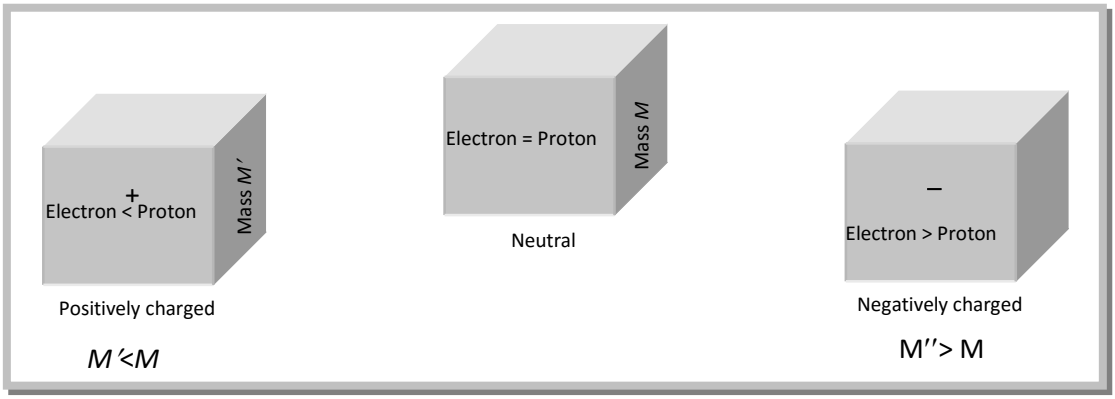
Electric Charge

(1) **Definition:**Charge is the property associated with matter due to which it produces and experiences electrical and magnetic effects.

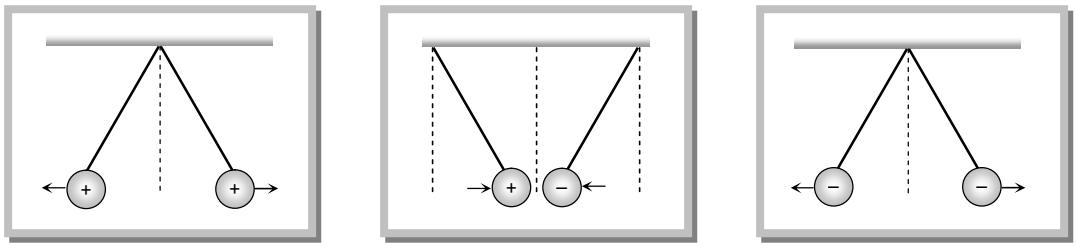
(2) **Origin of electric charge:**It is known that every atom is electrically neutral, containing as many electrons as the number of protons in the nucleus.

Charged particles can be created by disturbing neutrality of an atom. Loss of electrons gives positive charge (as then $n_p > n_e$) and gain of electrons gives negative charge (as then $n_e > n_p$) to a particle. When an object is negatively charged it gains electrons and therefore its mass increases negligibly. Similarly, on charging a body with positive electricity its mass decreases. Change in mass of object is equal to $n \times m_e$. Where, n is the number of electrons transferred and m_e is the mass of electron $= 9.1 \times 10^{-31}\ Kg$.



(3) **Type**: There exists two types of charges in nature (I) Positive charge (ii) Negative charge

Charges with the same electrical sign repel each other, and charges with opposite electrical sign attract each other.



(4) **Unit and dimensional formula:**Rate of flow of electric charge is called electric current i.e., $i = \frac{dQ}{dt} \Rightarrow dQ = idt$, hence S.I. unit of charge is – Ampere × sec = coulomb (C), smaller S.I. units are mC, μC, nC

$(1mC = 10^{-3}C, 1\mu C = 10^{-6}C, 1nC = 10^{-9}C)$. C.G.S. unit of charge is – Stat coulomb or e.s.u. Electromagnetic unit of charge is – ab coulomb $1C = 3 \times 10^9\ stat\ coulomb = \frac{1}{10}\ ab\ coulomb$. Dimensional formula $[Q] = [AT]$

Note: Benjamin Franklin was the first to assign positive and negative sign of charge.

- The existence of two type of charges was discovered by Dufog.
- Franklin (i.e., e.s.u. of charge) is the smallest unit of charge while faraday is largest (1 Faraday = 96500 C).
- The e.s.u. of charge is also called stat coulomb or Franklin (Fr) and is related to e.m.u. of charge through the relation $\frac{\text{emu of charge}}{\text{esu of charge}} = 3 \times 10^{10}$

(5) **Point charge:**A finite size body may behave like a point charge if it produces an inverse square electric field. For example an isolated charged sphere behave like a point charge at very large distance as well as very small distance close to its surface.

(6) **Properties of charge**

(i) **Charge is transferable:**If a charged body is put in contact with an uncharged body, uncharged body becomes charged due to transfer of electrons from one body to the other.

(ii) **Charge is always associated with mass**, i.e., charge cannot exist without mass though mass can exist without charge.

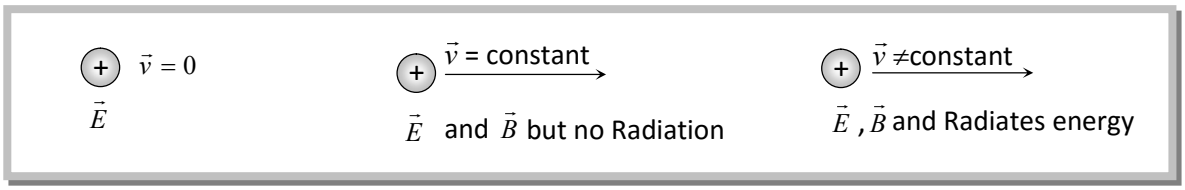
(iii) **Charge is conserved:**Charge can neither be created nor be destroyed. E.g.In radioactive decay the uranium nucleus (charge $= +92e$) is converted into a thorium nucleus (charge $= +90e$) and emits an α-particle (charge $= +2e$)

$_{92}U^{238} \rightarrow_{90} Th^{234} +_2 He^4$. Thus the total charge is $+92e$ both before and after the decay.

(iv) **Invariance of charge**: The numerical value of an elementary charge is independent of velocity. It is proved by the fact that an atom is neutral. The difference in masses on an electron and a proton suggests that electrons move much faster in an atom than protons. If the charges were dependent on velocity, the neutrality of atoms would be violated.

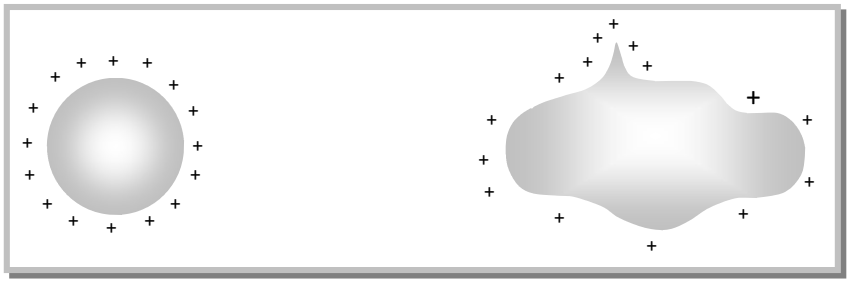
(v) **Charge produces electric field and magnetic field**: A charged particle at rest produces only electric field in the space surrounding it. However, if the charged particle is in unaccelerated

motion it produces both electric and magnetic fields. And if the motion of charged particle is accelerated it not only produces electric and magnetic fields but also radiates energy in the space surrounding the charge in the form of electromagnetic waves.



(vi) **Charge resides on the surface of conductor:** Charge resides on the outer surface of a conductor because like charges repel and try to get as far away as possible from one another and stay at the farthest distance from each other which is outer surface of the conductor. This is why a solid and hollow conducting sphere of same outer radius will hold maximum equal charge and a **soap bubble expands on charging.**

(vii) **Charge leaks from sharp points :** In case of conducting body no doubt charge resides on its outer surface, if surface is uniform the charge distributes uniformly on the surface and for irregular surface the distribution of charge, i.e., charge density is not uniform. It is maximum where the radius of curvature is minimum and vice versa. i.e., $\sigma \propto (1/R)$. This is why charge leaks from sharp points.



(viii) **Quantization of charge:** When a physical quantity can have only discrete values rather than any value, the quantity is said to be quantized. The smallest charge that can exist in nature is the charge of an electron. If the charge of an electron ($= 1.6 \times 10^{-19}\, C$) is taken as elementary unit i.e. quanta of charge the charge on anybody will be some integral multiple of e i.e.

$\boxed{Q = \pm ne}$ With $n = 1, 2, 3 \ldots.$

Charge on a body can never be $\pm \frac{2}{3} e$, $\pm 17.2e$ or $\pm 10^{-5} e$ etc.

Note: Recently it has been discovered that elementary particles such as proton or neutron are composed of quarks having charge $(\pm 1/3)$e and $(\pm 2/3)$e. However, as quarks do not exist in Free State, the quanta of charge is still e.

- Quantization of charge implies that there is a maximum permissible magnitude of charge.