Lecture 13

ELECTRICITY

Electric charge

Coulomb's law

Electric field and potential

Capacitance

Electric current

ELECTRICITY

Many important uses

Light
Heat
Rail travel
Computers
Central nervous system
Medical/dental

Historical

6th century B.C., Greeks noticed sparks were produced when the fossilized tree resin called amber was rubbed with fur.

Greek word for **amber** is ***elektron*** from which the word electricity is derived.

End of the 19th and early 20th century:

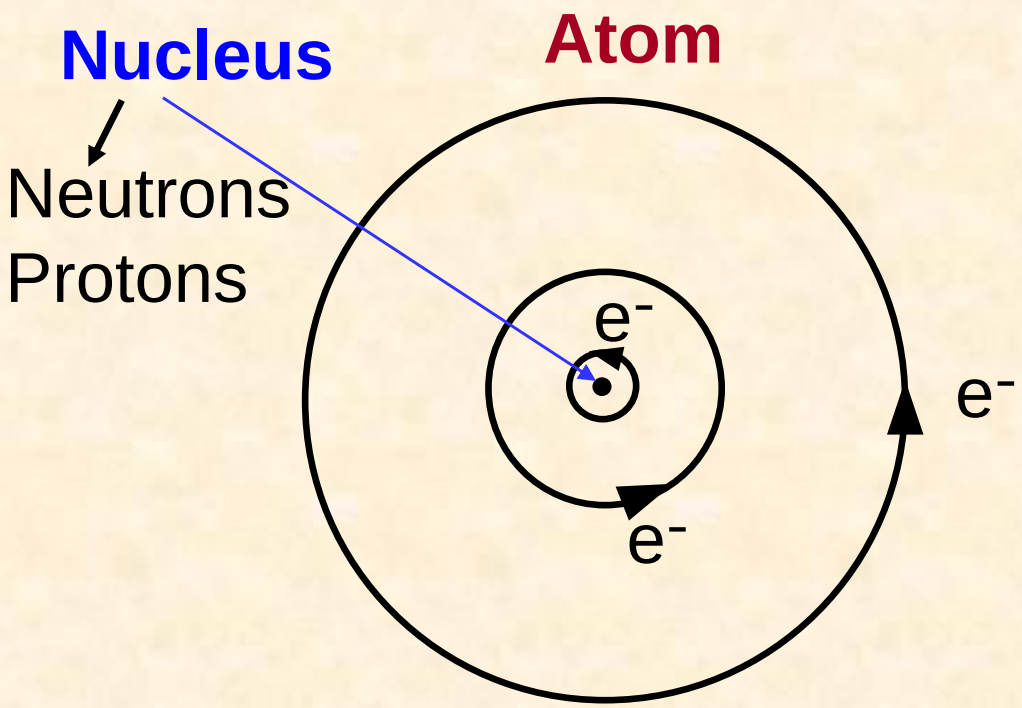
Fundamental discoveries concerning the electronic structure of the atom were made.

Electric charge and the atom

Electric charge is a characteristic of **sub-atomic particles.**

Simple View

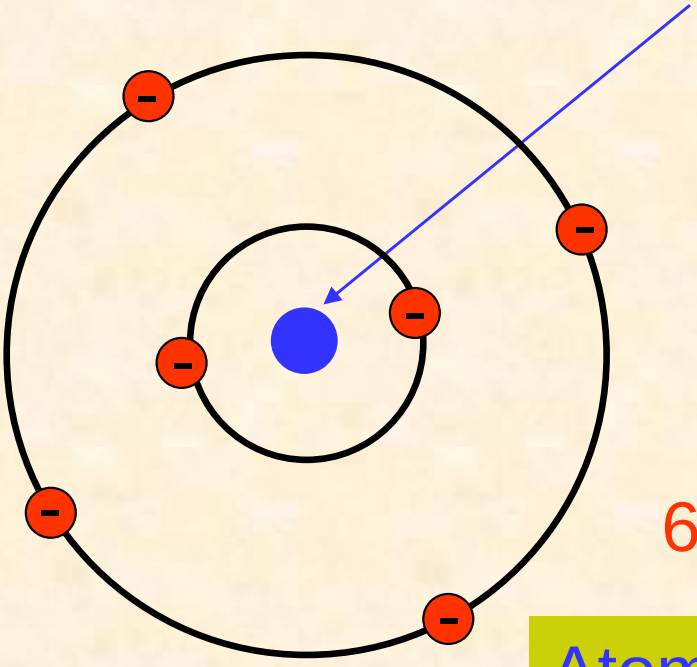
An atom is composed of 3 kinds of particles: **protons , electrons and neutrons.**



Particle	Charge	value
proton	**+e**	**1.6 x 10^{-19} Coulomb (C)**
electron	**-e**	**-1.6 x 10^{-19} Coulomb (C)**
neutron	**none**	**----------**

Electric charge and the atom

Carbon Atom



Nucleus

6 protons: charge +6e
6 neutrons: (no charge)

6 electrons: charge -6e

Atoms are electrically neutral

Total **positive charge** of the **nucleus** = **total negative** charge of the **electrons** around the nucleus.

In General, these particles

- neither created nor destroyed,
- **electrons** can be displaced from one atom to an other.

Electron removed – result → positive ion
Electron added – result → negative ion

Electric charge and the atom

Electric charge

- **basic physical property** of subatomic particles,

3 Characteristics of charge

1. Two types of charges, positive and negative

2. Charge **is conserved**
   Charges can be **separated** but **cannot be created or destroyed.**

3. **Like** charges **repel** and **unlike** changes **attract**

Electrostatic forces

result from the **separation** of positive and negative charges.

Electric charge

Basic unit of positive charge:

$+e = 1.6 \times 10^{-19}$ Coulomb

Basic unit of negative charge:

$-e = -1.6 \times 10^{-19}$ Coulomb (C)

Any charged object:

- Total charge is always a multiple of e
- Charge can only have values ±e, ±2e, ±3e ±..
- Charge is said to be **quantised**
- Never fractional charge ?

Electric charge

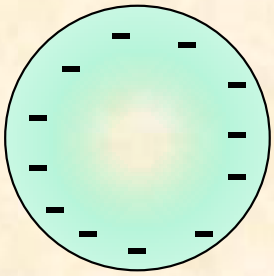
Electrically charged materials

Many examples

Almost any two non-conducting substances when rubbed together will become charged

Plastic comb run through your hair
comb will then attract bits of paper

Balloon and wool rubbed together:
balloon becomes
negatively charged



Friction associated with rubbing does not create the charge

Charge transferred by movement of electrons

Charge is conserved
Neither created or destroyed

Total amount of charge in universe: constant

Electric charge

Types of Materials

Conductors:

- Example: metals, copper etc.
- charges are free to move.

Insulators:

- Example: Rubber, plastic etc
- charges are not free to move.

Semiconductors:

- Example: Silicon, Germanium
- movement of charges can be controlled by temperature or doping of the material.

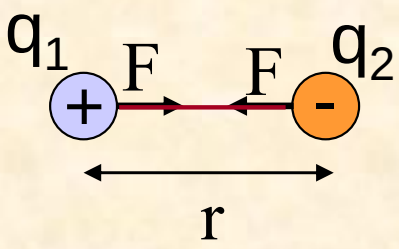
Application: electronic devices

Photoconductors:

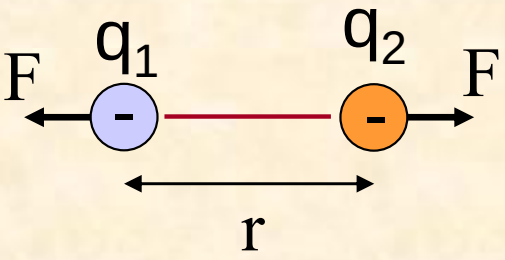
- **Example:** Selenium
- **In darkness:** Insulator (holds charge)
- **Exposed to light:** conductor (charge leaks away)
- Application: photocopier, laser printer

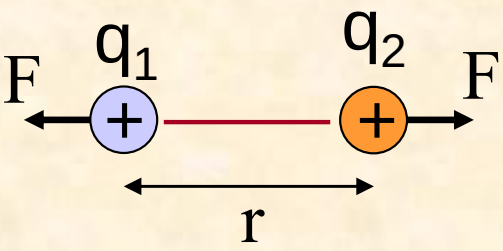
Electric charges and forces

Unlike charges



Like charges





$$F \propto \frac{q_1 q_2}{r^2}$$

Mathematical law that describes how **like charges repel and unlike charges attract** each other is called **Coulomb's law**.

Charles Coulomb (1736-1806) French physicist,

Coulomb's law: "the **force** between two point charges is **proportional** to the **product of their charge** and **inversely proportional** to the **square of their separation**"

Direction of the force: along line joining the point charges.

Coulomb's Law

$$F \propto \frac{q_1 q_2}{r^2} \qquad F = k\frac{q_1 q_2}{r^2}$$

SI unit of charge is called the Coulomb

Force F is known as the **Coulomb force** or **electrostatic force** and its units are Newtons

distance r is in metres

Hence units of k are Nm^2C^{-2}

The constant k is determined by experiment to be $9x10^9$ Nm^2C^{-2} (in a vacuum)

k is sometimes written as $k = \frac{1}{4\pi\varepsilon_0}$

where ε_0 is called the permittivity of vacuum

$$\varepsilon_0 = 8.85x10^{-12}\ C^2N^{-1}m^{-2}$$

$$F = \left(\frac{1}{4\pi\varepsilon_0}\right)\frac{q_1 q_2}{r^2}$$

Coulomb is a very large quantity of charge