Electric Field Mapping

Based on a similar lab from the University of Scranton

Electric Field

Charged particles and objects interact with one another through the forces of Coulomb's Law. Another very useful model for describing charge is called the *electric field*. While Coulomb's Law refers specifically to the electrical forces field between charges, the electric field draws a picture of how one charge alone affects the space around it. The forces between particles can still be found; however, instead of focusing on the two specific charges q_1 and q_2, we can instead draw an electric field in the space around q_1 that will describe how <u>any</u> other charge will react when placed within this space. Thus, electric fields serve as a more general representation of electric charges and the spaces around them.

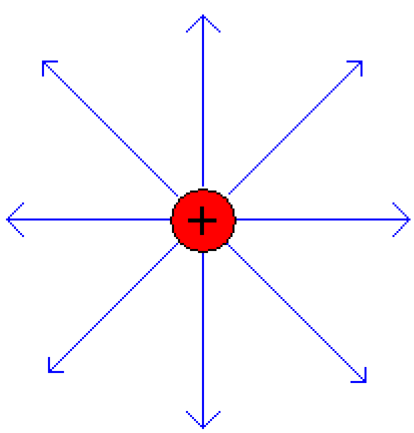
The electric field, **E**, is a vector that measures the electrostatic forces, $\mathbf{F_e}$, felt by a second charge, $\mathbf{q_2}$, placed at some point in space around the initial charge, $\mathbf{q_1}$. In other words:

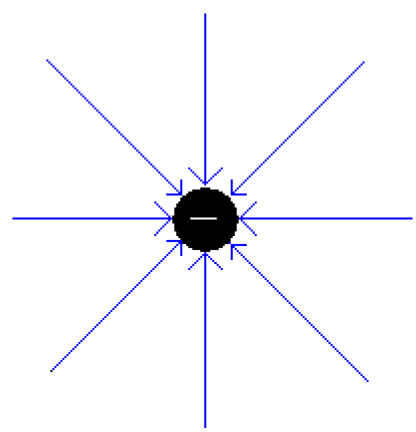
$$\textbf{[1]} \qquad \mathbf{E = F_e/q_2 = Kq_1/r^2}$$

where

$\mathbf{E}$ ≡ "electric field strength"
$\mathbf{F_e}$ ≡ "electrostatic force felt by $\mathbf{q_2}$"
$\mathbf{q_2}$ ≡ "charge placed in surround space of $\mathbf{q_1}$"
$\mathbf{K}$ ≡ "electrostatic constant" = 9×10^9 [Nm^2/C^2]
$\mathbf{q_1}$ ≡ "initial charge"
$\mathbf{r}$ ≡ "distance between $\mathbf{q_1}$ and $\mathbf{q_2}$"

Equation **[1]** only represents the electric field strength at a single point. However, the electric field exists in all the space surrounding the initial charge. When drawing an electric field emanating from an object, the electric field vectors represent which way a <u>positive</u> charge would accelerate due to Coulombic forces if it was placed in the field. The diagram below shows the electric field surrounding a positive and negative charge.





Notice how the blue *electric field lines* represent how a positive charge would react if placed somewhere within that field. For the initial positive (red) charge, they point away from the charge, representing the repulsive Coulomb force that would push the second positive charge away from the first.

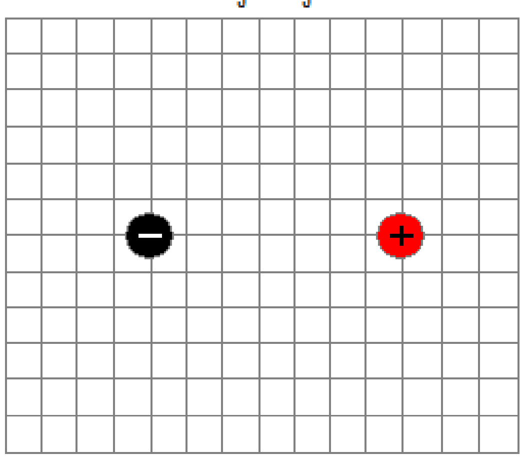
For the negative (black) charge, the electric field lines point into the initial charge. This makes sense, because a positive charge placed in that field would feel attractive forces, causing it to accelerate towards the negative charge.

The two electric fields above are the fields surrounding *point charges*, or tiny spots of charge. The electric field strength of point charges has the same *inverse-square of distance* relationship as Coulomb's Law, because they both deal with point charges. As you know, larger objects with excess charges have an overall net charge. These objects create their own unique electric field lines which may differ from those above. Some of these other charged objects include spheres of charge, finite and infinite lines of charge, planes of charge, loops of charge, and several others, each with their own electric field lines surrounding them.

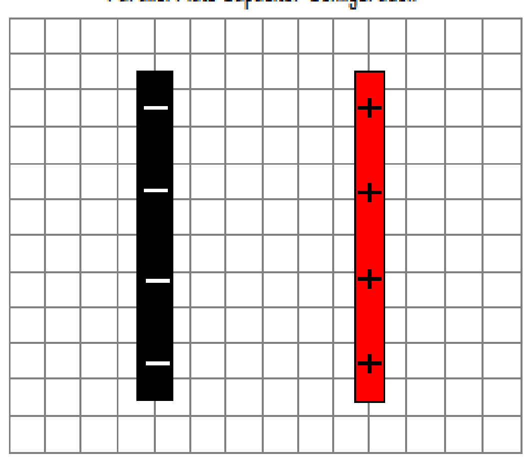
One important electric field configuration you will use is called the *parallel plate capacitor*, which is simply two oppositely charged finite lines of charge separated by a specific distance. One important aspect of the electric field inside the parallel plate capacitor is that the field is *uniform*, or constant. For point charges, the further away from the initial charge that you place your second charge, the weaker the electric field will be. For a parallel plate capacitor, however, no matter where you place a charge within the field, it will accelerate the same way and at the same rate. You will soon see in lecture the importance of creating a uniform electric field.

Your goal in this lab is to use a voltmeter to measure the greatest voltage difference between two points in space of a few charge configurations, and use that information to draw electric field lines like in the picture above. You will be examining point charges (two charged washers) and a parallel plate capacitor (two charged finite lines), and draw the electric field lines for each.

Point Charge Configuration



Parallel Plate Capacitor Configuration



Procedures

1) Take two washers and pin them securely (with metal thumb tacks) to the black conductive paper similar to the point charge configuration above. Attach the power source leads to the thumb tacks (red is positive, black is negative) and make sure the voltage dial is set to 10 [V].

2) Use the voltmeter prongs to measure the direction of greatest voltage between two points in space between the charges. This is done by placing only the black lead on the conductive paper, keeping the black lead fixed at that point, and placing, and slowly sweeping, the red lead in a circular motion around that point. Another group member should watch the voltmeter for the highest value of voltage. When the highest voltage is found, the points where the black and red leads are touching the conductive paper represent the direction of the electric field arrows. On your white paper, draw an arrow at that location in the proper direction (away from positive, toward negative).

3) Repeat procedure 2 several times to create a vector field, which is just a bunch of electric field arrows at several points in space that can be connected to show the overall field. Sketch the field lines to show where a positive charge would move within that field (like for the positive charge in the diagram above).

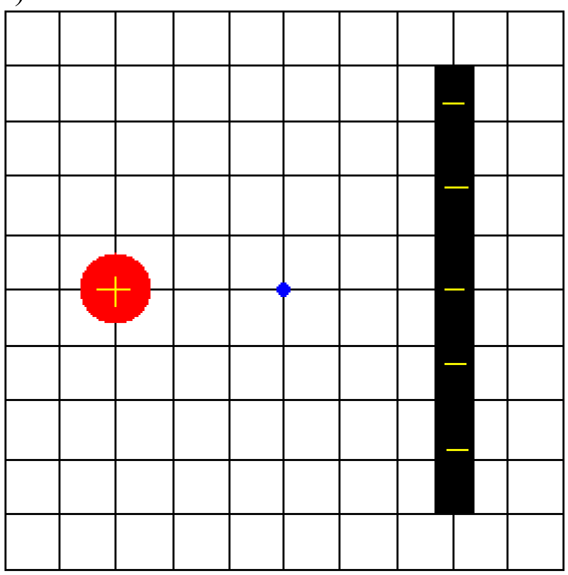
4) Once you complete the electric field between two point charges, select conductive paper with the parallel plate capacitor configuration. Repeat procedure 2 and 3 to sketch the electric field between the electrodes.

5) Set up Data Studio and use the magnetic field sensor to measure the magnetic field strength at different distances from the magnet (ask instructor for the Data Studio program). You should get a graph of Magnetic Field Strength vs. Position. Perform an inverse-square fit, and highlight a region of the graph that best fits the inverse-square curve. Print your graph.

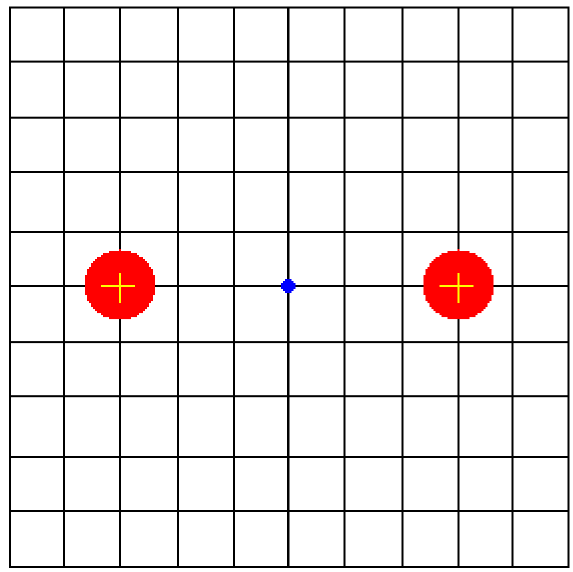
Questions

1) Using your drawn electric fields from lab as a guide, draw the electric fields for these different electrodes: (don't be confused by the number of yellow charges drawn on the electrodes – they only indicate positive or negative charge, not the strength of the charge)

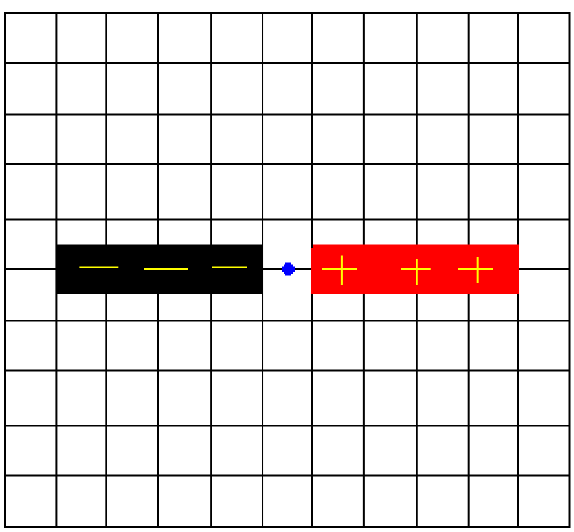
a)



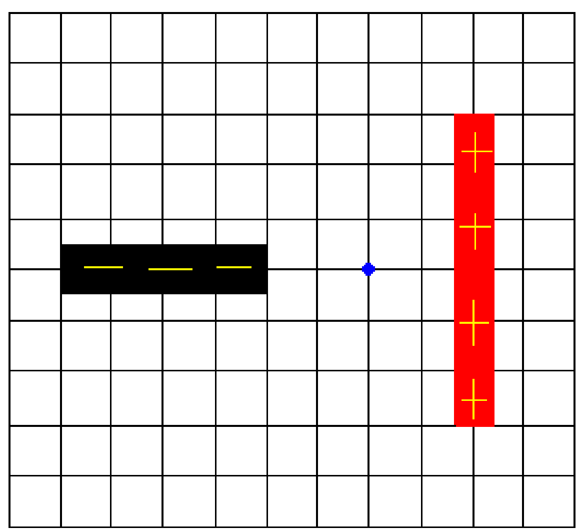
b)



c)



d)



2) Solve for the *expression* for the electric field (strength and direction) at the blue midpoint between the two electrodes from question 1a and 1b. Remember that each charge creates its own electric field strength at the center point, so $E = E_1 + E_2$. (Just call the distance from the electrode to the midpoint "r," the length of the line of charge "L," and the charges and charge densities "q" and "λ." Check your book for the expression for a finite line of charge if you are confused about 1a.)

1a)

1b)