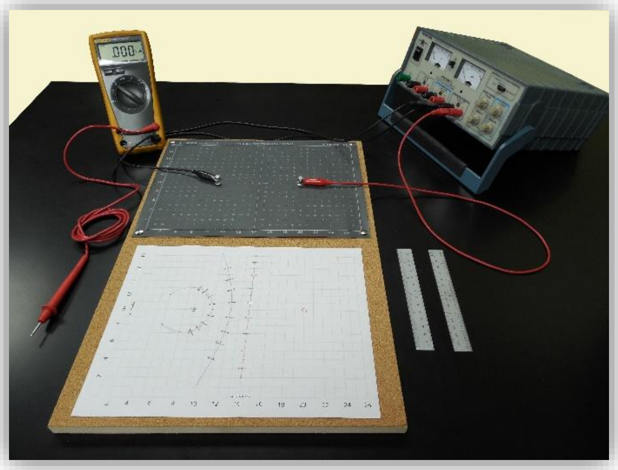
E2c: Electric Field and Electrostatic Potential

Introduction:

The main objectives of this experiment are to examine the electric field lines developed when electric charges are present and investigate the relationship between electric field, E, and the electrostatic potential, V. When two equal but opposite charges are some distance apart, a fixed potential difference, known as voltage, will exist between them. The space surrounding these charges will also develop potential differences ranging in value. All points in space have a certain potential difference, and in a three-dimensional space, the collection of points with the same voltage forms an equipotential surface. A two-dimensional sheet of paper will represent a slice of this surface in the form of a line. Since all points in this line are also at the same potential, they are called equipotential lines. Because of the weak electric field being used for this experiment, it is easier to map the electric field lines in an indirect way, by first measuring the voltages of these equipotential lines. The electric field lines are always perpendicular to the equipotential lines, so once several equipotential lines are obtained, it becomes possible to map the electric field.

Apparatus:

- Prepared conductive papers
- Multimeter
- Power supply
- Metallic Rulers
- Plastic Ruler
- Metal pushpins
- Graphing paper



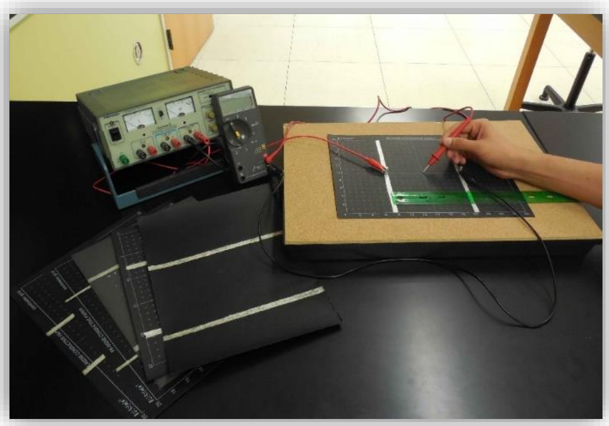


Figure 1

Discussion:

Before beginning this experiment, it is necessary to first read up on and understand the relationship between electric field lines and equipotential lines as well as the relationship between electric field and electrostatic potential. Furthermore, it is important to understand the basic concepts behind capacitors. *Please read the relevant material in your textbook for this experiment.*

The Electric Force and Field	Cutnell & Johnson. **Physics**, *Chapter* **18** *section* **5**, **6,7**
The Electric Potential Difference	Cutnell & Johnson. **Physics**, *Chapter* **19** *section* **2, 3, 4**
Equipotential Surfaces, Capacitors	Cutnell & Johnson. **Physics**, *Chapter* **19** *section* **4,5**

An electric charge creates an electric field in the region of space surrounding it. The electric field will influence other electric charges within the region to electrically interact with the charge creating the electric field. As such, the charges attract or repel depending on their polarities. The electric field and ensuing force interactions makes the chemical bonding of atoms possible and is responsible for the age of electronics which we now participate in.

Quite generally, the electric field, E, can be related to the electric force, F. Generally, these are vector quantities (they have both magnitude and direction), so vector symbolism will be employed:

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

Here, q_0 represents the testing charge placed in the electric field. Furthermore, a special case of electric field involves the point charge. Essentially, this is a charge that 'takes up no space', but can be considered to be a charge that occupies an extremely tiny area. For a point charge, the electric field produced as an effect is:

$$E = \frac{kq}{r^2}$$

Here, k is the coulomb constant: $8.99 \cdot 10^9 \frac{N \cdot m^2}{C^3}$ and r is the distance from the charge (q) responsible for the field and the point where we are trying to find the field.

Another important concept is electric potential, which is the amount of work required to move a unit positive charge from a reference point to another specific point inside the field without accelerating the charge. Typically, the reference point is taken to be infinitely far away (a very, very enormous distance), so that the potential at that point is zero. As such, a simple relationship to find the electric potential, V, of a point charge results:

$$V = \frac{kq}{r}$$

A parallel-plate capacitor is an object made of two parallel planes that have the capability to store potential energy within the electric field between the plates. Most electronic-grade capacitors include a dielectric substance between the plates of the capacitor (like ceramic or an electrolyte). A dielectric tends to reduce the magnitude of the electric potential between the plates. In this experiment, different conductive papers will be utilized, which represent the dielectric material of the capacitors observed.

Since the discussion has been about the electric field and the electrostatic potential, the next obvious question is how the two are related. Simply enough:

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

The electric potential, or voltage (ΔV), within the experiment will be measured using a digital multimeter (DMM). The black probe (the negative one) will be connected directly to the negative plate of the capacitor. The red probe (the positive one) will be used to pick a point between the plates, where the voltage will be measured. In the electric field equation, Δs is the distance between the negative plate and the probe. The negative sign here should not be overlooked! It represents the fact that electric field and electrostatic potential are negatively, linearly proportional.

Procedures:

Do not begin this experiment without first checking with a lab instructor.

This experiment consists of two different parts. The first portion finds the equipotential lines and the electric field lines for two point charges. The second portion finds the electric potentials between two bar charges and graphs the data to find the electric field. This is done for three capacitors with three different distances of separation between the plates.

Part I

1. Make sure the COM port on the digital multimeter (DMM) is connected to the negative terminal on the power supply.
2. Connect each cable on the power supply to the pushpins located in the conductive paper. Make sure these pins are located at the specified points: (x,y) where x=8 and y=10 for the first point (8,10) and x=20 and y=10 for the second point (20,10).
3. Turn on the power supply and set it to approximately 15V.
4. Using the positive (red) probe of the DMM, measure the voltage at the points listed in table one. Ask for an instructor's assistance if you are unfamiliar with using the DMM. Mark these points on the graph provided in the lab handout. You will want to record these voltages so you can find points corresponding to these equipotential lines later.
5. Using the DMM find another point on the conductive paper at y=8 corresponding to the voltage you found at (10,10). Mark this point on your graph.
6. Repeat step five for y=6. If you can't find a point with a matching potential along the line y=6 then move up one line (to y=7) and check there.
7. Repeat step five for y=12 and y=14. If you can't find a point with a matching potential at y=14 move down one line and continue.
8. Now use the positive probe of the DMM to find another point on the conductive paper at y=8 corresponding to the voltage you found at (12,10) and mark it on the graph. Repeat this step, moving down the y-axis by two units each time (e.g. y=6, y=4, etc.) until you reach y=2.
9. After reaching y=2 repeat step 8 for y=12 to y=18. You should have nine points between y=2 and y=18 at the end of this step.
10. Repeat steps eight thru nine for the points you found in step four at (14,10) and (16,10) in Table 1.
11. Repeat steps five thru seven for the point you found at (18,10). At the end of this step you should have five separate lines. Smoothly connect the dots in each of these lines using the French curve provided to form your equipotential lines.

12. Now it is possible to map the electric field lines. These lines start from the positive charge and finish on the negative charge always crossing the equipotential lines at 90º, so by intercepting each equipotential line by another line perpendicular to it, the electric field can be sketched. Draw seven electric field lines evenly spaced.

TABLE 1

x	y
10	10
12	10
14	10
16	10
18	10

Part II

1. Identify the conductive paper with the first capacitor and measure its distance of separation, d_1. Record this in the appropriate box on the data sheet.
2. Now, beginning 5 millimeters away from the negative bar, measure the voltage at this point using the Digital Multimeter (DMM). Record the distance from the negative bar and the voltage at this point in the appropriate places on the data sheet.
3. Now, move the probe 5 more millimeters away from the negative bar and measure the voltage once more. Record the voltage at this point in the appropriate place on the data sheet.
4. Repeat step 3 until you reach the positive bar of the capacitor.
5. Repeat steps 1 through 4 for the second capacitor with distance of separation d_2.
6. Repeat steps 1 through 4 for the third capacitor with distance of separation d_3.

Experiment E2c: Electric Field and Electrostatic Potential

Student Name____

*Lab Partner Name*____

*Lab Partner Name*____

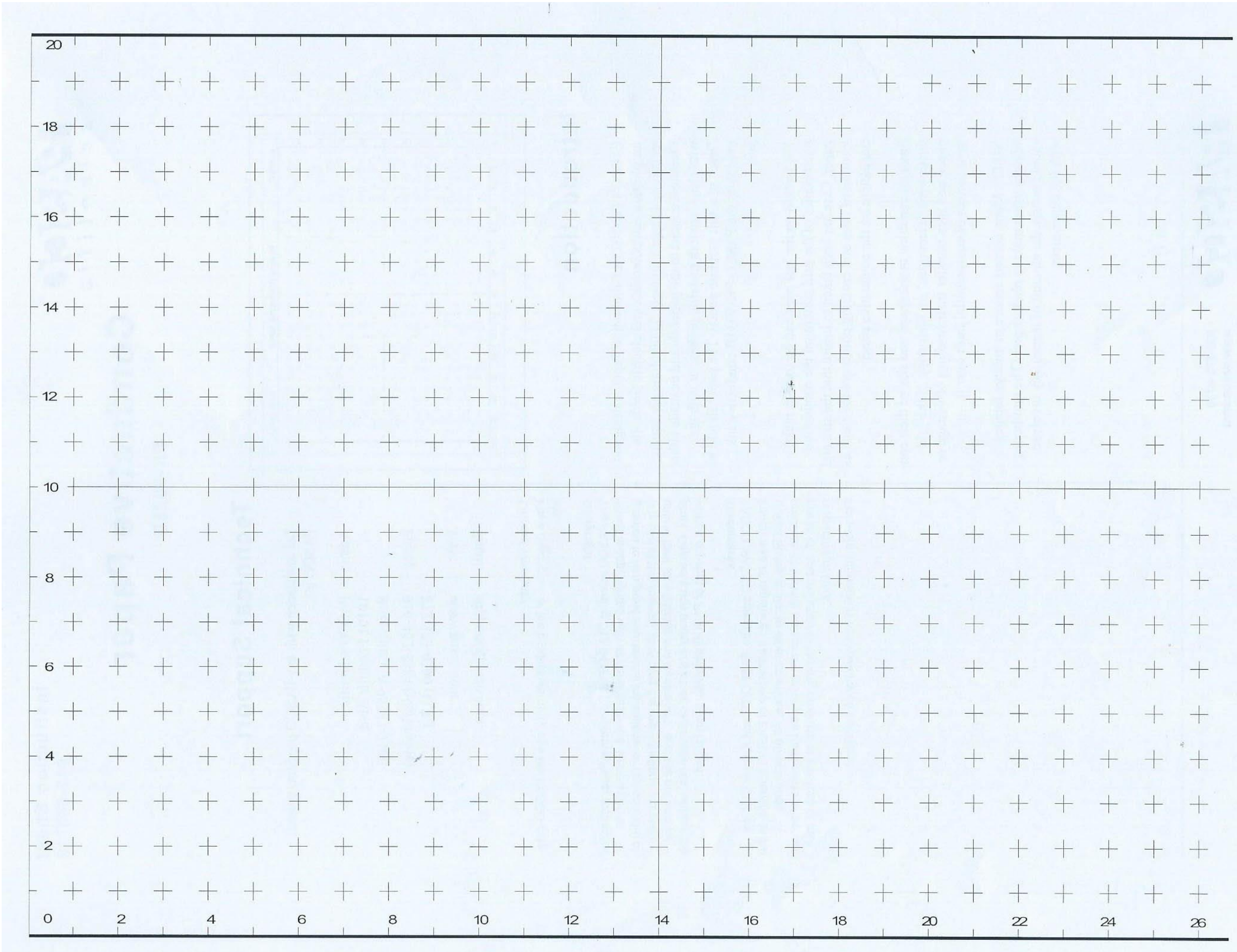
Physics Course____

Physics Professor____

Experiment Start Date__________________________________

Lab Assistant Name	*Date*	*Time In*	*Time Out*

Experiment Stamped Completed


20
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26

Data Sheets: E2c: Electric Field and Electrostatic Potential

NAME: ______________________________ DATE: __________________

DATA TABLE | PART II

Distance from Negative Plate (m)	Capacitor 1 Voltage d_1: ________ (V)	Capacitor 2 Voltage d_2: ________ (V)	Capacitor 3 Voltage d_3: ________ (V)

Analysis:

1. **<u>Contact a lab instructor for helping locating the appropriate Excel file for inputting and saving your data!</u>**
2. In the appropriate columns of each graph (for each capacitor), input the observed distances and voltages from the data sheet.
3. What is the physical meaning of the slopes of these graphs?

4. From the graphs provided (after inputting all of the relevant information from each of the three capacitors), determine the electric field, E, for each capacitor.

   Capacitor 1: ________________________________
   Capacitor 2: ________________________________
   Capacitor 3: ________________________________

5. According to the results, what is the relationship between electric field and the distance of separation between the plates of a parallel plate capacitor?