Atoms consist of a cloud of negatively charged electrons and a central nucleus consisting of positively charged protons, and uncharged neutrons. The total charge of an atom is zero: it has the same number of electrons and protons.

Rubbing two different substances together will in many cases transfer electrons from atoms in one substance in which electrons are loosely bound, to atoms in the other substance in which electrons are bound tightly. Thus one of the substances will develop a net positive charge (electrons lost) and the other a net negative charge (electrons gained).

The magnitude of charge of electron and proton is called e and has the value 1.6×10^{-19} Coulombs. The Coulomb is a fairly large amount of charge and the normally encountered charges are typically of the order of a microCoulomb, μC, which is 10^{-6} C.

Solid matter typically falls into three categories:

• Conductors, namely metals, in which there are loose electrons free to drift around inside the solid.

• Insulators, namely nonmetals, in which all electrons are tightly bound to atoms.

• Semiconductors, mainly silicon and germanium, which are normally nonconductors but which can be made to conduct by simple changes in their environment. These substances are the basis of all modern electronics, and physicists are frantically searching for other materials whose conductivity can be switched on and off simply.

Ways of Charging:

(1) Contact, or dumping, or "conduction"— Charge is transferred to an object by putting it in direct physical contact with another object that is charged.

(2) Non-contact or induction or polarization charging— An uncharged conductor will be attracted to a charged object, because electrons in the conductor will move toward or away from the object in such a way that the side of the conductor nearest the object will have the opposite charge to the object. An uncharged insulator will be attracted to a charged object, because the atoms in the insulator will actually be deformed in such a way that the atoms become "dipoles," with the ends nearest the object having the opposite charge to the object.

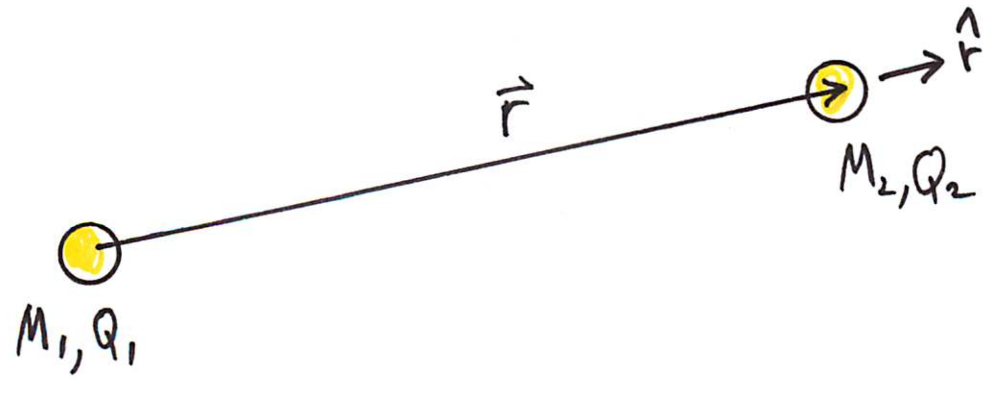
Coulomb's Law:

$$\mathbf{F}_{12} = \hat{\mathbf{r}} \frac{k_e Q_1 Q_2}{r^2}.$$

Compare to Newton's Law of Gravity:

$$\mathbf{F}_{12} = -\hat{\mathbf{r}} \frac{G M_1 M_2}{r^2}.$$

The value of the Coulomb constant k_e is about 9 $\times 10^9$ N-m^2/C^2.



The Coulomb force is the second strongest force in nature. The "nuclear force" is about 3 to 100 times stronger, and the so-called "weak force" is about 10^{-5} the strength of the Coulomb force. Gravity is weaker than the Coulomb force by an astonishing 10^{-40}!

Forces are vectors and combine like vectors. For example if a charge Q_5 is acted on by other charges Q_1, Q_2, Q_3 and Q_4, the net force on charge 5 is

$$\mathbf{F}_5 = \mathbf{F}_{15} + \mathbf{F}_{25} + \mathbf{F}_{35} + \mathbf{F}_{45}.$$

Carefully review Ch. 3, sections 1 and 2, to make sure you clearly remember the ins and outs of vector addition. There is no shortcut. The only way to add vectors is to add vectors.

The Electric Field:

The electric field $\mathbf{E}$ at any point in space is the force per unit charge that would be exerted on a positive test charge placed at that spot. Note that even if we have just a single charge Q, the electric field $\mathbf{E}$ of that charge *extends over all space, and is defined at every point in all space.*

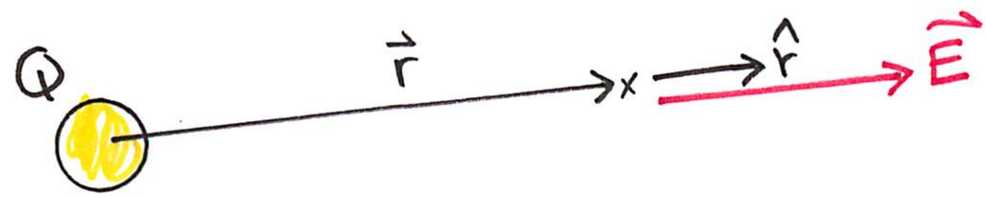
The magnitude of $\mathbf{E}$, due to a single point charge at the origin of coordinates, is clearly $E = k_e Q/r^2$. The vector field is

$$\mathbf{E} = \widehat{\mathbf{r}}\frac{k_e Q}{r^2}.$$

Electric Field:

$$\mathbf{E} = \widehat{\mathbf{r}}\frac{k_e Q}{r^2}.$$

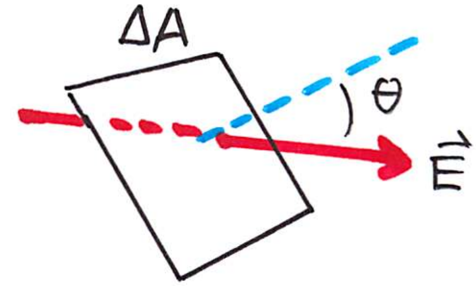
The electric field, as defined at every point in space, is the force that would be exerted by charge Q on a unit test charge placed at that point.



In physics and mathematics a field is a rule that assigns some quantity to every point in space.

A vector field, such as $\mathbf{E}$, assigns a specific and unique vector, namely $\mathbf{E}$, to each point in space.

Electric Flux:

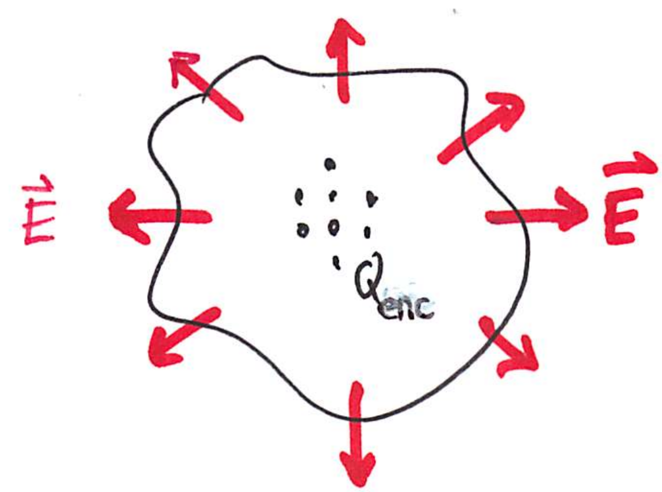


$$\Phi_E = \Delta A E \cos\theta.$$

Gauss's Law:

$$\Phi_E = \frac{Q_{\text{enclosed}}}{\epsilon_0},$$

where $\epsilon_0 = \frac{1}{4\pi k_e}$, for any surface completely enclosing a net charge Q_{enclosed}.



SYMMETRY!

Isolated Conductor in Equilibrium:

- The **E** field is zero everywhere inside the conductor.
- Any net charge present resides on the outer surface of the conductor.
- Surface charge concentrates on parts of the surface that have very small curvature.
- The **E** field just outside the surface is precisely perpendicular to the surface at all points.