GENERAL PHYSICS II

EXPERIMENT 2

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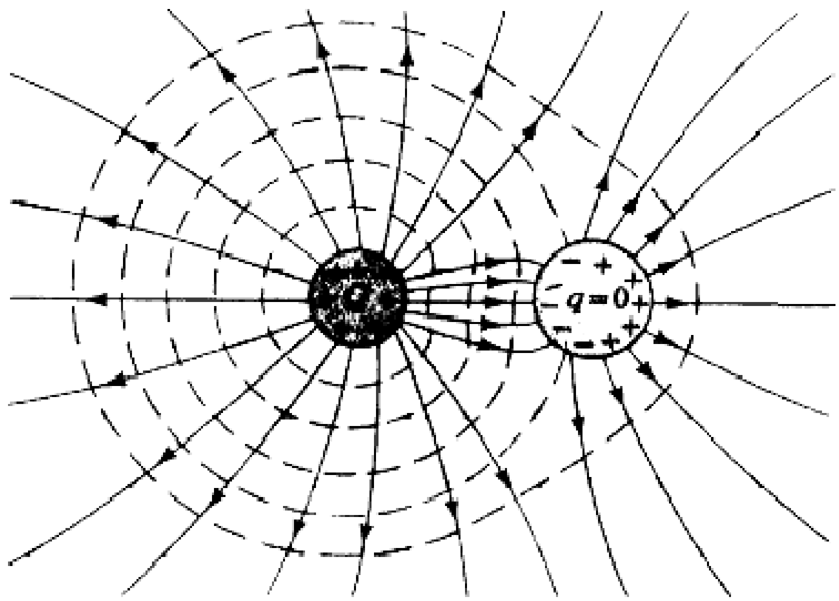
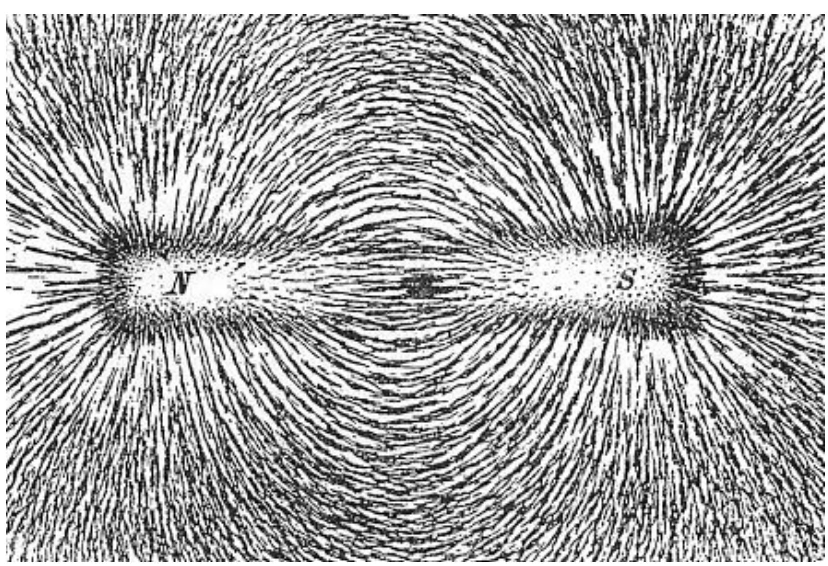
COLLIN COLLEGE

Electric Charges and Electric and Magnetic Fields





Produced by the Physics Staff at Collin College

Purpose

In this experiment you will investigate the electric force field.

Equipment

This lab will be performed entirely with simulations.

Introduction

Electric Fields

Coulomb's law is the relationship between the magnitude of the electric force F, two point charges Q_1 and Q_2, and the distance d between them:

$$F = k\frac{Q_1 Q_2}{d^2} \qquad \textbf{Equation 1.1}$$

with the constant of proportionality $k = 9.0 \times 10^9\ \mathrm{Nm^2/C^2}$. You can infer the direction of the vector F from the law of charges, which states that like charges repel and unlike charges attract. The electric field E is defined as the electrical force per unit charge. You can determine the electric field in the space around a given charge Q by using a unit positive charge Q_o. The electric field at a distance d from Q is:

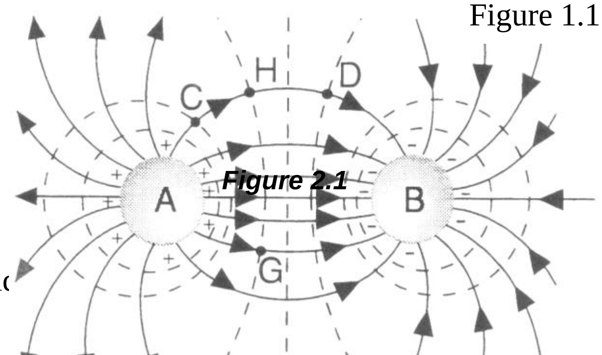
$$E = \frac{F}{Q_o} = k\frac{Q_o Q}{Q_o d^2} = k\frac{Q}{d^2} \qquad \textbf{Equation 1.2}$$

You can determine the electric force on a unit charge located at various points surrounding an electric charge configuration. From these considerations, you can then calculate the electric force that any specific charge would experience at those locations.

The electric force per unit charge is defined as the *electric field intensity* or, simply, the electric field E. By calculating the electric force on a unit positive charge at different locations around a given charge configuration, you can map out the electric field generated by that configuration. The resulting field pattern is called *lines of force* and was first introduced by the English physicist Michael Faraday (1791–1867) as a means for visualizing the direction and magnitude of the electric field.

Continuous lines drawn through and in the direction of each E vector form lines of force which are a graphical representation of the electric field. At any a specific location, the direction of E is tangent to the line of force at that point (see Figure 1.1). A unit positive charge released near the positive source charge A would move away from A along a line of force in the direction indicated by the arrows. A unit negative charge would move in the opposite direction along the same line of force. The spacing of the lines of force at any location is proportional to the magnitude of E at that location. Moving a free electric charge within this electric field involves work if the electric force acting on

Figure 1.1



the charge has a component in the direction of the motion. The work W per unit charge Q_O in moving that charge from point C to point D is defined as the potential difference ΔV between those points:

$$\Delta V_{CD} = V_D - V_C = \frac{W}{Q_0} \qquad \textbf{\textit{Equation 1.3}}$$

If Q_O is moved perpendicular to the lines of force from point G to point H, then no work is done ($W = 0$) since there is no component of force along the path. Along such a perpendicular path,

$$\Delta V = V_H - V_G = \frac{W}{Q_0} = 0 \qquad \textbf{\textit{Equation 1.4}}$$

So $V_G = V_H$, or the potential remains the same. Such a path is called an *equipotential* line (dashed lines in Figure 1.1).

You can experimentally determine both the magnitude and direction of the electric field around a system of charged objects by mapping either the lines of force or the equipotential lines. Either method involves measuring the potential difference between every two points in a low-conductivity medium surrounding two charged conducting electrodes. You can measure the potential difference between any two points in the medium with a high quality voltmeter. If there is no potential difference between two specific points, they must be at the same potential and hence lie on the same equipotential line. If two other points have a maximum potential difference between them, the straight line between the points must be perpendicular to the equipotential lines, hence the points must lie on a *E*-field line (see Figure 1.1). Therefore, equipotential lines are always perpendicular to *E*-field lines.

Magnetic Fields

Similar to electric fields, magnetic fields or lines of force may be mapped around a magnet. As a contrast to isolated “+” and “-“ electric charges, a single magnetic north (N) or south (S) has not been observed. The direction of a magnetic field may be mapped using the north pole of a magnetic dipole like a compass. When the compass is moved in the direction as indicated by its north pole, the magnetic field or lines of force may be mapped or traced out. By sprinkling iron filings over a magnet covered with a transparent sheet, the magnetic field becomes visible.

An electric charge “q” that is moving nonparallel to a magnetic field (with a speed of v) will experience a force given by $F=qvB \sin \theta$, where θ is the angle between the direction of “v” and the direction of the magnetic field “B.” Solving for B, the magnetic field may then be defined as $B=F/qv$. The units for a magnetic field “B” which also like the electric field “E” is a vector quantity expressed as N/Am or tesla (T).

Procedure

Part A: Electric Fields

Start by opening up the electric field simulation in your web browser (either copy paste the following URL into your browser, or CTRL+Click on the link below):

https://phet.colorado.edu/sims/html/charges-and-fields/latest/charges-and-fields_en.html

Once the simulation is open, follow these steps:

1. Make sure the following checkboxes (center right) are selected: Electric Field, Grid, and Values.

The Dipole:

2. Click and drag a single +1 nc charge at the bottom of the chart onto the "center left" of the grid pattern. Now click and drag a single -1 nc charge 3 meters directly to the right of the +1 nc charge (you'll see the scale in meters near the bottom of the chart). Note the electric field pattern that you observe for the dipole.

3. Next click and drag the blue "Volt" tool (it has 0.0 V and a crosshair on top) into the chart. Starting close to the positive charge (and on the line between it and the negative charge), line up the crosshairs about 0.25 m from the positive charge, and click on the pencil "button." You will see a labeled green line appear. Go a bit (0.25 or so) meters closer to the negative charge and click again. Repeat this procedure until you are about 0.25 m from the negative charge. These points that you are now mapping are the equipotentials and they will form a circular pattern near the charges and straighten out in the center of the field.

4. Take a screenshot of your "Dipole electric field with Equipotentials;" and place it in the Screenshots tab of the Lab Report Template. **Hint:** How you take screenshots depends on your computer, but a method that almost always works it to hit the PrtScn button (which will often save it as screenshot located under Pictures automatically), then open up the Lab Report template, click on the "Screenshots" tab and then click CTRL+V… you'll likely need to resize the screenshot to make it a bit smaller.

5. Now triple the number of either "+" or "- " (but not both) charges onto your grid and observe the result. Whichever charge you decide to triple, place the charges on top of each other (for example: add two more "+" charges on top of the one you already placed). Take a screenshot of the result and upload it to the Lab Report (put it below your first screenshot).

6. Next, delete all of the charges (you can remove a charge by dragging it off the chart and back into the "box with charges", then click and drag two single "+" charges alone onto the grid (again, make them 3 meters apart horizontally) and observe the result. (that

means chart out the equipotentials!) Try the same for two “-“charges. Take a screen shot of each, and place it in your Lab Report (under the screenshot from step 5).

A Single Charge and a Line of Charges

7. Next click and drag eight negative charges onto the grid pattern and place them in a straight line in a vertical direction. Place each charge about 0.5 from its neighbors, and make the vertical line about where your original single negative charge was. Place a single positive charge about 3 meters away from the center of the line of negative charge (similar position to where your original positive charge was). Once again map the equipotentials, make a screenshot of your work, and place in in the Lab Report.

8. Now **predict** what you think will happen if you “expand” your positive charge into a vertical line of eight positive charge (mirroring the line of negative charge you created). Specifically, **what do you think the electric field lines will look like between the two lines of charge, and what will the equipotentials look like?**

9. Now actually **do the experiment –** expand your positive charge into a vertical line of eight positive charges spaced 0.5 m apart (each). **Does the resulting electric field and set of equipotential match your prediction?** Take a screenshot and add it to your growing collection in your Lab Report.

Answer the questions in the Lab Report (first tab), and then move on to the next simulation.

Part B: Magnetic Fields

Download this simulation for magnetic fields and follow the steps outlined below:

https://phet.colorado.edu/en/simulation/faraday

1. For this simulation, select and click on Show Field, Show Compass, and Show Field Meter.

2. Note the small compass that you can move around the bar magnet. What happens to the red end of the compass as you move it towards the south end of the bar magnet? The white end of the compass?

3. From your observations, what can you conclude about the polarity of the compass; specifically, what is the polarity of the red end (“north” or “south”) and the white end of the compass?

4. Now move the compass in the magnetic field from one end of the bar magnet to the other end. What pattern does the compass follow?

5. Select or click the “Field Meter” option and move the compass around the magnetic field. What observations can you make concerning the magnitude or strength of the magnetic field? Specifically, what happens to the strength of the field as you get closer to one of the poles? What about the direction of the field (use “Bx” and “By” as a clue to this) as you go from the south to the north pole?

6. Use the Field Meter to probe the field strength inside the magnet: what do you observe about the field strength at all points in the magnet? What about the direction of the field?

Is this what you'd expect? How does it compare to even short distances outside the magnet?

7. Finally, the experiment does not display equipotential lines. Based on your experience with Part A, **how do you expect the magnetic equipotential lines to relate to the magnetic lines of force? If a magnet were moved along an equipotential line, would you expect any work to be done? What if it was moved along a line of magnetic force?**