Problem: The concept of a field is an abstract one. Many high school students struggle more with this concept than many others. It is my experience that students will have the most difficulty coming to an understanding of this concept. Therefore it is essential to provide hands on laboratory activity in determining the electric field pattern around charge objects.

Abstract: The students will measure the potential in a wet field apparatus and plot the potentials. From this pattern, they will draw a corresponding electric field pattern. The student will compare a hand drawn pattern to a computer generated pattern of their own data.

State Standards for Physics:
SCSh3. Students will identify and investigate problems scientifically.
   a. Suggest reasonable hypotheses for identified problems.
   b. Develop procedures for solving scientific problems.
   c. Collect, organize and record appropriate data.
   d. Graphically compare and analyze data points and/or summary statistics.
   e. Develop reasonable conclusions based on data collected
   f. Evaluate whether conclusions are reasonable by reviewing the process and checking against other available information.

SCSh4. Students will use tools and instruments for observing, measuring, and manipulating scientific equipment and materials.
   a. Develop and use systematic procedures for recording and organizing information.
   b. Use technology to produce tables and graphs.
   c. Use technology to develop, test, and revise experimental or mathematical models.

Advanced Placement Standards for Physics
2. Electric field and electric potential (including point charges)
a) Students should understand the concept of electric field, so they can:
   (1) Define it in terms of the force on a test charge.
   (2) Describe and calculate the electric field of a single point charge.
   (3) Calculate the magnitude and direction of the electric field produced by two or more point charges.
   (4) Calculate the magnitude and direction of the force on a positive or negative charge placed in a specified field.
   (5) Interpret an electric field diagram.
   (6) Analyze the motion of a particle of specified charge and mass in a uniform electric field.
b) Students should understand the concept of electric potential, so they can:

1. Determine the electric potential in the vicinity of one or more point charges.
2. Calculate the electrical work done on a charge or use conservation of energy to determine the speed of a charge that moves through a specified potential difference.
3. Determine the direction and approximate magnitude of the electric field at various positions given a sketch of equipotentials.
4. Calculate the potential difference between two points in a uniform electric field, and state which point is at the higher potential.
5. Calculate how much work is required to move a test charge from one location to another in the field of fixed point charges.
6. Calculate the electrostatic potential energy of a system of two or more point charges, and calculate how much work is required to establish the charge system.

**Objective:**

To plot the equipotential lines of various conductive configurations and to derive electric field patterns or basically to determine where an electric force on a charge is strongest and weakest in an electric field. The student’s work will be compared to a computer generated plot using mathematica.

**Anticipated Learner Outcomes:**

1. The learner will be able to use a multimeter to measure the potential at a point in a charged system.
2. The learner will be able to plot this data on a graph and draw the equipotential line pattern.
3. The learner will be able to draw an electric field pattern from the equipotential pattern he or she drew.
4. The learner will be able to determine the direction of the electric field from the gradient of the potential.
5. The learner will be able to determine the direction of charge flow, for both positively and negatively charged particles.
6. The learner will recognize that the density of the field lines in a region indicate the relative strength of the field.
Lab: Electric Field

Objective: To plot the equipotential lines of various conductive configurations and to derive electric field patterns or basically to determine where an electric force on a charge is strongest and weakest in an electric field.

Background Information: Although electric fields cannot be seen, we can use models that represent electric field lines to see the strength and direction of the field in different points in space. The number of lines are proportional to the electric field strength. Lines that are closer together indicate a stronger field and lines that are farther apart show a weaker field.

Rules for drawing electric field lines:
1. The lines must begin on positive charges or at infinity and must terminate on negative charges or at infinity.
2. Force lines are smooth curves or straight lines touching conductors perpendicularly.
3. No two field line can cross each other.
4. Equipotential lines and electric field lines cross at right angles.

Equipment:
- Multimeter
- Circular Charge Grid (2 copper cylinders)
- Parallel Plate Grid
- Power Supply or Battery Pack
- Wire with Alligator clips

Procedure:
1. Set the multimeter to measure 20V DC.
2. Attach the ground (black) probe of the multimeter to the ground of the power supply or the negative terminal of the battery.
3. Use the positive (red) probe and probe each grid point measuring the voltage at each grid point. Record the voltage at each point.
4. Measure the voltage inside the cylinder. Does this voltage vary at any point in the cylinder or is it constant inside the cylinder?
4. Repeat Steps 1 – 3 for the parallel plate grid.

Results:
1. To find the equipotential pattern, prepare an excel file using the Potential Measurement Grid 26 x 17 template in the assignments folder in the share drive. Input each voltage measurement into its correct grid point. Save the file with the file name Equipotential Pattern Name where name is the last name of your group leader and drop it into the student work folder.

Using the data you collected, find voltages that are within a few tenths of a volt near each other. Plot these on the grid paper provided and draw line or curve that connects these points. Try to draw smoothly. Repeat this for different voltages until you have at least 6 equipotential lines. Mark the approximate voltage of each line. Label which plate or point was positive or negative on the plot and which was ground. (0V)
Followup: Compare what you drew to the printout of the equipotential pattern the mathematica program plotted.
Did you get a similar pattern? Compare the two. Comment on this comparison.

Draw a field pattern from your plot. Each line needs to start at the plate or cylinder that is at a higher potential and go to the plate or cylinder at the lower potential. Draw arrows indicating direction of the field pattern. Field lines must start out perpendicular to the surface of the plate or cylinder and can only cross a potential line at a right angle. Draw at least 7 field lines between the cylinders or plates. Draw additional lines that are not in the region between the cylinders or plates.

Questions: Which way would an electron move in the water when the voltage is hooked up? What about a positive ion?

What would happen to the pattern if the voltage of the power supply was changed?

Conclusion:
Summarize what you have learned in the lab.

Lab Set Up

Power Supply

Students turn on power supply. Then no touching! Turn off at the END of the lab.

Set Voltage Knob at 20V (Turn 3 clicks to the left)

Use red wand to probe around grid measuring voltage

Hold black wand to push pin

Student holds black probe to ground on the power supply
Student uses red probe to look around the grid for voltage.
Materials and Supplies:

1. Each station will require a tray for water. Plant trays work well for this. Place a transparency with a grid pattern in the tray and glue this to the bottom. You can also tape this. Plant trays can be purchased for less than $4.00 for each tray.

2. Copper cylinders are available at a hardware store in plumbing or electrical. Two of these form the point charges. These can be glued to the transparency so they do not move during the lab.

3. Copper plates to form a parallel plate setup can be purchased from a chemical supplier. I recommend 22 gauge plate that is 12 in. by 12 in. This can be cut into 12 one inch strips. You will needs 1 plate to make 6 trays. If you want more, another plate is needed. I mount the strips onto rubber stoppers with glue, and the stoppers are attached to the side of the plant tray. This allows for measurement behind the plate.

4. Multimeters, wire and Power Supplies are needed. Most teachers have these.

Plan:
Depending on time, the activity takes at least 4 days if the students do both setups.
Day 1: Explain the use of the multimeter to measure voltage.
Day 2: Students will take data on once tray. This is at least 400 data points, so it takes a 50 minute period. Have the students start in the middle and work out, in case they do not get all of the data points completed.
Day 3: Measure the second tray. Have both sets of data placed into tabular form and submitted to the instructor electronically. The instructor will then prepare the mathematica plots for each group. If the students have access to mathematica, allow them do run the plots.
Day 4: The students hand draw the potential plots and the field patterns.

Summary:
Abstract concepts in physics are the most difficult for a student to grasp. Teachers tend to spend less time in lab here because of this fact. More time needs to be spent on such concepts. Potential and Electrical Fields is the concept that my students struggle the most with. Laboratory is a critical concept to build connections in the learner, so that a student can connect these concepts to their prior knowledge. This lesson plan allows the student to see the concept in graphical format that the student creates from their own data.