\ \frac{q}{r^2}$$

Since a positive test charge will move away from a positive source charge, the direction of the electric field is described as pointing away from a positive charge. Similarly a positive test charge will move towards a negative source charge so that the direction of the electric field is described as pointing towards a negative charge:

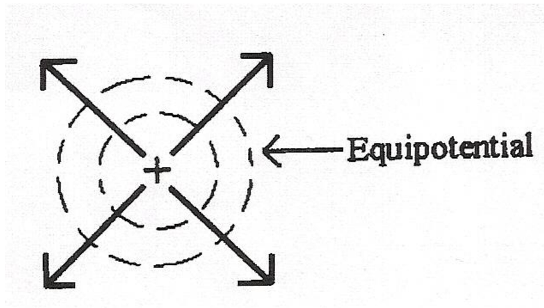
It is in general difficult to measure electric fields directly, but we can obtain a graphical representation of the electric field by measuring the electric potential at a sufficient number of points. When a positive test charge q_0 moves from A to B the electric force does a certain amount of work on it. The negative of the work done per charge is called the **potential difference** between these two points:

$$\Delta V_{AB} = V_B - V_A = -\ \frac{W}{q_0}$$

Only potential ***differences*** have a physical meaning; the potential itself is defined only up to a constant which can be chosen for convenience.

If a charge is moved perpendicularly to the field lines no work is done since there is no force component along this path. In such a case the potential is constant, VA=VB. In two dimensions such paths are called **equipotentials**. In three dimensions these paths form an **equipotential** surface.

Once several equipotentials have been found the electric field lines can be easily determined. Since the potential is constant along paths perpendicular to the field lines, all one has to do is draw a number of lines which are normal (perpendicular) to the equipotentials.



Finding the *magnitude* of the electric field is not so easy, except when the field is uniform (constant). In this case the force on a test charge q_0 is also constant, and given by

$$\vec{F} = E\, q_0$$

Therefore when the charge moves a distance   in the direction of the field lines, the work done on it is

$$W = \vec{F}\,\Delta s = E\, q_0\, \Delta s$$

Therefore the potential difference is

$$\Delta V = V_B - V_A = -\frac{W}{q_0} = -E\,\Delta s$$

It follows that the relation between the field and the potential is

$$E = -\frac{\Delta V}{\Delta s}$$

In the general case when E is changing from place to place, this has to be replaced by the ***infinitesimal*** rate of change of the potential V along the field line**:**

$$E = -\frac{dV}{ds}$$

In this case to get E with a reasonable precision we will need to draw equipotential lines which are sufficiently close to each other so that E does not change very much from one line to the next.

Experimental Procedure:

Part I:

Parallel Plate

1) Attach the parallel plate (figure 1) to the underside of the mapping apparatus (figure 2). Make sure the parallel plate is pointed *down* (towards the desk) and make contact with the mounting screws.

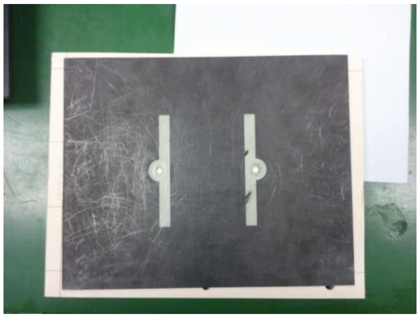


Figure 1

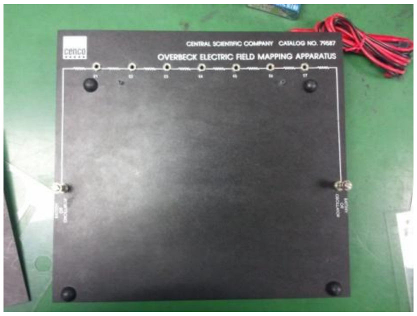


Figure 2

2) Using a blank sheet of paper. Attach paper to the surface of the mapping apparatus under the plastic tabs. Apply four (4) pieces of tape on the corners of the paper to prevent the paper from moving.

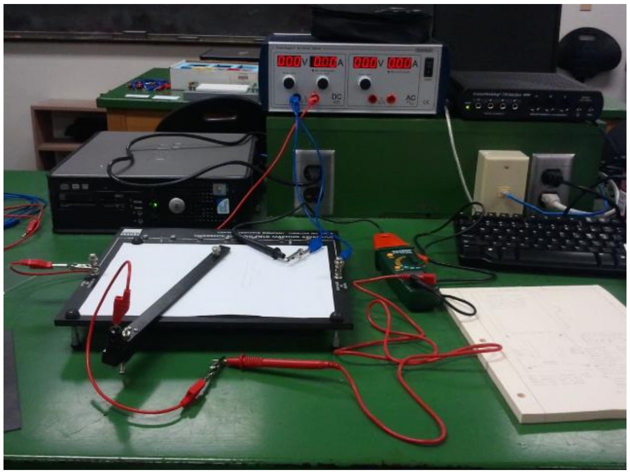
3) Use the parallel plate stencil; trace the parts that look like the parallel plate onto the blank sheet of paper in the center of the paper which is attached to the mapping apparatus.

4) Connect one (1) *red* wire from the **+DC** port on the power supply to one of the "*battery or oscillator terminal*" of the mapping apparatus. *Hint: You may have to connect more than one wire together.

5) Connect one *blue/black* wire from the **–DC** to the black **[com]** port on the multi-meter. *Hint: you will have to use the alligator clip to attach to the multi-meter.

6) Connect the *red* wire from the multi-meter **[VΩHz]** port to the "U-Shaped Probe". *Hint: you will have to use the alligator clip to attach to the multi-meter.

7) Connect one *blue/black* wire from the **–DC** to remaining "*battery or oscillator*" terminal of the mapping apparatus.



8) Turn on the power supply. On the DC side turn the left knob until the LED read out reads 10V. *Hint: if the red light is lit on the "max current reached", turn the knob under the Amp LED read out all the way to the right till the light is no longer active. If this light fails to turn off, notify your instructor.

9) Turn the knob on the multi-meter to $[\,V\frac{AC}{DC}\,]$

10) Using the "U-Shaped Probe", find six (6) or more points (the more points found the clearer the lines will be) in which the voltage reads the same on the multi-meter between the parallel plates. It is important to

make sure some of the points are not between the parallel plates. *Hint: if you are reading voltage in the mili-volt (mV) range, you need to check your placement of the parallel plate.

11) Record your voltages for parallel plate in table 1. V_1 will be the FIRST voltage you choose. You will find at least six (6) points that match this voltage. V_2 will be the next voltage you choose and find six (6) points with this voltage.

TABLE 1					
V1	V2	V3	V4	V5	V6

12) Find five (5) more voltages like in previous step for a total of six (6) voltages.

13) Connect the dots with the same voltage using a pencil to form lines. *Hint: Using a straight edge will have negative effects on your results.

14) ***<u>Turn off both the power supply and the multi-meter</u>***. Since equipotential lines are perpendicular to the electric field lines, use a colored pencil or color pen to draw the electric field lines between the plates. Make sure you denote which "*battery or oscillator*" terminal is positive and negative.

15) Compute the approximate value of the electric field at a sufficient number of points to get an over of the field using your data in table 1. Use the equations above for both force and electric field to determine the electric field at each voltage measured.

16) Draw at least five (5) vectors and make sure you denote direction of the vector using your data in table 1. *Hint: use this to determine which terminal is positive and which is negative. Use equation:

$$\mathbf{E} = -\frac{\Delta \mathbf{V}}{\Delta \mathbf{s}}$$

17) Write the equation and solutions to the electric field and potentials on the edge of the parallel plate data.

18) Remove the parallel plate from the mapping apparatus. **DO NOT DISCONNECT ANY OF THE WIRES!!**

<u>PART II:</u>

<u>DIPOLE PLATE:</u>

1) Attach dipole plate to the mapping apparatus in the same fashion as in Part I.

2) Attach a blank sheet of paper to the mapping apparatus as done in Part I.

3) Using the dipole stencil trace the dipole circles on the paper as done in Part I and remember to secure the page to the mapping apparatus.

4) Repeat steps done in Part I to find the voltages of the equipotential lines and electric fields. Record data in table 2.

TABLE 2					
V1	V2	V3	V4	V5	V6

5) ***Turn off both the power supply and the multi-meter.*** Since equipotential lines are perpendicular to the electric field lines, use a colored pencil or color pen to draw the electric field lines between the plates. Make sure you denote which "battery or oscillator" terminal is positive and negative.

6) Compute the approximate value of the electric field at a sufficient number of points to get an over of the field using your data in table 2.

7) Draw at least five (5) vectors and make sure you denote direction of the vector using your data in table 1. *Hint: use this to determine which terminal is positive and which is negative. Use equation:

$$\mathbf{E} = -\frac{\Delta \mathbf{V}}{\Delta \mathbf{s}}$$

8) Write the equation and solutions to the electric field and potentials on the edge of the dipole plate data.

Questions:

1) We have physically shown the electric field line is perpendicular to the equipotiental line, why is this always the case?

2) Why is the Dipole Plate electric field different from the Parallel Plate electric field?

3) Will the fields be different if we used 20V instead of 10V? Why or why not? DO NOT ATTEMPT THIS EXPEIRMENT!