Intro to Quantum Physics F3241

Dr Lily Asquith (Lily)

04 - 08 Oct 2021 (Week 2)

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This Week: The Electron

We have two lectures a week (Monday & Thursday - your calendars should reflect this now.)

- Understanding electricity
- The discovery of the electron

The Electrical Force

Electric fish: Thunderers of the Nile, protectors of all other fish.

Triboelectricity (*tribo: rubbing*)

- Evidence suggests first **use** of electricity was amber spindles, used in weaving.
- Amber attracts feathers when rubbed, glass repels them: 'Resinous' and 'Vitreous'.
- Amber, resin, rubber, polystyrene : positively charged
- Glass, skin, fur, silk : negatively charged

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Electrical Effluvia

- Gilbert 1600 hypothesized that the amber effect could be explained by an effluvium (a small stream of particles that flows from the electric object, without diminishing its bulk or weight) that acts on other objects
- Gray 1729 noticed that a cork placed in a glass tube took on its charge. Also wires across hundreds of metres. Also showed that you don't need objects to touch.
- Were there two kinds of effluvium? This was a popular idea, to explain the attraction or repulson depending on the materials
- Franklin 1750 : actually we only need one fluid. A rubbed glass received the same, but opposite, charge strength as the cloth used to rub the glass

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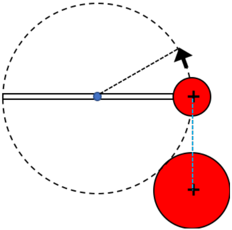
Investigating electricity

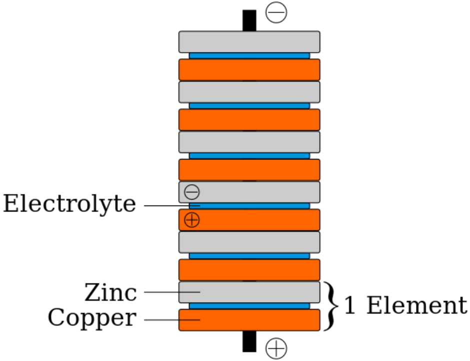
Charles-Augustin de Coulomb was first (1785) to publish: electrostatic force follows an inverse square law.

Coulomb's Law: $F = k\frac{q_1 q_2}{r^2}$



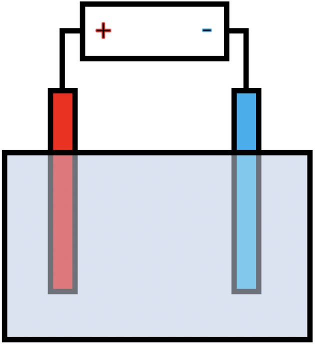
A new era

Volta 1800: came up with a way to store charge, providing continuous current.
Also, $Q = CV$



Investigating electricity

Michael Faraday devised an *inspired* experiment (1833) to investigate electricity.



Two massive things

1. All substances have something fundamental in common, and this is encoded in N_A
2. The behaviour of all substances is described using a common parameter: the fundamental unit of charge e

Reminder: N_A is the number of atoms with $Z = n$ in n grams of a substance made of those atoms.
Note for H, $Z = 1$, so there are N_A atoms in 1 gram of H.

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Another massive thing

Why are these people all of a particular type?

Once dominance is achieved, often by terrible means or just by pure luck, no type of human is expected to give that privilege up...

... but, vast amounts of evidence that all parts of society, including science, benefit from diversity in background and in opinion

Let us remember that if Newton had been female, he would probably have been burned as a witch.

Let us also remember that most of the history of science is completely unknown to us: we just have the part that is written.

Yuval Noah Harari: Sapiens

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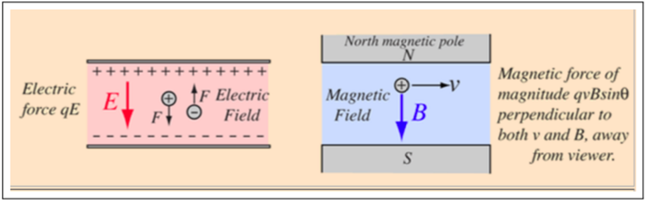
Further investigations

Thomson's experiments with a 'cathode ray tube', 1897

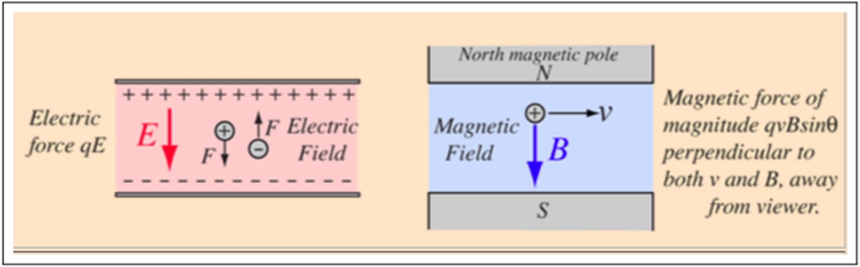
Millikan's experiments with an 'oil drop' 1909

Both of these experiments relied on **equating forces**:

The Lorentz force (1895) $F = q\underline{E} + q(\underline{v} \times \underline{B})$ links the forces arising from electric and magnetic fields (E and B)



The electric and magnetic forces



Further investigations

The Lorentz force $F = q\underline{E} + q(\underline{v} \times \underline{B})$ is very useful for understanding the properties of charged particles.

A trick we can use for things moving in circular motion is $\underline{F} = \frac{mv^2}{r}$.

It is based on the observation that all circular motion has a related force (gravity, tension, contact, etc)

Another trick we can use, for things near Earth's surface, is $F = mg$

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An example problem - part 1

We accelerate a mixed beam of electrons and protons to 3×10^7 ms^{-1}, and allow them to enter a region with a uniform magnetic field perpendicular to their direction with a strength of 8T. What happens to the particles?

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An example problem - part 2

We accelerate a mixed beam of electrons and protons to 3×10^7 ms^{-1}, and allow them to enter a region with a uniform magnetic field perpendicular to their direction with a strength of 8T. What happens to the particles?

Next Lecture

See you all Thursday when we will think about the Thomson and Millikan experiments.