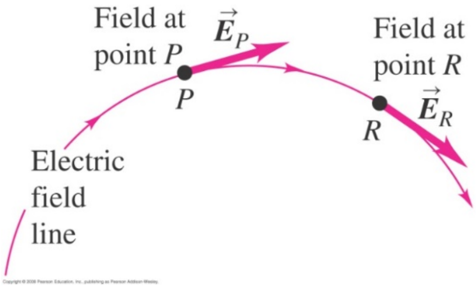
Electric Field Lines

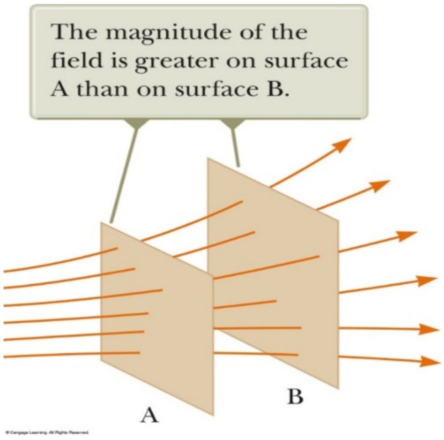
We've already defined the electric field mathematically by the equation **E** = **F**/q. However, how do we visualize the E-field since we cannot see it physically? One way to visualize the electric is to use ***Electric-Field Line***. Electric field lines are related to the electric field in a region of space in the following manner:

1. The electric field vector E is tangent to the electric field line at each point.



Since the **E**-field vector is tangent to the **E**-field lines at any given point, a charge *q* will experience a force **F** = *q***E** in same direction of the **E**-field vector. Thus, the electric force **F**=*q***E** and the acceleration of the chare are both tangent to the **E**-field lines. In general, the direction of motion of a charged particle is not the same as the **E**-field.

2. The number of electric field lines per unit area through a surface perpendicular to the lines is proportional to the magnitude of the electric field in that region. Therefore, the field lines are close together where the electric field is strong and far apart where the field is weak.


The magnitude of the field is greater on surface A than on surface B.

Rules for drawing electric field lines:

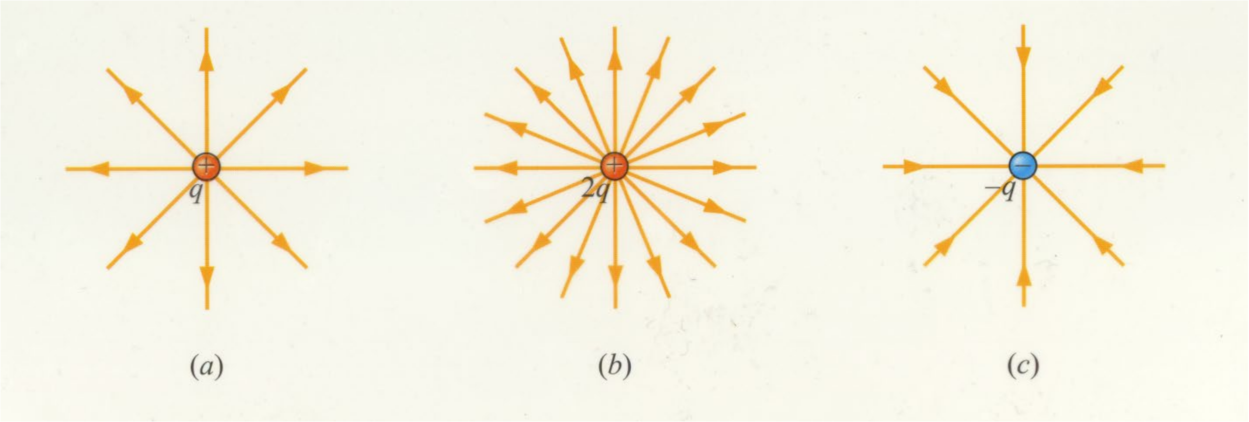
1. The lines must begin on a positive charge and terminate on a negative charge. In the case of an excess of one type of charge, some lines will begin or end infinitely far away.

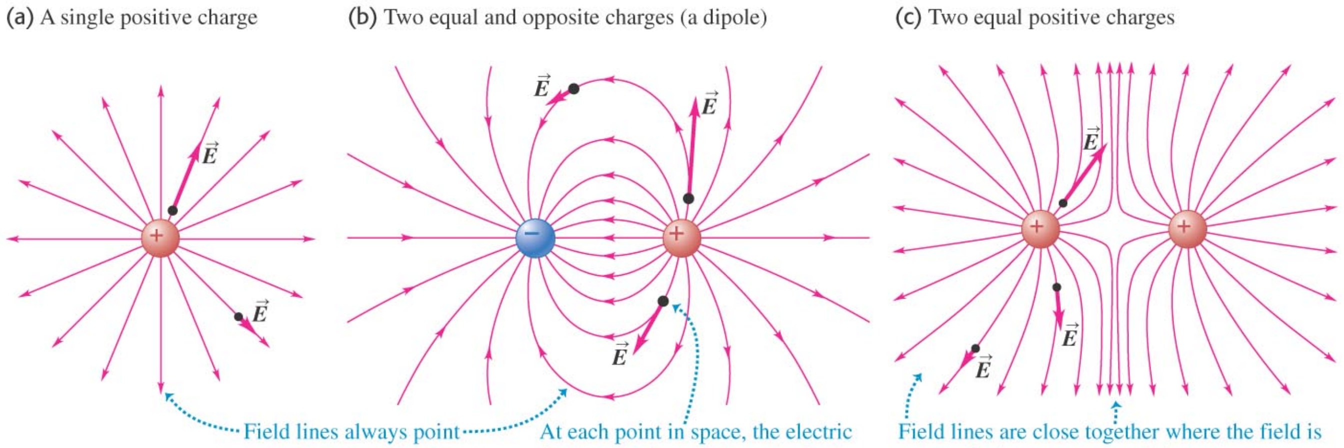
2. The lines are drawn uniformly spaced entering or leaving an isolated point charge.

3. The number of lines drawn leaving a positive charge or approaching a negative charge is proportional to the magnitude of the charge.

4. No two field lines can cross.

One problem with the electric-field line model is that we draw a finite number of lines for a charge. Thus, it appears that the **E**-field may exist in certain directions only. This is not true! The field lines are continuous at every point around the charge. The density of the lines only represents the strength of the **E**- field.





(a) A single positive charge

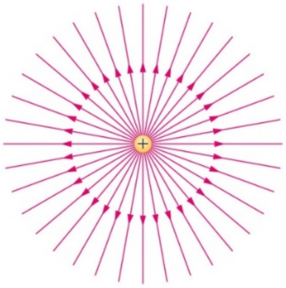
(b) Two equal and opposite charges (a dipole)

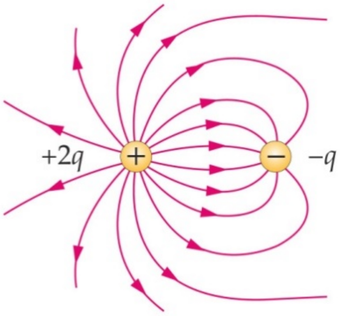
(c) Two equal positive charges

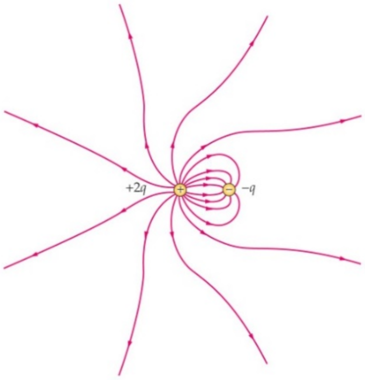
Field lines always point *away from* (+) charges and *toward* (−) charges.

At each point in space, the electric field vector is *tangent* to the field line passing through that point.

Field lines are close together where the field is strong, farther apart where it is weaker.



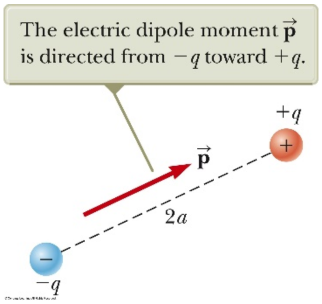




In the middle figure note that only half of the lines leaving the positive charge enter the negative charge. The remaining half terminate on a negative charge assumed to be located at infinity.

Electric Dipoles

DEF: *An electric dipole consists of two point charges of equal magnitude but opposite sign held at a fixed distance apart.*



The electric dipole moment $\vec{\mathbf{p}}$ is directed from $-q$ toward $+q$.

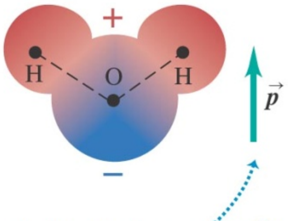
Many different system can be described as electric dipoles. Some of these systems include antennas and polarized molecules. A good example of a polarized molecule is H_20 (water). The bonding of the H and O atom cause a slight separation of charge that make H_20 a polar molecule with a permanent electric dipole. The electric dipoles of polar molecules play a very important role in their properties.

Microwave ovens take advantage of the polar nature of the water molecule. Microwaves ovens generate a rapidly changing E-field that causes the polar molecule to swing back and forth, absorbing energy from the field in the process. During such process the molecules collide with each other and the energy they absorb from the E-field is converted to internal energy, which in turn increases the temperature of the food.

Two questions:

1. What force and torque does an Electric Dipole experience in an external E-field?
2. What is the potential energy of an Electric Dipole?

(a) A water molecule, showing positive charge as red and negative charge as blue



The electric dipole moment $\vec{p}$ is directed from the negative end to the positive end of the molecule.