

## Lab 8: Electric Potential Energy and Electric Potential

Name:

Group Members:

Date:

TA's Name:

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### Objectives

1. To understand the electric potential of a point charge.
2. To understand the electric potential of a dipole.

**Simulation link:** [http://phet.colorado.edu/sims/charges-and-fields/charges-and-fields\\_en.html](http://phet.colorado.edu/sims/charges-and-fields/charges-and-fields_en.html)  
Type "Charges and Fields -PHET" in Google and click the link.

### Part 1: Electric field and potential of a point charge

In the last experiment we investigated the electric field of a point charge and a dipole. Electric field acts as an agent to the source charges and is present everywhere in space. Therefore, the electric field from one charged object will exert forces on other charged objects. The strength and direction of the electric field at a given point in space can be measured by measuring the electric force acting on a unit positive test charge. If the electric field due to a source charge or charge distribution is known then one can find the electric force on a charge  $q$  in the field by using the equation:  $\vec{F}_E(x, y, z) = q\vec{E}(x, y, z)$ .

So far we have studied electrical interaction in terms of electric force concepts. In this lab we are going to take a look at a system of charges with a different perspective. We want to study a system of charges in terms of its electrical interaction energy or the *electrical potential energy*,  $U_{elec}$ . For that purpose we define a quantity called *electric potential*,  $V$ . Electric potential is defined as the electric potential energy per unit charge. Once we know the electric potential at some location, we can use it to find the electrical potential energy of charges placed at that location. This should remind you of the way we calculate electric force on a point charge in an electric field. According to the definition electric potential energy and electric potential are related by the equation:  $U_{elec} = qV$ . Here  $V$  is the electric potential at the location in space which the object with charge  $q$  is located. Since energy is a scalar quantity, then  $V$  is also a scalar quantity. In future experiments you will find that one use of electric potential is for analyzing electrical circuits.

1. What is the unit of electric potential? Use the units for potential energy and charge to find express it in terms of other units.

2. Open up the electric field simulation, turn on the Grid and Show Numbers, and place a positive point charge of  $+1 \text{ nC}$  at the center of the grid. Make measurements of electric potential and the magnitude of the electric field at the following **points to the right** of the point charge. Use the voltmeter to measure electric potential. The meter measures the electric potential at the point where the center of the cross is located. Be sure to put the units for  $E$  and  $V$ .

Distance, $r(m)$	Magnitude of Electric Field, $E$	Electric Potential, $V$
0.5		
1.0		
1.5		
2.0		
2.5		
3.0		

3. What creates the electric field and electric potential you measured?
4. Does the electric potential around the point charge decrease or increase with increasing distance?
5. Equipotential lines are lines with equal electric potential (for example, all the points with an electric potential of  $5.0 \text{ V}$ ). Using the plot tool that comes with voltmeter make two equipotential lines at  $r = 0.5 \text{ m}$  and  $r = 1.5 \text{ m}$ . Enable electric field vectors in the simulation. Put an electric field sensor at different points on the equipotential and note the direction of the electric field vector. What can you conclude about the direction of the electric field vector in relation to the equipotential lines?

Take a snap shot of the simulation showing equipotential lines and paste to a word document.

6. Use the electric field sensor to investigate points in between the two equipotential lines. Does the electric field vector point toward the higher electric potential, toward lower electric potential, or along an equipotential line?

7. Using your data from Question #2, plot electric potential vs.  $r$  in Excel. This is called the “Potential Graph.”
8. One of the students in the class says that the electric potential at locations around a source charge is inversely proportional to the distance from the source charge to that location. Use your data to test this hypothesis. Explain what you did to test the hypothesis, the result of the test, and your conclusion.

Label your graph and axes and include units. Copy and paste your graph along with any fitting you have done to test the hypothesis into your Word Document.

## Part 2: Electric force and potential energy for two charges

9. Assume that you are going to bring another  $+1 \text{ nC}$  charge to the locations where you measured electric field and potential from the first  $+1 \text{ nC}$  charge in Question #2. Copy the values (with units) for  $E$  and  $V$  you found in Question #2. Then calculate the magnitude of the electric force on the second charge, the direction of the force, and the electrical potential energy of the system. Refer back to the first page if you aren't sure how to calculate  $F$  or  $U$ .

$r(m)$	$E$	$V$	Force (N)	Force Direction	$U_{elec} (J)$
0.5					
1.0					
1.5					
2.0					
2.5					
3.0					

10. Using the ideas of electric field and force, explain what would happen to a proton if released from rest at  $r = 2.0 \text{ m}$ . (simulation does not show this).
11. Would the proton released from rest move to a region of higher electrical potential or lower electrical potential?
12. Would the proton released from rest move such that the system would have higher potential energy or lower potential energy?
13. Now we will investigate the force, energy, and potential when a negative charge is placed in the field created by the first positive charge. Assume that instead of using a second positive charge, you brought a  $-1 \text{ nC}$  charge to each of the locations where you measured electric field and potential from the first  $+1 \text{ nC}$  charge in Question #2. Again copy the values (with units) for  $E$  and  $V$  you found in Question #2. Then calculate the magnitude of the electric force on the second charge, the direction of the force, and the electrical potential energy of the system. Again refer back to the first page if you aren't sure how to calculate  $F$  or  $U$ .

$r(m)$	$E$	$V$	$Force (N)$	$Force Direction$	$U_{elec} (J)$
0.5					
1.0					
1.5					
2.0					
2.5					
3.0					

14. Using the ideas of electric field and force, explain what would happen to an electron if released from rest at  $r = 2.0 \text{ m}$ ? (simulation does not show this).
15. Would the electron released from rest move to a region of higher electrical potential or lower electrical potential?
16. Would the electron released from rest move such that the system would have higher potential energy or lower potential energy?
17. Compare your answers in Questions 10 and 14. Summarize how the direction of the electric field and the sign of the charge placed in that field determine the direction of the force.
18. Compare your answers in Questions 11 and 15. Do electric forces always push the charged object toward a region of higher or lower electric potential? Support your answer.

19. Compare your answers in Questions 12 and 16. Electric forces are conservative forces. Do electric forces always push the system toward higher or lower potential energy? Support your answer.

### **Part 3: Conclusions**

20. Summarize the relationship of electric field to electric force.

21. Summarize the relationship between electric field vectors and equipotential lines.

#### **Instructions on how to submit the graphs:**

1. Open a word document and type the names of all present group members.
2. Copy the snapshot of your simulation from Question 5 in to your Word document.
3. Copy your Excel graph from Question 8 (with title and axis labels) to your Word document.
4. Print your Word document and attach it to your lab report.