Notes

Physics Tool box

- **Field Theory** – the theory that explains interactions between bodies or particles in terms of fields.
- **Field of force** –A field of force exists in a region of space when an appropriate object placed at any point in the field experiences a force.
- The electric $\vec{\varepsilon}$ field at any point is defined as the electric force per unit positive charge and is a vector quantity : $\vec{\varepsilon} = \frac{\vec{F}_E}{q} = \frac{kq_1q}{r^2q} = \frac{kq_1}{r^2}$.
- **Electric field Lines** are used to describe the electric field around a charged object.

How can one piece of matter affect the motion of another across a void, whether gravitational or electrical? The dominant theory today is **Field Theory**.

Another way of asking this question is say how do two electrically charged particles in empty space interact, how does each one know the other is there? What goes on in the space between them to communicate the effect of each one on the other?

You can begin to answer these questions (and at the same time reformulate Coulomb's law in a very useful way) by using the concept of a **Electric Filed**.

Suppose particle B has a charge q_0, and let $\vec{F}_0$ be the electric force of particle A on particle B. One way to think about this force is as an "action-at-a-distance force" – that is, as a force that acts across empty space without the need of any matter (as a push or pull) to interact with it.

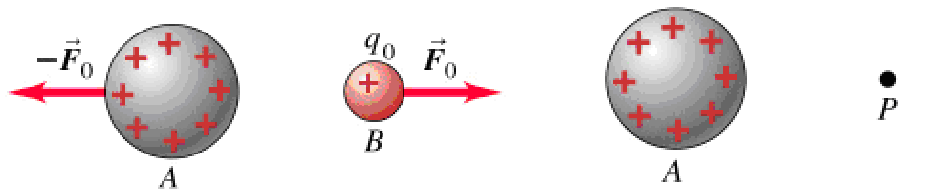
A better way to understand this repulsion between particle A and particle B is a two stage process.

- First we visualize that particle A, as a result of the charge it carries, somehow modifies the properties of the space around it.
- Particle B, as a result of the charges that it carries, senses how space has been modified at its position.

The response of particle B is to experience the force $\vec{F}_0$.

Let's elaborate this process:

- First consider a particle A and Particle B. Remove the body of particle B and label its former position as point P.

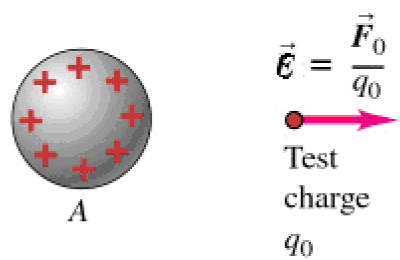


(a) How does charged body *A* exert a force on charged body *B*?

(b) Remove body *B* and label its former position as *P*

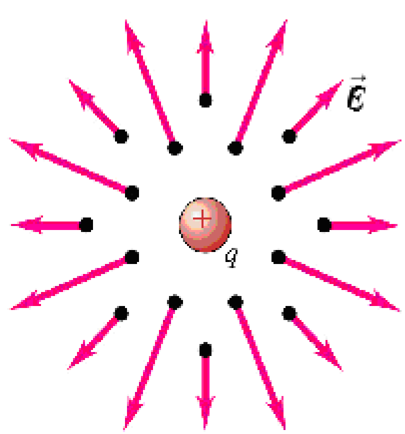
- The charged body A produces or causes a electric field at point P (and all other points in the neighbourhood). This electric field is present at P even if there is no other charge at P.

- Now if a point charge q_0 is then placed at point P, it experiences a the force $\vec{F}_0$. We take the point of view that this force is exerted on q_0 by the field at P. Thus the electric field is the means through which body A communicates its presence to q_0.



(c) Body *A* sets up an electric field $\vec{\mathcal{E}}$ at point *P*:
$\vec{\mathcal{E}}$ is the force per unit charge exerted by *A* on a test charge at *P*

- We can likewise say that the point charge q_0 produces a electric field in the space around it and that this electric field exerts a force $-\vec{F}_0$ on body A.



For each force (the force of a on q_0 and the force q_0 on A), one charge sets up an electric field that exerts a force on the second charge. The electric force on a charged body is exerted by the electric field created by other charged bodies.

Definition of electric field as electric force per unit charge: $\vec{\varepsilon} = \frac{\vec{F}_E}{q_0}$

In SI units, in which the unit of force is 1 N and the unit of charge is 1 C, thus the nit of charge of the electric field magnitude is 1 Newton per Coulomb (1N/c)

Note: $\vec{\varepsilon} = \frac{\vec{F}_E}{q} = \frac{kq_1 q}{r^2 q} = \frac{kq_1}{r^2}$.

Example:

Two charges, $q_1 = 6.1\times10^{-9}C$, the other $q_2 = 4.1\times10^{-9}C$, are 36 cm apart. Calculate the net electric field at a point P, 11 cm from the positive charge q_1, on the line connecting the charges.

Solution:

The net field at P is the vector sum of the fields $\vec{\varepsilon}_1$ and $\vec{\varepsilon}_2$ from the two charges. We calculate the fields separately, then take their vector sum.

$$\varepsilon_1 = \frac{kq_1}{r_1^2} = \frac{\left(9.0\times10^9 N\cdot\frac{m^2}{C^2}\right)\left(6.1\times10^{-9}C\right)}{(0.11m)^2} = 4.53719\times10^3\frac{N}{C}[right]$$

$$\varepsilon_2 = \frac{kq_2}{r_2^2} = \frac{\left(9.0\times10^9 N\cdot\frac{m^2}{C^2}\right)\left(4.1\times10^{-9}C\right)}{(0.25m)^2} = 5.904\times10^2\frac{N}{C}[left]$$

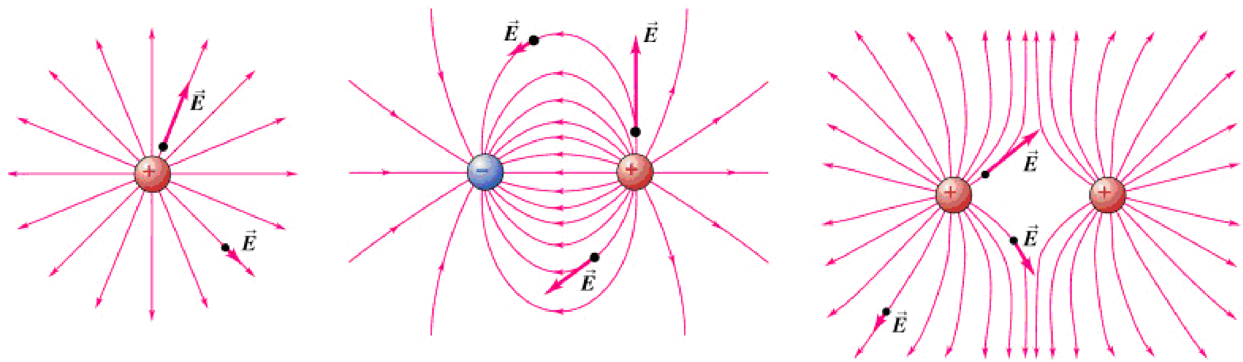
$$\sum\vec{\varepsilon} = \vec{\varepsilon}_1 + \vec{\varepsilon}_2 = 3.9\times10^3\frac{N}{C}[right]$$

The net electric field is $3.9\times10^3\frac{N}{C}$ to the right.

Electric field

The concept of an electric field can be a little elusive because you cannot see an electric field directly. Electric field lines can be a big help for visualizing them and making then seem more real.

- An **Electric Field Line** is an imaginary line or curve drawn though a region of space so that its tangent at any point is in the direction of the electric-field vector that points in that direction.



(a) A single positive charge

(b) A positive charge and a negative charge of equal magnitude (an electric dipole)

(c) Two equal positive charges

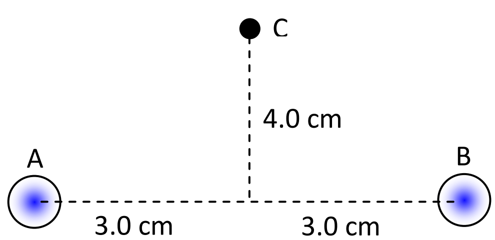
Electric Field Problem Solving Technique

Determining the Electric Field

- ***Units***: **in calculations using the Coulomb constant *k* ($\frac{1}{4\pi\varepsilon_0}$), charges must be expressed in coulombs and distances in meters.**
- ***Calculating the electric field of point charges:*** **to find the total electric field at a given point, first calculate the electric field at the point due to each individual charge. The resultant field at the point is the vector sum of the fields due to the individual charges.**
- ***Symmetry***: **with both distributions of point charges and continuous charge distributions, take advantage of any symmetry in the system to simplify your calculations.**

Example

Determine the magnitude and direction of the electric field at point C due to $+2.0\times10^{-8}C$ charges at points A and B.



Solution:

First we must determine the distance between point A and C (this is the same as the distance between B and C).

Because they form a 3-4-5 triangle, the distance is 5.0 cm

Because the electric field is a vector we will need the angle C is above A (and thus B).

$$\theta = \tan^{-1}\left(\frac{4.0cm}{3.0cm}\right) = 53°$$

Now $\vec{\varepsilon}_{CA} = \frac{kq_A}{r_{CA}^2} = \frac{\left(9.0\times10^9 N\cdot\frac{m^2}{C^2}\right)\left(2.0\times10^{-8}C\right)}{\left(5.0\times10^{-2}m\right)^2} = 7.2\times10^4\frac{N}{C}$

Thus $7.2\times10^4\frac{N}{C}[53°]$

Similarly $\vec{\varepsilon}_{CB} = 7.2\times10^4\frac{N}{C}[53°]$

We must not add these two vectors to determine the electric field at C.

Components in the x-direction

$$\left(7.2\times10^4\frac{N}{C}\cdot\cos(53°)\right)+\left(-7.2\times10^4\frac{N}{C}\cdot\cos(53°)\right)=0$$

Components in the y-direction

$$\left(7.2\times10^4\frac{N}{C}\cdot\sin(53°)\right)+\left(7.2\times10^4\frac{N}{C}\cdot\sin(53°)\right)=1.15\times10^5\frac{N}{C}$$

Combining these two component vectors.

$$\vec{\varepsilon}_C = 1.2\times10^5\frac{N}{C}[up]$$

The electric field is $\vec{\varepsilon}_C = 1.2\times10^5\frac{N}{C}$ in the up direction.

Extra Notes and Comments