Electric Field

Theory

The idea of **electric field** is used to model how an electric charge exerts a force on another charge located at some distance. The presence of a charge in space infuses the surrounding space with a quality whereby a second charge placed in that space will experience a force. The first charge, sometimes called the **source charge**, is said to have created an electric field in the surrounding space. Besides this qualitative description, there is also a quantitative aspect of the electric field.

Electric field, ***E***, is a vector quantity. In both its magnitude and direction, electric field at a point in space is equal to the force that a unit positive charge would experience when placed at that point. In practice, a unit charge (1 C) is so big that it would move the source charges and therefore alter their field. So, in order to measure the electric field at a point a much smaller charge, q_0, called a **test charge**, is placed at the point. The measured force, ***F***, experienced by the test charge can then be used to calculate the electric field at the point using the equation:

$$\boldsymbol{E} = \frac{F}{q_0} \qquad (1)$$

The **direction** of the electric field at a point in space is the direction of the force that a positive charge would experience when place at that point. If a negative charge is placed at the point, it would experience a force in the opposite direction.

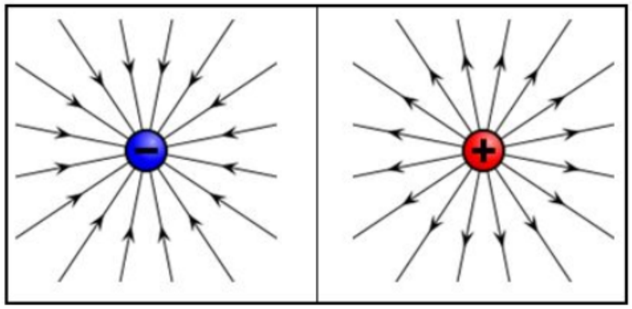
The electric field created by a system of source charges is a vector sum of the field created by each charge in the system. This is called the **principle of superposition**.

The magnitude of electric field due to a single charge, q, at a distance, r, from it is given by the equation:

$$E = \frac{kq}{r^2} \qquad (2)$$

Electric fields are commonly represented by lines or curves drawn in a two-dimensional plane, or a three-dimensional space, with arrows on them. These are called **electric field lines**. At any point in space, the direction of the electric field is along the tangent to the curve (or along the line) as indicated by the arrow. The distribution of field lines is indicative of the magnitude of the field. Sparser field lines indicate weaker field and denser field lines indicate stronger field.

Electric field lines originate at positive charges and terminate at negative charges. The image below, on the left, shows the electric field lines for a single negative charge. The image on the right shows the electric field lines for a single positive charge.



Pre-lab Questions

1. Think of Equation 2 as the equation of a straight line. What would be the slope of an E versus q graph.

2. In what direction does the electric field point at a point in space?

3. What is the magnitude of the electric field at a point in space?

4. What does the density of electric field lines tell us about the magnitude of the field?

Procedure

Setup

1. Google "Phet Electric Field" and click on the first link that shows up.
2. Click on the Play button.
3. Click the Values and Grid boxes.

Dependence of Electric Field on Distance

4. Drag the +1.0 nC charge to a point where two major grid lines intersect. Do that two more times so that the total charge is +3.0 nC. Record this value as q = 3.0 nC above the data table below.
5. Drag the sensor to a point 1.0 m away from the charge along the horizontal direction. In the table below, record the value of the electric field as measured by the sensor in the first row.
6. Complete the rest of the table.

q = ____________________

r (m)	E ( )
1.0	
2.0	
3.0	
4.0	
5.0	
6.0	
7.0	
8.0	
9.0	
10.0	

7. In Capstone, plot a graph of E versus r and perform an Inverse Power fit. Record the values of the fit parameters.

   A = ____________________________

   x_0 = _____________________________

   n = _____________________________

   B= ______________________________

8. Compare the equation of the fit, $y = \frac{A}{(x-x_0)^n} + B$, with Equation 2 and determine the expected expression for A and expected values of A, x_0, n, and B.

   Expected Expression for A = __________________________

   Expected value of A = _______________________________

   Expected x_0 value = ____________________________

   Expected n value = _____________________________

   Expected B value = ______________________________

9. Calculate and record the percent error in A and n.

   Percent error in A = _______________________________

   Percent error in n = ______________________________

Dependence of Electric Field on Charge

10. Click the reset button then click the Values and Grid boxes.
11. Drag the +1.0 nC charge to a point where two major grid lines intersect.
12. Drag the sensor to a point 3.0 m away from the charge along the horizontal direction. Record that distance as *r* below.
13. In the table below, record the value of the electric field as measured by the sensor in the first row.
14. Increase the charge, 1.0 nC at a time, and complete the rest of the table.

r = ____________________

q (nC)	*E* ( )
1.0	
2.0	
3.0	
4.0	
5.0	
6.0	
7.0	
8.0	
9.0	
10.0	

15. Graph *E* versus *q* and perform a linear fit.
16. Record the value of slope from the linear fit.

    m = ________________________________

17. Get your answer to Pre-Lab question 1 checked by the instructor. Then use the answer to calculate the expected value of slope.
18. Calculate and record the percent error in slope.

Expected value of slope = ________________________________

Percent Error in slope = ________________________________

Sketching Electric Field Lines

19. Click the reset button and click the Grid button.
20. Place a +1.0 nC and a -1.0 nC charge 5.0 m away from each other. This arrangement of a negative and a positive charge of equal magnitude placed near each other is called an **electric dipole**.
21. Use the electric field vectors displayed by the simulation as a guide to sketch below the electric field lines of the electric dipole as smooth and continuous curves.

22. Repeat Steps 19 – 21 for two positive charges of equal magnitude.

Post Lab Questions

1. A charge of −5.0 mC experiences a force of 23 N due east when placed at a point A in space. Calculate the magnitude of the electric field at the point.

2. In what direction is the field at A in the previous problem?

3. What would be the magnitude and direction of the force that a + 10.0 mC charge would experience when place at A.

4. If the electric field at A is created by a 7.0-mC charge, how far is it from A?