Online laboratory assignment 2 – Electric field and electric potential

Purpose: to study the electric field from a single charge and a set of opposing charges.

Introduction

Coulomb's Law describes the magnitude of the electrostatic force that exists between two charged particles (a and b)

$$\left|\vec{F}_{ab}\right| = \frac{1}{4\pi\varepsilon_0}\frac{|q_a q_b|}{r^2}$$

where $\vec{F}_{ab}$ is the force exerted by particle a on particle b. The charges are q_a and q_b, and the distance between the two charges is r.

Another way to describe the interaction of the two charged particles is to utilize the concept of a field. We say that particle a generates an electric field with magnitude,

$$\left|\vec{E}_a\right| = \frac{1}{4\pi\varepsilon_0}\frac{q_a}{r^2}$$

This field from point a exerts a force on particle b

$$\vec{F}_{ab} = q_b\vec{E}_a$$

The electric field vector points in the same direction as the force on a positively charged particle, and in the opposite direction as the force on a negatively charged particle. If more than one charge produces an electric field, the principle of superposition is applied and all of the individual electric field vectors are added to produce the resultant electric field vector.

In the absence of any external forces, a charged particle in a region of space where an electric field exists will spontaneously move in such a fashion as to decrease its electric potential energy. Electric potential energy U per unit charge q,

$$V = \frac{U}{q}$$

which is called the electric potential (V). It has units of joules/coulomb, which are called volts. Since there is no absolute frame of reference for any type of potential energy, there is no absolute frame of reference for electric potential, and we always work with changes in potential (ΔV) rather than with absolute potential values. Electric potential is a scalar because energy and charge are both scalars.

As one would expect, there exists a relationship between electric potential changes and electric field. The electric field is related to the negative of the gradient of the electric potential,

$$\vec{E} = -\nabla V = -\left(\frac{\partial V}{\partial x}\hat{\imath} + \frac{\partial V}{\partial y}\hat{\jmath} + \frac{\partial V}{\partial z}\hat{k}\right)$$

A derivative can be approximated by a finite difference. For example, let us assume that the electric field points in the x-direction. Then, $E_x = -\frac{\partial V}{\partial x} \approx -\frac{\Delta V}{\Delta x}$. We will use finite difference approximations along the direction of the electric field in this laboratory assignment to study the relationship between the electric field and the electric potential.

In addition to a monopole (a single point charge), dipole can be formed by placing two charges of equal magnitude q and opposite sign a distance d apart. The dipole moment is defined as

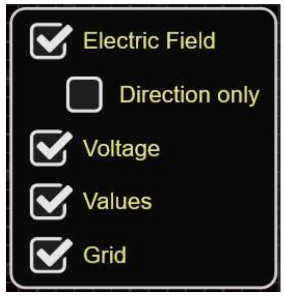
$$\vec{p} = q\vec{d}$$

As more charges are introduced into a system the equipotential surfaces and electric field lines can become more intricate.

Laboratory assignment

Part 1: Monopole

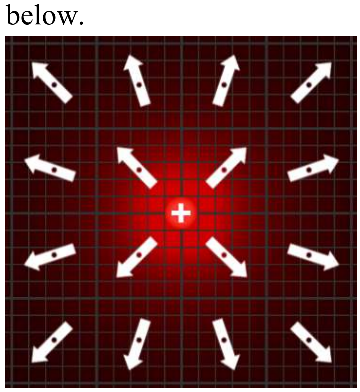
1. Run the “Charges and fields” PhET simulation.
2. Check the boxes as shown below.



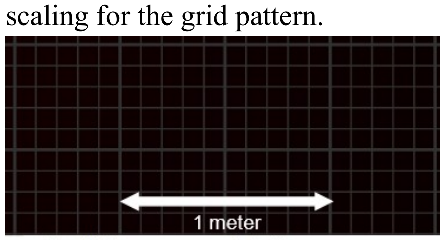
3. Click and drag a negative charge to the center of the screen. Describe what you see.

4. Click and drag a positive charge to the center of the screen. Describe what you see.

5. Position the positive charge near the center of the screen and with its center at the crosshairs of two major gridlines as shown below.

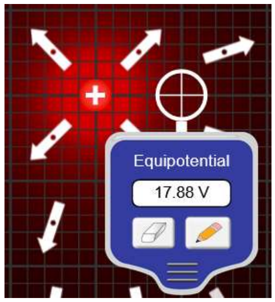


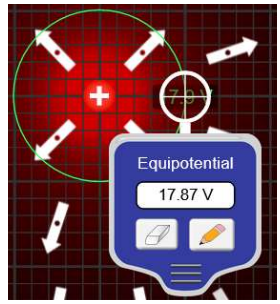
6. Make note of the distance scaling for the grid pattern.



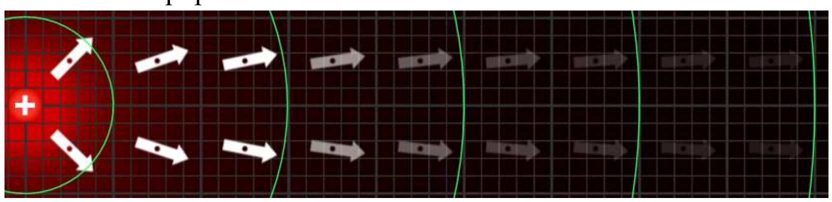
2 big divisions = 10 small divisions = 1 meter

7. Drag the Electric Potential meter (referenced with neutral ground infinitely far away) to point along the horizontal direction half a meter away as shown below. Then click on the pencil so a cross-section of an electric potential surface appears (the screen is a two-dimensional slice of the three-dimensional system).





8. Move the potential meter a meter to the right and click the pencil button again. Continue to do this for a total of five equipotential surfaces as shown below.

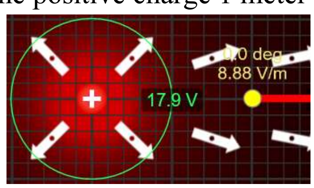


9. Place all of the values of the potential in Table I.

Table I: Monopole electric potential values.

r (m)	0.5	1.5	2.5	3.5	4.5
V (V)					

10. Approximate the magnitude of the electric field to the right of the charge and at the midpoint between electric potential surfaces the using finite differences. Place the values in Table II.
11. Drag the sensor to the right of the positive charge 1 meter away as shown below.

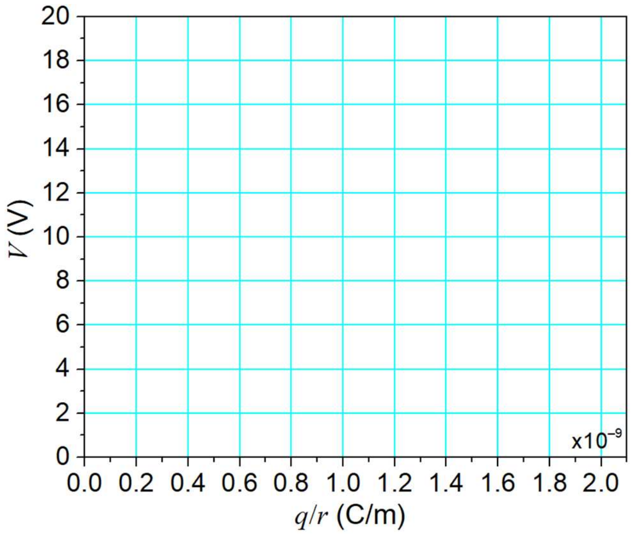


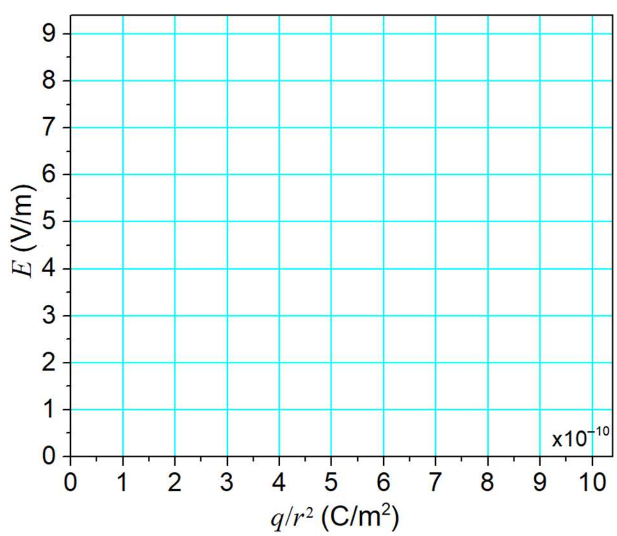
12. Place the value that you measured for the electric field magnitude in Table II.
13. Repeat the measurement for all other distances given for the measurements of the electric field in Table II.
14. Complete Table II by determining the percent differences between the measured and approximated values of the electric field magnitude.

Table II: Monopole electric field magnitude values.

r (m)	1.0	2.0	3.0	4.0
E_{meas} (V/m)				
E_{calc} (V/m)				
% difference (%)				

15. Plot V as a function of $\frac{q}{r}$ and E_{meas} as a function of $\frac{q}{r^2}$ in the graphs below.





16. Determine the slope of each graph including units (not necessary to determine the uncertainty).

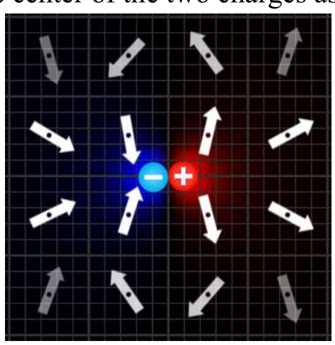
Slope of electric potential graph = _______________. Slope of electric field graph = ________________.

17. Calculate the % difference of each slope with respect to the accepted value of the Coulomb constant, $8.99\times10^9\ \mathrm{N\,m^2\,C^{-2}}$.

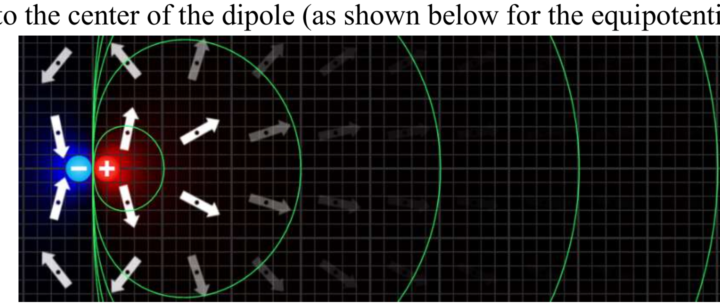
% diff (slope 1) = _______________. % diff (slope 2) = ________________.

Part 2: Dipole

18. Place two charges of ±1 nC a distance of 0.2 m apart in the center of the screen such that there is a major gridline crossing at the center of the two charges as shown below.



19. Repeat the experiment for the monopole and apply it to the dipole situation. As you take measurements to the right of the horizontal dipole, make sure to take the distance measurements with respect to the center of the dipole (as shown below for the equipotential surface placement).



20. Fill in measured values of the electric potential in Table III.

Table III: Dipole electric potential values in direction of dipole moment.

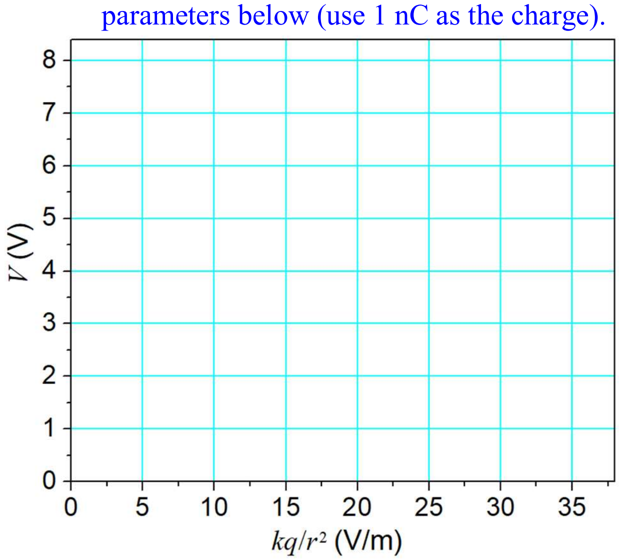
r (m)	0.5	1.5	2.5	3.5	4.5
V (V/m)					

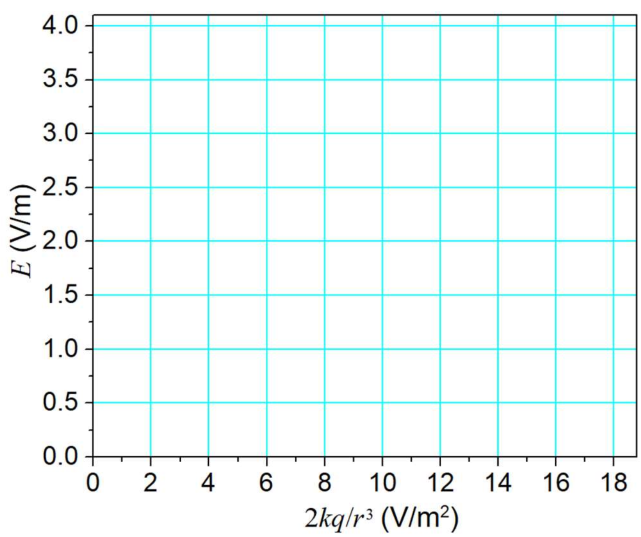
21. Calculate the magnitude of the electric field in the horizontal direction of the dipole and place the values in Table IV.
22. Take measurements of the electric field using the yellow sensor. Place the values in Table IV.
23. Complete Table IV by determine the percent difference between the calculated and measured values of the electric field.

Table IV: Dipole electric field magnitude values in direction of dipole moment.

r (m)	1.0	2.0	3.0	4.0
E_{meas} (V/m)				
E_{calc} (V/m)				
% difference (%)				

24. Graph the electric potential and the electric field magnitude as a function of the horizontal parameters below (use 1 nC as the charge).





25. Determine the slope of each graph including the units (unnecessary to include the uncertainty).

Slope of dipole potential graph = ______________. Slope of dipole field graph = _______________.

26. Calculate the % difference of each slope with respect to the charge separation of $d = 0.2$ m.

% diff (slope 1) = ______________. % diff (slope 2) = _______________.

27. If you were far from a source of an electric field, would a monopole or a dipole source feel stronger? Explain.

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28. Write a conclusion to this laboratory assignment.

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