

Name \_\_\_\_\_ Date \_\_\_\_\_ Time to Complete \_\_\_\_h \_\_\_\_m  
Partner \_\_\_\_\_ Course/Section \_\_\_\_/\_\_\_\_ Grade \_\_\_\_\_

# Electric Fields I

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## Introduction

This week you will explore electric fields using a computer program, *EM Field*, that simulates electric fields produced by one, two, or several point charges in two and three dimensions. As you proceed through this lab exercise you should recall from your textbook readings that the magnitude of the electric field produced by a single charge varies inversely as the square of the distance from the charge.

## 1. Visualizing field vectors

### Introduction

In this part of the lab you will become familiar with the use of field *vectors* to illustrate and map the electric field. Later in the lab you will be introduced to an alternate method for illustrating the field, a method that utilizes field *lines* rather than field vectors. You will conduct a qualitative examination of the field produced by a single charge in Part 1a and then by multiple charges in Part 1b.

### a. Field caused by a single charge

#### Procedure

- Start the program *EM Field*. Maximize the application so that it fills the entire screen. When the information screen appears, use the mouse to choose *Sources* from the menu bar. Choose the item *3D point charges* from the drop-down menu that appears. A set of numbered white and red circles will appear along the bottom of your screen. These represent point charges. Drag the positive point charge (filled in red circle) with the number 1 into the center of your screen.
- Now you will turn the cursor into a test charge carrying an electric force meter. Starting from one side of the screen, hold the mouse button down and slide the cursor around on the screen. The cursor becomes your “electric force meter”. It displays the force a test charge would feel at the point where the cursor is located. When you are finished exploring the force, slide the cursor off the bottom of the display area before releasing the mouse button.
- As you have learned, the electric field at a point is defined as the force on a test charge located at that point, divided by the magnitude of the test charge. Therefore, the length of the electric field vector is proportional to the length of the electric force vector. *EM Field* assumes that the magnitude of the test charge is one unit, so the two vectors have the same length. Thus, the cursor is also an “electric field meter”.

What happens to the direction of the electric field vector as you approach the point charge?

What happens to the magnitude of the electric field vector as you approach the point charge?

- Now grab the charge with the mouse and drag it off the bottom of the screen. Pick up the negative point charge (open circle) labeled -1, and place it in the center of the screen. Use your “field meter” to explore the field caused by this charge. Remember to hold down the mouse button until you are finished exploring and have slid the cursor off of the display area.

What happens to the direction of the electric field vector as you approach this point charge?

What happens to the magnitude of the electric field vector as you approach this point charge?

## **Conclusions**

In what ways are the fields produced by the single positive and negative point charges the same? In what ways are they different?

## b. Field caused by several charges

### Procedure

- Place a variety of charges, some positive and some negative, on the screen. Make sure you have at least four charges present. Sketch their placement in the box below.



- Now use the cursor as before to explore the field created by your system of charges.
- When we are trying to compare the field vectors at different points in space, it is necessary to move the cursor from one point to another, and it is difficult to remember exactly what each field vector looked like. Fortunately, *EM Field* can help us remember what we have found. If you release the mouse button when the cursor is at some point, the program will “drop” the field vector at that point and leave it there for future reference. Go around the screen and “drop” field vectors at a number of different points. Place vectors at enough points so that you can begin to see the pattern produced by the field vectors. Sketch your results in the box above.
- Select one of the charges to be removed from the screen. Circle the one you have chosen in the box above. While you conduct the next step carefully observe how the field vectors change. Now grab the selected charge and drag it down below the bottom margin of the display. It should disappear.

Comment on how the field vectors changed when the charge was removed. (You should be commenting on where the field vectors changed the most, where the field vectors seemed unaffected, and how the field vectors changed in length and direction.)

With a different color pen or pencil, sketch new field vectors, where they changed significantly, in the box above.

[Note: If your display becomes too cluttered, or you want to start over, you can remove all the field vectors from the display, without affecting the charges, by choosing *Display>Clean up screen* from the menu bar. To remove all the charges from the display, choose *Sources>3D point charges* from the menu bar. This will also remove all the field vectors. To add additional charges to an existing display, choose *Sources>add more charges* from the menu. The field vectors will readjust to include the effects of the new charges.]

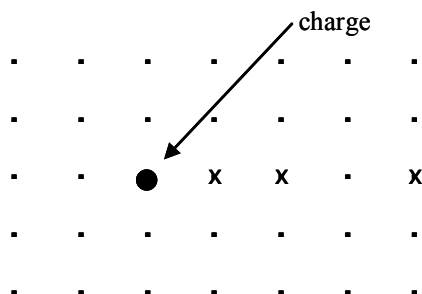
## 2. Quantitative examination of the field from one charge

### Introduction

In this section you will explore the field produced by a single charge semi-quantitatively. For this you will need a centimeter ruler in order to measure distances and the lengths of field arrows.

### Procedure

- To help you be precise in your measurements, choose *Display>Show Grid* from the menubar. Go back to the menubar and choose *Display>Constrain to Grid*. This will allow charges to be placed only on grid points. However, you will still be able to probe the field at any location, even between grid points.
- To study the field, begin by placing a +5 charge somewhere near the center of your screen. In succession “drop” a field vector one, then two and four, grid point(s) to the right of the charge, with your ruler carefully measure the length of the field vector on the screen, and then remove the field vector. The x’s in *Figure 1* show where you should be placing field vectors. Record your results in *Table 1* below.



*Figure 1: Vector drop points for field measurements*

Distance from Charge (grid units)	Length of Field Vector (cm)
1	
2	
4	

*Table 1*

- The lengths of the three field arrows will be proportional to the strength of the electric field at the point where the tail of the arrow is located. Your three

measurements contain quantitative information about how the magnitude of the electric field decreases as you move away from the charge. To extract this information from your data minimize *EM Field* and open the program *Graphical Analysis*. Enter your data into the data table. Enter distance-from-charge data as  $x$ , the independent variable, and field-vector-length data as  $y$ , the dependent variable. Click in the graph region to activate the graph. Click on *Analyze* and select *Curve Fit*. From the list of fitting functions select the one labeled *Power*. Click on *Try Fit*. If the fit was successful click *OK*; otherwise, consult the instructor. The power law function that best fits your data should appear. (Print the graph and attach it to the back of your report.)

Write the best fit power law here as you might see it in a math class. Use the symbol  $x$  for the independent variable and the symbol  $y$  for the dependent variable. Place numerical values to *two* significant figures for the constants A and B directly in your formula.

Now rewrite the best fit power law here as you might see it in a physics class. In other words, replace the generic symbols  $x$  and  $y$ , with symbols appropriate for what  $x$  and  $y$  represent physically.

**Conclusion**

In words, describe how quickly the magnitude of the electric field decreases with distance from a point charge according to your data. What should you have been expecting and how does this result compare? Explain.

### 3. Examination of the field from two charges

**Introduction**

In this section you will explore the field produced by two charges, including the important case of the electric dipole, both qualitatively and semi-quantitatively.

**a. Qualitative observations of a dipole field****Procedure**

- Completely clear the screen of all charges from the previous investigation. Now place a charge of + 3 units near the center of the screen, and a second charge of -3

units two grid points to the left of the positive charge so there is only one “empty” grid point between them.

- Get a feel for the field produced by these two charges by sliding the cursor around while holding the mouse button down. Then go around and “drop” lots of arrows around the two charges.

Describe the field to the left and right of the dipole. Discuss both magnitude and direction.

Describe the field above and below the dipole. Discuss both magnitude and direction.

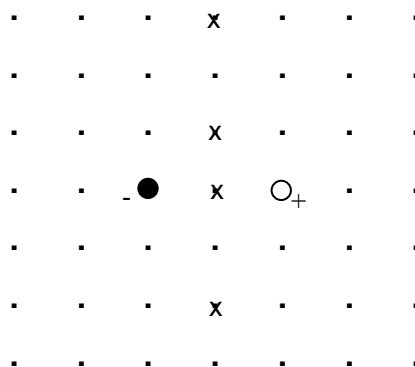
## **Conclusion**

Look at the pattern of arrows illustrating the field of a dipole. Let your eyes scan 360 degrees around the dipole in a large circle. Focusing specifically on the direction of the field, how does the field behave as you scan around this circle as compared to its behavior if you were to scan around a single positive point charge?

## b. Superposition as revealed by the dipole field

### Procedure

- Clear the screen of arrows by choosing *display>clean up screen* from the menubar. “Drop” field measurements on the grid points up and down the perpendicular bisector of the line joining the two charges as shown in *Figure 2*. Adding arrows to the diagram, reproduce the field vectors at each of the marked points in *Figure 2* as they appear on the screen. Be as accurate as possible in depicting both the magnitude and the direction of your arrows.



*Figure 2:* Field arrows at select points for the dipole

- Without clearing the screen, drag the negative charge out of the grid area. On *Figure 2* above, using a different colored pencil or pen, reproduce the field arrows as they appear on the screen at the same points as you did before. Again, be as accurate as possible.
- Return the negative charge to its original place and remove the positive charge. Using still a different color pen or pencil, again draw the field arrows at the same points, being as accurate as possible.

### Conclusion

You should have three arrows attached to each of the marked grid points in *Figure 2*. What is the relationship among the arrows in a given set of three? Describe the relationship in words and mathematically if possible.

## c. Quantitative observations of a dipole field

### Procedure

- Explore how the electric field weakens as you move away from the dipole along the line joining the two charges. At each marked grid point in *Figure 3* first drop a field arrow, measure the length of the field arrow with a ruler, and then remove the arrow. Record your results in *Table 2*. The distance from the dipole is to be measured in

grid units **from the midpoint** of the two charges; that is, the first “X” is two grid units away from the midpoint, the second is three, and so on.

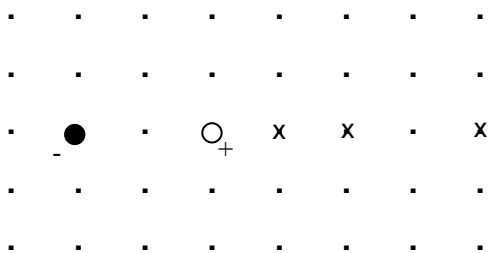


Figure 3: Select points for examining the dipole field decrease with distance

Distance from Dipole (grid units)	Length of Field Vector (cm)
2	
3	
5	

Table 2

- Using Graphical Analysis determine the power law that best fits these data. Record the best fit power law here as you would see it in a physics class; in other words, use symbols for  $x$  and  $y$  that are appropriate for what they represent physically. (Print the graph and attach it to the back of your report.)

## Conclusion

How does the rate at which the field weakens as you move away from the dipole compare to the rate of decrease as you move away from a single point charge? Does the dipole field decrease at a faster, slower or the same rate?



#### **d. Qualitative observations of the field due to two positive charges**

##### **Procedure**

- Replace the negative charge with a charge of  $+3$ , the same as the other positive charge.
- Get a feel for the field produced by these two charges by sliding the cursor around while holding the mouse button down. Then go around and “drop” lots of arrows around the two charges.

Describe the field to the left and right of the pair. Discuss both magnitude and direction.

Describe the field above and below the pair. Discuss both magnitude and direction.

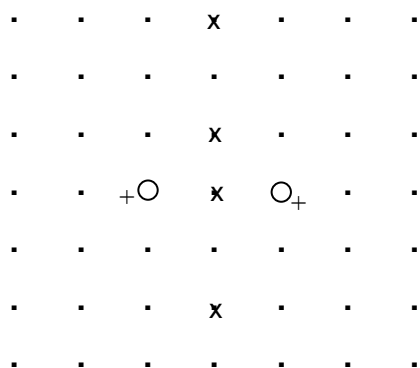
##### **Conclusion**

Look at the pattern of arrows illustrating this pair of like charges. Let your eyes scan 360 degrees around the pair in a large circle. Focusing especially on the direction of the field, how does the field behave as you scan around this circle as compared to its behavior if you were to scan around a) a single positive point charge, and b) a dipole?

### e. Superposition as revealed by the field due to a like pair

#### Procedure

- Clear the screen of arrows by choosing *display>clean up screen* from the menubar. “Drop” field measurements on the grid points up and down the perpendicular bisector of the line joining the two charges as shown in *Figure 4*. Adding arrows to the diagram reproduce the field vectors at each of the marked points in *Figure 4* as they appear on the screen. Be as accurate as possible in depicting both the magnitude and the direction of your arrows.



*Figure 4:* Field arrows at select points for a like pair

- Without clearing the screen, drag the left charge out of the grid area. On *Figure 4* above, using a different colored pencil or pen, reproduce the field arrows as they appear on the screen at the same points as you did before. Again, be as accurate as possible.
- Return the left charge to its original place and remove the right charge. Using still a different color pen or pencil, again draw the field arrows at the same points, being as accurate as possible.

#### Conclusion

You should have three arrows attached to each of the marked grid points in *Figure 4*. What is the relationship among the arrows in a given set of three? Describe the relationship in words and mathematically if possible.

Moving away from a single point charge, the field weakens as  $1/r^2$ . Moving away from a dipole, the field weakens at a faster rate, as your measurements should have shown in the previous section. When far from *two like charges*, and moving away from them, how quickly would you expect the field to weaken as compared to these two other cases? Explain.

## 4. Electric field lines

### Introduction

Most textbook representations of electric fields do not show field vectors. As you have seen, when you place many field vectors on the screen, you may produce a cluttered, confusing picture of the electric field. Instead, the electric field is depicted with *electric field lines*. It will help you to understand the pictures of the field lines you are going to produce below if you know how *EM Field* constructs field lines. Select *Options>How we plot field lines* from the menubar and read the explanation provided there.

### a. Field lines for a single point charge

#### Procedure

- After you have read the explanation, place a +6 charge near the center of a blank screen. Then select *Field and Potential>Field Lines* from the menubar. Place eight field lines on the screen by clicking on the eight grid points which form a box around the charge. Notice that the changing color along a field line indicates the changing strength (magnitude) of the field.
- Now select *Field and Potential>Field Vectors* from the menubar and drop some field vectors on the field lines by clicking.

#### Questions

When using field *vectors* to illustrate the electric field what property of the vectors allows you to determine the relative strength of the field at some point in space?

Now think about how field strength can be determined from field *lines*. Note that in many pictures showing field lines the lines are not multicolored to indicate variations in field strength. If the field lines were a single color how could you tell from the field lines themselves where the field was strong and where it was weak?

### b. Field lines for a dipole

#### Procedure

- Create a dipole by placing two equal but opposite charges on the screen. Create some field lines by selecting *Field and Potential>Field Lines* from the menubar and clicking on the grid points shown in *Figure 6* below.

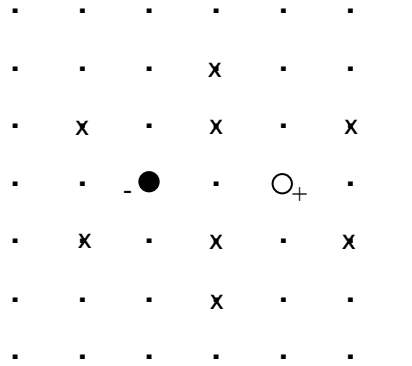
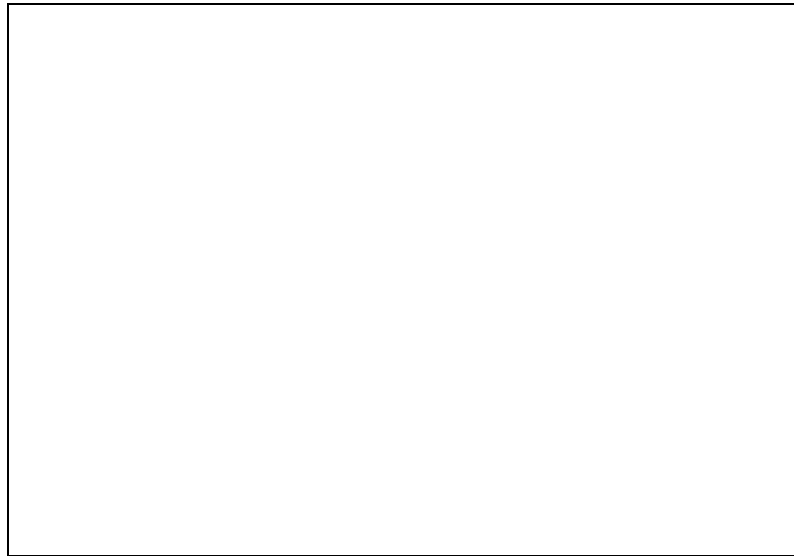


Figure 6: Positions around dipole to generate field lines

- Sketch the pattern of field lines in the box below.



- There were no curved field lines for the isolated positive point charge. Investigate the meaning of the curved lines in this field map by selecting *Field and Potential > Field Vectors* from the menubar and dropping field vectors on the lines where they are curved. Note the directions of the field vectors.

**Questions**

When using field *vectors* to illustrate the electric field what property of the vectors allows you to determine the direction of the field at some point in space?

Now think about how field direction can be determined from field *lines*. Based on your observations, write out a rule for determining the direction of the electric field at a point on a field line.

**c. Field lines from two like charges**

**Procedure**

- Replace the negative charge with a positive charge of equal magnitude. Generate a symmetric set of field lines on the screen for this system.
- Sketch the pattern of field lines in the box below.



**Questions**

What are the similarities and differences between the field lines for a dipole and those for two positive charges?