A Companion to Physics in the Enlightenment - part 2

Slides 3-4 give a short summary of the most important events in the history of electricity and magnetism.

Slide 5. One of the chapters in *De magnete* by William Gilbert (1600) contains the first modern account of electrical studies. As the court physician to Queen Elisabeth Gilbert had access to her treasury. He decided to check how many different materials, including precious stones and gems, could be electrified by rubbing in the same way as amber. He provided himself with the first electroscope, a device to show the presence of electric charge on a nearby body:

„Make yourself a rotating needle, *versorium*, of any sort of metal, three or four fingers long, pretty light, and poised on a sharp point after the manner of a magnetic pointer. Bring near to one end of it a piece of amber or a gem, lightly rubbed, polished and shining: at once the instrument revolves...”

By making use of the *versorium* Gilbert was able to divide all studied materials into „electrics” (those which could be electrified by rubbing), and „non-electrics”. He introduced these terms by taking example of the Greek name for amber - ήλεκτρον. He also recognized several differences between magnetic and electric interactions. e.g. that lodestone attracts only iron whereas amber acts on many kinds of bodies, that the magnet attracts only towards its poles, amber - everywhere, that the magnet pulls heavier weights than amber can.

Slide 6 shows several examples of early graphic representation of magnetic field; the concept of the field did not yet exist.

Around 1650 Otto Guericke invented the first electrostatic machine which facilitated electrization. He took a large spherical glass phial, filled it with finely ground sulphur, then heated the phial so that the sulphur melted. When the phial cooled down the glass was broken and a fine spherical sulphur globe was obtained. It was then fitted with a handle and placed in a wooden frame. When rotated and rubbed by hand it acquired a large electric charge which could then be transferred to other bodies (Slide 7, upper left figure). In 1705 Englishman Francis Hauksbee replaced sulphur globe by a glass sphere which was much more easily produced. Slide 8 shows later constructions of electrostatic machines. Experiments with electricity became quite popular.

Slides 9-13. In November 1745 Ewald von Kleist in Kammin by accident invented the first condenser; it was invented independently by Pieter van Musschenbroek and his coworkers in Leyden in the beginning of 1746. The news from Leyden to Paris arrived first, so that the new instrument obtained the name „Leyden jar”. It could store large electric charges and opened the field for various impressive experiments (Slide 12). The early attempts to measure the speed of electricity in wires (Slides 13-14) did not give any conclusive result.

Benjamin Franklin in Philadelphia learned about electrical experiments in Europe and began his own studies. He treated electricity as a fluid composed of particles repelling each other (Slides 15-18). He invented the lightning rod which was first tried in May 1752 in France (Slide 23). It originated a new fashion: personal lightning conductors (Slide 24).

In Paris Jean-Antoine Nollet performed numerous public experiments with electricity and magnetism (Slides 19-22). It is worth noting that for the first time women were seen to participate in these experiments.

Early attempts to quantify electric interaction (Slides 25-28) led to construction of electrometers and to Volta's law which related the quantity of electricity Q localized on an isolated conductor with its capacity C and „tension" T.

Charles Augustine Coulomb was trained as a military engineer but performed physics experiments in his free time. He made use of the torsion balance and was able to deduce from his experiments that electric interaction falls off as the square of the distance. His results were initially accepted only in France while in other countries several eminent physicists, such as e.g. Alessandro Volta and Christian Oersted remained sceptical. We know now that the maverick English scholar Henry Cavendish had deduced $1/r^2$ law earlier than Coulomb but he did not bother to publish the result. Hundred years later James Clerk Maxwell uncovered Cavendish's results while browsing through his manuscripts (Slides 29-30).

Slides 31-34. Animal electricity.

In 1791 an Italian physician Luigi Galvani, professor of anatomy at the university of Bologna, published a short booklet *De viribus electricitatis in motu musculari* (*On electric forces in movements of muscles*) in which he announced discovery of „animal electricity". The English translation of the most important excerpts from that brochure is provided in Slides 32 -34. Galvani insisted that animal (as well as human) muscles are sources of electricity. That view was strongly criticised by Alessandro Volta who found the true cause of electric effects observed by Galvani. Volta discovered the existence of contact potential between different metals. It led him to construction of the electric battery, the so-called Volta's pile, which could serve as a source of electricity for considerable time (Slide 39). The construction of that instrument is described in Volta's own words in Slides 40-43.

Let's also take note that in that time an Austrian physician Franz Anton Mesmer propagated „animal magnetism", which he employed in his medical practice. He tried to cure his patients by touching them with magnets. Later he abandoned magnets and used only his hands which allegedly produced magnetism. Special commission of physicists set by the French Academy of Sciences observed Mesmer's doings and after failing to find any real physics effects came to the conclusion that Mesmer simply exploited gullibility of his patients.

Slide 44 shows a collection of typical instruments used in electrical experiments.

Slide 45. The largest electrostatic machine ever built was constructed in Haarlem in the Netherlands. It consisted of one hundred connected large Leiden jars of 30 cm diameter each. This giant generator produced sparks almost 70 cm long. It was used by Martinus Van Marum for various experiments. The investment, however, did not pay off, because no new discovery was made with its use. The machine has been preserved and is now on display in the Tyeler's Museum in Haarlem.

Slides 46-50 Reform of weights and measures

For many centuries no common system of weights and measures existed in Europe. Each town had its own set of measures. An example of establishing the standard of length is presented in Slide 47. The first sixteen men leaving the church after Sunday mass were asked to stand in a row so that their feet could touch each other. The total length of their sixteen feet was measured and one sixteenth part of it was defined as the length of one foot.

The measures of length in various places differed quite considerably (Slide 48). The English foot was equal to 12 inches. In many European towns the feet was shorter or longer, e.g. the Strasburg foot had only 11,04 English inches, the one of Venice 13,944 inches. The longest foot of Riga had as much as 21,972 inches.

Similar multitude of measures existed for weights.

On May 8, 1790, the National Assembly of France decreed that a new system of weights and measures must be based on a suitable choice of physical constants, so that the new units could be adopted by all nations. The new unit of length called *mètre* was defined as one ten-millionth part of the length of a quarter of the earth meridian. One hundredth part of it was called centimetre. The new unit of weight called *gramme* was defined through the new unit of length as the weight of water contained in a volume of one cubic centimetre.

The new measures were approved as legal in December 1799, but their introduction in France met with strong resistance and was very slow. The government was forced to allow   simultaneous use of the traditional measures such as e.g. the *toise*.

Other countries accepted new measures with reluctance and it took several decades until most countries in Europe agreed to adopt the French system. In 1889 The Convention of the Meter was signed by eighteen countries.

In 1793 The French National Assembly introduced also decimal system for measuring time. The day (from midnight to midnight) was to be divided into 10 hours, each new hour having 100 minutes, each new minute having 100 seconds and so on. It did not work because of the strongly established tradition of 24 hours of 60 minutes each. The new system was officially suspended in 1795. Slide 50 shows an example of a decimal clock, now found only in museums.