Lab: Electric Fields Hockey *

Objective: To investigate experimentally the concept of the electric field and to map (to represent graphically) some electric field lines for particular configurations of charge.

Background: The electric field intensity is defined as the electrical force per unit of charge, or \( E = \frac{F}{q} \). Theoretically, the electric field is determined by using a positive test charge \( q \) and determining the force acting on it at every point in space. The direction of the field is found by the laws of vectors and the rule that tells you whether the force is attractive or repulsive.

Since a free charge moves in an electric field by the action of the electric force, then work \( (W = F \cdot d) \) is done by the field in moving charges from one point to another (e.g., point “a” to point “b”). To move a positive charge from “b” to “a” against the electric field would require work supplied by an external force. The ratio of the work done, \( W \), to the charge, \( q \), in moving the charge between two points in an electric field is called the potential difference, \( V_{ab} \), between the points: \( V_{ab} = \frac{W}{q} \). If a charge is moved along a path at right angles (i.e., perpendicular) to the field lines, there is no work done \( (W = 0) \) since there is no force component along the path. No work means no potential difference from point to point. Hence, the potential is constant along paths perpendicular to field lines.

Such paths are called equipotentials. Thus, an electric field set up by charges may be "mapped" by determining the equipotential lines (equipotential surfaces in three dimensions) that exist in the region around the charges. Potential difference is easily read by a voltmeter, whereas the measurement of forces would present numerous experimental problems.

Procedure: Launch the program Electric Field Hockey.

The screen should look like the figure shown at the right. Be sure the check boxes in the control bars at the bottom of the screen are set as follows:

In the yellow bar:
- Puck is positive (checked)
- Trace, field, antialias (unchecked)

In the green bar:
- Practice (checked)

A) Your goal is to manipulate the motion of the test charge (black) into the goal (purple bracket) at the right of the screen by judicious placement of positive (red) and negative (blue) charges.
a. To see how this works, use the mouse to take a negative charge from the cache of charges and place it behind (to the right of) the goal. Press start and describe what happens.

b. Hit the reset button and try to place a single positive charge so that it drives the test charge into the goal. Where did you place the charge and why?

B) Reset (keeping in practice mode and turning off Trace, Field, and Antialias) and place a positive (red) source charge directly to the left of the test charge (black) and at the edge of the screen. The program will display a small red arrow showing the force the red charge exerts on the test charge. Then place a negative (blue) source charge directly below the test charge so that it is at about the same distance from the test charge as the positive charge. The program will show you a blue arrow showing the force the blue charge exerts on the test charge.

a. In what direction will the test charge start moving?
   Explain your reasoning.

Now turn on Trace, Field, and Antialias (this makes the field vectors easier to see) and Start. Only pay attention to the path that the test charge follows until it leaves the screen.

b. How does this compare to your prediction above? Did it always move in the direction you predicted? If not what happened and why do you think this happened?
(The situation we are studying -- two fixed sources of force and a particle moving under their influence -- is called a restricted three-body problem. Problems of this type can almost never be solved in terms of formulas and often show extreme sensitivity to the starting conditions known as chaos.)

c. As the particle moves under the influence of the forces of the two charges, does it move in the direction of the E-field at the point where it is? That is, do the E-field vectors point along the path the particle follows? If so, explain why. If not, explain why not.

D) Reset the program and click on difficulty level 1. Put down source charges until you can get a path that leads you to your goal. Print the result with Trace, Field, and Antialias turned on and include the figure in your homework.

a. Describe how you found your solution.

b. Did you find it more effective to have Field turned on or off in your search? Explain why.

E) Try solving difficulty levels 2 & 3. Enjoy!
Analysis:

1. Sketch and describe the electric field lines for a single positive charge?

2. Sketch and describe the electric field lines for a single negative charge?

3. What do the direction and strength of the field lines indicate for the (positively charged) “puck?”

4. Did the (positively charged) puck always move in the same direction as the field lines it was passing over? If not, how did it move?
5. Describe what happened (or would happen) if you changed the charge of the puck from positive to negative?

6. Describe what happened when you increased the mass of the puck?

7. Describe how did the distance between the puck and the particles affect the motion of the puck?

*Lab adapted from Electric Field Hockey Homework by Joe Redish and Electric Field Hockey Post Game Analysis by Lucy Jameson using the PhET simulation Electric Field Hockey provided by the University of Colorado at Boulder.*