**Lab 201: Electric Field by Point Charges**

**Name: Arsh Bhamla, Kevin Gettler, Yosif Ismail** **Group: G**

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**Course: PHYS 121A 016** **Instructor: Subodh Dahal**

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# 1. INTRODUCTION

## 1.1 OBJECTIVES

To use software to calculate and visualize the electric field produced by various configurations of point charges.

## 1.2 THEORETICAL BACKGROUND

Objects with charge apply electric forces on each other; the mutual forces are repelling when the objects have the same kind of charge, while they are attractive when the objects have different types of charge. As investigated previously, objects can have one of two charges which are arbitrarily assigned to be positive (associated with protons) or negative (associated with electrons).

The magnitude of the electric force between two *point* charges can be quantified by Coulomb's law, where $q_1$ and $q_2$ are the charges of the two points, $r$ is the distance between them, and $k$ is an empirical proportionality constant ($k$ = 8.9876 · $10^9$ $Nm^2/C^2$):

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


Since electric force is a function of space, it is often more helpful to formulate Coulomb's law as a vector function as follows, where $\vec{r}_{12}$ is a unit vector pointing from point 1 to point 2:

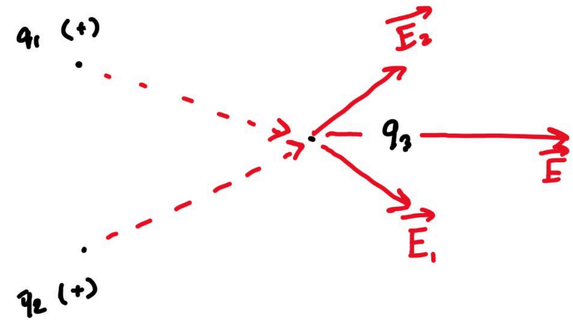
$$\vec{F}_e = k\frac{q_1 q_2}{r^2}\vec{r}_{12}$$

The absolute value signs are dropped so that the direction of the vector will point away from point 1 if point 2 is of the same charge, and towards point 2 if point 2 is off the opposite charge.

We can make another helpful manipulation by noting that we often do not actually care about the interaction between two specific charges; we more frequently care about how one specific charge affects any arbitrary charge in space. We can account for this in our quantification as well by dividing out one of the charges from the previous equation. The new equation produces a vector field that predicts how a particular point charge will affect any point in space. This field is known as the *electric field* of that point:

$$\vec{E} = \frac{\vec{F}_e}{q_2} = k\frac{q_1}{r^2}\vec{r}_{12}$$

The electric fields produced by multiple point charges can be summed together (due to the superposition of forces) to produce the net electric field produced by the entire set of points. To visualize the electric field produced by a set of point charges, it can be helpful to draw *electric field lines* that are tangent to the electric field at various points. These lines generally show the direction of the force (but *not necessarily* the acceleration) of a point charge placed at that point.



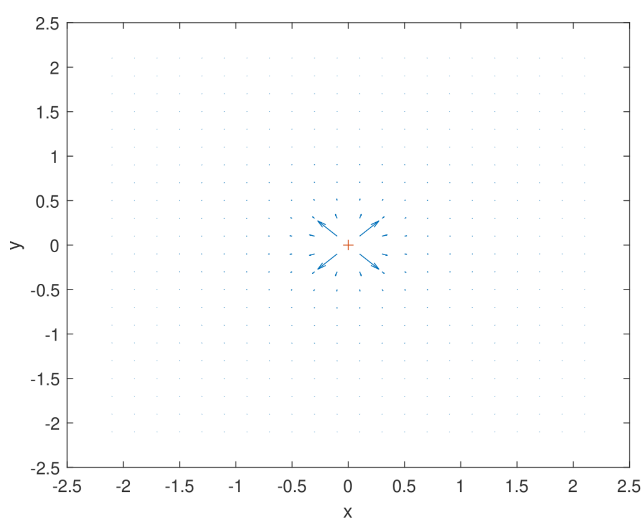

## 2. EXPERIMENTAL PROCEDURE

Researchers manipulated previously written MATLAB files to produce figures that visualize the electric field of three particular charge set-ups:

- The first set-up places a single positive point charge on the origin of the xy-plane. The visualization plots the electric field produced by this point at various points in space.
- The second set-up places two point charges of equal positive charge at points (a, 0) and (-a, 0) on the x-axis (*a* being an arbitrary distance). The visualization graphs the value of the electric field produced along the x-axis.
- The first set-up places two point charges of equal magnitude of charge but opposite signs on the y-axis such that the positive charge lies at the point (0, a) and the negative charge lies at the point (0, -a). The visualization plots the electric field produced on the xy-plane, both as vectors and as electric field lines.

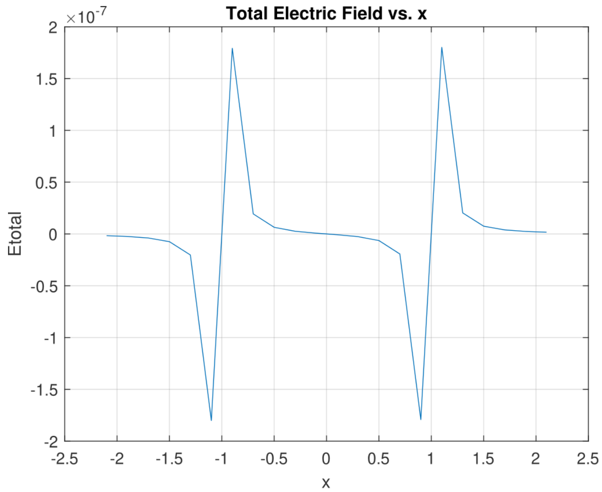
## 3. RESULTS

Figure 1. 2D Electric Field of a Single Point Charge



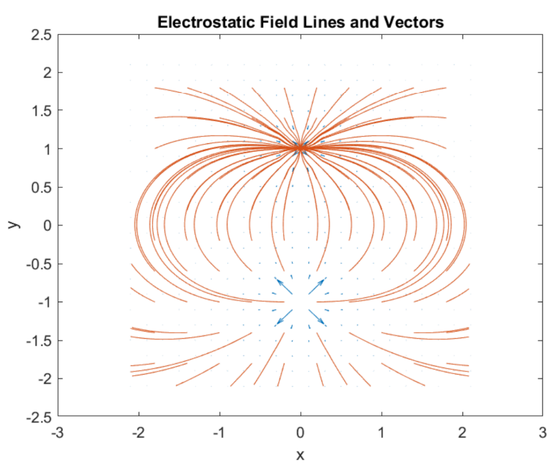

```
eps0 = 8.854e-12; k = 1/(4*pi*eps0);
q=3;
[x, y] = meshgrid(-2.1:0.2:2.1,
-2.1:0.2:2.1);
E = k*q./(x.^2 + y.^2);
[px] = cos(atan2(y,x));
[py] = sin(atan2(y,x));
xcomp = E.px; ycomp = E.*py;
quiver(x, y, xcomp, ycomp)
hold on
x=0; y=0; plot(x, y, ‘+’)
xlabel ‘x’, ylabel ‘y’
```

Figure 2. 1D Electric Field of Two Equivalent Point Charges




```
eps0 = eps0 = 8.854e-12;
k = 1/(4*pi*eps0);
q1 = 2e-9; q2 = 2e-9; a = 1;
x = [-2.1:0.2:2.1];
E1 = q1*k*(x+a)./abs(x+a).^3;
E2 = q2*k*(x-a)./abs(x-a).^3;
Etotal = E1 + E2;
plot(x,Etotal);
xlabel 'x'; ylabel 'Etotal'
grid
title 'Total Electric Field vs. x'
```

Figure 3. 2D Electric Field and Electric Field Lines of a Dipole




```
q1 = 2e-9; q2 = -2e-9; a = 1;
eps0 = 8.854e-12; k =
1/(4*pi*eps0);
[x,y] = meshgrid(-2.1:0.2:2.1,
-2.1:0.2:2.1);
r1S = (x).^2 + (y-a).^2; r1 =
sqrt(r1S);
r2S = (x).^2 + (y+a).^2; r2 =
sqrt(r2S);
e1x = (x)./r1; e1y = (y-a)./r1;
e2x = (x)./r2; e2y = (y+a)./r2;
E1m = (q1*k)./r1S; E2m =
(q2*k)./r2S;
E1x = E1m.*e1x; E1y = E1m.*e1y;
E2x = E2m.*e2x; E2y = E2m.*e2y;
Ex = E1x + E2x; Ey = E1y + E2y;
quiver(x, y, Ex, Ey)
xlabel('x'); ylabel ('y');
title('Electric Field Lines and
Vectors')
hold on
[X, Y] = meshgrid(-3:0.4:3,
-3:0.4:3);
streamline(x, y, Ex, Ey, X ,Y)
```

**Calculations**

The calculations are in the results.

We used these formulas for calculations 1- $F_e = k\frac{|q_1||q_2|}{r^2}$

2- $\vec{F_e} = k\frac{q_1 q_2}{r^2}\vec{r}_{12}$

3- $\vec{E} = \frac{\vec{F_e}}{q_2} = k\frac{q_1}{r^2}\vec{r}_{12}$

4. **ANALYSIS and DISCUSSION**

Before putting it into MATLAB and changing the values, we had to understand what the code was trying to accomplish, and what result we should expect the code to produce. We also needed an understanding of how MATLAB operates in order to properly create, edit, and output the figures. By comparing the code structure to the formulations of Coulomb's law and the formula for the electric field, it is evident that each program produces a coordinate space,

For Figure 1, we noticed that the field vectors are all pointing outwards, which is the characteristic of positive charges. A negative charge would have had an opposite effect, having vectors pointing inwards towards the source charge. In Figure 3, the charges if the positive and negative are pointing towards one another. This is because opposite charges repel each other. Had the charges been alike, they would have not been able to touch, repelling one another. There is no error analysis to conduct since this experiment did not have any experimental data to compare with our theoretical calculations.

Several discussion questions were included in this lab. The first asked why it is important to exclude the points x = 1 and x = -1. These points are a distance *a* away from the origin, which means those are the points where $q_1$ and $q_2$ are located. It is important that we exclude these points because they are unable to act on themselves. Furthermore, by including these points, we would have to assume that the two positive charges are pushing each other away (since they share the same charge), meaning that we would be unable to make assumptions about the rest of the points. The second question asks why we used the distance cubed rather than the traditional squared that's used in the electric field formula. The reason for this is that we are trying to get the sign from (x+a) or (x-a), which is in the numerator, and cancel that out by a third factor in the denominator. If we used the traditional value of r^2, we would not get a sign because anything squared will be positive. By doing this instead, we negate a change but get the correct sign that we need.

There are four subparts of question three. Part a asks if the electric field is 0, which it is. For part b, we ask if it should be, and the value is supposed to be 0 because the charges and distances are the same, which means that the magnitude should be equal to 0. For part c and d, it asks how a positive test charge would be at a stable equilibrium. The answer would be yes, because it would have two forces acting in opposite directions, essentially canceling each other out. The same would apply for a negative charge, because it would be equally pulled in either direction, so it too would be at static equilibrium. At any other point we would not see an equilibrium, because although the charges are the same, the distances would be different.

## 5. CONCLUSIONS

In conducting this experiment we learned about Coulomb’s law and electric fields. We were able to determine the magnitude and direction of the electrical fields due to the charges and forces. The law of electrostatic repulsion states that two things or particles will repel one another if their signs are equal. The rule of electrostatic attraction will apply if the signs of these two items are different. Due to the electrostatic force and distance having an inverse relationship, a lower distance between two charged particles, or objects, will result in a bigger electrostatic force between them. The principle of electrostatic repulsion states that test charges containing both positive and negative charges will resist one another.This is because the rule of electrostatic attraction states that test charges with different charges will attract each other. In the center of two charged particles, a positive or negative test charge would either increase or decrease the electric field vector at a reference frame.

MatLab is a great way to code and compute Electric fields concerning point charges. The field's magnitude may be determined using functions, and MatLab's graphing capabilities let users plot the lines of the electric field. The electric field's flow is depicted by these field lines. We confirmed our knowledge from the previous lab for electric charge and force. As the last lab was more like actual touchable experiments and this lab is more about coding, but they both connect perfectly to each other. We explored the electric charges created by friction and their interplay, comprehended how conduction and induction work to electrically charge an item, and used the conduction of the lab to show many of the qualitative aspects of electrostatics.

As instructed in class, there is no raw data for this lab report.