

Lab 4: Electric Field

Name:

Group Members:

Date:

TA's Name:

Simulation link: http://phet.colorado.edu/sims/charges-and-fields/charges-and-fields_en.html

Type "Charges and Fields –PHET" in Google and click the link.

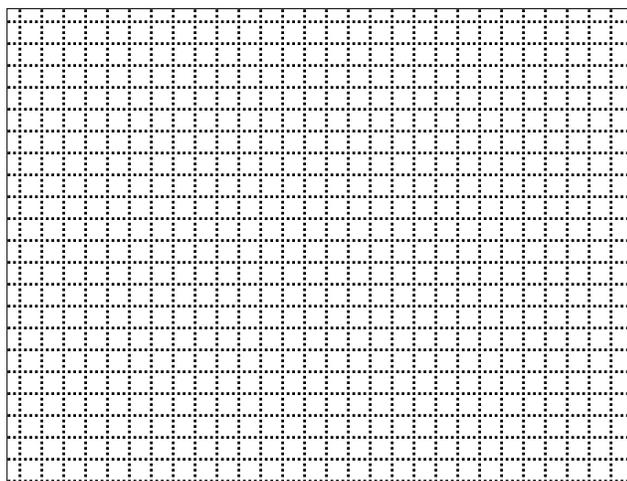
Objectives:

1. To understand the magnitude and direction of the electric field produced by a point charge at different directions and distances around the point charge.
2. To understand the magnitude and direction of the electric field produced by a dipole at different directions and distances around the dipole.

Before you begin: Your TA has set up a demonstration using two charged electrodes, a pan of water, and an electric field sensor. This sensor has LEDs (light emitting diodes) whose brightness is proportional to the electric field component in the direction that the sensor is pointing. Take a few minutes to move the sensor around and observe how the magnitude and direction of the electric field depends on location. In this lab you will be using a simulation where electric field sensors operate in a similar fashion.

Part 1: Electric Field from One Point Charge

1. The strength of the electric field around a positive point charge Q at a distance r from the center of the charge is given by the equation $E = \frac{1}{4\pi\epsilon_0} \frac{Q}{r^2}$. The direction of the electric field vector is radially outward. Sketch E vs. r graph for a positive charge. Label the horizontal and vertical axes of the graph.



- Now open the simulation. Activate “grid” and “show numbers” to read values. Place a 1 nC positive (red color) charge on the grid. This is sometimes called a “source charge” since it’s the source of the electric field we are going to measure. To make a measurement of electric field, grab an E-field sensor and place it where you want to measure the electric field. The arrow of the sensor indicates the direction of the E-field at that point and the length of the arrow is proportional to the strength of the electric field.

Move the sensor around and observe how the electric field is different in magnitude and direction at different locations. Summarize what you observe about how the **magnitude** of the electric depends on location.

Summarize what you observe about how the **direction** of the electric field depends on location.

- Make a measurement of the electric field at 1.0 m away from the charge (scale is shown at bottom of the screen). Note that the units of electric field are $\text{V/m} = \text{N/C}$. Record the value below.

$E =$ _____

- Predict what the strength of the electric field will be at the same point if you double the amount of charge?

$E =$ _____

- Place another 1 nC positive charge on top of the previous charge and measure the electric field again at the same place. Record your result below and put back the added charge in the charge bucket.

$E =$ _____

- Did your prediction agree? What can you conclude about the dependence of electric field on the amount of charge?

7. Now we want to investigate how the strength of the electric field depends on distance from the 1 nC positive charge. Make measurements of the magnitude of the electric field at different r values and complete the following table, where r is the distance measured in meters.

$r(\text{m})$	$E\text{ (N/C)}$
0.50	
1.00	
1.50	
2.00	
2.50	

8. Plot the electric field vs. r graph in Excel. Does your graph show the behavior of the electric field with distance as you predicted in #1, Yes or No?
9. Select a Power Law trend line to fit the data and display the equation. Does your power law fitting give the same dependence of the electric field with distance as you described in #1, Yes or No?
10. Find the equation of the trend line from Excel and record it below. Also copy your Excel graph into your Word document.

Power Law Equation: _____

Now rearrange this equation to be in the same form as the theoretical equation and re-write it in the box.

Electric field around a point charge(Theoretical)	Electric field around a point charge (experimental)
$E = \frac{Q}{4\pi\epsilon_0} \frac{1}{r^2}$	

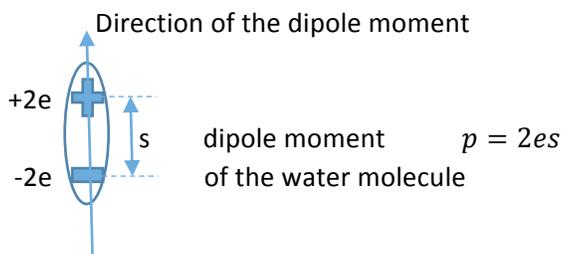
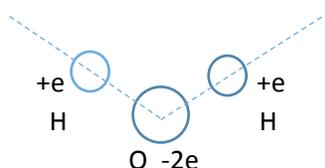
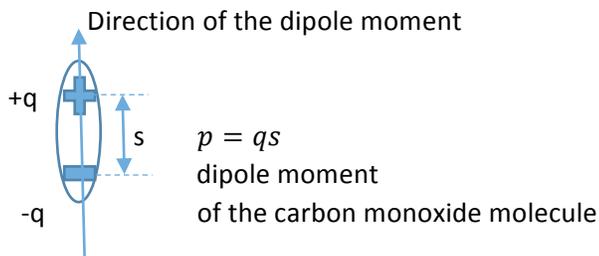
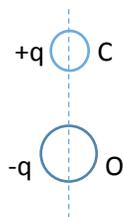
Compare the equation you obtained with the theoretical equation of electric field around point charge. From your comparison calculate your experimental determination of the electrostatic constant, k .

$$k = \frac{1}{4\pi\epsilon_0} =$$

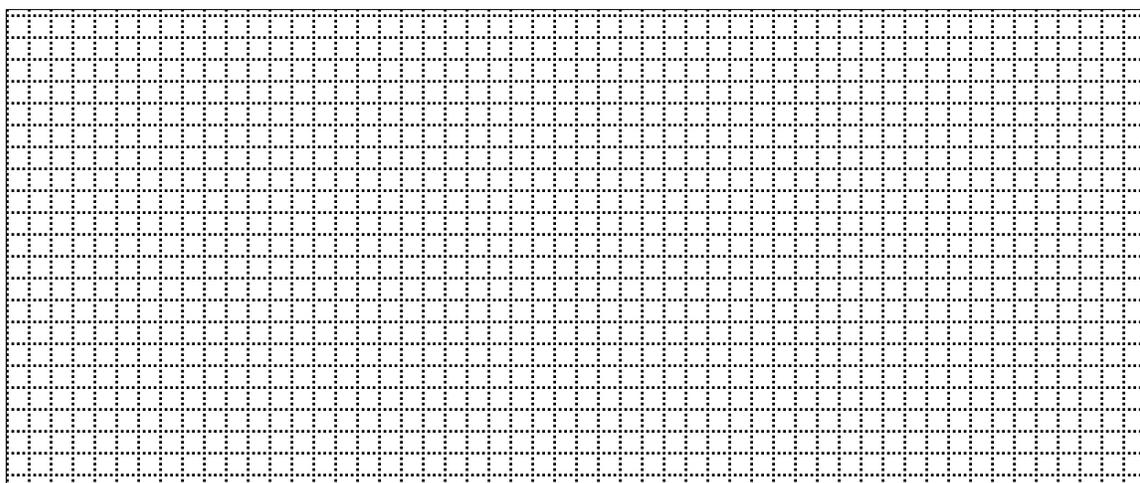
11. Remove the positive charge and place a 1 nC negative (blue color) charge at the same place. What is different and what is the same about the electric field due to 1 nC negative charge compared with 1 nC positive electric charge?

Part 2: Electric Field from an Electric Dipole

Since atoms in a molecule often carry a net charge, many molecules are permanent electric dipoles. The figures below shows a carbon monoxide molecule, CO , and a water molecule, H_2O . A dipole is characterized by the dipole moment with a magnitude of $p = qs$, where p is the charge and s is the distance between the charges. The direction of the dipole moment is defined from negative charge to positive as shown. The units of dipole moment are units of charge multiplied by units of distance, such as Cm .



12. Now we will examine the electric field of a dipole. The magnitude and direction of the electric field depends on the distance and the direction. We will investigate in detail just two directions. With charges available in the simulation how do you create a dipole with dipole moment $1 \times 10^{-9} Cm$ with a direction for the dipole moment pointing to the right? Look back at the figure at the top of the page to make sure you determined the direction of the dipole moment correctly. Make a sketch below that shows the amounts of charge and the distance between the charges. There are many correct answers.



13. On your drawing in #12, mark the center of the dipole as the origin ($x=0, y=0$). Pick a point to the right of the charges and mark it as P_1 . At that point draw vectors to represent the electric field contributions from each of the individual charges in your dipole. Each electric field vector should be drawn with its tail at point P_1 . Also draw a vector to represent the net electric field produced by all the charges in the dipole. Label that vector as \vec{E}_{net} .

14. Now reproduce the dipole on the grid in the simulation making sure that the dipole moment is directed to the right and the magnitude of the dipole moment is $1 \times 10^{-9} \text{ Cm}$. We'll make the center of the dipole to be our origin ($x=0 \text{ m}$, $y=0 \text{ m}$) on the grid.
15. Make measurements of \vec{E} at a series of points along the x-axis to the right of the dipole and record its magnitude and direction at each position.

x(m)	y (m)	E(N/C)	Direction
1.0	0.0		
1.5	0.0		
2.0	0.0		
2.5	0.0		
3.0	0.0		

16. Does the magnitude of the electric field of a dipole depend more strongly on distance than the electric field of a single point charge? Complete following table using your data in #7 and in #15 and then use normalized values of E, that is $E(x,y)/E(1,0)$ at each position to support your conclusion.

x(m)	y (m)	Normalized E Single charge: $E(x,y)/E(1,0)$	Normalized E Dipole: $E(x,y)/E(1,0)$
1.0	0.0		
1.5	0.0		
2.0	0.0		
2.5	0.0		
3.0	0.0		

17. Make some measurements of \vec{E} at points along the x-axis to the left of the dipole. How do the magnitude and direction of the electric field on the left side of the dipole compare to the right side for the same distance?
18. On your drawing in #12, pick a point above the center of the dipole and mark it as P_2 . At that point draw vectors to represent the electric field contributions from each of the individual charges in your dipole. Each electric field vector should be drawn with its tail at point P_2 . Also draw a vector to represent the net electric field produced by all the charges in the dipole. Label that vector as \vec{E}_{net} .

19. Make measurements of \vec{E} at a series of points along the y-axis above the dipole and record its magnitude and direction at each position.

x(m)	y (m)	E (N/C)	Direction
0.0	0.5		
0.0	1.0		
0.0	1.5		
0.0	2.0		
0.0	2.5		

20. Make some measurements of \vec{E} at points along the y-axis below the dipole. How do the magnitude and direction of the electric field above the dipole compare to below the dipole?

Part 3: Conclusions

21. Summarize what you observed about the magnitude and direction of the electric field from a single point charge. In particular, how does it depend on distance and direction from the point charge?
22. Summarize what you observed about the magnitude and direction of the electric field from a dipole. In particular, how does it depend on distance and direction from the dipole?

Instructions on how to submit the graphs:

1. Open a word document and type the names of all present group members.
2. Copy your Excel graphs (with title and axis labels) to your Word document.
3. Print the document and attach it to the lab write-up.