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Technological Developments: Electricity

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The nineteenth century was a key period in the development of scientific knowledge about electricity. Electricity was transformed from a scientific curiosity into a practical tool, which was increasingly present in the lives of ordinary people. There were two threads of development: first the scientific developments in the theory and understanding of electricity, then the related developments in the practical uses of electricity for everyday purposes.

Electrical phenomena had been of interest to scientists for hundreds of years, although purely as a matter of intellectual curiosity until after 1600. Even by 1800, the ideas of the physical phenomena connected with electricity were relatively confused. This was to change during the nineteenth century, when significant developments in the understanding of various aspects of electricity occurred. These were not limited to one country or group of scientists, but relied on acquaintances and links which transcended local and national boundaries.

Nineteenth-century advances began with the invention of the Voltaic pile, which was completed in 1800. The culmination of the work of the Italian Alessandro Volta, the Voltaic pile (which consisted of a series of electrical cells, thus forming a battery) provided the first means of generating a continuous electrical current. This changed electricity from a transient phenomenon to one which could be properly studied. The fruits of this invention appeared rapidly. Within a year, Nicholson and Carlisle managed to electrolyse water. It was further used by Humphry Davy to decompose various substances, leading to the discovery of potassium and sodium. The battery was developed further during the nineteenth century. The first mass-produced battery was designed by William Cruickshank, and was the default until the invention of the non-polarising cell in 1836. The cell, a primary battery, was further improved in 1868 by Georges Leclanché, making it a reliable source of power. As well as primary batteries, secondary batteries also came to play an important role in the practical use of electricity, as they allowed electricity to be stored and saved until it was needed. These batteries were an integral part of the direct current systems used for domestic electricity production. The nineteenth century therefore saw significant developments in the battery as a way to produce and store electricity.

Another key area of development was in the field of electromagnetism. In 1819, the Danish scientist Hans Christian Ørsted discovered that a compass needle deflected away from a wire containing electrical current. This provoked more research within the field. André-Marie Ampère, a French scientist, quickly picked up on Ørsted's discoveries, developing a mathematical theory which explained the electromagnetic phenomena already observed, and predicted many others. Michael Faraday, the British chemist and physicist, built upon this work and made some extremely significant discoveries in the field. In 1831, his experiments led him to discover mutual induction, a form of electromagnetic induction, laying the foundations for many subsequent developments. Over the next few decades, various scientists and experimenters attempted to learn more about and improve upon these mechanisms, with these efforts leading to patchy and complicated advances. However, the principle of the induction coil was better understood and advanced in this period, impacting on further developments.

Advances in electromagnetism were important for the development of the mechanical generation of electricity. The study of the link between motion and electricity began in the 1820s and 1830s, and the first patent was obtained by Thomas Davenport in 1837. The machines were based on theory rather than efficient practice and had little impact. The next few decades saw further developments in the principle of electrical movement. A significant development was Tesla's invention of the induction motor in 1883, a device which had previously been thought impossible. Advances in electromagnetic understanding also led to the development of the generator. A major step towards effective generators was the introduction of "self-excitation". This used the current produced by the generator to energise its own wires. Several individuals hit upon the discovery independently in 1866, and the late 1860s saw significant developments in this type of model. This development in the generation of electricity made current more reliable, and led to renewed interest in electric lighting. Electrical generation technology continued to improve during the rest of the century, and by 1887 the first high-pressure power station in the world was constructed at Deptford. It was not a commercial success, but it demonstrated the viability of the large scale production and dissemination of electricity.

The development of induction coils also led to the development of the transformer, which could transfer electrical energy from one circuit to another by inductively-coupled conductors. The use of such devices had been suggested for several decades, and a practical system was developed by Gaulard and Gibbs in 1883. This allowed voltages to be altered between circuits, solving several practical problems associated with the transfer of electricity over long distances and connecting equipment of different voltages to the same supply. Until the 1880s, almost all transformers were the "open" type, lacking an iron bar connecting the circuit. There was controversy over the efficiency of these models, but the practicalities demonstrated that "closed" transformers were more efficient, and these became the norm by the end of the century. The development of transformers demonstrated the importance of practical knowledge as well as theory in the development of electricity.

Another key aspect of the development of electrical technology was the "war of the currents". The conflict concerned whether electrical supply should be provided by direct current (DC), usually produced by batteries, or alternating current (AC), produced by generators. Alongside a number of practical problems with generation, storage and demand fluctuations, the debate also involved contentious discussions of the relative safety of each system, with the key proponents on both sides arguing that the other system posed a threat to the safety of users and the general public. However, the practical problems of the DC system and the advantages of the AC system for transmission over long distances meant that by 1900 the AC system had been accepted as the most suitable for public supply, although much domestic electricity continued to be produced on the DC system.

Alongside developments in the understanding of electrical phenomena, towards the end of the nineteenth-century technological developments increasingly made electricity a practical tool. The first of these was the telegraph. The idea had been suggested in the eighteenth century, but the discovery of electromagnetic forces in the nineteenth century enabled it to be developed further. The first commercially viable telegraph was developed by Cooke and Wheatstone in 1837, closely followed by Samuel Morse's system in 1838. All of the systems relied on the deflection of magnetised needles from an electric current. Morse's invention was initially regarded as a curiosity, and Cooke and Wheatstone's telegraph was not initially commercially successful. Nevertheless, telegraphs soon became more widespread. In 1870-1, 9.8 million messages were sent within the UK. The impact on communications within and between nations was dramatic. Submarine telegraph cables were developed later, after the discovery of suitable coating material for the wires, and the first (albeit short lived) cross-Channel cables were laid in 1850, followed in 1866 by longer-lasting cables across the Atlantic. By the end of the century, telegraphy had become the main electric technology with which the average person was familiar.

Other communications technologies were developed in the nineteenth century. A crude system for transmitting sound by electricity was invented in the 1860s, but it was not until the parallel work of Bell, and House and Grey that the telephone was invented. Bell is frequently credited with the invention, but much of the work was undertaken at the same time by House and Grey. Although Bell was granted the patent for the invention in 1875 it proved very contentious, leading to over 600 law suits. Telephony then developed rapidly. The nineteenth century also saw the discovery and development of radio. In 1877, Clerk Maxwell published his famous 'Treatise on Electricity and Magnetism', in which he proved the existence of and predicted many of the properties of the waves which later became known as radio waves. In 1886, Heinrich Rudolf Hertz demonstrated the production and detection of these waves, and in 1896 Guglielmo Marconi used them for radio communication over a couple of miles. The first commercial radio company was founded in 1897, and the first commercial message sent in 1898. The close of the nineteenth century therefore saw the first stirrings of electrical communications technology, as regards telephony and radio.

Another application of electricity was lighting. The first type to be developed was arc lighting, which relied on a current running between two carbon rods to cause a series of sparks and thus light. The electrical principles behind this had first been demonstrated by Davy in 1802, but practical problems meant that the technology took several decades to develop further. Significant development occurred in 1876 with the invention of the Jablochkoff candle, an improved version of the arc light which burnt out less rapidly. Arc lamps began to appear in public places from 1878 onwards. Many more patents were lodged in the 1880s and 1890s, but the two most important developments in arc lights were the "enclosure" of the light in a glass tube and the addition of flame-providing salts to the carbon rods. By 1890, about 1,400 arc lamps were in use in England, increasing to around 21,400 by 1910. However, arc lamps were superseded by a new, more reliable and convenient form of lighting: incandescent lighting.

In 1860, John Wanamaker, an English scientist, invented what is commonly regarded as the first incandescent lamp. However, the problems associated with the filament burning out rapidly meant that little progress in the technology was made over the next twenty years. No practical lamp could appear until a suitable vacuum could be produced within the bulb; this was achieved with the invention of the Sprengel mercury pump in 1875. Improved filaments were also necessary, with various experiments being undertaken by figures including Swan and Edison. These two, among others, eventually came up with viable filaments, and started producing lamps commercially from around 1880 onwards. There were serious disputes between Edison and Swan as to who had developed the improvements, and disputes over the fact Edison had acquired the patent, but the Swan company amalgamated with the Edison company in 1883, thus bringing an end to the problems. While the patent lasted, the bulbs were relatively expensive, but dropped in price as demand increased. The patent expired in 1893 and the Edison company encountered significant competition from other manufacturers. The 1890s saw further development in the filament lamp, with various metals being used as filaments, culminating in the tungsten filament lamp, first introduced in 1909.

Electric lighting became increasing utilised in public places in the late nineteenth century. Public spaces including the British Library, were among the first to employ the bright and harsh arc lighting. Electric lighting also began to enter the domestic sphere from the 1880s onwards, although at first only the aristocracy could afford the expensive and as yet experimental lighting technology. Electricity within the home was regarded as dangerous by some, and was presented as such by its opponents, including the gas industry. Early light bulbs were relatively quick to break, relatively expensive, and were feared as a potential cause of fire. Home generators could be unreliable, as could some mains electricity. The 1882 Electric Lighting Act put the burden of safety on the suppliers of mains electricity, and various safety expedients were developed. However, despite these problems the number of houses with domestic lighting in the London area grew from a dozen in the mid-1880s to a few thousand by the end of the decade. This number continued to rise up to the end of the century, demonstrating the increasingly wide acceptance of electrical lighting within the home as a replacement for gas lighting.

The nineteenth century saw important developments in the understanding of the science behind electricity, with work by scientific greats such as Faraday laying the foundations for the development of more practical technology which turned electricity from a scientific curiosity into a day-to-day practical tool, laying the foundations for the mass electrification programmes which would emerge in the twentieth century.

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