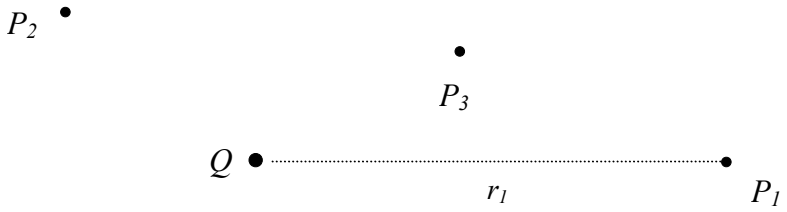
Electric Fields



A positive charge Q is fixed in position as shown above. Point P_1 is located a distance r_1 from Q; points P_2 and P_3 are also shown. Initially, however, the only charge in the region is Q.

1. Suppose you put a positive charge q_A at point P_1. Use Coulomb's law to write an algebraic expression for F_{q_A}, the magnitude of the electrical force acting on charge q_A. Make use of the constant k $(=9 \times 10^9\ N\,m^2/C^2)$, but do not substitute in a numerical value (i.e., leave the expression in terms of k).

$$F_{q_A} =$$

2. What is the value of the ratio $\frac{F_{q_A}}{|q_A|}$? (Write an algebraic expression involving *k, Q, and* r_1.)

$$\frac{F_{q_A}}{|q_A|} =$$

Draw an arrow with its tail at point P_1 to indicate the direction of the electrical force acting on the charge q_A. Make this arrow approximately one centimeter long.

3. Suppose we remove the charge q_A and replace it with a ***different*** positive charge q_B, again located at point P_1. What will be the magnitude of the electrical force acting on charge q_B? Call this quantity F_{q_B}.

$$F_{q_B} =$$

4. Suppose that $q_B = 3q_A$; what will be the ratio of F_{q_B} to F_{q_A}?

$$\frac{F_{q_B}}{F_{q_A}} =$$

5. Write an expression for the ratio $\frac{F_{q_B}}{|q_B|}$.

$$\frac{F_{q_B}}{|q_B|} =$$

How does $\frac{F_{q_B}}{|q_B|}$ compare to the ratio $\frac{F_{q_A}}{|q_A|}$? (Is it *larger than*, *smaller than*, or *equal to* $\frac{F_{q_A}}{|q_A|}$?)

6. How would the ***direction*** of the force acting on charge q_B compare with the direction of the force on charge q_A? If it is the same, explain why it is the same. If it is different, draw an arrow to show the correct direction and label it "$\overrightarrow{dir}_{q_B}$."

The magnitude of the electric field $\vec{E}$ at a point in space is defined to be equal to the ratio $\frac{F_q}{|q|}$ where F_q is the magnitude of the force acting on a test charge q located at that point in space. A "test" charge is, essentially, a particle with a very small amount of charge, used as a probe.

7. What are the units of electric field?

8. What is the magnitude of the electric field at point P_1? Write an expression that involves Q. *Hint: You have already written down this expression somewhere above.*

$$\left|\overrightarrow{E_1}\right| = \frac{F_q}{|q|} =$$

9. Does the magnitude of the electric field at a point depend on which test charge is placed at that point? Explain your answer.

The direction of the net electric field at a point in space is ***defined*** to be the same as the direction of the net electrical force that would act on a positive charge located at that point.

10. If you have already drawn an arrow that represents the direction of the electric field at point P_1, label it "$\overrightarrow{E_1}$." If you have not yet drawn such an arrow, draw one and label it accordingly.

11. How does the direction of the electric field at point P_1 relate to the relative locations of the charge Q and the point P_1? Describe this in words. *(Suggestion: If you were trying to explain to someone on the telephone how to draw the electric field vector at point P_1, what would you say? Assume that this person doesn't know any physics at all.)*

12. If point P_2 is a distance r_2 from the origin, what is the magnitude of the electric field at P_2?

$$\left|\overrightarrow{E_2}\right| =$$

13. Will the magnitude of the electric field at point P_2 be *greater than*, *less than*, or *equal to* the magnitude of the electric field at point P_1? Explain your reasoning.

14. Draw arrows at points P_2 and P_3 to represent the electric field vectors at those two points. Make sure the relative lengths of the arrows correctly correspond to the relative magnitudes of the field at those points, and are consistent with the magnitude of the electric field at P_1.

15. Suppose a negative charge were placed at point P_3 and then released and allowed to move freely. In blue pencil, draw a dotted line indicating the path that it would follow. How is the direction of the force acting on a negative charge at a point related to the direction of the electric field at that same point?

16. The mathematical expression for the force $\vec{F}$ acting on *any* charge q located at some point in space, in terms of the electric field $\vec{E}$ at that point in space, is the following:

$$\vec{F} = q\,\vec{E}$$

a) Explain how this equation is consistent with what you have worked out in #6-12 above.
b) Is it valid for negative charges, as well as positive charges? Explain.
c) Does the magnitude of the ***force*** on a test charge placed at a certain point in space depend on which test charge is placed at that point? Explain why this answer is ***different*** from the answer to #9. [Continue your answer on the reverse side of this sheet, if necessary.]