# Electrostatics

## Definitions

| Concept | Definition |
|---|---|
| **Electrostatics** | Study of electrical charges at rest. |
| **Charge** | Excess or shortage of electrons on an object. |
| **Electrification** | Process through which an object loses electrons |
| **Triboelectric effect** | Process through which an electrons are transferred from one object to another one through friction. It is a type of electrification. |
| **Conduction** | The process through which an uncharged object is charged by bringing it in contact with a charged object. |
| **Induction** | The process by which an object is polarized when a it is brought near to a charged object. |
| **Polarization** | Forming a polar substance by redistributing the substance's electrons to form a positive side and a negative side. |
| **Dipole** | An object with to opposite sides like north and south or positive and negative. |
| **Principle of charge conservation** | The net charge of an isolated system says constant during physical process. Charge cannot be created or destroyed but only transferred from one object to another. |
| **Quantization** | An entity's value is unchangeable and cannot be divided. |
| **Quantum** | A single unit of an entity who's value cannot be devided. |
| **Quantization of charge** | An objects' charge is always an integer multiple of its elementary building blocks' charge. |

## Static electricity and charge

### Types of charge

Inside the atom:

- Protons: *Positively* charges particles
- Neutrons: *Neutral* particles
- Electrons: *Negatively* charged particles

Protons = Electrons → no charge
Protons > Electrons → $+^e$ charge
Protons < Electrons → $-^e$ charge

- Protons and electrons have equal but opposite charges.
- Protons and neutrons are in the **nucleus** and are **non-removable**.
- Electrons **surround** the nucleus and are **removable**.

∴ objects are charged by adding or removing electrons.

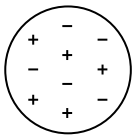
All objects are made up of electrons, ∴ contains protons and electrons, ∴ has a charge.

| Substance |
|---|
| Dry skin |
| Bunny fur |
| Perspex |
| Cellulose acetate |
| Glass |
| Human hair |
| Nylon |
| Wool |
| Cat hair |
| Silk |
| Paper |
| Cotton (Neutral) |
| Steel (Neutral) |
| Wood (Almost neutral) |
| Ebonite |
| Rubber balloon |
| Rugged rubber |
| Nickel, Copper, Silver |
| Foam plastic |
| Cling wrap |
| Polythene |
| Polyethylene |
| Vinyl (PVC) |
| Silicon |

Sterker Positief

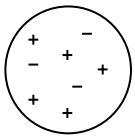
Sterker Negatief

## How an object is charged



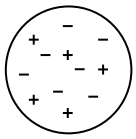
$5 +^{e} = 5 -^{e}$

∴ net charge = 0



$5 +^{e} > 3 -^{e}$

∴ net charge = 2 +



$5 +^{e} < 7 -^{e}$

∴ net charge = 2 –

## Friction

- Two materials rubbed against each other (especially isolators) → one material transfers electrons to the other material.
  ∴ One becomes positively charge while the other one becomes negatively charged.
- The charge on a substance is dependent on the tendency of the substance to take UP electrons rather than donating electrons.
- Can be determined from the triboelectric series.

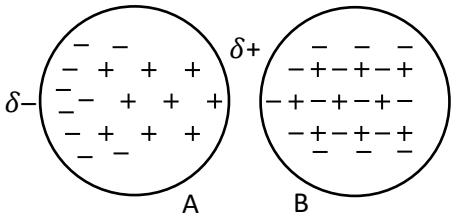
Only electrons are transferred.
Protons stay where they are.
Total number of protons and electrons stays constant between the two substances.

## Induction

= charged by being near to charged objects, ∴ no contact
= temporary (loses charge and polarity when taken away from charged object)

Before:

- Object A is neutral because its electrons are evenly distributed.
- Object B is negatively charged while its electrons are evenly distributed.




During:

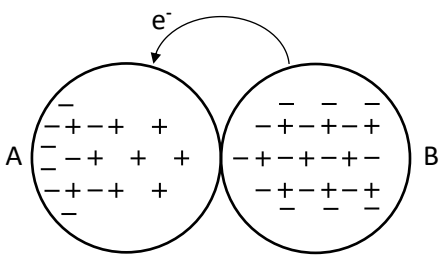
- Object A's electrons are repelled by the positive charge on object B.
- The one side of A becomes positive while the other side becomes negative, A is now polarized.

## Conduction

= charged by making contact
= continues (the object loses its charge over time)

Before contact:

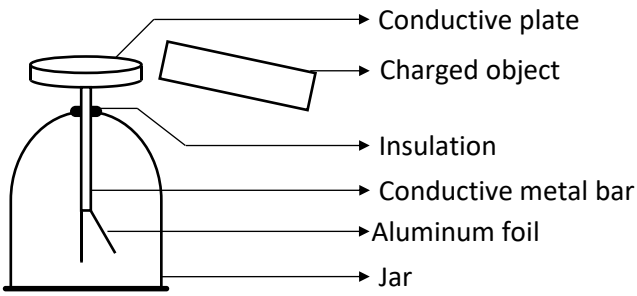
- Object A is neutral and its electrons are distributed evenly.
- Objects B is negatively charged while its electrons are evenly distributed




During contact:

- The negative charge on B pushes object A's electrons to one side, creating positive and negative poles
- The positive charge on the one side of A causes electrons to be transferred from A to B.
- The original negative object (B) becomes less negative, while the neutral object (A) becomes more negative.

## The Electroscope




An electroscope is used to determine the size and nature of a charge on an object.

### A negatively charged object

*Without contact*

1. The negatively charged object is brought closer to the neutral electroscope's conductive plate.
2. The large number of electrons on the charged object causes the electrons in the conductive plate to move Down the conductive bar to the pieces of aluminum foil.
3. Both pieces of aluminum is charged
4. The pieces of foil repel each other which increases the angle between them. The electrons will return to the plate when the charged object is removed.

*With contact*

If the object touches the plate, electrons will be transferred from the charged object to the conductive plate. The pieces of foil will repel each other even if the charged object is removed.

### Positively charged object

*Without contact*

1. The positively charged object is brought closer to the conductive plate.
2. The difference in charge causes the electrons of the pieces of foil, the conductive bar and the conductive plate to move towards the positive object.
3. Both pieces of foil becomes positively charged.
4. The pieces of foil repel each other which causes the angle between them to increase. When the charged object is removed, the pieces of foil will return to their original positions.

*With contact*

If the objects makes contact with the conductive plate, electrons will be transferred from the plate to the object. The foil pieces will become positively charged which will cause them to repel each other even if the charged object is removed.

## Electrostatic forces

= attractional and repelling forces

∴ = non-contact forces.

***Explain everything in terms of power***

***Stronger powers dominate!***

### Between charged objects

- **Similar** charges **repel** each other (+ en + of – en –)
- **Opposite** charges **attract** each other (+ en –).

Attractional and repelling forces = indirectly proportional to the distance between the objects,

∴ ↑ distance between charged objects → ↓ attractional and repelling forces

### Between a charged and a neutral object

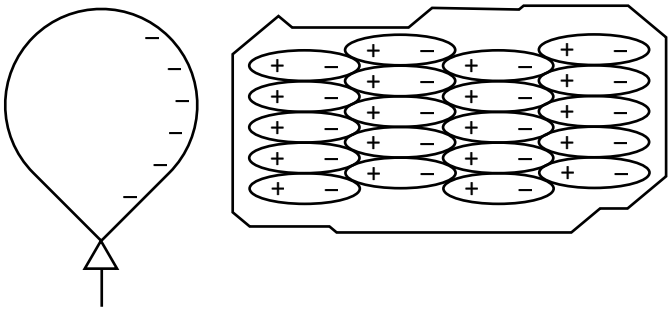
Attractional forces exists between charged and neutral objects.

## Polarization

= uneven distribution of electrons, but the charge on the object stays neutral.
∴ no transfer of charge takes place.

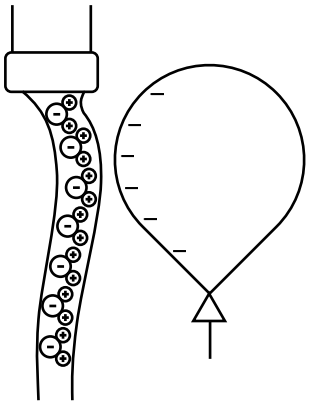
*In isolators:*

- Electrons
  ≠ not removable from atoms,
  ∴ do not freely move through a substance.
  ∵ nucleus' attractional force on the electrons is stronger than the attractional forces caused by the external charge.
- Atoms can still re-orientate ∴ → forms ***induced* dipole**.
  = ***INDUCED POLARIZATION***
  (polarization due to an external influence).



*In molecules:*

Some molecules = polar (like water),
∴ has a positive and negative side (dipole), but still have a neutral charge.
Molecules rotate due to external influences.



## Calculations using charges

### Unit and symbol of charge

| | |
|---|---|
| **Symbol:** | **Q** |
| **Unit:** | **Coulomb** |
| **Symbol of energy:** | **C** |
| **Symbol of the charge of a single atom:** | **$q_e$** |

| | | |
|---|---|---|
| **Electron** | Negative (–) | $-1{,}6 \times 10^{-19}\ C$ |
| **Proton** | Positive (+) | $+1{,}6 \times 10^{-19}\ C$ |
| **Neutron** | Non | $0\ C$ |

### Conservation of charge

Charges are only transferred, ≠ not created or destroyed.

Algebraic sum of all charges in a closed system (= no external influences) stays constant.

All charges before interaction = All charges after interaction

### Formulas

The units of charges must be the same in a formula.
Keep **C with C**, *mC with mC*, **µC with µC**, *nC with nC*, and **pC with pC**.

$$Q = nq_e$$

**Calculate:**

- The total charge (Q in C) transferred as the individual charges of the transferred electrons ($q_e$) combined. **$Q = nq_e$**
- Amount of electrons (n) which is responsible for the charge (Q in C) that is transferred to a object due to each electrons individual charge ($q_e$). *Can't be a fraction!* ∴ $n \in \mathbb{Z}$. **$n = Q/q_e$**
- The charge of each electron ($q_e$) which in conjunction (n) attribute to the total charge (Q in C) transferred to the object. **$q_e = Q/n$**

$$Q = \frac{(Q_1) + (Q_2) + \ldots + Q_n}{n}$$

Only applicable on identical conductors.

*After contact* all objects that made contact at the same time will have the same charge.

Charge lost by one object = charge gained by other object.

**Calculate:**

- The charge (Q) on an object after all the charged objects ($Q_1, Q_2, \ldots Q_n$) have touched.
- n = the amount of objects that touch at the same time.
- If objects touch, then are separated and brought into contact with newly charged objects, the charge after the second contact must be calculated.

$$\Delta Q = Q_f - Q_i \text{ of } \Delta Q = Q_A - Q_B$$

**Calculate:**

- The difference (Δ) in charge (Q) of an object before ($Q_i$) and after ($Q_f$) an interaction
  ∴ otherwise stated: how much energy is transferred?.
- The difference (Δ) in charge (Q) of two objects ($Q_A$ and $Q_B$).

## Quantization of charge

= a unit that cannot be divided.

For example: an electron's charge $= -1{,}6 \times 10^{-19}\ C$

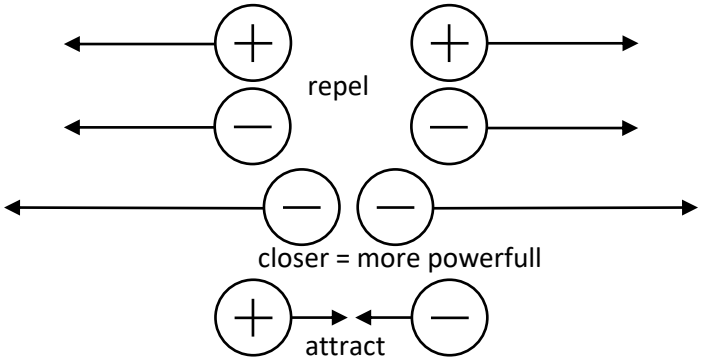
- Cannot be something else.
- Cannot get half of an electron or proton.
- Can only be multiples of $1{,}6 \times 10^{-19}$.

| | | |
|---|---|---|
| Coulomb | $C$ | $\times 10^{0}$ |
| Millicoulomb | $mC$ | $\times 10^{-3}$ |
| Microcoulomb | $\mu C$ | $\times 10^{-6}$ |
| Nanocoulomb | $nC$ | $\times 10^{-9}$ |
| Picocoulomb | $pC$ | $\times 10^{-12}$ |

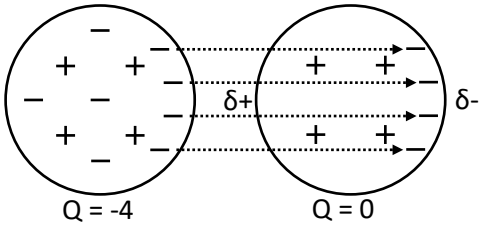
## Charg

Electron Negative (–) $-1{,}6 \times 10^{-19}\ C$

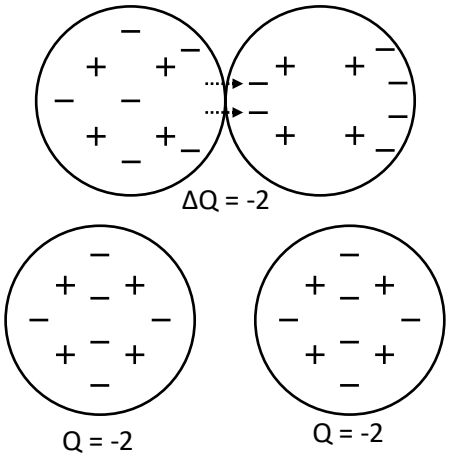
Proton Positive (+) $+1{,}6 \times$




## Induction

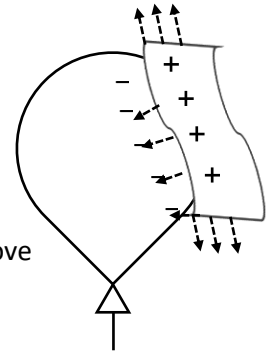



## Conduction




## Friction

Triboelectric series



Protons stay
Electrons move

# Electrostatics

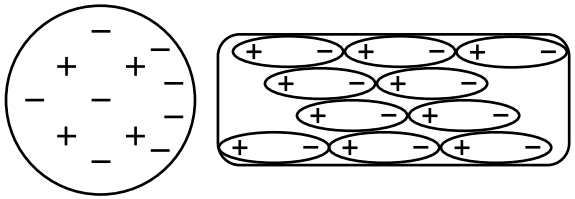
**Principle of charge conservation**

The net charge of an isolated system says constant during physical processes. Charge cannot be created or destroyed but only transferred from one object to another.

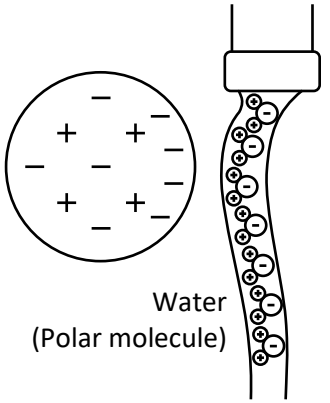
| Charge (Q) |
|---|
| Coulomb (C) |
| Charge on an electron ($q_e$) |
| Charge on a proton ($q_p$) |

| | | |
|---|---|---|
| Coulomb | $\boldsymbol{C}$ | $\times\ \mathbf{10^0}$ |
| Millicoulomb | $\boldsymbol{mC}$ | $\times\ 10^{-3}$ |
| Microcoulomb | $\boldsymbol{\mu C}$ | $\times\ 10^{-6}$ |
| Nanocoulomb | $\boldsymbol{nC}$ | $\times\ 10^{-9}$ |
| Picocoulomb | $\boldsymbol{pC}$ | $\times\ 10^{-12}$ |

## Polarization



## Orientation




## Formulas

$$\boldsymbol{Q = nq_e}$$

$$\boldsymbol{Q = \frac{(Q_1) + (Q_2) + \ldots + Q_n}{n}}$$

$$\boldsymbol{\Delta Q = Q_f - Q_i} \text{ of } \boldsymbol{\Delta Q = Q_A - Q_B}$$