Electricity

Electricity is the most commonly used form of energy for tasks ranging from simple heating and lighting to the powering of computers for the most complex of applications. In the modern world electric power is taken for granted. Its production, distribution, use and reliability are so commonplace that we only consider it when there is a power cut or when a fuse blows.

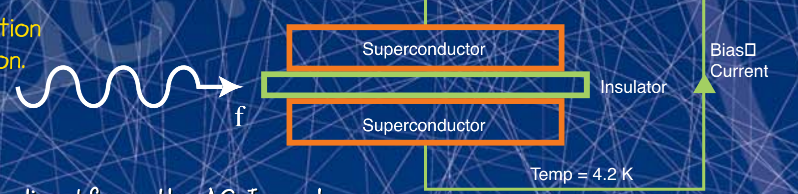
Discovery of electricity

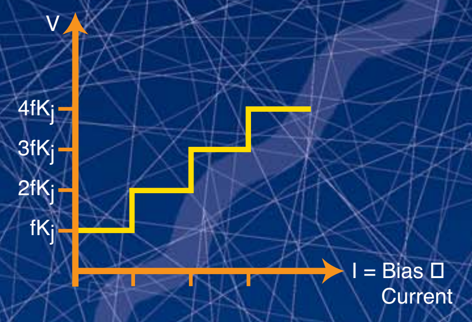
As early as 600 BC it was found that rubbing a piece of amber created a build-up of charge which could attract small pieces of straw. Around 1600 AD the word 'electric' was introduced to describe this effect, derived from the Greek word for amber, elektron. Benjamin Franklin demonstrated the electrical origin of lightning in 1745 with his kite-flying experiments during thunderstorms. He suggested the existence of two different charges: positive and negative. In 1800 Alessandro Volta generated a constant electrical current by placing layers of copper and zinc in a saline (salt) solution. His 'Voltaic pile' was the first battery. The next breakthrough was in 1820 when Andre-Marie Ampere established a relationship between electricity and magnetism. The final crucial step was the discovery of electromagnetic induction, in 1831, by Michael Faraday who managed to convert magnetism into electricity by moving a magnet through a coil of wire. This led the way for the development of electrical generators and in 1881 the first public electrical supply was introduced in Godalming in Surrey for street lighting.

Modern-day realisation of the ampere and volt

The ampere is difficult to realise in practice with sufficient accuracy, so it is realised via the watt (SI unit for power). The electrical power generated in a controlled experiment is compared to mechanical power, and using an accurate measurement of resistance the ampere can be calculated (as Power = (Current)^2 x Resistance).

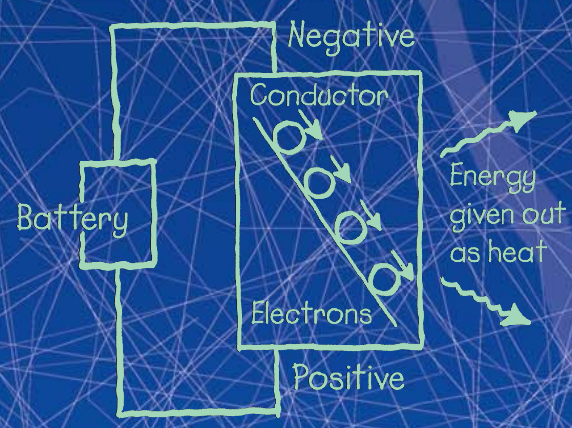
Schematic representation of a Josephson junction.





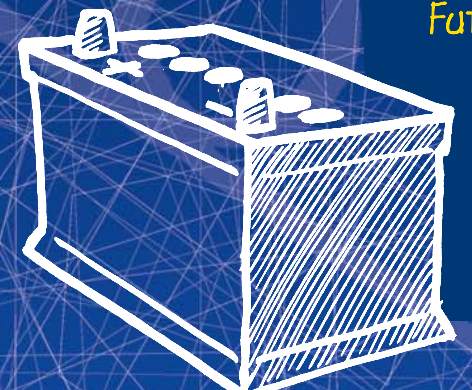
Discrete voltage steps characteristic of a Josephson junction.

At NPL the volt is realised from the AC Josephson effect. Due to this effect the potential difference between two superconductors separated by a narrow gap and exposed to electromagnetic radiation, takes discrete values dependent on the Josephson constant (K_j = 483597.9 GHz/V) and the frequency of radiation (f). This gives the volt to an accuracy of 1 hundred millionth of a volt (0.000 000 01 V).



How does electricity flow?

In metals and certain other materials, negatively charged particles called electrons are free to move around. These materials are called conductors. When a battery is connected across a conductor, a potential difference is set up along it and electrons 'flow' down the 'potential gradient'. However, as electrons are negatively charged, down the potential gradient is from the negative to the positive end of the conductor. This flow of electronic charge is called a current. It is described as direct current (DC) if it flows continuously in one direction and alternating current (AC) if its direction of flow alternates back and forth.



Future realisation of the ampere

Future current standards may be based on counting the single electrons flowing in a sophisticated semiconductor circuit. In a device under investigation at NPL, single electrons can be carried by a surface acoustic wave (phonon) which travels across the device. The current is easily compared with theory as it is simply the charge on an electron times the number of electrons carried by the wave per second (the frequency of the wave).

The relationship between current and voltage

Georg Simon Ohm discovered that the amount of current that flows through a material is proportional to the potential difference or voltage applied across it. His famous law states that $V = IR$; if a certain voltage (V) is applied across a conductor, the size of the current (I) which flows is inversely proportional to the resistance (R) of the conductor.

Alternative power sources

The majority of the electrical power used throughout the world is produced by generators containing a rotating magnet usually powered by steam created from burning fossil fuels. Renewable sources of energy, however, are becoming more commonly used across the globe. The government has set a target to generate 10% of the UK's electricity needs from renewable sources by the year 2010. Alternative energy sources include solar panels, wind generators and hydro-electric power. Solar panels convert sunlight directly to electricity but in general have low efficiency. Wind power is used directly to rotate turbines to generate electricity. Hydro-electric power converts the kinetic energy from falling water into electricity and nuclear power uses the energy locked in the nuclei of atoms instead of fossil fuels.

The ampere

The SI base unit for electrical quantities is the ampere. The definition of the ampere adopted in 1948, is: The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per metre of length.

Electric vehicles

Due to advances in designs of electric batteries, electric powered vehicles have become a reality, although the take up by customers so far has not been large. Several motor manufacturers are currently manufacturing electric vehicles that can travel at speeds of up to 75 mph and need recharging only after every 70 miles. Mixed or 'hybrid fuel' cars are also being developed that combine the best qualities of electric engines and internal combustion engines to produce a vehicle with low pollution and good speed and range.

Measuring electric currents

The measurement of direct electrical current can be carried out using a galvanometer. This instrument works on the principle that a magnetic needle placed next to a conductor, with a current flowing through it, is deflected perpendicularly to the direction of the current. The extent to which the needle turns is dependent on the strength of the current. In 1823 Johann Schweiger amplified this effect using a coil to produce the first working galvanometer.

Superconductors

Superconductors are materials, such as metals or alloys, which have zero resistance to electric currents at low temperatures, typically below -260 °C. Superconductors are used to make powerful electromagnets but the temperatures needed to exhibit superconducting properties are too low for widespread practical use. New types of materials, called high temperature superconductors, remain superconducting in much warmer conditions, typically -200 °C. Unfortunately these materials are brittle and not easy to make into wires. If superconductors could be used in electric power cables, there would be absolutely no loss of power in the transportation of electricity across the world.

Current Scale

Typical current in a lightning bolt 30 000 A

Electric kettle 10 A

Computer 1 A

Household light bulb 0.25 A

Typical lethal current 0.1 - 0.2 A

Current from an electric eel 0.07 A

Typical currents in nerve impulses in the body 0.000 000 010 A (10×10^{-9} A)

Current corresponding to electrons passing a point in a circuit at the rate of one per second 0.000 000 000 000 000 000 16 A (1.6×10^{-19} A)

If you have a measurement related scientific question contact us on: telephone 020 8943 6880 email: enquiry@npl.co.uk or visit our web site which has lots of measurement related information at http://www.npl.co.uk

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