PY 106

Section: Name: BU ID: .

Partner: Name: BU ID: .

Lab 2: Electric Field and Potentials

Part 1. Theory.

The purpose of this lab is to investigate the relation between electric field lines and equipotential surfaces (or lines) in two dimensions. You will use two metal electrodes and study the electric field and equipotential patterns associated with them.

1. Electric field is

[ ] a scalar. [ ] a vector. [ ] it depends on the nature of the charges generating the field.

2. Potential is

[ ] a scalar. [ ] a vector. [ ] it depends on the nature of the charges generating the field.

3. Check all statements that are correct.

[ ] Electric field lines are always parallel to equipotentials.

[ ] The angle between field lines and equipotentials depends on the nature of the charges generating the field.

[ ] Electric field lines are always perpendicular to equipotentials.

[ ] For any two points on the same E-field line, electric field line always points from a lower potential toward a higher potential.

[ ] For any two points on the same E-field line, electric field line always points from a higher potential toward a lower potential.

[ ] Electric field lines can cross each other.

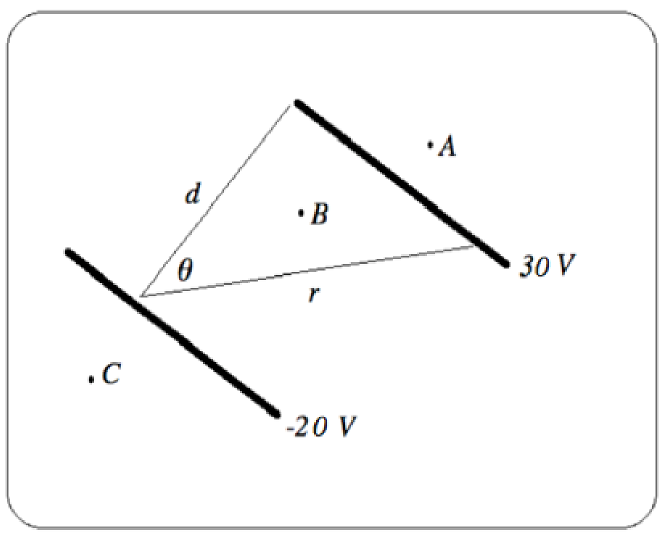
[ ] Electric field lines never cross each other.

The picture on the right shows a region with a *uniform* electric field in it (field lines are not shown).

The two thick lines represent two equipotentials.

4. Sketch electric field *vectors* at points A, B, and C.

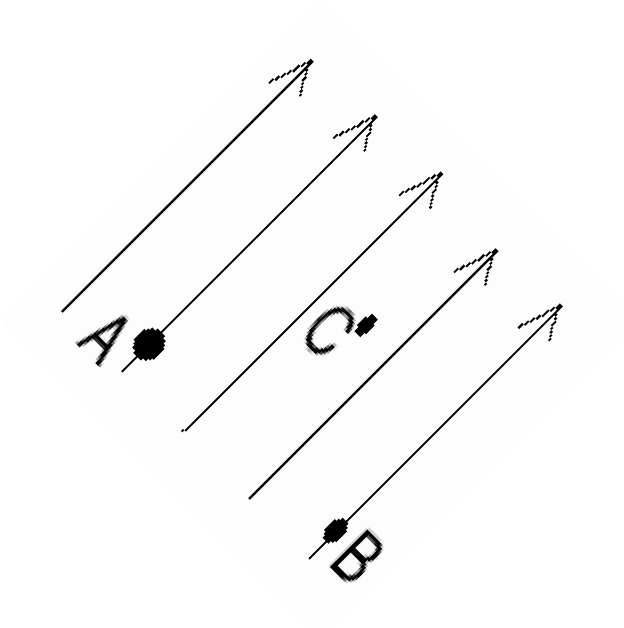
5. Write an equation which you should use to calculate the magnitude of the electric field, $|E|$, at point B.



6. Name only *one* (!) additional variable (shown in the picture) which value you need to know in order to calculate $|E|$.

7. Use a *specific measuring device* (you can find it on your table), measure the value for the variable named in question 6 and using that value calculate the magnitude of the electric field, $|E|$, at point B in the region shown in the picture on page 1.

The picture on the right shows a region with a *uniform* electric field in it (field lines are shown).



Note: if you draw a line which passes through point A and is *perpendicular* to the field lines, it also passes through point B.

8. Draw an equipotential line through point A; draw an equipotential line through point C.

9. In the picture on the right, the distance between points B and C is equal to the distance between points A and C and equal to 5 m; the distance between points A and B is equal to 6 m; the potential at point C is equal to -200 V; the magnitude of the electric field in the region is 100 V/m.

Use the data to find potential, V_A, at point A. Also find, V_B, at point B.

$V_A =$ $V_B =$

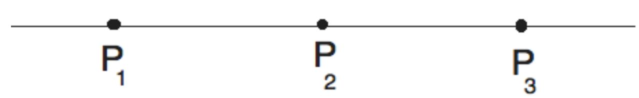
10. What is the *change* in the potential when moving from point A to point C?___________________

11. When moving from point A to point C potential _____________(state if it drops or rises)

What is the potential *drop/rise* when moving from point A to point C? _________________

12. What is the *potential difference* between points A and C? ________________________

The picture on the right shows a field line and three points on it. Potentials at the points are $V_1 = -3$ V, $V_2 = 0$ V, $V_3 = 3$ V. Assume that in the region between points P_1 and P_3 electric field is *uniform*.



13. In which direction does electric field point at point P_2? Explain the reason for your answer.

14. If you start at point P_2 and move in the direction of the electric field, what is the *change* in the potential when you reach the next point shown in the picture?

15. If you start at point P_2 and move in the direction of the electric field, what is the potential drop/rise when you reach the next point shown in the picture?

16. Check below all statements that are correct.

[ ] Equipotentials are always parallel to electric field lines.

[ ] Equipotentials are always perpendicular to electric field lines.

[ ] Electric field vector always points in the direction of the fastest increase in the potential.

[ ] Electric field vector always points in the direction of the slowest increase in the potential.

[ ] Electric field vector always points in the direction of the fastest decrease in the potential.

[ ] Electric field vector always points in the direction of the slowest decrease in the potential.

Part 2.

The purpose of this part is to experimentally investigate the relationship between electric field lines and equipotential surfaces (lines) in two dimensions. At first you will use two bar electrodes. Then you will use a point electrode and a bar electrode and study the electric field and equipotential patterns associated with them.

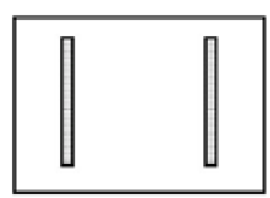
APPARATUS

⚐ DC power supply (25-40V max) ⚐ Multimeter
⚐ Conductive paper ⚐ Copper foil tape with conductive adhesive
⚐ Scissors ⚐ Cork board
⚐ Assorted leads ⚐ Push pins

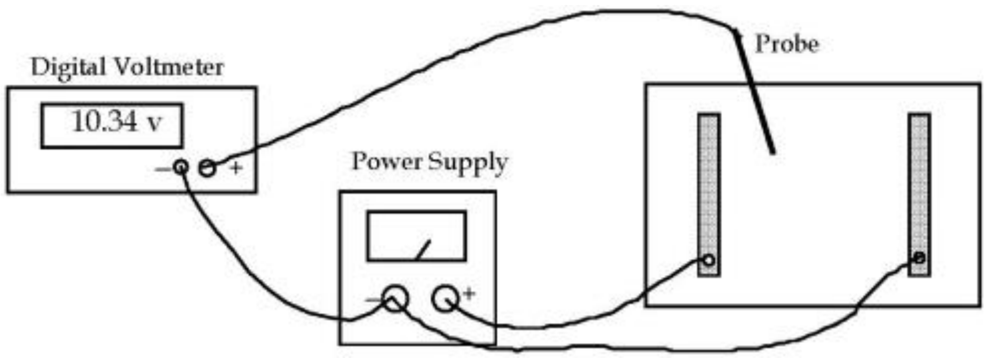
The apparatus consists of a sheet of conductive carbonized paper, metallic tape used as the electrodes, push pins for connecting the power supply to the electrodes, and a multimeter with various probes for making measurements of potential, V.

Potentials are often defined relative to some standard reference point that is taken to be zero. The reference point is often referred to as *ground*. In your lab the ground is the electrode with 0 potential (usually connected to the black prong of a power supply). The SI unit of potential is Joule/Coulomb that has been given the name V*olt*.

<u>1. Making Electrodes</u>: Use the 20 x 28 cm grid markings as a guide for dimensions. Make 2 parallel bar electrodes ~20 cm in length each. Have your electrodes spaced 20 - 25 cm apart so that measurements are more easily made. You will need to make measurements on both sides of the electrodes, so be sure to leave a couple of centimeters of space between the edge of the paper and your electrodes. Use the metallic tape and construct two parallel electrodes (see the picture on the right). Make sure that the tape is tightly adhered to the paper and free of wrinkles (by rubbing with the edge of your fingernail).



2. Because the black paper is conductive, potential difference between the electrodes sets up an electric field in the paper between them. You will be able to measure the potential rise/drop between any two points using two probes that are connected to a digital multimeter. You will use the multimeter as a *voltmeter*, which measures the potential rise/drop between its terminals. It is calibrated in volts with several scale settings.



3. Effective Electrode Potential: Since the adhesive on the back of the tape somewhat insulates the metal from the paper, it is necessary for you to determine the *effective electrode potential* for each electrode. To do this, insert push pins through each metal electrode and connect them with wires to a + (usually red) and a — (or ground, usually black) terminals/prongs of the power supply respectively (see the schematics above). Label the positive (+) and negative (—) electrodes on the carbonized paper. Increase the voltage of the power supply to 25-30 volts. Setup the multimeter as a voltmeter on the appropriate scale.

Connect the ground terminal (—) of the multimeter to the ground terminal (—) of the power supply. Make sure that when you touch the electrodes by a probe you read 0 V (when touching the grounded electrode) and +25-30 V (when touching the positive electrode). *The potential difference between the electrodes should be very close to the voltage setting of the power supply. If not, check that you have connected everything correctly and that your pushpins are making contact with the metal part of the tape.* These potentials would have been the electrode potentials if the tape made perfect contact with the carbon impregnated paper, but it does not. Hence, determine the *effective electrode potential* for each electrode by measuring the potential on the paper very near to (~ 1 mm) but not touching the conductive tape. Make several measurements along each electrode and use the average value as the *effective electrode potential*. **Write the effective potentials next to each electrode**.

You should observe no more than a ~5 volt difference between the potential measured directly on the tape and the potential measured 1 mm away from the tape on the paper. If that is not the case adjust the power supply voltage or rub the tape more tightly to the paper.

Write the value for *effective electrode potentials* of your electrodes.

V_- = V_+ =

(**ATTENTION:** the difference between V_- and V_+ has to be at least 12 V! Otherwise, make adjustments to your setup)

4. Equipotential Lines: Using the apparatus you will plot the equipotential lines -- lines on which the electric potential is constant. Touch the probe of the meter to the paper approximately half way between the effective potentials. Mark this point with a pencil. Press the probe (keep it vertical), read the voltage, write it down. Now move the probe around the paper to find other points *with the same potential* (try to apply *the same pressure* every time when you use the probe). Mark each of these points with your pencil (note: keep about 1 cm between the points). Find at least six more equipotential points, then connect them together to form an equipotential line. Draw the equipotential line; label it with its potential.

5. Repeat the procedure to plot more equipotential lines on each side of your first equipotential line; when drawing new lines increase/decrease your voltage by about 1 or 2 V.

6. You have to plot at least 7 equipotentials between the electrodes. Label all the lines with their voltages.

7. Take your conductive paper off the board and using your equipotential pattern draw five electric field lines. Calculate the average magnitude of the electric field for two different E-lines. Show your work.

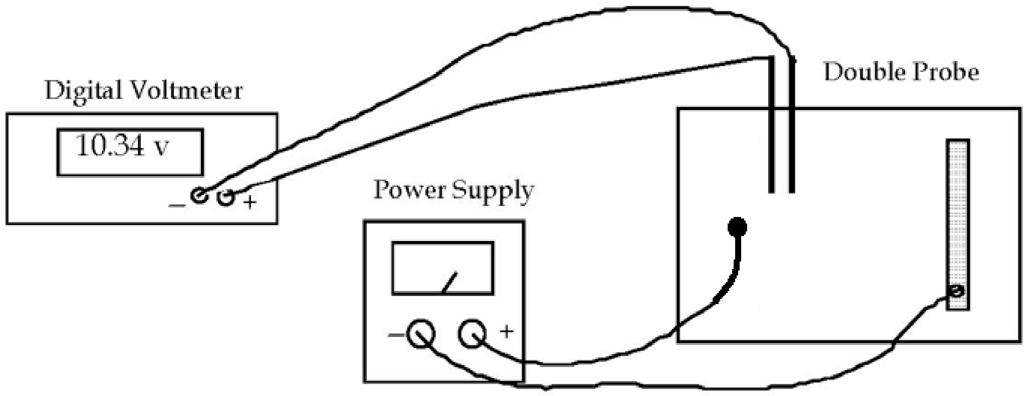
8. What kind of a line (E-field or equipotential) runs along, or "hugs", the boundary of a conductor (an electrode)? What kind of a line comes out a conductor and perpendicular to it?

9. Your textbook says that for two parallel electrodes $|E| = |\Delta V|/d$ where ΔV is the potential difference between the electrodes. This formula suggests that *E* is uniform between the plates. Is this what did you observe? Explain any deviations.

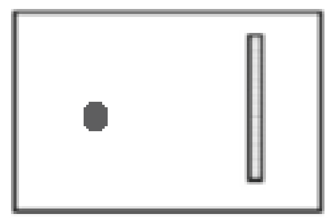
10. Did you observe field lines or equipotential lines crossing each other?

11. Choose two equipotentials and calculate the work *electric field* would do when a 2μC charge is moved from the lower potential to the higher one. Show your work below.

12. Take a new page of conductive paper, replace the paper on the board with the new one.



13. Making Electrodes: Plan your electrode configurations by outlining them in pencil on the carbon impregnated paper. Use the 20 x 28 cm grid markings as a guide for dimensions. Make a bar electrode at least 20 cm long and a point electrode about 10 cm away from the bar electrode. Construct your electrodes using the metallic tape as shown in the picture on the right. Be sure the tape is tightly adhered to the paper and free of wrinkles by rubbing with the edge of your fingernail.



Connect these electrodes to a power supply to create a potential difference between.

You will be using now *the double probe*, which measures the difference in potential between two points *separated by 1 cm*.

14. Let's say the potential difference measured by the probe has the magnitude of 4.5 V. What is the magnitude of the average electric field *between the tips of the double probe*? Show your work.

15. Connect the double probe to a multimeter. Turn on the power supply and set it to about 30 V. Chose *one* point close to an electrode with a *higher* potential (about 1.5 cm from the electrode) and mark it with a pencil. Place the *grounded* tip of the probe at the marked point (we call it a resting tip; it has to be connected to the grounded terminal of the multimeter). Hold it nearly vertically. Carefully rotate the probe through 360° about the resting tip (keep your resting tip still, slightly lift the moving tip off the paper and place it back at a different location). The multimeter shows the potential rise/drop between the resting tip and the moving one. Describe what do you observe happening to the readings on the multimeter? **Note: in all questions below "a value" represents an *actual* reading and could be positive or negative ("a magnitude" is never negative).**

16. Make a sketch of the situation you observed in part 15 when you were moving the tip (electrodes, two points with potentials, show which point represents the resting tip), and show the location of the moving tip when the reading on the multimeter *reached its maximum value*.

17. Write the *maximum* **value** for the reading between the resting tip and the moving tip observed while you had made a 360^0 rotation

V_{max} =

18. Write the *minimum* **value** for the reading between the resting tip and the moving tip V_{min} =

19. For the values in questions 17 and 18, the electric field points … (check all correct answers)

[ ] from the moving tip toward the resting tip when V_{max} is reached.

[ ] from the moving tip toward the resting tip when V_{min} is reached.

[ ] from the resting tip toward the moving tip when V_{max} is reached.

[ ] from the resting tip toward the moving tip when V_{min} is reached.

20. In the picture you drew above (for question 16), does the electric field at the resting tip point toward the *moving tip* (a.k.a. electrode) or away from it?

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Keeping the resting tip fixed at a point near an electrode, rotate the probe and stop when the meter reads the ***minimum value***. *Make sure your resting tip is connected to a grounded terminal of the multimeter*. It is best to rock the probe back and forth a little when you are near the minimum to close in on it from either side.

When you find the location of the moving point which gives you the *minimum value* for the reading, mark it with a pencil. Move your resting tip to that point and repeat the procedure. Repeat the procedure until you almost reach another electrode. Connect the points.

21. The line you drew is

a) [ ] a field line b) [ ] an equipotential line

22. Using different initial points, repeat the measurement and draw four more lines. *For each line show its direction.*

23. Sketch at least four lines *perpendicular to the lines drawn in part 22*. The new lines are …

a) [ ] field lines b) [ ] equipotentials (equipotential lines)

Unplug the double probe. Return to the original setup, but with the new electrodes (a bar and a dot): i.e. connect the electrode with the lowest potential to a grounded terminal of the multimeter (use a wire with a banana plug at one end and an alligator plug at another end); plug in a single probe into the positive terminal of the multimeter.

24. Choose two equipotentials, mark them 1 and 2. Use the single probe and measure the potential at each of the equipotentials:

V_1 = V_2 =

25. Calculate the work YOU would have to do in order to move a point charge of 2μC from the first equipotential to the second one.

Equipment

Lab 2 (12 tables): Electric Field and Potential Apparatus

Unit layout

L2: 140 min

PE2: 60 min

Breaks when needed

Practice Exercise 2:

Two very large uniformly charged parallel plates generate electric field (in the "outer" space, meaning, you can ignore the rest of the universe). Each plate is a 10^5 m by 10^5 m square. The first plate caries a -10 C charge, the second plate caries a 20 C charge. The distance between the plates is 200 m. Plot the graph *for the x-component of the net electric field as a function of x* (see the picture below). Then plot the graph for the *net potential of the field as a function of x* (set the potential of the negative plate to be equal to 0 V).