1 Overview

Many forces in nature cannot be modeled as contact forces, such as those you have used to describe collisions or friction interactions. Forces sometimes characterized as "action-at-a-distance" involve objects exerting forces on each other although not in physical contact. The gravitational force, in fact, fits this characterization. You are just now learning about another action-at-a-distance force: the electric force. Action-at-a-distance can be difficult to fit into our physics framework for two reasons. First, it is hard to conceive of objects interacting when they are not touching. Second, objects that interact by these action-at-a-distance forces form systems that can have potential energy. The concept of action-at-a-distance does not satisfactorily describe where this potential energy resides.

The notion of a *field* solves these problems. In a field theory, an object affects the space around it, creating a field. Another object entering this space is affected by that field and experiences a force. In this picture the two objects do not directly interact with each other; one object creates a field and the other object interacts directly with that field. The magnitude of the force on an object is the magnitude of the field at the space the object occupies (caused by other objects) multiplied by the property of that object that causes it to interact with that field. In the case of the gravitational force, that property is the mass of the object. In the case of the electrical force, it is the electric charge. The direction of the electrical or gravitational force on an object is along the direction of the field (at the object's position). The potential energy of the system can be envisioned as residing in the field.

Thinking of interactions in terms of fields solves the intellectual problem of action-at-a-distance. It is, however, a very abstract way of thinking about the world. We use it only because it leads us to a deeper understanding of natural phenomena and inspires the invention of new devices. The activities in this laboratory are primarily designed to give you practice visualizing fields and their associated potentials.

In this laboratory, you will explore the relationships between electric field and potential for various charge distributions. We will use computer simulations developed by a group at the University of Colorado Boulder. You will be using two simulations: *Charges and Fields* (`http://phet.colorado.edu/en/simulation/charges-and-fields`), and *Electric Field Hockey* (`http://phet.colorado.edu/en/simulation/electric-hockey`). To do this you will take data on the electric potential at various points. Be sure to alternate who is "driving," so that both partners get a chance to directly interact with the simulation.

As you progress through the laboratory, pay particular attention to learning about relationships among (and differences between) the oft-confused concepts of field, force, potential, and potential energy.

2 Procedure

2.1 Point & lines of charge

1. Open the simulation *Charges and Fields* and click "run now." Play around with it for a few minutes to explore what the simulation does.

2. Place a single charge. Using the voltage probe box (see Figure 1) and the ruler, plot a series of equipotential lines and measure the position of each one, relative to the charge.

3. Now make two parallel lines of charges. One line should be positive and the other should be negative. Your goal here is to simulate two parallel conducting plates. Using the voltage probe box and the ruler, plot a series of equipotential lines and measure the position of each one, relative to the line of positive charge.

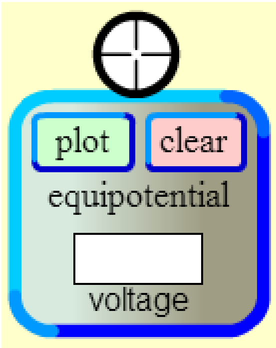

Figure 1: Voltage probe box will give the value of the potential at the spot in the "crosshairs." Clicking plot will plot an equipotential line for that value.

2.2 Electric field hockey

1. Open the simulation *Electric Field Hockey* and click "run now." (Depending on how the web browser is configured, it may open up automatically, or it may download a `.jnlp` file that you need to open.) Play around with it for a few minutes to explore what the simulation does.

2. Click the checkbox to show field lines.

3. For each difficulty level, place charges so that the hockey puck goes into the goal. Do this with as few charges as possible, and write your best score on the board. Difficulty level three is not required, but is encouraged. Take a screenshot and print out enough copies for each member of your group.

3 Analysis

3.1 Point & lines of charge

1. Make a graph of potential vs. distance from the charge. Include a trendline.
2. Make a graph of potential vs. the inverse of distance from the charge (V vs. $^1/_x$). Include a trendline.
3. Make a graph of potential vs. distance from the positive line of charge. Include a trendline.

3.2 Electric field hockey

Go back to the *Charges and Fields* simulation. Re-create the distribution of charges you used for each difficulty. Using the *Charges and Fields* simulation for reference, sketch in equipotential lines on your printed-off screenshot for each difficulty level. Label each equipotential line with a value.

4 Questions

1. For the Point Charge Source, what does your graph of potential versus distance tell you about the relationship between potential and distance? Is this what you would expect? Explain. For the potential vs. inverse distance graph, what does the slope represent?
2. For the Parallel Lines Source, what does your graph tell you about the relationship between potential and distance? Explain. What was the strength of the E-field between the two lines?
3. For the *Electric Field Hockey* printouts, describe the relationship observed between the equipotential lines and the electric field lines.

5 Grading

You will not write a formal report for this lab. Instead, turn in organized data tables, graphs, observations, etc., and answer all questions. The writeup that you turn in must be typed, organized well, and must have your name and your lab partner's name.