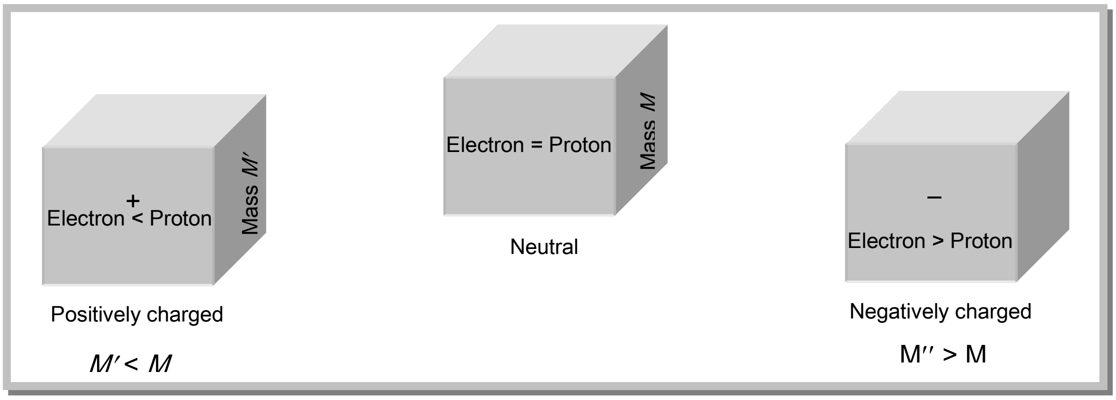
Electric Charge

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



Unit and dimensional formula

$1C = 3\times10^9 \; stat\,coulomb \;= \frac{1}{10} ab\,coulomb$. Dimensional formula $[Q]=[AT]$

- Franklin (*i.e.*, *e.s.u.* of charge) is the smallest unit of charge while faraday is largest (1 *Faraday* = 96500 *C*).

Properties of charge

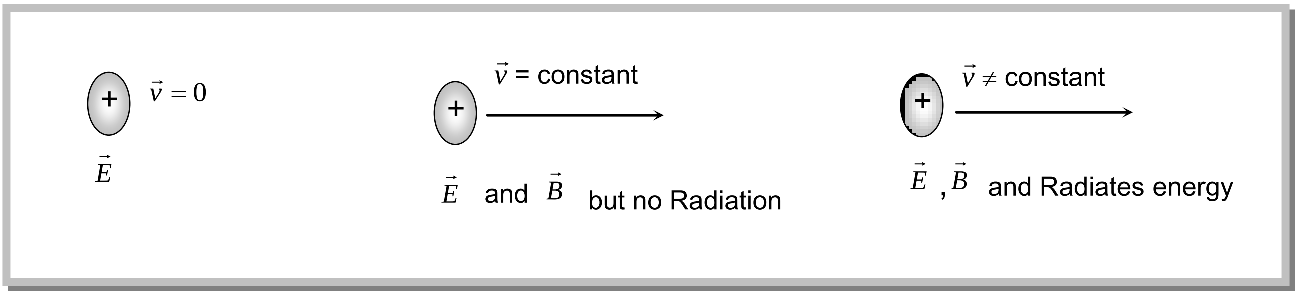
(i) **Charge is transferable**

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

(iii) **Charge is conserved**

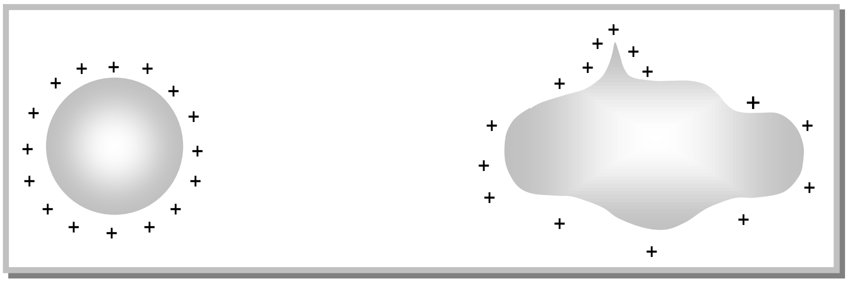
(iv) **Invariance of charge**

(v) **Charge produces electric field and magnetic field**



(vi) **Charge resides on the surface of Conductors**

(vii) **Charge leaks from sharp**



(viii) **Quantization of**

$\boxed{\boldsymbol{Q = \pm ne}}$ with $n = 1, 2, 3 ....$

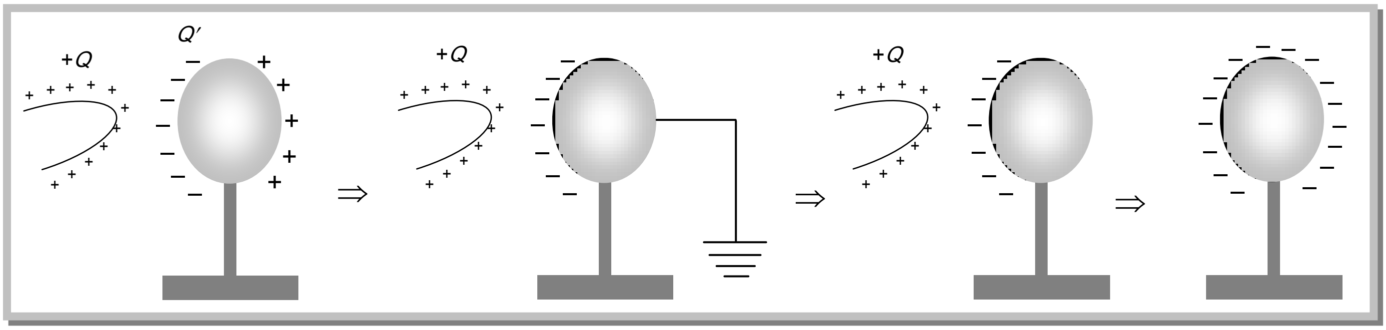
Charge on a body can never be $\pm\frac{2}{3}e$, $\pm 17.2e$ or $\pm 10^{-5} e$ *etc.*

Methods of Charging

A body can be charged by following methods :

(1) **By friction**

(2) **By electrostatic induction**



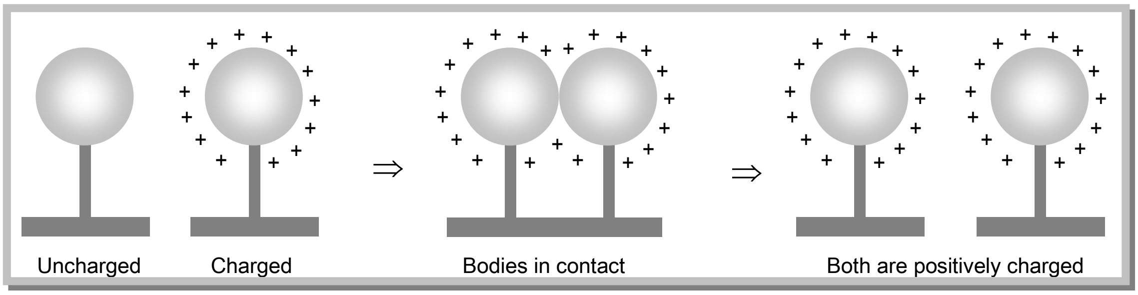
- Inducting body neither gains nor loses charge.
- Induced charge can be lesser or equal to inducing charge (but never greater) and its maximum value is given by $Q' = -Q\left[1 - \frac{1}{K}\right]$ where Q is the inducing charge and K is the dielectric

constant of the material of the uncharged body. Dielectric constant of different media are shown below

Medium	K
Vacuum / air	1
Water	80
Mica	6
Glass	5–10
Metal	∞

- Dielectric constant of an insulator can not be ∞
- For metals in electrostatics $K = \infty$ and so $Q' = -Q$; i.e. in metals induced charge is equal and opposite to inducing charge.

(3) **Charging by conduction**



- A truck carrying explosives has a metal chain touching the ground, to conduct away the charge produced by friction.

Electroscope

(1) Uncharged electroscope

(2) Charged electroscope

Examples based on properties of charge

Example: 1 A soap bubble is given negative charge. Its radius will

(a) Increase (b) Decrease (c) Remain unchanged (d) Fluctuate

Example: 2 Which of the following charge is not possible

(a) $1.6 \times 10^{-18} C$ (b) $1.6 \times 10^{-19} C$ (c) $1.6 \times 10^{-20} C$ (d) None of these

Example: 3 Five balls numbered 1 to 5 balls suspended using separate threads. Pair (1,2), (2,4) and (4,1) show electrostatic attraction, while pair (2,3) and (4,5) show repulsion. Therefore ball 1 must be

(a) Positively charged (b) Negatively charged (c) Neutral (d) Made of metal

Example: 4 If the radius of a solid and hollow copper spheres are same which one can hold greater charge

(a) Solid sphere (b) Hollow sphere

(c) Both will hold equal charge (d)None of these

Example: 5 Number of electrons in one coulomb of charge will be

(a) 5.46×10^{29} (b) 6.25×10^{18} (c) 1.6×10^{19} (d) 9×10^{11}

Example: 6 The current produced in wire when 10^7 electron/sec are flowing in it **[CPMT 1994]**

(a) 1.6×10^{-26} *amp* (b) 1.6×10^{12} *amp* (c) 1.6×10^{26} *amp* (d) 1.6×10^{-12} *amp*

Example: 7 A table-tennis ball which has been covered with a conducting paint is suspended by a silk thread so that it hangs between two metal plates. One plate is earthed. When the other plate is connected to a high voltage generator, the ball

(a) Is attracted to the high voltage plate and stays there

(b) Hangs without moving

(c) Swings backward and forward hitting each plate in turn

(d) None of these

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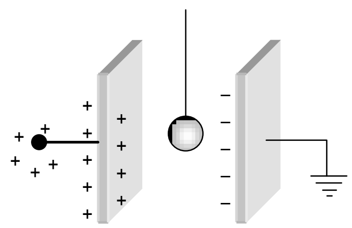


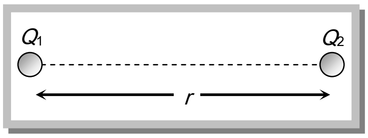
Tricky example: 1

In 1 *gm* of a solid, there are 5×10^{21} *atoms*. If one electron is removed from everyone of 0.01% atoms of the solid, the charge gained by the solid is (given that electronic charge is 1.6×10^{-19} *C*)

(a) + 0.08 *C* (b) + 0.8 *C* (c) – 0.08 *C* (d) – 0.8 *C*

Coulomb's Law

If two stationary and point charges Q_1 and Q_2 are kept at a distance *r*, then it is found that force of attraction



Note : ❑ ε_0 = Absolute permittivity of air or free space = $8.85 \times 10^{-12} \frac{C^2}{N-m^2} \left(= \frac{Farad}{m}\right)$. It's Dimension is $[ML^{-3}T^4A^2]$

❑ ε_0 Relates with absolute magnetic permeability (μ_0) and velocity of light (*c*) according to the following relation $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$

Examples based on Coulomb's law

Example: 8 Two point charges $+3\mu C$ and $+8\mu C$ repel each other with a force of 40 *N*. If a charge of $-5\mu C$ is added to each of them, then the force between them will become

(a) $-10N$ (b) $+10N$ (c) $+20N$ (d) $-20N$

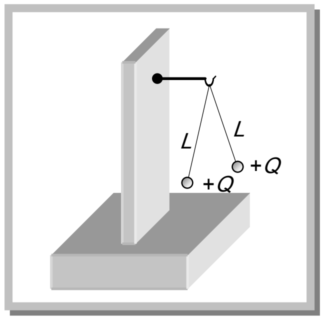
Example: 9 Two small balls having equal positive charge Q (coulomb) on each are suspended by two insulated string of equal length L meter, from a hook fixed to a stand. The whole set up is taken in satellite into space where there is no gravity (state of weight less ness). Then the angle between the string and tension in the string is

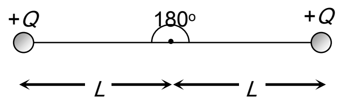
(a) $180^o, \frac{1}{4\pi\varepsilon_0}.\frac{Q^2}{(2L)^2}$

(b) $90^\circ, \frac{1}{4\pi\varepsilon_0}.\frac{Q^2}{L^2}$

(c) $180^\circ, \frac{1}{4\pi\varepsilon_0}.\frac{Q^2}{2L^2}$

(d) $180^o, \frac{1}{4\pi\varepsilon_0}.\frac{QL}{4L^2}$





Example: 10 Two point charges 1 μC & $5\mu C$ are separated by a certain distance. What will be ratio of forces acting on these two

(a) $1:5$ (b) $5:1$ (c) $1:1$ (d) 0

Example: 11 Two charges of $40\mu C$ and $-20\mu C$ are placed at a certain distance apart. They are touched and kept at the same distance. The ratio of the initial to the final force between them is

(a) $8:1$ (b) $4:1$ (c) 1 : 8 (d) 1 : 1

Example: 12 A total charge *Q* is broken in two parts Q_1 and Q_2 and they are placed at a distance *R* from each other. The maximum force of repulsion between them will occur, when

(a) $Q_2 = \frac{Q}{R}, Q_1 = Q - \frac{Q}{R}$ (b) $Q_2 = \frac{Q}{4}, Q_1 = Q - \frac{2Q}{3}$ (c) $Q_2 = \frac{Q}{4}, Q_1 = \frac{3Q}{4}$ (d) $Q_1 = \frac{Q}{2}, Q_2 = \frac{Q}{2}$

Example: 13 The force between two charges 0.06m apart is 5 N. If each charge is moved towards the other by 0.01m, then the force between them will become

(a) 7.20 N (b) 11.25 N (c) 22.50 N (d) 45.00 N

Example: 14 Two charges equal in magnitude and opposite in polarity are placed at a certain distance apart and force acting between them is F. If 75% charge of one is transferred to another, then the force between the charges becomes

(a) $\frac{F}{16}$ (b) $\frac{9F}{16}$ (c) F (d) $\frac{15}{16}F$

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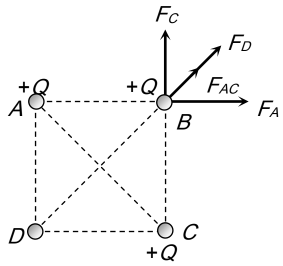
Example: 15 Three equal charges each $+Q$, placed at the corners of on equilateral triangle of side a what will be the force on any charge $\left(k = \frac{1}{4\pi\varepsilon_0}\right)$

(a) $\frac{kQ^2}{a^2}$ (b) $\frac{2kQ^2}{a^2}$ (c) $\frac{\sqrt{2}kQ^2}{a^2}$ (d) $\frac{\sqrt{3}kQ^2}{a^2}$

Example: 16 Equal charges *Q* are placed at the four corners *A*, *B*, *C*, *D* of a square of length *a*. The magnitude of the force on the charge at *B* will be

(a) $\frac{3Q^2}{4\pi\varepsilon_0 a^2}$ (b) $\frac{4Q^2}{4\pi\varepsilon_0 a^2}$ (c) $\left(\frac{1+1\sqrt{2}}{2}\right)\frac{Q^2}{4\pi\varepsilon_0 a^2}$ (d) $\left(2+\frac{1}{\sqrt{2}}\right)\frac{Q^2}{4\pi\varepsilon_0 a^2}$

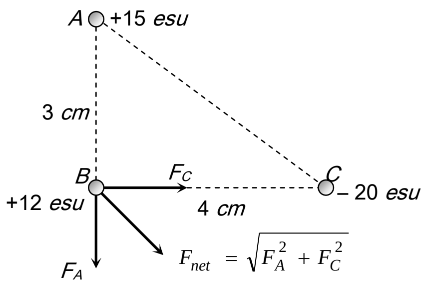


Example: 17 Two equal charges are separated by a distance *d*. A third charge placed on a perpendicular bisector at *x* distance, will experience maximum *coulomb* force when

(a) $x = \frac{d}{\sqrt{2}}$ (b) $x = \frac{d}{2}$ (c) $x = \frac{d}{2\sqrt{2}}$ (d) $x = \frac{d}{2\sqrt{3}}$

Example: 18 *ABC* is a right angle triangle in which *AB* = 3 *cm*, *BC* = 4 cm and $\angle ABC = \frac{\pi}{2}$. The three charges +15, +12 and – 20 e.s.u. are placed respectively on *A*, *B* and *C*. The force acting on *B* is

(a) 125 *dynes* (b) 35 *dynes* (c) 25 *dynes* (d) Zero



Example: 19 Five point charges each of value $+Q$ are placed on five vertices of a regular hexagon of side L. What is the magnitude of the force on a point charge of value $-q$ placed at the centre of the hexagon **[IIT-JEE 1992]**

(a) $k\frac{Q^2}{L^2}$

(b) $k\frac{Q^2}{4L^2}$

(c) Zero

(d) Information is insufficient

Example: 20 Two small, identical spheres having $+Q$ and $-Q$ charge are kept at a certain distance. F force acts between the two. If in the middle of two spheres, another similar sphere having $+Q$ charge is kept, then it experience a force in magnitude and direction as

(a) Zero having no direction

(b) $8F$ towards $+Q$ charge

(c) $8F$ towards $-Q$ charge

(d) $4F$ towards $+Q$ charge

Tricky example: 2

Two equal spheres are identically charged with q units of electricity separately. When they are placed at a distance $3R$ from centre-to-centre where R is the radius of either sphere the force of repulsion between them is

(a) $\frac{1}{4\pi\varepsilon_0}\cdot\frac{q^2}{R^2}$ (b) $\frac{1}{4\pi\varepsilon_0}\cdot\frac{q^2}{9R^2}$ (c) $\frac{1}{4\pi\varepsilon_0}\cdot\frac{q^2}{4R^2}$ (d) None of these