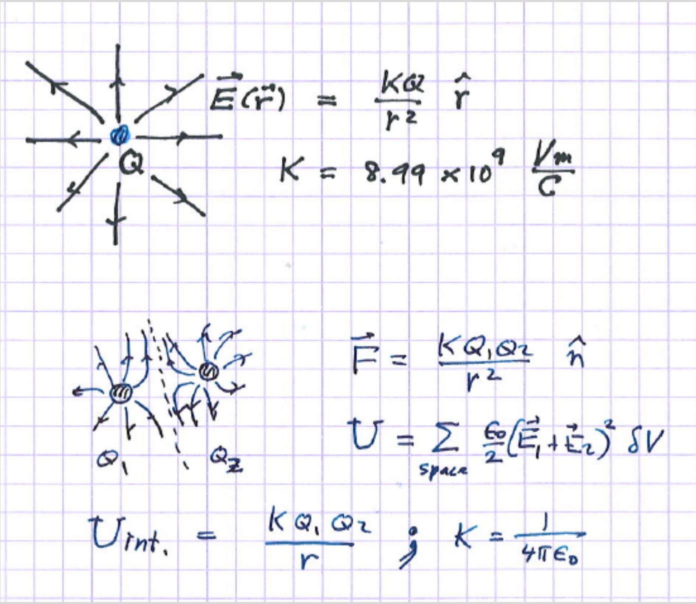
Electric currents

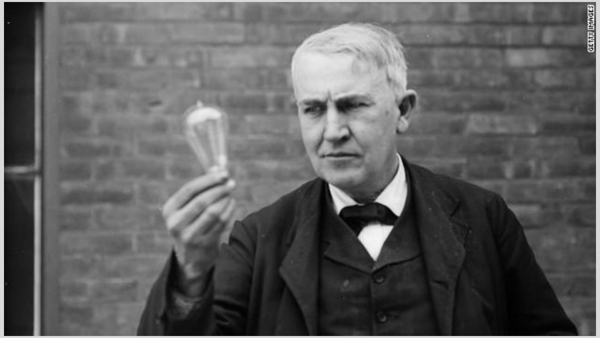
Review: Charge and Field



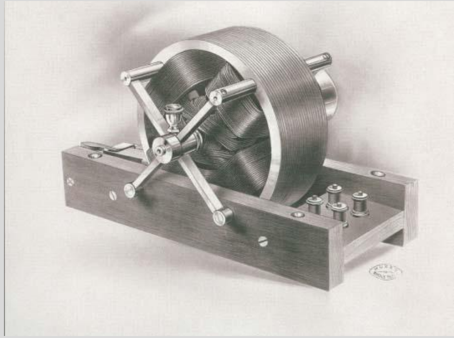
The development of electric power technology was driven by two inventions.

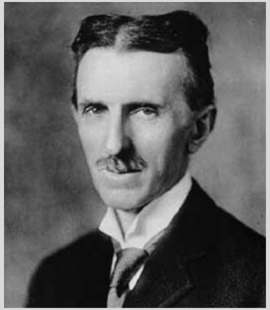
Edison,

1880



Tesla, 1888





Electric currents

What is electric current?

/// Electric current is the flow of electric charges.

/// Atoms are electrically neutral, but subatomic particles (electron and atomic nuclei) are charged;

electron charge = - e

proton charge = + e

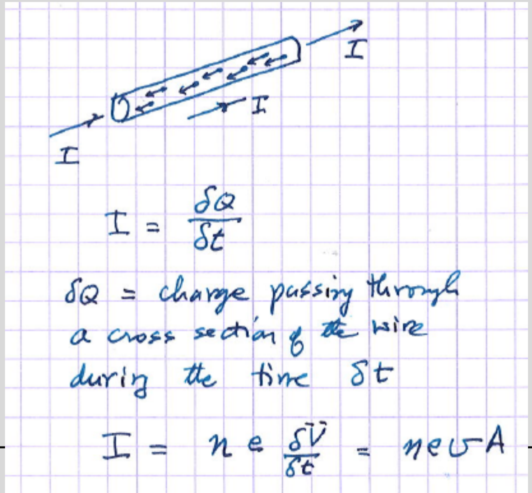
nuclear charge = Z e ; Z is the atomic number

/// In some materials, called conductors, some of the electrons can separate from their atoms, and move “freely” through the material.

Examples:

Metals; Plasma; Chemical solutions

/// The most familiar electric current is the flow of electrons in a metal wire.



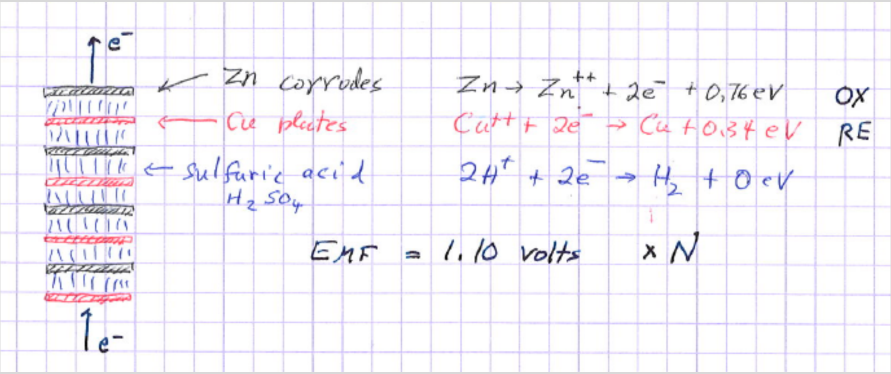
Batteries

<u>How do we create electric currents?</u>

➡ A sparks is an example of a current, but it is not continuous.

➡ The first battery, a device capable of producing a continuous current, was invented by Alessandro Volta in 1800; his goal was to disprove Galvani's claim that electric current required a biological component.

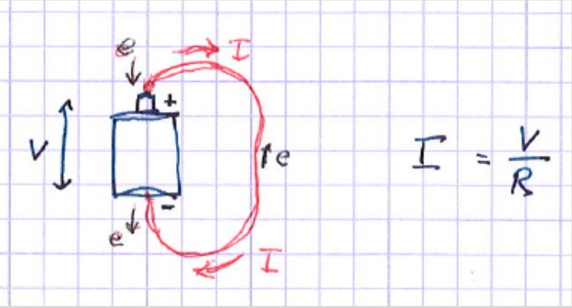
➡ A battery is a chemical reactor that maintains a constant potential difference (or, *voltage*, or *electromotive force*, or *emf*) between two electrodes.



➡ Electric generators produce voltage and current by electromagnetic induction (esp. ***A***lternating ***C***urrent).

Ohm's law

Georg Ohm showed that current is proportional to voltage when a wire is connected to the two electrodes of a battery (1827).



I = V/R

R is the resistance of the circuit;

the unit of resistance is the ohm (or, **Ω**).

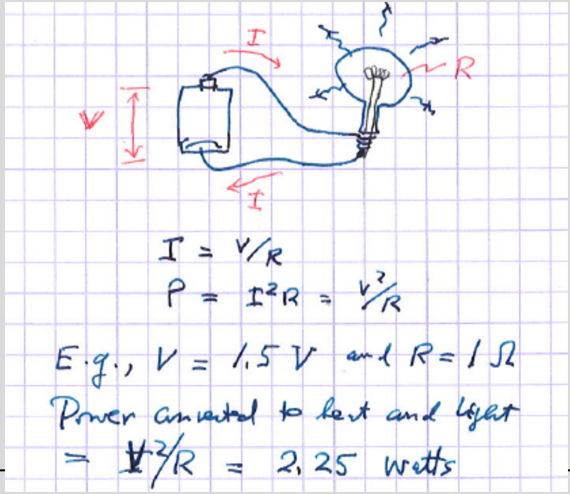
Joule's law

James Joule showed that the power released as heat when a wire is connected to a battery is

Power = δU / δt = $I^2 R$;

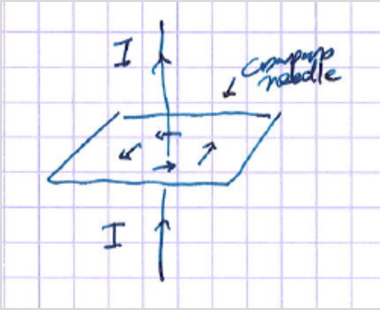
or, equivalently, P = I V. (1840)

The electric light bulb (***D***irect ***C***urrent)

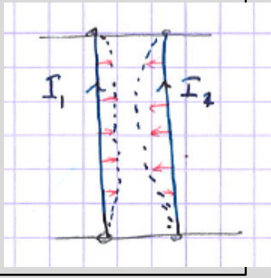


Electric current and magnetism

[1.] An electric current creates a magnetic effect. (Oersted, 1820)



[2.] Electric currents exert forces on each other. (Ampere, 1820) This is an example of magnetism.



[3.] Later, Faraday and Maxwell developed the field theory of magnetism.

Magnetic field = **B(r)**

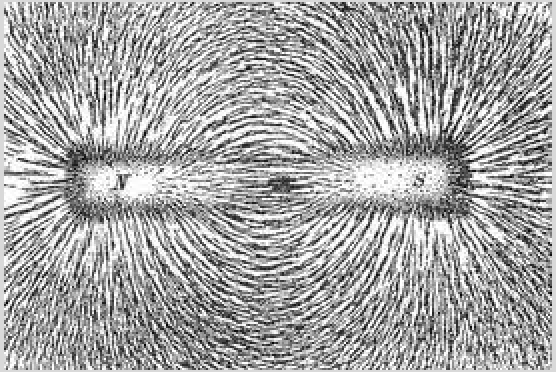
[3a.] The field can be created by a permanent magnet (e.g., magnetized iron; first observed by Thales of Miletus and named by William Gilbert);

or it can be created by an electric current.

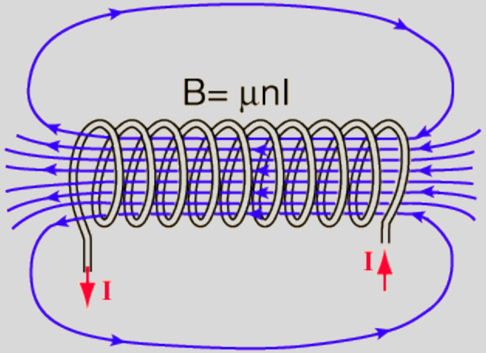
[3b.] Currents and moving charges experience a force when moving through a magnetic field.

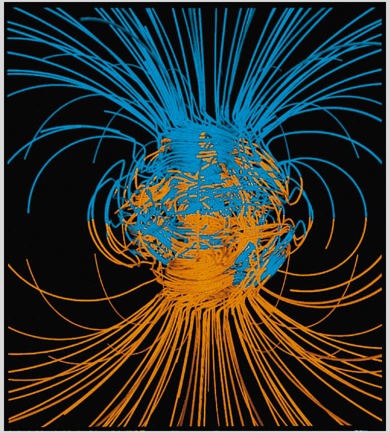
Magnetic fields

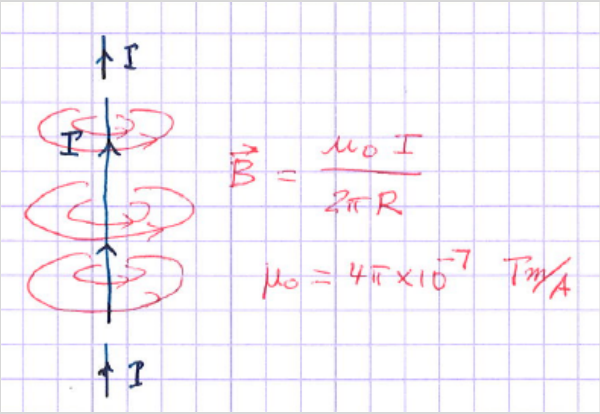
from a permanent magnet ...



from electric current ...







Magnetic forces

The magnetic force on a moving charge is

$$\mathbf{F} = q\,\mathbf{v} \times \mathbf{B}(\mathbf{r})$$

(q = charge, **v** = velocity, **r** = position)

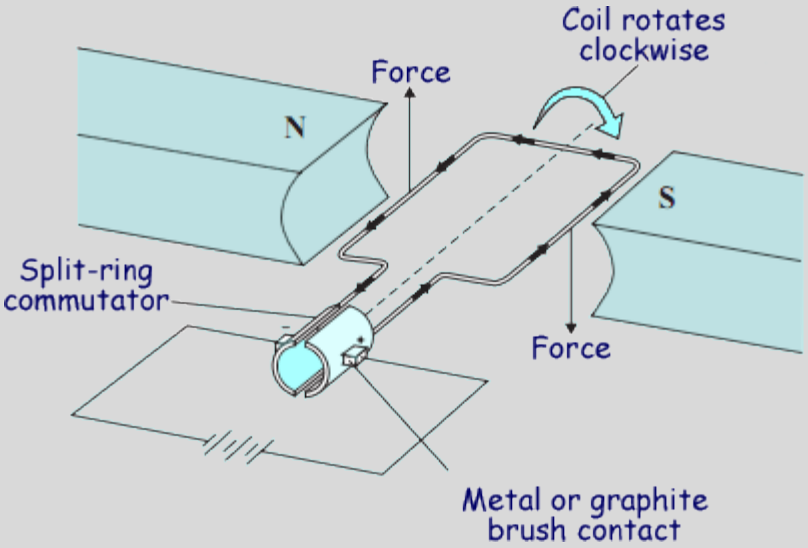
Application: Particle accelerators, like the cyclotron

The magnetic force on a small segment of a current carrying wire is

$$d\mathbf{F} = I\,d\mathbf{l} \times \mathbf{B}(\mathbf{r})$$

(**dF** = force on the segment, I = current, **dl** = length of the segment)

Application: Electric motors



Torque = **r x F** = $I\,A$ B sin(θ) **n**

(This is a DC motor.)