

Electric Field

Safety and Equipment

- No special safety precautions are necessary for this lab.
- Computer with modern Web Browser supporting HTML5.

Introduction

An electric field is the effect produced by the existence of a “source” - an electric charge, such as an electron, ion, or proton, in the volume of space or medium that surrounds it. Another charge placed in the volume of space surrounding the "source" charge has a force exerted on it. The magnitude of the electric force applied by two charges on each other is described by Coulomb's law:

$$F = k \frac{|q_1||q_2|}{r^2}$$

Where q_1 and q_2 are the two charges involved, $k = 8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2$ is the Coulomb constant, and r is the distance between the charges.

In Coulomb's Law, one of the charges could be viewed as a "source" of the field and another charge could be viewed as a "recipient" experiencing a force produced by the field. Using symbols Q for the "source" charge and q for the "recipient" charge,

$$F = k \frac{|Q||q|}{r^2}$$

The “recipient” charge is called a test charge because it “tests” the force produced by the field. A ratio of force to charge is defined as a field vector and describes the properties of the field at a point of space. Following the definition of the field vector, Coulomb’s Law could be modified to express the magnitude of the electric field vector at distance r from the source:

$$\vec{E} = \frac{\vec{F}}{q} \text{ or } E = k \frac{|Q|}{r^2}$$

If the “source” of the field is unknown but the field certainly exists in a point of space where it is described by field vector \vec{E} , then the force that this field exerts on a test charge q at this point is

$$\vec{F} = q\vec{E}$$

The direction and magnitude of the force exerted by the electric field on an arbitrary test charge of 1C in a point of space could be used to describe the field vector \vec{E} existing in this point and therefore is useful for mapping the field. A charge of 1C is dangerously large and it would be not practical to place an actual 1C charge in any real-life electric field. However, the safety of a computer simulation makes this convenient setting possible. In the simulation, one could explore an electric field around the source charge by placing 1C test charges at different points of space. Monitoring the reading of the field vector while manipulating the distance from the source could unveil the trends in distribution of the field vectors around different sources.

The simulator also allows to explore an electric field from energy point view by measuring an electric potential at different points around different sources. An increase in values of electric potential indicates moving toward higher electric elevation or “hill”; where a decrease in values of electric potential indicates moving toward lower electric elevation or “ditch”.

Objectives:

- Investigate what affect the direction of an electric field around an isolated electric charge.
- Investigate what affect the magnitude of an electric field around an isolated electric charge.
- Investigate the distribution of the electric field vectors around two closely spaced charges.

Part #1. Single Positive Charge

1. Go to: <http://phet.colorado.edu/en/simulation/charges-and-fields> and run the simulation (⏮).
2. Once inside the program, set the following checkboxes:
 - Uncheck: Electric Field, Voltage
 - Check: Grid, Values
3. Place a single positive charge in the middle of the field perfectly aligning it with the grid.
4. Place “test charges” (i.e. E-Field Sensors) in each cardinal direction (up, down, left, right) at a distance of 1.0 m from the source charge. (Note the scale bar at the bottom.) Make sure to align the arrows representing force vectors with the grid.
5. Record the electric field at each point. Round off the values to integer. **Note:** The units N/C and V/m are equivalent.

Distance from source charge (m)	Magnitude of E-Field (N/C)	Direction of Electric Field (toward/away)	Electric Potential (V)
1.0			
1.0			
1.0			
...			

Table 1. Electrical field readings at the multiple distances from a single positive source charge. (Add rows as necessary)

6. Place four more test charges at distances of 1.2 m, 1.5 m, 2.0 m, and 2.5 m from the source charge and ***in the space between the prior test charges***; use the measuring tape by anchoring the body of the tape to the charge you are measuring from, then dragging the end of the tape until it is the appropriate distance and direction from that charge. The little red + signs on the tape are the reference points for the measuring tape.
7. Extend **Table 1** for the new values and record the E-Field measurements.
8. Examine the readings of the field from **Table 1** and conclude how the magnitude of the field in a given point relates to the distance from this point to the source.
9. ***Check your conclusion by predicting the magnitude of the field at point 3.0 m from the charge, and then place a test charge in such point to verify your prediction. Report on the degree of the agreement between predicted and actual values by calculating %Difference = $\frac{|\text{predicted value} - \text{actual value}|}{\text{actual value}} \times 100\%$.***
10. Examine the directions of all field vectors and compose a general rule for the direction of the field at any point around the positive single source charge.

11. Measure the electric potential (Φ or V) caused by the source charge in each point: use the blue widget on the right (labeled 0.0 V in the tool area).
12. Examine the electric potential in each point. Conclude how the value of the electric potential changes in the direction of the field vector (increases/decreases/keeps constant).
13. Organize your findings for 8 – 12 in one statement describing the electric field around a single positive charge. Include this statement in the abstract.
14. Take a screen shot by one of the methods suggested below. Label it as **Figure 1**.
 - Hit Alt-PrtScr. That puts the screen onto the clipboard so you can paste it into Word.
 - Use the “Snipping Tool”, a program installed on the lab computers.
 - In MacOS, the utility called “Grab” may accomplish the same thing.

Part #2. Single Negative Charge

1. Replace a single positive source charge in the middle of the field with a single negative source charge.
2. Leave all the “test charges” (i.e. E-Field Sensors) at the original positions.
3. Record the electric field and the electric potential at each point. Round off the values to integer.

Note: The units N/C and V/m are equivalent.

Distance from source charge (m)	Magnitude of E-Field (N/C)	Direction of Electric Field (toward/away)	Electric Potential (V)
1.0			
1.0			
1.0			
...			

Table 2. Electrical field readings at the multiple distances from a single negative source charge. (Add rows as necessary).

4. Use data from **Table 2** to make a graph *Magnitude of E-Field vs. Distance from the source charge*. Label it as **Graph 1**
5. Fit the resulting curve into an appropriate function and display the trendline equation on the graph.
6. Examine the directions of all field vectors and compose a general rule for the direction of the field at any point around the negative single source charge.
7. Examine the **electric potential** in each point. Verify if the rule for the relationship between the value of the electric potential and the direction of the field vector determined in part 1 stands.
8. Use data from **Table 1 (NOT Table 2)** to make a graph *Electric Potential vs. Distance from the source charge*. Label it as **Graph 2**.
9. Fit the resulting curve into an appropriate function and display the trendline equation on the graph.
10. Compare and contrast two graphs (from 4 and 8) and their trend lines; comment how both curves reflect the Coulomb’s Law. Include your findings in the abstract.
11. Organize your findings for in one statement describing the electric field around a single negative charge. Include this statement in the abstract.
12. Take a screen shot. Label it as **Figure 2**.

Part #3. Electric Dipole

1. Clear the screen by clicking on “refresh” icon.
2. Once again, select the following checkboxes:
 - Grid
 - Values
3. Place positive and negative charges in the middle of the field, 2.0 m apart from each other.
4. Place “test charges” (i.e. E-Field Sensors) in each cardinal direction (up, down, left, right) at a distance of 1.0 m *from each charge* (i.e. between them). Make sure to align the arrows representing force vectors with the grid.
5. Record the electric field at each point. Round off the values to integer. **Note:** The units N/C and V/m are equivalent.

Distance from \oplus (m)	Distance from \ominus (m)	Magnitude of E-Field (N/C)	Direction of Electric Field (toward/away)	Electric Potential (V)
1.0	1.0			
1.0	3.0			
1.0 (above)	(calculate)			
1.0 (below)				
3.0	1.0			
	1.0 (above)			
	1.0 (below)			

Table 3. Electrical field readings at the multiple distances from a dipole.

6. Place three more test charges at further distances of your choice from both source charges and in the space between the prior test charges (three per each source charge).
7. Extend **Table 3** for the new values and record the E-Field measurements.
8. Measure the electric potential Φ or V caused by the source charge in each point.
9. Examine the directions and magnitudes of all field vectors and compose a general rule for the field distribution around a dipole.
10. Examine the electric potential in each point. Conclude which of the charges is a high elevation or “hill” and which is a low elevation or “ditch”.
11. Organize your findings for 8 – 9 in one statement describing the electric field around a dipole. Include this statement in the abstract.
12. Take a screen shot by one of the methods suggested below. Label it as **Figure 3**.

Requirements for the Report:

The report must contain a **Header** at the top (Title of Lab, Authors, and Date)

Abstract Section must contain the following in paragraph form:

- Brief Introduction that includes objectives and basic theory of the lab. Include:
 - What parameters are used to describe an electric field?
 - What is the difference between a source charge and a test charge?
 - Describe the approach if the field is due to multiple sources.
- Methodology describing broadly what was done, using what tools, and what was measured/recorded.
- Data Summary including quantities worked into sentences.
 - Describe magnitude and direction of the electric field around a positive charge. Be specific about the relationship between magnitude and distance (don't only say that magnitude increases or decreases). Describe electric potential around a positive charge and how it changes with distance in the direction of electric field.
 - Describe magnitude and direction of the electric field around a negative charge. Describe electric potential around a negative charge. Incorporate the graphs into your discussion about the electric field and electric potential. Analyze the graphs and interpret their trendlines (include equations using physics variables).
 - Describe magnitude and direction of the electric field around a dipole. Describe electric potential around a dipole.
- The lab manual contains questions and/or imperatives throughout that will guide you with the Data Summary. **Always incorporate the questions and/or imperatives from the lab manual.**
- Sources of Error and a ballpark estimate of their contribution. DO NOT use "human error". That term is too vague to be meaningful.

Data Section must contain the following:

[Each table, figure, and graph should be labeled and descriptively captioned]

- 3 Screenshots (simulation window with trimmed borders)
- 3 Tables
- 2 Graphs