Electric Field

GOAL.
• to determine the electric vector field for a point charge.
• to examine the spatial dependence of the strength of the electric field for a point charge.
• to determine the electric vector field for a dipole.
• to examine spatial dependence of the electric field along the axes of a dipole.
• to understand the electric vector field for various charge distributions.

EQUIPMENT.
• Computer with Charges and Fields software.

THEORY.
It is straightforward to do qualitative charge and force experiments with tape, plastic, fur, glass, wool, etc. like you did in a previous lab. However, for technical reasons it is quite difficult to do quantitative experiments measuring small forces and charges. Instead we are going to use a simulation program to explore the characteristics of the electric field.

1a. Single point charge: electric vector field.

Open the file Charges and Fields. It will look like Figure 1. You can place +/- point "charges" down and then examine the electric field by using a "test charge." Various properties of the program are set using the "control box."

• The potential meter is not needed for this lab, move it to the side.
• Move a positive particle (charge = 1.0 nC) near the center of the screen. [Click on the charge, move it, then release it.]
• Move a test charge (E-field sensor) to a spot near the positive charge. (You should now see the electric field vector at that location in space.)
• Grab the test charge and move it around paying attention to the magnitude and direction of the electric field. Go closer/farther, above/below, left/right. If you want a view of the whole vector field at once place many test charges at different locations.

Q1. By looking at the electric field vector what do you know about the sign of the test charge? (Answer questions in space provided at the end.)

• In the DATA section, make a sketch of the electric vector field for the positive point charge. Be sure the relative magnitudes correct. Indicate the magnitude by the length of the vector, do not use intensity.
• Compare your sketch with the simulation by turning on "Show E-field". The simulation uses arrows of the same length, the relative strength is indicated by the intensity of the arrow, darker is stronger.
1b. Single point charge: electric field strength.
Now look at the spatial dependence of the strength of the electric field. NOTE: 1 N/C = 1 V/m.
- Check the "grid" box in the control box.
- Check the "show numbers" box in the control box.
- Move the positive charge to a grid intersection near the left side of the screen.
- Move the test charge (E field sensor) away from the positive along a line. At distances of 0.1, 0.2 m, 0.3 m, …1.0 m, 1.5 m, …4.0 m from the positive charge record the corresponding strength of the electric field in Table 1. Use the distance scale in the lower left corner or use the "tape measure."
- Plot $E$ vs. $r$. Be sure to label your axes with quantity and units, e.g., "$r$ (m)." Is it a straight line?

Q2. From previous mathematical experience, list three different functions that have roughly this shape.

- Using the plotting program try to fit the data to a straight line, $y = Ax + B$.
- Using the plotting program try to fit the data to a power law, $y = Ax^B$.
- Using the plotting program try to fit the data to an exponential, $y = Ae^{Bx}$.
- Choose the functional form that fits best, print out this graph and attach it in the DATA section. If you cannot decide which is best take some more data, especially at small distances.

The electric field strength of a point particle is
$$E = \frac{KQ}{r^2},$$
(Eq. 1)
where $K (= 8.99 \times 10^9 \text{N} \cdot \text{m}^2/\text{C}^2)$ is a constant, $Q$ is the charge of the point particle causing the field, and $r$ is the distance from the charge to the field location. Is this consistent with your fit?
- Using Eq. 1 find the electric field for the positive charge you used in the simulation at a distance of 1.5 m, does it agree with what you measured in the simulation?

2. Dipole: electric field.
The standard dipole configuration is shown in Figure 2, point particles $( \pm Q )$ located at $\vec{r} = ( \mp a, 0 )$.

![Figure 2. Dipole configuration.](image)

2a. Dipole: electric field calculation.
- You should have already calculated the electric field (magnitude and direction) at the five locations shown in Figure 2. The locations are A=(0,0), B=(-a/2, 0), C=(a/2, 0), D=(0, a/2), E=(0, -a/2). The
results should be algebraic expressions in terms of $K$, $Q$, $a$, and numbers, put them in row 1 of Table 2 in the DATA section. (Recall superposition, $E_{\text{net}} = E_{\text{due to } 1} + E_{\text{due to } 2} + \ldots$)

2c. Dipole: electric vector field simulation.

- Start Charges and Fields. (If already running click just "Clear All.")
- Put down a single positive charge and a single negative charge in a dipole configuration (as in Fig. 2) near the center of the screen. It is easiest if you use the grid and place the particles 2.0 m apart.
- By moving around the test charge (or using many test charges) make a sketch (or print the screen) of the electric vector field for the dipole situation and put it in the DATA section.
- Compare the sketch with the simulation by clicking on "Show E-field" box.

2d. Dipole: electric field strength, $E_x$ vs $x$.

- Move the test charge along the line joining the charges ($x$-axis) and, in columns 3&4 of Table 1, record the location and the electric field (careful of the sign) for several points. (It is easiest if the center between the charges is $x=0$). To get reasonable graphs you will need at least 5 points in each region of the axis: to the left of the positively charged particle, between them, and to the right of the negatively charged particle. Be sure to include the special locations A, B, and C and put in row 3 of Table 2.

Q3. What is the direction of the electric field along the $x$-axis? What is the $y$-component of the electric field?

- Plot $E_x$ vs $x$. Be sure to label your axes with quantity and units, e.g., "$x$ (m)."

2e. Dipole: electric field strength, $E_x$ vs $y$.

- Move the test charge along the perpendicular bisector ($y$-axis) between the particles and, in columns 5&6 of Table 1, record the electric field (careful of the sign) for a dozen or so points. Start high up on the $y$-axis and finish low down on the $y$-axis. Be sure to include the special locations D, and E and put in row 3 of Table 2.

Q4. What is the direction of the electric field along the $y$-axis? What is the $y$-component of the field?

- Plot $E_x$ vs $y$. Be sure to label your axes with quantity and units, e.g., $x$ (m).

Continued on next page…
PART II.

Using the tools and techniques developed above examine the electric field for the following charge configurations.

For each configuration

- Find the electric vector field.
- Predict and then determine how the electric field components $E_x$ and $E_y$ depend on position as you move along the $x$ and $y$ axes: $E_x$ vs. $x$, $E_y$ vs. $y$, $E_x$ vs. $y$, $E_y$ vs. $y$.
- Based on what you have done, can you sketch the electric field strength along the $x$-axis for the configuration in the figure below? You might check this with the simulation.
- Also for the figure below sketch the electric field strength along the $y$ axis.
• NAME:____________________________  
  COURSE/SECTION:__________________  

REPORT.  
ANSWERS TO QUESTIONS (Q1-4).
DATA.
Sketch of the electric vector field for a point charge.

![Electric Field Sketch](image)

<table>
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<th>Distance (m)</th>
<th>Electric field strength (V/m)</th>
<th>$x$ (m)</th>
<th>$E_x$ (V/m)</th>
<th>$y$ (m)</th>
<th>$E_x$ (V/m)</th>
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Electric field strength vs. distance for point particle.

\[ E \text{ (V/m)} \]

\[ r \text{ (m)} \]

Dipole field strength.

<table>
<thead>
<tr>
<th></th>
<th>( E_A )</th>
<th>( E_B )</th>
<th>( E_C )</th>
<th>( E_D )</th>
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Table 2. Electric field at special locations for the dipole.
Sketch of the electric vector field for a dipole.

Qualitative sketches.
Electric field, $E_x$ vs $x$.

Electric field, $E_x$ vs $y$.
Data from simulation.
Electric field, $E_x$ vs $x$.

Electric field, $E_x$ vs $y$.