

Student's Name:

Student's Name:

Lab day & time: __________
Date: _____

Charges and Fields (E2) – Data Sheets

Write all results on the data sheets in ink. Complete all steps, prepare required graphs and answer all questions on the data sheets before you leave.

"PhET Interactive Simulations, University of Colorado Boulder, <https://phet.colorado.edu>."

The "Charges and Fields" simulation is a part of the collection of interactive simulations called PhET, which was developed at University of Colorado Boulder. To run the "Charges and Fields" simulation, download "*charges-and-fields_en*" file from the Brightspace page for Physics 221 or Physics 252 lab activities folder. Save it to the desktop. Next, double-click on it to start the simulation. Save it to the desktop. Since this is an html document, it should start the default browser application.

Simulation #1: A Point Charge

(1.5 p.)

In the first simulation, we will analyze the electric field and electric potential as a function of distance from a single charge.

After you start "Charges and Fields" simulation, set the following **initial conditions**:

"Values" and "Grid" should be checked. "Electric Field", "Voltage" and "Direction only" should not be checked. From "Options" menu select "Projector Mode" and activate it.

- 1.1. **Select one intersection of major grid lines that is located at the center of the "Charges and Fields" window as the point with coordinates (x=0, y=0) and measure all distances from this point.** Next, grab +1 nC ($1 \text{ nC} = \text{one nano-Coulomb} = 1 \cdot 10^{-9} \text{ C}$) charge and move it to point (0, 0). Make sure to put the charge at exact intersection of major grid lines selected as point (0, 0), not just near that point.
- 1.2. Drag the "Sensors" tool (a small orange circle) to the point located 0.50 m away from the charge. For example, you could move it in horizontal direction from the point (0, 0). Read the value of the electric field E at point (0.50 m, 0) and write it in the table below. Next, move the measuring tool to align the cross hair with the same point located $r = 0.50 \text{ m}$ from the charge. Read the electric potential V and write it in the table below. Draw the equipotential line that goes through the same point. To draw the equipotential line, click on a small pencil icon.

- 1.3. Move the "Sensors" tool to another location (1 m, 0), i.e., $r = 1.00$ m away from the +1 nC charge. Repeat the electric field measurement and electric potential measurement. Draw the equipotential line through this point.
- 1.4. Repeat the procedure for the following horizontal distance values: $r = 1.50$ m, 2.00 m, 2.50 m and 3.00 m from the +1 nC charge.
- 1.5. Once you have completed measurements for listed distances and drawn equipotential lines, **print** the "Charges and Fields" window with point charge equipotential lines and attach it to your lab report.

r (m)	r² (m²)	E (V/m)	V (V)
0.50	0.25		
1.00	1.00		
1.50	2.25		
2.00	4.00		
2.50	6.25		
3.00	9.00		

- 1.6. **Create and print** a graph showing the electric field E and electric potential V as a function of distance r . Attach the graph to your lab report.
- 1.7. According to the Coulomb's law, the electric field: $E \propto 1/r^2$, so $E \times r^2 = \text{const}$. In a similar way, the electric potential: $V \propto 1/r$, so $V \times r = \text{const}$. Calculate these two products for various distances r .

r (m)	E*r² (V*m)	V*r (V*m)
0.50		
1.00		
1.50		
2.00		
2.50		

3.00		
Average (0.50 - 3.00)		

Based on the Coulomb's Law, the **electric field** created by $+1 \text{ nC} = 1 \cdot 10^{-9} \text{ C}$ charge should be equal to:

$$E = \frac{F}{q_2} = k_C \frac{q_1}{r^2} = 9.0 \cdot 10^9 \times 1 \cdot 10^{-9} \cdot \frac{1 \text{ N}}{r^2 \text{ C}} \rightarrow E \times r^2 = 9.0 \frac{\text{Nm}^2}{\text{C}} = 9.0 \text{ Vm}$$

In a similar way, the **electric potential** created by $+1 \text{ nC}$ charge should be equal to:

$$V = E \cdot r = k_C \frac{q_1}{r} = 9.0 \cdot 10^9 \times 1 \cdot 10^{-9} \cdot \frac{1 \text{ Nm}}{r \text{ C}} \rightarrow V \times r = 9.0 \frac{\text{Nm}^2}{\text{C}} = 9.0 \text{ Vm}$$

Do the average values of $E \cdot r^2$ and $V \cdot r$ products agree with the theoretical value = 9.0 Vm within the accuracy of this simulation (i.e., the relative error < 5%)? YES / NO

Relative error of $E \cdot r^2 =$ _____ (%) Relative error of $V \cdot r =$ _____ (%)

1.8. Focus on any location that you made measurements previously, e.g., the one located 2.00 m from the point charge at (0, 0). If we would double the charge that is the source of the electric field from $+1 \text{ nC}$ to $+2 \text{ nC}$, then what would be the change to the electric potential V at that point?

"no change" "double" "quadruple" (*circle one answer*)

1.9. If we would double the charge that is the source of the electric field from $+1 \text{ nC}$ to $+2 \text{ nC}$, then what would be the change to the electric field E at that point?

"no change" "double" "quadruple" (*circle one answer*)

1.10. Add another $+1 \text{ nC}$ charge on the top of the existing $+1 \text{ nC}$ charge at point (0, 0) to double the charge and verify your predictions from steps 1.8 and 1.9.

Simulation #2 : Two point charges

(1 p.)

A. In part A of this simulation, we will deal with two positive $+1 \text{ nC}$ charges located at points (-1m, 0) and (1m, 0). Later, we will search for spots with zero electric field.

2.1. After setting charges at the required location, move the "Sensors" tool around the screen to find a point that has the electric field close to zero (i.e., electric field $E < 0.20 \text{ V/m}$).

2.2. Write the coordinates of this point here: (,)

2.3. Measure the electric potential at the same point. Is it also equal to zero?

2.4. Try to find a point with electric potential equal to zero on the screen. Can you find that point? If not, then briefly explain why not.

2.5. Draw ten equipotential lines near these two positive charges.

B. In part B, we will use one positive +1 nC charge located at point (-1m, 0) and one negative charge -1 nC located at point (1m, 0). This configuration of two charges with the same value, but opposite sign is called **electric dipole**.

2.6. After setting charges at the required location, move the measuring tool and find the spot where the electric potential is close to zero (i.e., electric potential $V < 0.10$ V).

2.7. Write the coordinates of this point here: (,)

2.8. Using the "Sensors" tool, measure the electric field in the same point. Is it also equal to zero?

2.9. Explain how the electric field could have a nonzero value in a point that has zero electric potential.

2.10. Draw ten equipotential lines near these two charges.

Simulation #3: Four Point Charges

(1 p.)

In the first simulation, we will analyze electric field and electric potential created by four point charges - two positive +1 nC located at points (-1m, 1m), (1m, -1m) and two negative

charges located at points $(-1\text{m}, -1\text{m})$, $(1\text{m}, 1\text{m})$. This configuration of four charges is called **electric quadrupole**.

- 3.1. After setting charges at the required location, move the "Sensors" tool around the screen to find a point that has the electric field close to zero (i.e., electric field $E < 0.20 \text{ V/m}$).
- 3.2. Write the coordinates of this point here: (,)
- 3.3. Measure the electric potential in the same point. Is it also equal to zero?

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- 3.4. Draw sixteen equipotential lines near these four charges (four lines near each charge).
 - 3.5. **Print** the "Charges and Fields" window with quadrupole's equipotential lines and attach it to your lab report.

Return the lab report to your lab teaching assistant.