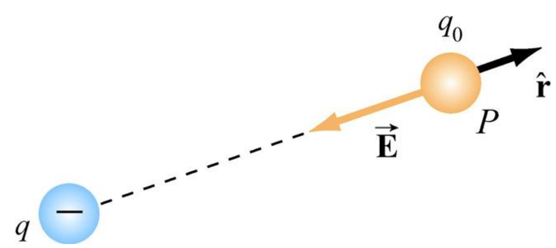
Electric Field:

- An electric charge *q* produces an electric field everywhere.
- The electric field $\vec{E}$ is defined as:

  $\vec{E} = \lim_{q_0 \to 0} \frac{\vec{F}_e}{q_0}$

  - $q_0 \to$ Positive test charge (infinitesimally small).
- the charge *q* creates an electric field $\vec{E}$ which exerts a force $\vec{F}_e = q_0\vec{E}$ on a test charge q_0.
- the electric field at a distance *r* from a point charge *q* is given by

$$\vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}\,\hat{r}$$



- **superposition principle**

  The total electric field due to a group of charges is equal to the vector sum of the electric fields of individual charges:

$$\vec{E} = \sum_i \vec{E}_i = \sum_i \frac{1}{4\pi\varepsilon_0}\frac{q_i}{{r_i}^2}\,\hat{r}$$

Example: In the classical model of the hydrogen atom, the electron revolves around the proton with a radius of $r = 0.53 \times 10^{-10}$m. The magnitude of the charge of the electron and proton is $e = 1.6 \times 10^{-19}$C.

(a) What is the magnitude of the electric force between the proton and the electron?
(b) What is the magnitude of the electric field due to the proton at *r*?
(c) What is ratio of the magnitudes of the electrical and gravitational force between electron and proton? Does the result depend on the distance between the proton and the electron?
(d) In light of your calculation in (b), explain why electrical forces do not influence the motion of planets.

Solution:

(a) The magnitude of the force is given by

$$F_e = \frac{1}{4\pi\varepsilon_0}\left(\frac{e^2}{r^2}\right) = \frac{(9.0 \text{ x } 10^9 \text{N.}\frac{m^2}{C^2})(1.6 \text{ x } 10^{-19}\text{C})^2}{(0.53 \text{ x } 10^{-10}\text{m})^2} = 8.2 \text{ x } 10^{-8} \text{ N}$$

(b) The magnitude of the electric field due to the proton is given by

$$E = \frac{1}{4\pi\varepsilon_0}\frac{q}{r^2} = \frac{(9.0 \text{ x } 10^9 \text{N.}\frac{m^2}{C^2})(1.6 \text{ x } 10^{-19}\text{C})}{(0.53 \text{ x } 10^{-10}\text{m})^2} = 5.76 \text{ x } 10^{11}\text{N/C}$$

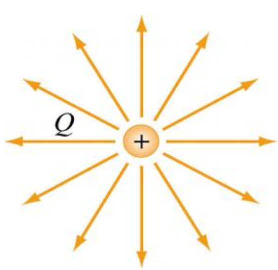
(c) The mass of the electron is $m_e = 9.1 \text{ x } 10^{-31}$ kg and the mass of the proton is $m_p = 1.7 \text{ x } 10^{-27}$kg. Thus, the ratio of the magnitudes of the electric and gravitational force is given by

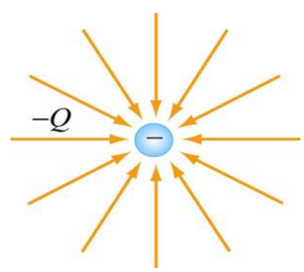
$$\gamma = \frac{(\frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2})}{(G\frac{m_p m_e}{r^2})} = \frac{\frac{1}{4\pi\varepsilon_0}e^2}{G m_p m_e} = \frac{(9.0 \text{ x } 10^9 \text{N.}\frac{m^2}{C^2})(1.6 \text{ x } 10^{-19}\text{C})^2}{(6.67 \text{ x } 10^{-11}\text{N.}\frac{m^2}{kg^2})(1.7 \text{ x } 10-27\text{kg})(9.1 \text{ x } 10-31 \text{ kg})} = 2.2 \text{ x } 10^{39}$$

Which is independent of *r*, the distance between the proton and the electron.

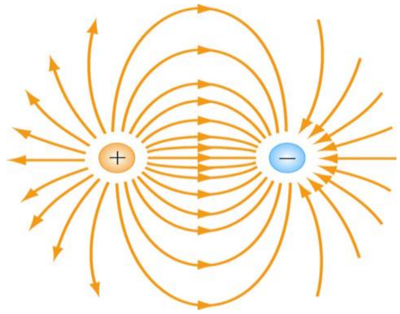
(d) The electric force is 39 orders of magnitude stronger than the gravitational force between the electron and the proton. Then why are the large scale motions of planets determined by the gravitational force and not the electrical force. The answer is that the magnitudes of the charge of the electron and proton are equal. The best experiments show that the difference between these magnitudes is a number on the order of. Since objects like planets have about the same number of protons as electrons, they are essentially electrically neutral. Therefore the force between planets is entirely determined by gravity.

Electric Field Lines: Electric field lines provide a convenient graphical representation of the electric field in space.





[***Field lines for positive (radially outward) and negative charges (radially inward)***.]



[**Field lines for an electric dipole (a pair of charges of equal magnitude but opposite sign)**]

❖ The properties of electric field lines:

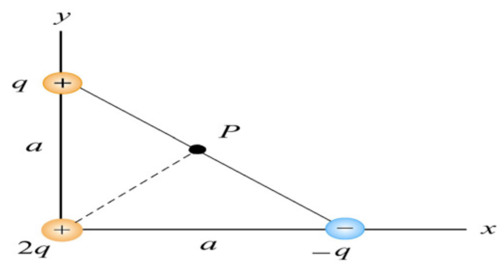
- The direction of the electric field vector $\vec{E}$ at a point is tangent to the field lines.
- The number of lines per unit area through a surface perpendicular to the line is devised to be proportional to the magnitude of the electric field in a given region.
- The field lines must begin on positive charges (or at infinity) and then terminate on negative charges (or at infinity).
- The number of lines that originate from a positive charge or terminating on a negative charge must be proportional to the magnitude of the charge.
- No two field lines can cross each other; otherwise the field would be pointing in two different directions at the same point.

H.W:

1. Two opposite charges are placed on a line as shown in the figure below.

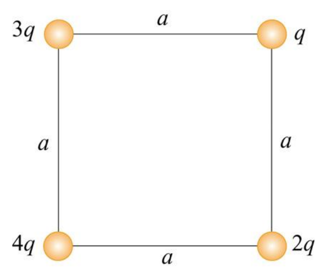
The charge on the right is three times the magnitude of the charge on the left. Besides infinity, where else can electric field possibly be zero?

2. A right isosceles triangle of side *a* has charges *q*, +2*q* and −*q* arranged on its vertices, as shown in Figure.



What is the electric field at point *P*, midway between the line connecting the +*q* and −*q* charges? Give the magnitude and direction of the electric field.

3. Four point charges are placed at the corners of a square of side *a*, as shown in Figure.



(a) What is the electric field at the location of charge *q*?

(b) What is the net force on 2*q*?