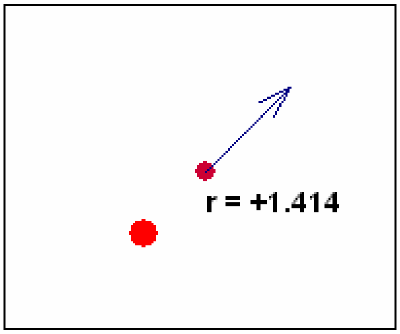
# *Worksheet for Exploration 23.1: Fields and Test Charges*




If interactions between charges can be described by the forces on them, and the electric field is related to the electric force, why talk about electric fields at all? We will consider this issue in the following Exploration.

The animation shows a positive charge of 4 C located at (0 m, 0 m) and a test charge of 1 C located at (1 m, 1 m). The distance between the test charge and the charge at the origin is shown along with a vector representing the force on the test charge **(position is given in meters and charge is given in coulombs)**. The slider allows you to change the charge on the test charge.

a. Drag the test charge to x = 2 m and y = 2 m. Relative to the force on the charge in its initial position, is the force now greater, less or the same? How will the force on the test charge compare to its initial force when it is at (-1 m, 1 m)? What about when it is at (0.5 m, -1 m)? What determines the relative magnitude of the force on the test charge?
    i. For each of the positions indicated you should be able to calculate the magnitude of the force and also indicate the direction with an angle. When indicating the angle make sure you know where you measure angles from.

| x | y | r | Force | Direction |
|---|---|---|---|---|
| 1m | 1m | | | |
| 2m | 2m | | | |
| -1m | 1m | | | |
| 0.5m | -1m | | | |

b. Now consider leaving the test charge at its initial location but increasing the positive charge to 2 C. How does the force on the test charge change? How will the force on the test charge compare to its initial force when the test charge is 0.5 C? What about when it is -1 C? What determines the relative magnitude of the force on the test charge?

F(2C)=_______

F(0.5C)=_______

F(-1C)=_______

Now suppose you wanted to describe the force that would be felt due to the charge at the center. Can you describe the force in general terms, without specifying the value of the charge to be acted upon? Your answer to Parts (a) and (b) should have shown you that you must know both where the charge is located and its value in order to talk about the force it would feel. If you could talk about the force in terms of the force on a test charge you will run into difficulty. The force is entirely dependent on the test charge! Change the value of the test charge and you will find a different force. We need a description of the field that is independent of our detecting device.

c. Can you think of a way of quantitatively describing the region around the center charge that does not depend on the properties of a test charge? Write down at least one proposal BEFORE going to part (d).
   i. To sum up some of the results you have seen, the force doubles when you double the test charge, it is halved when you cut the charge in half. You want proposal here that describes a quantity that will be independent of the test charge.

d. The physicist's answer to this dilemma is the creation of the concept of the electric field. The electric field is defined to be the force on a test charge divided by the value of the test charge, $E = F/q$. For a single charge like the one at the center of the animation, $F = (k*Q*q)/r^2$, so the electric field becomes $E = k*Q/r^2$.
   i. Note that the electric field is a property of a location in space. The measurement of a force vector and the choice of a test charge as a probe (q) always determines the electric field. The simple Coulombs law like statement above is for the special case of the electric field caused by a single point charge. It is a theoretical statement that predicts what you should measure. One can always consider adding the cumulative pushing effects due to many point charges.

e. Repeat parts (a), (b), and (c) considering the electric field instead of the force.
    i. Electric field at various distances from the point charge at the center.

| x | y | r | Electric Field Strength | Direction |
|---|---|---|---|---|
| 1m | 1m | | | |
| 2m | 2m | | | |
| -1m | 1m | | | |
| 0.5m | -1m | | | |

ii. Electric field magnitude at 1m, 1m for various test charge sizes.

E(2C)=_______

E(0.5C)=_______

E(-1C)=_______

f. Does the force depend on the value of the test charge? Does the electric field depend on the value of the test charge? Test your predictions by changing the value of the test charge and watching the effect on the force vector and the electric field vectors. (Turn the electric field vectors on using the link.)

g. In your own words, why is it useful to define the electric field in the way it is defined? Why not just talk about forces?

h. As an additional exercise think about gravitational fields. Recall what the gravitational field strength is at the surface of the Earth. Think about what the units for this should be and how to define it. Rather than “force/charge” for electric fields, you should consider force/mass. Charge is the source of electric fields; mass is the source of gravitational fields. Consider the gravitational field at a 1.00kg block you hold in your hand (there no acceleration). What is the gravitational force per kilogram acting on it?