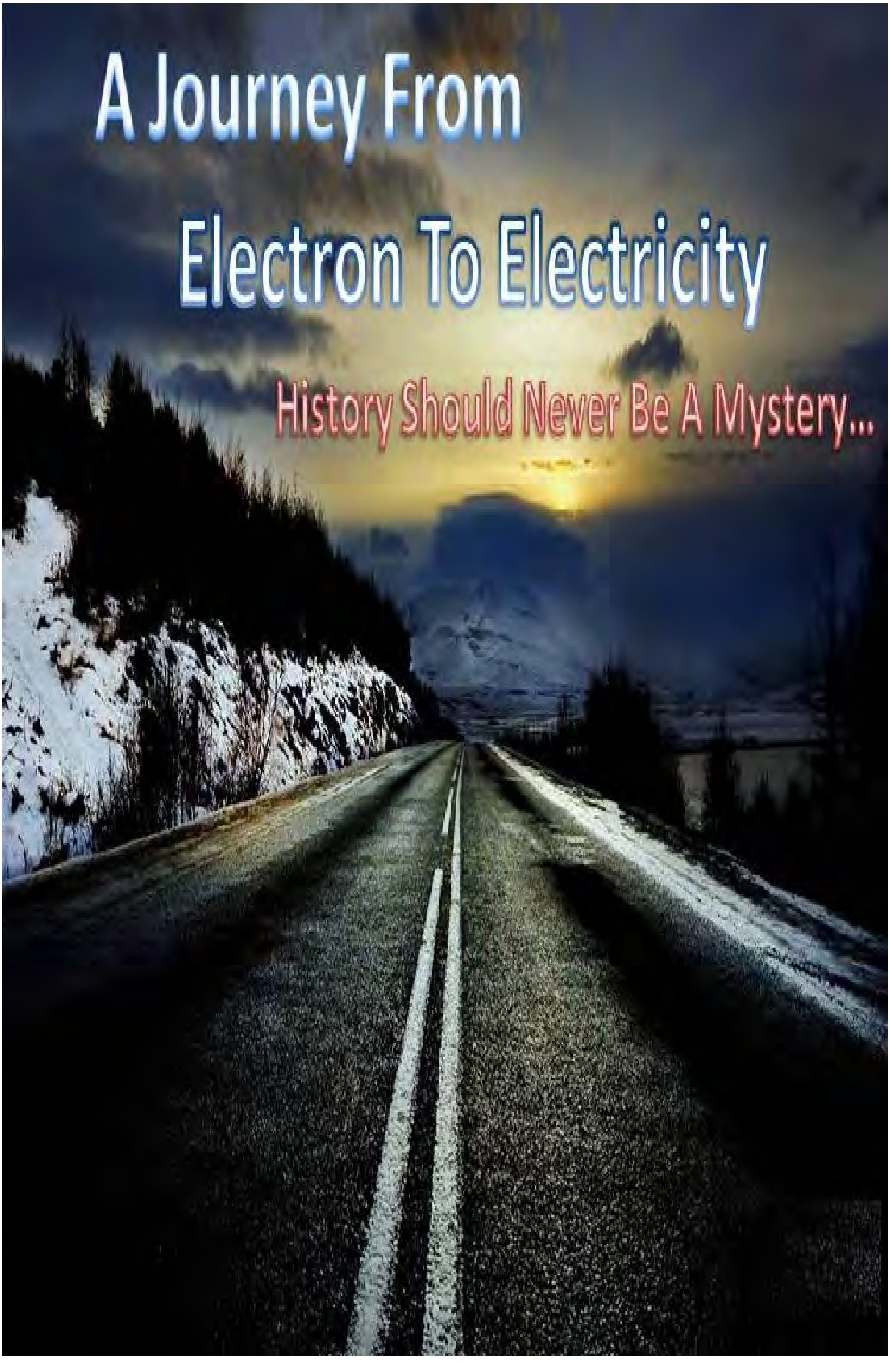

A Journey From
Electron To Electricity
History Should Never Be A Mystery...

A Journey From

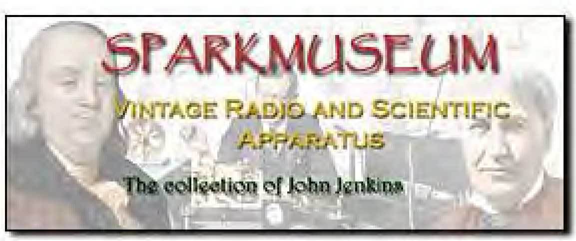
Electron To Electricity

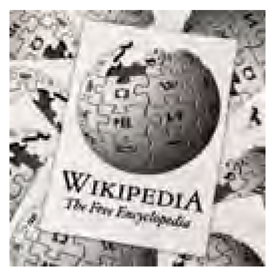
History Should Never be a Mystery………….

Contents

In this book the required information is collected from many websites, books, articles, newspapers & some documentary videos. In some cases only one word or one sentence or one image is taken from a particular website/book. So considering space & some other factors we are unable to provide all the references but only sources from where maximum information collected is mentioned. We apologize for using information from any website/book & not mentioning. The major source of information is from Wikipedia & Spark Museum. At initial stages we were unable to find required information & also we were not clear about the topics to be included at that time these two sources provided a proper path for us. So we are glad for an opportunity to thank them for their direct or indirect help.

A special Thanks to





GiriBabu K E
Girike4@gmail.com
http://journeytomysteriouslife.wordpress.com/

Letter to Spark Museum

Respected Sir,

My name is Giri Babu K E and I am currently pursing my Bachelor's in Electrical Engineering from Sri Jayachamarajendra College of Engineering in Mysore, Karnataka India. Being a student of Electrical Engineering, I was felt the urge to contribute something towards the development of my branch. In this regard, Some of my friends and myself, have collated a book called " History Of Electricity" to serve the purpose, the major intent being to arouse interest in the students towards electricity and make education as lively as possible.

The information in the book is collected from different websites across the internet, some books and documentaries. Among these, the major source of information is your website. When we first started the project we did not know how to go about with it. We were totally confused about the topics to be included, at this juncture, your help proved to be crucial for us. So we are very glad to take this opportunity to thank you for the support and also request you to permit us to utilize the information present in your website.

At the present moment, we are still undecided about approaching any publisher for the book. Our main aim still remains to make an effort to spread the book to everyone who needs it. We have worked more than three years on the book, collecting information from various sources, and arranging information in a suitable format hoping to create eagerness in our fellow students.

We are also sending one copy to you , if there are any mistakes, or additions to be made on our behalf, please intimate us. We would be glad to hear from you Sir.

Thanking you in advance
yours faithfully

Giri Babu K E

Letter from Spark Museum

Hello Giri,
You are welcome to use my site as a source for your PDF (very nice job, by the way). Before I can grant publishing rights in any other form I would need to know more specifics, so please do let me know if you plan to publish in print.

Best regards,
John Jenkins
www.sparkmuseum.com

Introduction

An enormous part of our lives is affected by electricity, from dawn to dusk, from the geyser which we turn 'ON' on the morning wake, the power to our coffeemaker, the traffic lights on our way to workplace, and the computers and equipment we use once we get to place. Without electricity, life, as we know, would be dramatically different. Still, most of the people never stop to think about how this essential utility became such a huge part of our lives.

There requires no deep research in the pages of antiquity to trace the rise & progress of the science of electricity. Electricity existed as lightning in the skies since the beginning of the universe, even before there was life on earth. Early-times our ancestors, those who were residing in caves, probably recognized the force of electricity when lightning struck. There are evidences that, we were aware of electricity as far back as 600 BC. Thales of Miletus is thought to be, the first to study the creation of electrical energy. While experimenting with amber rods, Thales found that, after rubbing them, they attracted lightweight objects. But it sprang into being in comparatively recent times; & after the first halting-stages of its existence were surmounted, it advanced from infancy to manhood with the rapidity of its own lightning spark; it has attained a degree of importance scarcely to be equalled by any of the physical sciences.

There are many great names, great souls who contributed for the development of this field. The pain, tears, stress they have experienced physically, mentally, emotionally in the development of this field is something which is immortalized in the annals of Electrical history. But even then, in this 21st century with technology at the tip of fingers why are we still failing in the proper utilization of natural energy? Why even today almost half of the power generated is lost before it is utilized by a consumer? Why electrical field is still lagging in R & D field compared to other, why in electrical we talk much about evolution rather than revolution. Why many villages are still not electrified? Can you believe according to R.E.B (Rural Electricity Board) & S.E.B (State Electricity Board) still around 80,000 villages are yet to be electrified in India (according to 2004 senses). Sounds unbelievable but still there are people who have not seen a glowing bulb in their entire life. Electricity-one of the science's most wonderful blessings is still out of their reach. Why have we failed to make ourselves 'electricity-self sufficient' though we are blessed with the most resourceful nature?

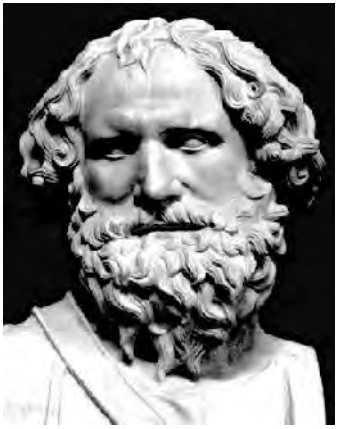
We are confident that the topics we have discussed in this book would be of intellectual interest to you. *We do not claim any credits for this! The credit goes to the topics themselves.* Let we stop this preamble here , may we now invite you dear reader for a journey from electron to electricity, please do bear in mind that we are only a tourist guide & fellow-travellers!.

Before will get into the discussion, I know what all might be thinking why should we know about history? What so important about it? After all, it has already happened. There is nothing we can do to change it. What is the big deal? In fact, a vital part of a successful future depends on knowing about the successes and failures of the past. If you are not agree, let me tell you a story to make the disagree; agree.

The following story describes how important it is to know the history.

Source: *Documentary on Archimedes by PBS-NOVA titled "Infinite Secrets-The Genius of Archimedes"*

This is the book that could have changed the history of the world, it contains the revolutionary ideas of a genius who was centuries ahead of his time Archimedes. The book was lost to the world for more than thousand years, passing through the hands of scribes, monks, forgers. Yet no one seems to know the book's true value until it surfaced at auction selling for 2 million dollars. The buyer who was a billionaire instead of hiding it away he put the manuscript into the hands of those who could unlock it secrets.



But interpreting Archimedes manuscript proved to be more difficult than any one had imagined, the newly invisible tracings of his words lay under the writings of prayer book. As scientists worked to recover the text from this fragile document they discovered that the Archimedes was further ahead of his time than they had ever believed, if his secrets were not hidden for so long the world today could be a very different place. We could have been on Mars today; we could have accomplished all of the things people are predicting for centuries from now.

This book is nothing but Archimedes brain & it for us to dig into that & pull out new thought & what he has to say in the combination of remarkable journey one that began 2000 years ago.

A typical page from the Archimedes Palimpsest. The text of the prayer book is seen from top to bottom, the original Archimedes manuscript is seen as fainter text below it running from left to right.

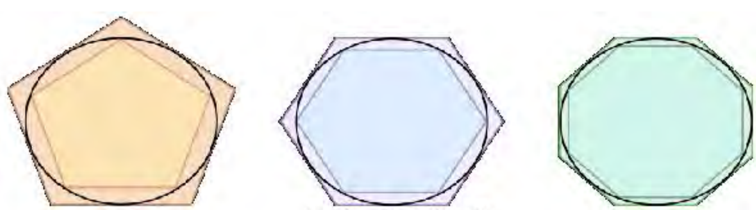
As soon as you heard Archimedes name you will remember the story of crown, if you haven't here is the story for you. "On one particular day Archimedes was trying to solve about a problem of golden crown given to the king of Syracuse, the king suspected that the jeweller had cheated him and substituted some less precious metal for the gold. King asked Archimedes to find a way to demonstrate that the crown was not pure gold without melting it."

Archimedes struggled with the problem for a very long time. Then, one day, as he stepped into a bathtub filled with water, he saw that the water overflowed. He "noticed that the amount of water that overflowed the tub was proportional to the amount of his body that was submerged." & this would apply to the crown too, he could find density of the crown by immersing it in a vessel of water & seeing how much water is displaced. He is so excited by this discovery that he immediately leaped out of his bath & without throwing any clothes on he ran naked through the streets shouting the Greek word 'Eureka' means I found it.

What he had discovered was the principle of liquid displacement & a way to prove the king's crown was too big to be a pure gold.

Archimedes not only excels in mathematics but he was an inventor as well, many of his ideas were used in machines today, but he was best known & feared for his weapons of war. But Archimedes true love was mathematics; he devised an ingenious method using straight lines to measure a circle finding the value of 'Π'. It's one of the most widely used mathematical values today; Archimedes wants to find a value as close as possible to the ratio of circumference of a circle to its diameter.

Discovering the value of 'Π'



Archimedes polygon's

We come across many formulas in our daily life but none of us know the meaning & true value of it. Let me give you an example, suppose if I tell you to *calculate area of a circle with radius 5 cm. you just take calculator press 'π' multiply by 5^2 & press '=' the result is 78.53 sq.cm. How much time you needed to solve this? Assuming you had calculator in your hand it will not take more than 5 seconds. What if I tell you that it actually takes 5 days, you will laugh at me. But it actually does if you had not appreciated the value of 'π'. Like everyone else I was also not knowing the meaning of it until I read about Archimedes.*

In 2000 years ago they didn't had any instrument/ technique to find the area of a circle. They could be able to find area of geometry with only straight lines. This was the puzzle for many in those days. Then Archimedes venture to find a solution for the same with the help of polygons.

What he did was, He began with a circle & then inscribed a triangle in it like a shell, he could find the perimeter of triangle since it has straight sides & now the perimeter of triangle is less than the perimeter of the circle. This represented first approximation a lower bound to the circumference of a circle. Continuing further he inscribed the pentagon then hexagon & determining its circumference he had better approximation. He continued this way going from 6,12,24,48 & finally ended with 96 & he didn't stopped their he repeated the same for the outside the perimeter of a circle. The circumference lies between the perimeter of outer & inner polygons which can be measured because they have straight sides. Like this he took the circles with different sizes & repeated the same procedure. By examining the results closely he could sense something common among them. Then he tried to fit the diameter around the circumference of a circle, to his surprise he found that how big/small the size of circle the diameter will fit around the circle 3.14 times a very good approximation for what we now call 'π'. With this he can find the area of any circular object by a simple formula A=πr^2.

Archimedes death in 212 B.C. brought golden age in Greek mathematics to an end. There was no one who could follow him. The Greek mathematicians slowly declined & then the Dark Age, the ages were all interest in mathematics was lost & as a result nothing really interested there scientifically.

But many of Archimedes writings did survive, copied by scribes who passed on his precious mathematics from generation to generation until in the 10th century one final copy of his the 'Method' was made. But interest in mathematics had now died Archimedes name was forgotten then, but one day in 12th century a monk ran out of parchment. The paper were reused to make a prayer book, the page was washed or scraped clean enough so that it would be then possible to write over them. The manuscript was become what's known as palimpsest.

At last science had advanced far enough for scholars to re-discover & understand the Archimedes surviving works. Renaissance mathematicians had to grapple with concepts & problems that Archimedes had worked out centuries before. If mathematicians & scientists of Renaissance had been aware of these discoveries of Archimedes that could have a tremendous impact on development of mathematics.

The book 'Method' revealed that Archimedes had come up with a radical approach that no mathematicians had come close to inventing. In his head he dreamt up entirely imaginary scales to compare the volumes of curve shapes he used this to try & work out the volume of sphere. Using very complex mathematics in his head in which he imagined cutting the shapes into an infinite number of slices & summing all the slices. The final result after all the arithmetic was done was the volume of sphere is precisely 2/3rd of the volume of the cylinder that enclosed the sphere; it is an important mathematical discovery.

Working out volumes using infinite slicing suggested by the Archimedes was taking the first step towards the vital branch of mathematics known as calculus 1800 years before it was invented. Building on Archimedes discoveries scientists beginning with Newton & Gottfried Leibniz created the calculus we know today It was Archimedes work with infinity that ultimately let him to the beginning of calculus. The new findings reveal that Archimedes was more sophisticated & closer to modern science than any one was realized.

Perhaps the most interesting question of all is 'what might have happen if this document had not been lost for a millennium' suppose it was available to those mathematicians of the Renaissance; who knows how different modern world might look.

So the only way to create interest among the students is to explain them the history of electricity; like how electricity became an essential part of our life, who are the great personalities contributed for the development of this field, what are the struggles they have overcome in their journey, many more facts which have been revealed & the facts which are buried beneath the earth, the secrets in the history of electricity. So here we have made an effort to present all *the above topics in suitable format hoping to create eagerness in the students. The topics which we dealing are the questions, which the thinking man has been asking himself from millennia.*

The research has taken many years, has necessitated the gathering of a large collection of ancient, and now exceedingly scarce, writings, not commonly found even in great libraries, and the sifting of an immense mass of recorded facts and theories, often arising in fields far removed from those in which it might naturally be supposed the requisite data would be discovered.

With this we will wind up our discussion, next we will introduce you to 'History of electricity'. Enjoy your ride................

Know More

Have you ever thought of why all the equipments in our home are rated at 240 volts & 50Hz? Why not some other voltage & frequency, also in India 3 phase power supply is standard? Not only in India almost in all the countries 3 phase 50 Hz supply is standard. The choice of the frequency & voltage is not as arbitrary as one might think. When an alternating voltage is considered several types of alternating voltages are possible, like sinusoidal, block or triangular-shaped, but why sinusoidal alternating voltage is the right choice? What happens if supply frequency is changed from 50Hz to some other value & also if we change voltage levels & number of phases. Try to find answers to above questions if not you will get to know in your journey.

Beginning

Before the nineteenth century, electricity was a science of sparks & shocks. Most early experiments were intended to display this mysterious power of nature in the most spectacular fashion possible or to bring out the strange subtleties of its action. The history of the advancement of science shows that its progress has not lacked continuity. No one man, or no generation of men, can be justly credited with all that is involved in any one of the great inventions or memorable discoveries with which science has enriched the world. All have built upon the labours of their predecessor, & to understand the completed work it is necessary to know something of the history of its various stages.

The initial idea—the germ—found its lodgement in some brain existing at an epoch far beyond the limits of history. As stated already the existence of Electricity was observed as lightning in the skies since the beginning of the universe, even before there was life on earth. There are evidences that people were aware of electricity as far back as 600 BC. Thales of Miletus, father of Ionic philosophy is thought to be the first to study about the creation of electrical energy. While experimenting with amber rods, Thales found that, after rubbing them, they attracted lightweight objects.

The dates of Thales' life are not known precisely. The time of his life is roughly established by a few dateable events mentioned in the sources and an estimate of his length of life. Thales involved himself in many activities, taking the role of an innovator. Some say that he left no writings, others that which he wrote "On the Solstice" and "On the Equinox" neither have survived. Many investigators were fascinated with lodestone & over the years many experiments were conducted with it.

In the 11th century, the Chinese scientist Shen Kuo (1031–1095) was the first person to write of the magnetic needle compass and that it improved the accuracy of navigation by employing the astronomical concept of true north (Dream Pool Essays, AD 1088), and by the 12th century the Chinese were known to use the lodestone compass for navigation.

It wasn't until 1600A.D. that Thales' study was significantly expanded upon. While many were curious about electricity, no one made any substantial advancement in the field until an Englishman named William Gilbert studied electricity along with magnetism and argued that they were not the same thing.

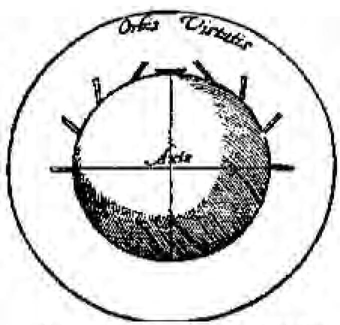
Gilbert, also known as William of Colchester, performed important early studies of "Electricity and Magnetism". He spent 17 years experimenting with Magnetism and, to a lesser extent, Electricity. For his work on magnets, Gilbert is known as the "Father of Magnetism." He was the founder of the modern sciences of Electricity and Magnetism. He discovered various methods for producing and strengthening magnets. For example, he found that when a steel rod was stroked by a natural magnet the rod it became a magnet, and that an iron bar aligned in the magnetic field of the earth for a long period of time gradually developed magnetic properties of its own. In addition, he observed that the magnetism of a piece of material was destroyed when the material was sufficiently heated.

De Magnete

The first book on electricity and magnetism, considered one of the greatest books in the history of science.

In his famous book "De Magnete" (1600), he was the first to describe the earth's magnetic field and to assume the relationship between electricity and magnetism. This is one of the great classics of experimental physics.

He also wrote about the electrification of many substances in his book. He first coined the term "Electricity" from the Greek word for amber. Gilbert was among the first to divide substances into Electrics (spar, glass, amber) and Non-electrics. He was also the first person to use the terms Electric force, Magnetic pole, and Electric attraction. William Gilbert was a pioneer of the experimental method and the first to explain the "Magnetic Compass"



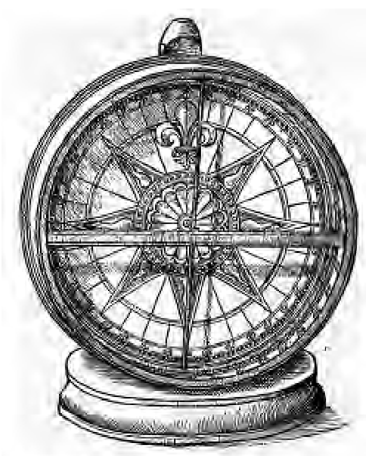
Gilbert's terrella, a model of the magnetic Earth

Of his own experiments, the most important was conducted with a magnetized "terrella" ("little Earth"), a spherical magnet serving as a model for the Earth. By moving a small compass over the surface of the terrella, Gilbert reproduced the directional behaviour of the compass; reputedly, he also demonstrated this in front of Queen Elizabeth and her court.

He also developed Versorium. The Versorium is a needle constructed out of metal which is allowed to pivot freely on a pedestal. The metal needle would be attracted to charged bodies brought near it, turning towards the charged object. Since it is able to distinguish between charged and non-charged objects, it is an example of a class of devices known as electroscopes. It can be noted that the Versorium is of a similar construction to the magnetic compass, but is influenced by electrostatic rather than magnetic forces. At the time, the differences between magnetic and electrical forces were poorly understood and Gilbert did a series of experiments to prove they were two separate types of forces with the Versorium and another device called a Terrella (or "little Earth").

What was known before Gilbert about Magnets?

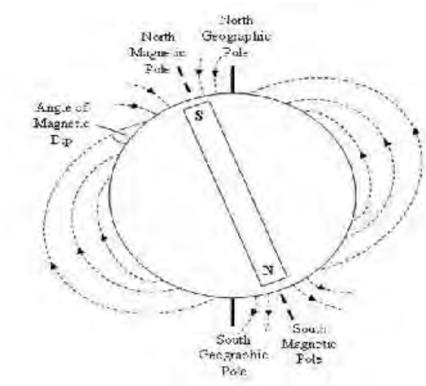
The ancient Greeks knew about lodestones (sometimes spelled loadstones), a Lodestone is a naturally occurring piece of magnetic iron oxide. It is often bound in a brass frame, and is oriented to place the magnetic poles at the ends. The word magnet comes from the region called Magnesia in Asia Minor. The early Chinese also knew about lodestones and about iron magnetized by them. Around the year 1000 they discovered that when a lodestone or an iron magnet was placed on a float in a bowl of water, is always pointed north. From this developed the magnetic compass, which quickly spread to the Arabs and from them to Europe. The compass helped ships navigate safely, even out of sight of land, even when clouds covered the stars. Compasses were also built into portable sundials, whose pointers had to face north to give the correct time.



Gilbert's dip circle, as represented in the De Magnete

The nature of magnetism and the strange directional properties of the compass were a complete mystery. For instance, no garlic was allowed on board ships, in the mistaken belief that its pungent fumes caused the compass to malfunction. Columbus felt the compass needle was somehow attracted by the pole star, which maintained a fixed position in the northern sky while the rest of the heavens rotated around it.

Two things were noted in those centuries. First, the compass needle did not point exactly north (towards the pole star) but veered off slightly to the east. And second, the force on the needle was not horizontal but slanted downwards into the Earth.



William Gilbert however explained that the earth actually has two sets of poles. One set of poles are the geographic poles. The geographic poles are the ends of the imaginary axis around which the world rotates. The other set of poles are the magnetic poles. The magnetic poles in the north are not in the same place as the north geographic pole. The location of the geographic poles of the earth does not change. However, the location of the magnetic poles of the earth change constantly, though not greatly, as time goes by. Due to the changing locations of the magnetic poles, we probably should think of the location of the magnetic poles as polar areas rather than exact points.

Previously to the announcement of Dr. Gilbert's discoveries, the only known electrics were amber, tourmaline, & jet, the accessions he made to the number must be regarded as an important first step in the progress of electricity. He added at least twenty to the list of electrics, including most of the precious stones, glass. Sulphur, sealing-wax, & resin; & he determined that those substances, when rubbed under favourable circumstances, attract not only light floating bodies, but all solid matters whatever, including metals, water, & oil. He observed also that the conditions most favourable to the excitement of attractive power are, a dry state of the atmosphere, & a brisk & light friction; whilst moist air & a southerly wind he found to be most prejudicial to the production of electrical effects.

William Gilbert died on 30 November 1603 and was buried in Holy Trinity, an Anglican church, in Colchester where a monument was erected to his memory. The Gilbert (Gi) is the CGS unit of Magneto motive force, equal to 10/4p = 0.795 775 ampere-turns, is named for him in honour.

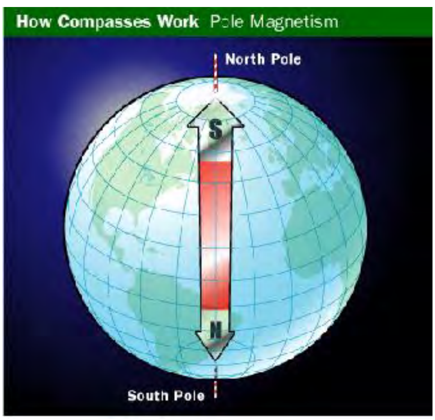
Gilbert's experiments led to a number of investigations by many pioneers in the development of electricity technology over the next 350 years. Many seventeenth-century scientists would discover rudimentary electrical phenomena & would take to rubbing electrics after reading De- Magnete.

After the discoveries & investigations of this father of electric sciences, there was a lapse of about many years with scarcely any progress.

We all know that compass will always point toward the North Pole. But what makes a compass work the way it does? And why is it useful for detecting small magnetic fields.

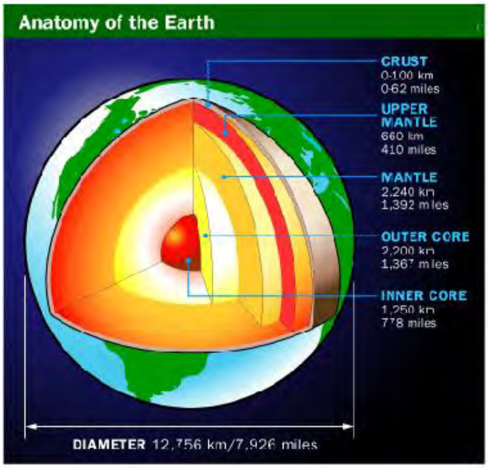
A compass is an extremely simple device. A magnetic compass consists of a small, light weight magnet balanced on a nearly frictionless pivot point.

Earth's Magnetic Field



The reason why a compass works is more interesting. It turns out that you can think of the Earth as having a gigantic bar magnet buried inside. In order for the north end of the compass to point toward the North Pole, you have to assume that the buried bar magnet has its south end at the North Pole, as shown in the diagram at the left. If you think of the world this way, then you can see that the normal "opposites attract" rule of magnets would cause the north end of the compass needle to point toward the south end of the buried bar magnet. So the compass points toward the North Pole.

The magnetic field of the Earth is fairly weak on the surface. After all, the planet Earth is almost 8,000 miles in diameter, so the magnetic field has to travel a long way to affect your compass. That is why a compass needs to have a lightweight magnet and a frictionless bearing. Otherwise, there just isn't enough strength in the Earth's magnetic field to turn the needle.



The "big bar magnet buried in the core" analogy works to explain why the Earth has a magnetic field, but obviously that is not what is really happening. So what is really happening?

There are very complicated theories to explain, but there is a working theory currently making the rounds. As seen on the left, the Earth's core is thought to consist largely of molten iron (red). But at the very core, the pressure is so great that this superhot iron crystallizes into a solid. Convection caused by heat radiating from the core, along with the rotation of the Earth, causes the liquid iron to move in a rotational pattern. It is believed that these rotational forces in the liquid iron layer lead to weak magnetic forces around the axis of spin.

It turns out that because the Earth's magnetic field is so weak, a compass is nothing but a detector for very slight magnetic fields created by anything. That is why we can use a compass to detect the small magnetic field produced by a wire carrying a current.

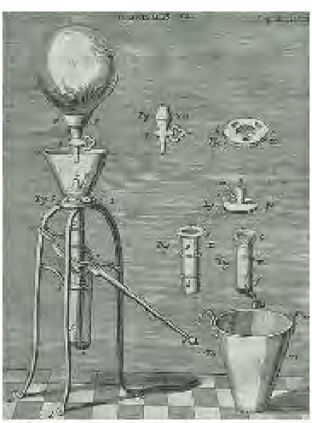
Source: *"How stuff works"*

http://adventure.howstuffworks.com/outdoor-activities/hiking/compass1.htm

Birth of first Electrical Generator

The most important advances in the science after Gilbert were made by a German physicist, engineer and natural philosopher Otto Von Guericke who built the first machine to create an electric spark. He used this electrical generator for many experiments with electricity; He invented the first air pump and used it to study the phenomenon of vacuum and the role of air in combustion and respiration.

On November 20, 1602, Otto Guericke was born as son of a patrician family resident in Magdeburg. Guericke studied astronomy and as a convinced Copernican, von Guericke was concerned with the nature of space and the possibility of empty space and the means of action across it. Guericke was conducting several scientific experiments in his yard. He become interested in the atmosphere, thus he studied the work of Galileo and Torricelli.



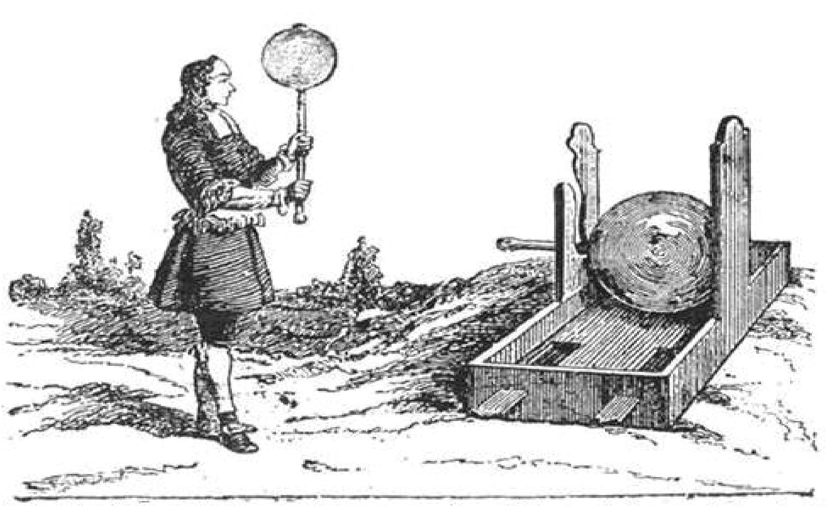
Otto von Guericke's air-pump

He made his first suction pump in 1647 and continued in the following years to work at improving it into a real air pump. In 1650 he invented the air pump, which he used to create a partial vacuum. Guericke used his pumps to study vacuums and the role of air in combustion and respiration. Otto van Guericke made several very spectacular experiments with his air pumps. In 1654 Guericke placed two copper bowls (Magdeburg hemispheres) together to form a hollow sphere about 35.5 cm (14 inches) in diameter. After he had removed the air from the sphere, two teams of eight horses were unable to pull the bowls apart, even though they were held together only by the air around them. Thus the tremendous force that air pressure exerts was first demonstrated.

Guericke used his air pumps for many other experiments including experiments with electricity and magnetism. He proved that a lodestone, or magnet, can attract iron even in a vacuum; and that electrical attraction works in a vacuum as well. Air is needed by neither magnets nor electrics. It was a great breakthrough.

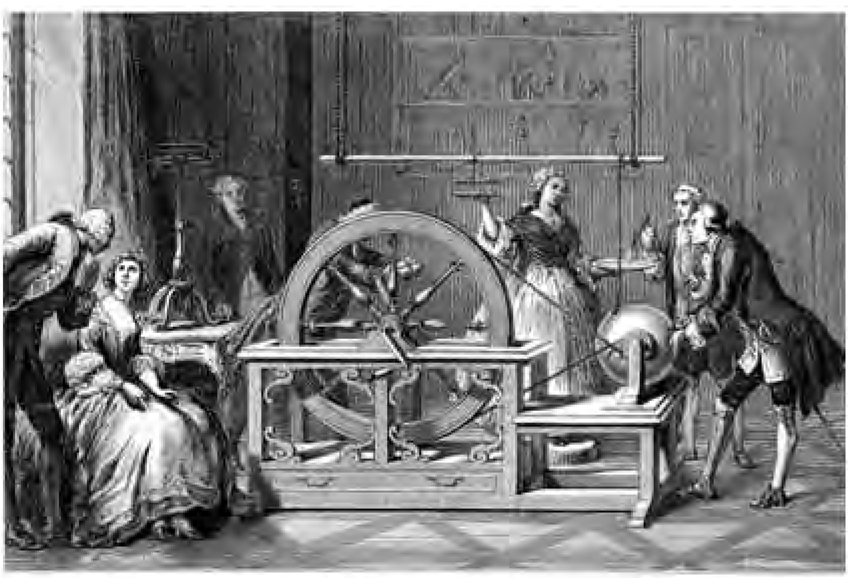
Guericke's electric generators

The apparatus with which electricians had experimented till near the end of the seventeenth century was of the simplest kind. A rod or flat surface of glass, resin, or sulphur, rubbed with the hand or with a piece of woollen, was their best means of exciting electricity; it may therefore be supposed that the quantity at any time under observation was very small. In 1663 Otto van Guericke invented the first electric generator, which produced static electricity by applying friction in the machine. The generator was made of a large sulphur ball cast inside a glass globe, mounted on a shaft. The ball was rotated by means of a crank and a static electric spark was produced when a pad was rubbed against the ball as it rotated. The globe could be removed and used as source for experiments with electricity.



The first Guericke's electric generator with a rotating sulphur ball

Later editions increased the speed of the rotation with a belt and rotating wheel. Electrical demonstrations became a favourite parlour trick for guests, but the electric machine also allowed scientists to perform experiments that could not be performed earlier.



In 1740 von Bose, a professor of physics at Wittemberg, substituted glass for the sulphur, and improved the rotating mechanism. He also suspended a metal cylinder above the globe by silk strings, with a metallic chain to conduct the electricity from the globe to the cylinder. This method of collecting is shown in figure above. From that time the electrical machine evolved rapidly. First, the shape of the rubbed body was modified: Watson employed four glass globes; Wilson, Cavallo, and Nairne used cylinders instead of spheres, Sigaud de la Fond, Le Roy, Cuthbertson, Van Marum, and Ramsden, used plates of glass instead of cylinders or globes. This allowed a larger surface area to be rubbed, and increased the speed of rotation.

Experimenta Nova Magdegurgica de Vacuo Spatio

Guericke published all his discoveries in a book titled "Experimenta nova Magdeburgica de vacuo spatio" . This remarkable work on experimental philosophy ranks next to Gilbert's in the number and importance of the electrical discoveries described.

The only property of electricity then known was that of attraction. Otto Von Guericke must also be conferred the honour of having discovered the property of electric repulsion. He ascertained that a feather, when attracted to an excited electric, after adhering to it for a short time, is repelled from the surface, & that it will not again approach until it has touched some other body to which it can part with the electricity it contains. He observed, also, that a feather when thus repelled by an excited electric, always keeps the same side presented towards it. As there was a correspondence between this fact & the position of the moon towards the earth, it was assumed that the revolution of the moon round the earth may be caused by electric attraction or repulsion. The discoveries of Sir Isaac Newton, shortly afterwards, dispelled this notion, & so far engaged the attention of scientific inquirers, that electricity for a time remained in abeyance.

Source:

- John Jenkins Spark Museum
- Wikipedia "http://en.wikipedia.org/wiki/Otto_von_Guericke"

Electroluminescence

Francis Hauksbee was English physicist who wrote a famous book "Physico-Mechanical Experiments on Various Subjects. Containing an Account of Several Surprising Phenomena Touching Light and Electricity" in 1709. It is one of the most important works in early electricity that introduced several new concepts and discoveries. He also invented a glass sphere, turned by a crank, which could build up an electric charge through friction.

He was also the first to study capillary action. Little is known of Francis Hauksbee's life; even the dates of his birth and death are not documented. He also made and sold instruments — e.g., cupping glasses used in surgery, air pumps, and barometers. He developed an improved air pump (though no one seems able to define precisely what Hauksbee's improvements were), and what was, in effect, the first static electric or frictional electric machine, a glass globe mounted on an axle (1706), and also a primitive electroscope to detect electric charges.

Hauksbee determined with reasonable accuracy the relative weights of air and water. Investigating the forces of surface tension, he made the first accurate observations on the capillary action of tubes and glass plates. He also made experiments on the propagation of sound in compressed and rarefied air, on freezing of water, and on elastic rebound. He measured specific gravities and refractive indices. He investigated the law of magnetic attraction and the time of fall through air.

Francis Hauksbee discovered that by putting a small amount of mercury in the glass of Von Guericke's generator and evacuating the air from it, when a charge was built up on the ball and then his hand placed onto it, it would glow. This glow was enough to read by and was similar to the phenomenon known as St. Elmo's Fire which was the name given to a strange glow seen around ships in electrical storms.

St. Elmo's fire (also St. Elmo's light) is an electrical weather phenomenon in which luminous plasma is created by a coronal discharge originating from a grounded object in atmospheric electric field (such as those generated by thunderstorms created by a volcanic explosion).

St. Elmo's fire is named after St. Erasmus of Formiae (also called St. Elmo, the Italian name for St. Erasmus), the patron saint of sailors. The phenomenon sometimes appeared on ships at sea during thunderstorms and was regarded by sailors with religious awe for its glowing ball of light, accounting for the name.

St. Elmo's fire is, in fact, a mixture of gas and plasma (as are flames in general, and also stars). The electric field around the object in question causes ionization of the air molecules, producing a faint glow easily visible in low-light conditions. Approximately 1000 volts a centimeter induces St. Elmo's fire; however, this number is greatly dependent on the geometry of the object in question. Sharp points tend to require lower voltage levels to produce the same result because electric fields are more concentrated in areas of high curvature, thus discharges are more intense at the end of pointed objects.

Conditions that can generate St. Elmo's fire are present during thunderstorms, when high voltage is present between clouds and the ground underneath, electrically charged. Air molecules glow due to the effects of such voltage, producing St. Elmo's fire.

The nitrogen and oxygen in the Earth's atmosphere causes St. Elmo's fire to fluoresce with blue or violet light; this is similar to the mechanism that causes neon lights to glow.

Source: Wikipedia *"http://en.wikipedia.org/wiki/St._Elmo%27s_fire"*

Early Electric Machines

(Static Electricity Generators)

Source:

- *John Jenkins Spark Museum*
- *Wikipedia "http://en.wikipedia.org/wiki/Electrostatic_generator"*

An electric machine consists of the combination of two materials, which when rubbed together produce static electricity, and of a third material or object which acts as a collector for the charges.

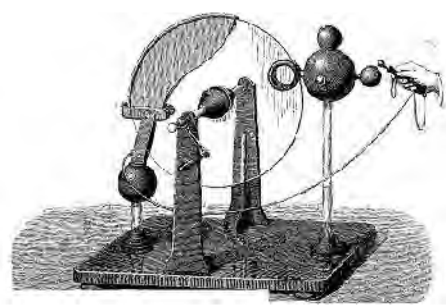
The first devices for producing electricity were very simple. The ancient Greeks discovered the strange effects of amber rubbed with fur and other material. In the 17th century, scientists used sticks of resin or sealing wax, glass tubes and other objects. By the time of Benjamin Franklin large glass tubes about three feet long and from an inch to an inch and a half in diameter were popular; these were rubbed either with a dry hand or with brown paper dried at the fire.

There are two major categories of electrical machines: Friction and Influence. A friction machine generates static electricity by direct physical contact; the glass sphere, cylinder or plate is rubbed by a pad as it passes by. Influence machines, on the other hand, have no physical contact. The charge is produced by inductance; usually between two or more glass plates. The charge could then be stored in a Leyden jar or measured by an electroscope.

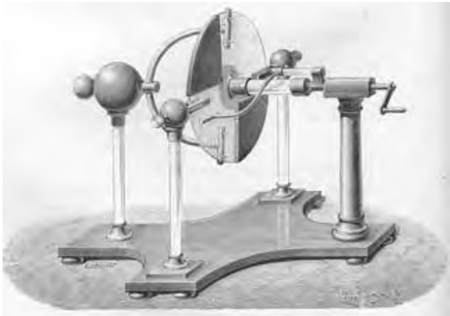
Ramsden Machine

One of the earliest and certainly classic friction machines is the Ramsden machine.

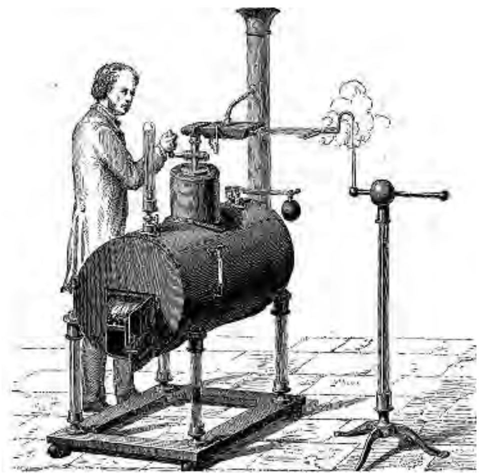
A large circular plate of glass is mounted vertically on a metal axle, about which it can easily be turned by a crank handle. When passing between the two wooden supports, the surface of the glass is rubbed by two pairs of pads fixed to the supports. The rotation of the glass then causes it to become electrified positively on both faces. The negative charge of the pads is neutralized by being connected to the ground through the frame, which is not insulated. Each pad is stuffed with hair, and is covered with leather: Its surface is coated with mosaic gold, or an amalgam of mercury with zinc, bismuth, or tin. Attached to the pads are silk cases which enclose the glass plate nearly as far as the combs, these are to prevent loss of charge.



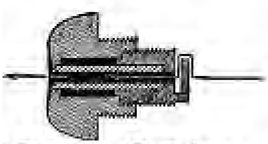
In 1772 Le Roy, a French physicist, constructed a glass plate machine with only one pair of pads; he had however used two insulated cylindrical conductors placed horizontally at opposite ends of a diameter, one attached to the pads and the other to the metallic comb, thus he collected both kinds of charge. Winter, an Austrian, slightly modified Le Roy's machine to a form shown in Fig above. The conductors are spheres; one is attached to the pads whilst the other is connected to 'the combs, constructed as two rings, one on each side of the glass. One conductor is charged positively, the other negatively. Winter's machine does not give a large quantity of electricity at each discharge, on account of the small size of the conductor, but it gives longer sparks than the other forms of machine of the same size.



Van Marum designed an electric machine, capable of acting at will to collect either positive or negative charges, or both kinds at the same time. If mercury is shaken up in a dry glass tube in the dark, a glow is seen, proving the production of small charges of electricity. In fact, enough electricity is produced to cause the tube to attract light bodies. This demonstrates that the friction of liquid bodies against solids can produce electricity.



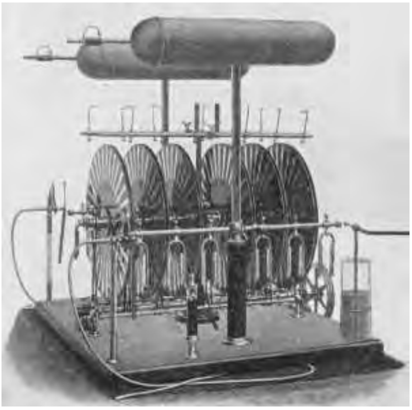
This method was not used, however, until, in 1840, an accident showed an easy method of producing large quantities of electricity by driving a jet of steam against a solid body. This is the principle of Armstrong's machine shown in figure left. An insulated boiler is filled with distilled water, which produces high pressure steam that escapes through a row of jets after being partly condensed by passing through pipes surrounded by cold water. The drops of water produced by the condensation strike against a plate of box-wood round which the steam has to pass before it escapes from the jets made of the same wood, as shown in Fig below.



Steam Orifice

Electricity is developed in proportion to the increase of the pressure of the steam; the jets become charged positively and the steam negatively. To collect the latter charge an insulated conductor is used, which is furnished with a series of points held opposite the jets. These hydro-electric machines are very powerful but were so difficult to use that they were never adopted in place of friction machines. There was one at the Polytechnic in London with forty-six jets, and which gave sparks two feet long, and one at the Sorbonne, in Paris, has eighty jets, and produced sparks several inches in length.

Wimsshurst Machine



Wimshurst machines are the end point of the long development of electrostatic disk machines. They caused very good results and were frequently used to power X-ray tubes. The characteristic construction element of these machines are disks which are laminated with radially arranged metal sheets. The advantage of disks is that they can be stacked onto one axle in order to multiply the effect.

All through the 18th and 19th centuries there was tremendous interest in electricity. Scientists such as Franklin, Nollet, Coulomb, Volta, Oersted, Ampère, Ohm, Faraday, Joule and others made major advances. Prior to Faraday's invention of the induction coil in 1831 however, the only way to generate high voltage electricity was via a static generator such as those stated above.

Why 50Hz power supply is standard in all countries?

The reason is that this is in the optimum range for power supply on a national scale. The use of lower frequencies would cause the size, weight and cost of the installed equipment to increase and the flicker of lights to become noticeable (as it was on early 25Hz systems). The use of higher frequencies would cause increase in the operational losses due to eddy currents, hysteresis, skin effect, radiation etc. and reactive voltage drops.

In physically smaller power systems such as those on planes, ships, submarines and even railways, higher frequencies are used because they allow reduction in the power equipment size and weight - i.e. the optimisation is different.

System frequency is standardized for economic reasons - if the same frequency is used over a wide area, then it is possible to interconnect systems. That makes it possible to share reserve energy supplies across that area resulting in lower costs and improved reliability for everyone.

50 Hz however, is not universal. Many countries use 60 Hz which is close to the same optimum as 50. 60 Hz users mainly are: almost all the Americas and some countries in Asia. Korea even uses both frequencies! 50 Hz prevails in Europe and ex-British colonies.

In the very early days of electrification, electrical loads were served by dedicated generation, so designers selected the frequency that they felt would result in the optimum design for loads and generation. Some of the early systems had frequencies as high as 135Hz. eventually, as the desire for interconnection emerged, it became necessary to standardize on a single frequency. The choice between 50Hz and 60Hz ultimately came down to the kind of lighting that was in widespread use in the region being served. In Europe, the prevailing practice (driven mainly by Siemens) was to use an enclosed-arc form of lighting at 50Hz. In North America, the practice was to use an exposed arc for m of lighting. Because the extinction time constant was shorter when the arc was exposed, there was a desire to supply those lights with a voltage that had a shorter period between zero crossings (to prevent 'flickering') - hence, the choice of 60Hz.

First experiment to show Electric Power can be transmitted over long distance

However, despite the enormity of scientific advancement during the seventeenth century, the laws of electricity stayed just out of reach. All this was about to change. Before the century was over, electricity would become a popular science with significant body of knowledge & many practical applications. The most ardent student of electricity in the early years of the eighteenth century was Stephen Gray. He performed a multitude of experiments, nearly all of which added something to the rapidly accumulating stock of knowledge, but doubtless his most important contribution was his discovery of the distinction between conductors & non-conductors.

Stephen Gray was born in Canterbury, Kent, England on December 26th 1666. His friendship with John Flamsteed most likely fired his interests in astronomy. From the 1690s to 1716 Gray devoted his scientific energies to astronomical observations. In the latter years of his life he devoted himself to electricity. His electrical interests first appear in a letter of 1708 to Hans Sloane, in which he described the use of down feathers to detect electricity. He is obviously fascinated by lights produced by rubbing a glass tube to charge it and realizes electricity and the lights are related. The idea of an effluvium released from the tube is giving way in his thoughts to ideas of a virtue, something akin to gravitational attraction and electrical conduction.

Gray's Apparatus

For his experiments, Gray used a simple 3.5 foot glass tube, 1.2" in diameter. When rubbed with a dry hand or dry paper the glass would obtain an electric charge. These glass tubes were popular - they were much more portable and less expensive and than the large "electrical machines" of the time.

Gray begins with some background on his reason for conducting these experiments he tells how he became interested in whether electric effluvia (scientists of the time believed electricity was a fluid) could be communicated between charged objects . This question came up as a result of his observation that his "tube communicated light to bodies", i.e. he saw sparks jump from the tube to objects held near it.

"He notices that the charged tube not only attracts a feather to the glass, but to the cork as well. From this he concludes that the "attractive virtue" is passed to the cork from the tube. Being a diligent observer, Gray proceeds to examine exactly how far the virtue can be passed. He attaches an ivory ball to a four inch piece of wood and inserts the other end of the wood into the cork. He finds that not only is the attraction and repulsion passed to the ball, it is even stronger than on the cork. So by accident Gray discovered one of the amazing phenomena that electricity can be transmitted to long distances, but how long is what Gray tries to find with his later experiments.

The first use of metal wire

Gray proceeds to try other materials between the tube and the ivory ball. He tries iron and brass wire which does pass the virtue, but vibration of the wire caused by rubbing the tube interferes with the experiment. So Gray uses pack-thread in place of the wire, and inserts a loop to absorb the vibrations of the tube. Again, he finds the effluvia is passed to the ball.

Gray searched around his house for any object that might be suitable for a test. He focused on metals first, testing several coins, pieces of tin and lead, a fire-shovel, tongs and iron poker, a tea-kettle (both empty and full, hot and cold water!) and a silver pint-pot. He found all of them to be conductive. Next he searched out what non-metal objects he could find, including several types of stone and some green vegetables, all of which he systematically hung from his harness of pack-thread, and all of which passed the "attractive virtue."

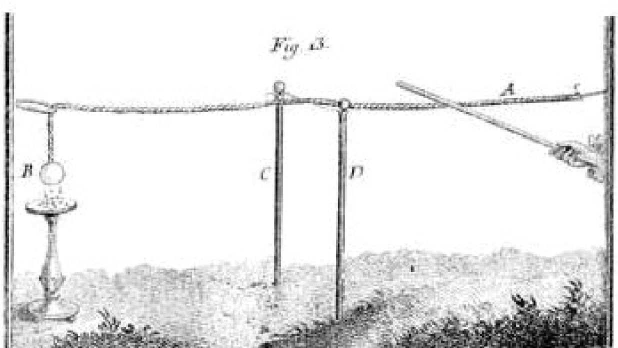
Over the next several days, Gray continued to experiment by extending the length of his apparatus, these experiments were performed vertically; that is, the assembly of rods, pack-thread, wire, etc., was hung vertically with the ivory ball at the bottom and the glass tube at the top. Gray did this out of simple practicality (hanging the thread required no supports to hold it above the floor, unlike a horizontal run would require), not because he believed the effluvia needed to run downhill. In any case, he extended his apparatus higher and higher, from 26 feet until he was as high as he could go on his balcony and still the virtues were carried the full 52 feet.

A horizontal run

Since he had reached the upper limits of the house, the next logical step was to run the thread horizontally. He attached one end of the thread to a nail in a beam and the other end looped over the tube. This time when he rubbed the tube nothing happened. He correctly concludes that the fault is in the connection from the thread through the nail to the beam; i.e. the 'electrical virtue" is passing into the beam rather than being carried to the ivory ball. His experiment was unsuccessful because he suspended the line by threads that conducted the electricity from it nearly as quickly as it entered.

At this point he decided to give up on the horizontal approach and perform more experiments with a vertical conductor. But where was he to find a building tall enough? Gray visited his young friend Granville Wheeler, who lived in a large house that would be very suitable for further tests. After several successful attempts, and reaching the highest point of the house, Wheeler suggested they try a horizontal span. Gray explained that his previous attempt had failed, and his theory as to why. It was then suggested by Mr. Wheeler, that cause of the escape of electricity was the thickness of the packthread employed, & he recommended that silk threads should be tried, because being much thinner, it was supposed the electric fluid would not be able to flow through it so readily Gray agreed this was worth a try, thinking that less of the electric virtue would leak out through the small silk thread.

On July 2, 1729, they assembled the experiment shown in Fig. below, using silk thread and poles to hold the packing thread above the ground. With a run of 80.5 feet, the leaf-brass was attracted to the ivory ball.



Gray's conduction experiment

Gray and his friend, conducted experiments which showed that objects such as cork, as far as eight or nine hundred feet away, could be electrified by connecting them to the glass tube with wires or hempen string. They found material such as silk would not convey electricity. They discovered distant objects could not be electrified if the transmission line made contact with earth. The line for transmission was suspended by silk threads to prevent contact with the ground. It was found that metal objects held in the hand and rubbed showed no signs of electrification. However, when mounted on a non-conductor, they became electrified. Gray realized that somehow the earth was responsible for conducting electrical charge away from the body. After this realization Gray found he could electrify any material on earth by friction.

So little were experimenters aware that the difference in the effects was caused by the different conducting properties of the substances employed. With the notion that success with the silk suspenders was entirely owing to their superior fineness, that they endeavoured to obtain still better results by suspending the line on very fine wires. The total failure of experiment in this case induced them at length to consider that there must be a difference in the conducting properties of the substances employed.

The attention of electricians thus directed to this subject, list of conducting & non-conducting substances were made, when it was found that glass, resin, & all bodies known electrics, were bad conductors of electricity, & that those in which electricity could be excited were conductors. In the conducting & non-conducting properties of these substances great differences was soon detected; glass & resin being the worst, & metals the best conductors.

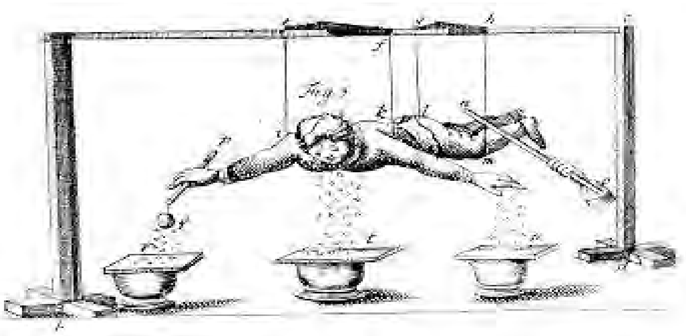
Grey sent many of his papers to the Royal Society, Gray's most important work, published in 1732, announced the discovery of electrical induction and the distinction between conductors and insulators. Despite the fact importance of his discoveries he received little credit at the time of his discoveries because of the factional dispute in the Royal Society, and the dominance of Newtonianism (which became the Masonic 'ideology'). By the time his discoveries were publicly recognized, experiments in electricity had moved rapidly on and his past discoveries tended to look trivial. For this reason, some historians tend to overlook his work.

There is no monument to Gray, and little recognition of what he achieved, against all odds, in his scientific discoveries.

Some Gray's papers fell into the hands of Charles François de Cisternay du Fay, an officer of the French army, who, after several years' service; he had resigned his post to devote himself to scientific pursuits. He repeated many of the experiments described by the Englishman, & became an enthusiastic student of the science. His work shows great acuteness of mind, as well as remarkable experimental skill. He made a critical examination of a curious experiment made by Gray, in which it appears that the colour of bodies influenced their susceptibility to electrical disturbance.

He had detected the existence of two distinct kinds of Electricity. This, like all other discoveries hitherto made, originated from accidental circumstances. A piece of gold-leaf having been repelled from an excited glass rod, M. Du Fay pursued it with an excited rod of sealing-wax, expecting that the gold-leaf would be equally repelled by that electric; but he was astonished to see it, on the contrary, attracted to the wax. On repeating the experiment he found the same result invariably to follow: the gold-leaf when repelled from glass was attracted by resin; and when repelled by the latter was attracted by glass. Hence M. Du Fay assumed that the electricity excited by the two substances was of different kinds; and as one was produced from glass, the other from resin, he distinguished them by the names VITREOUS and RESINOUS electricity.

At the time, there was a storage device named the Leyden jar. This was a glass jar, partially filled with water, and covered inside and out with tin foil. A wire ran through a cork stopper and, as electricity was generated, it passed through the wire into the jar, where it was stored. Since the Leyden jar could store a fairly large amount of electricity, Du Fay was able to perform some interesting (and potentially deadly) demonstrations. In one, he passed an electrical discharge through 180 soldiers who had joined hands in a circle (which also gave rise to the term "Circuit") by having the first soldier hold the jar and the last soldier touch the center wire. He (and others) apparently enjoyed themselves greatly, charging Leyden jars and shocking their friends and relatives. Unfortunately, they did not know that such shocks could be deadly.



One of the experiments devised about this period, which excited great astonishment, & tended to direct the attention of philosophic inquirers to the subject of electricity, was the development of sparks from the human body. Mr. Grey suspended a boy horizontally with hair lines, & communicated electricity to him by means of an excited glass tube, and then sparks were drawn from all parts of boy's body. This phenomenon, depending simply on the fact that the bodies of animals are conductors of electricity in consequence of the fluids they contain, was conceived to owe, in some mysterious manner, to a connection between the electric effluvium, as it was called, and the vital principle. M. Du Fay suspended himself in a similar manner for the purpose of experiencing the sensation, & the experiment soon afterwards became the most popular in the range of electrical phenomenon, when the more convenient mode of insulation by standing on a cake of resin, or on a glass stool, was introduced.

Water is found to be a conductor. It renders insulators conducting when the surfaces are wet or moist. This makes understandable the rapid loss of charge by electrified bodies on humid days.

In the last years of his life Du Fay did his work on the optical properties of crystals. Du Fay had taken the first steps toward a correlation of crystal form and optical properties. Unfortunately his early death prevented the full publication of his results. Du Fay died on July 16, 1739, after a brief illness. Du Fay's work was influential in Benjamin Franklin's later work with electricity, and he also influenced many other prominent scientists of the day.

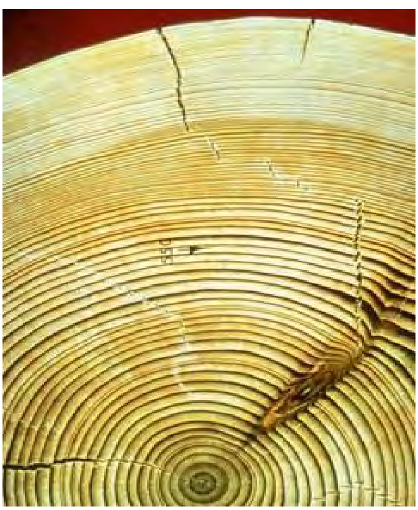
Source:

- Wikipedia http://en.wikipedia.org/wiki/Stephen_Gray_(scientist)
- John Jenkins Spark Museum

Tree Rings & Climate

Have you ever wondered how can we predict the age of a tree? Do you think trees are helpful in predicting the weather conditions?

Trees contain some of nature's most accurate evidence of the past. Their growth layers, appearing as rings in the cross section of the tree trunk, record evidence of floods, droughts, insect attacks, lightning strikes, and even earthquakes that occurred during the lifespan of the tree. Subtle changes in the thickness of the rings over time indicate changes in length of, or water availability during, the growing season.



Each year, a tree adds to its girth, with the new growth being called a tree ring. Tree growth depends upon local environmental conditions. In some areas the limiting factor for growth is water availability, in other areas (especially at high latitudes) it is the length of the growing season. In areas where water is limited and the amount of water varies from year to year, scientists can use tree-ring patterns to reconstruct regional patterns of drought. In areas where the length of the growing season is the limiting factor, the thickness of tree rings can indicate when growing seasons were longer (during warmer times) and when growing seasons were shorter (cooler times).

*The study of the growth of tree rings is known as **dendrochronology**. The study of the relationship between climate and tree growth in an effort to reconstruct past climates is known as **dendroclimatology**.*

A tree ring consists of two layers:

- A light colour layer which grows in the spring
- A dark colour layer which forms in late summer

At locations where tree growth is limited by water availability, trees will produce wider rings during wet and cool years than during hot and dry years. Drought or a severe winter can cause narrower rings too. If the rings are a consistent width throughout the tree, the climate was the same year after year. By counting the rings of a tree, we can pretty accurately determine the age and health of the tree and the growing season of each year.

Modern dendrochronologists seldom cut down a tree to analyze its rings. Instead, core samples are extracted using a borer that's screwed into the tree and pulled out, bringing with it a straw-size sample of wood about 4 millimetres in diameter, the hole in the tree is then sealed to prevent disease.

Computer analysis and other methods have allowed scientists to better understand certain large-scale climatic changes that have occurred in past centuries. These methods also make highly localized analyses possible. For example, archaeologists use tree rings to date timber from log cabins and Native American pueblos by matching the rings from the cut timbers of homes to rings in very old trees nearby. Matching these patterns can show the year a tree was cut, thus revealing the age of a dwelling.

Tree ring data is only collected outside of the tropics. Trees in temperate latitudes have annual spurts of growth in the summer and periods of dormancy in the winter, which creates the distinctive pattern of light and dark bands. Tropical trees grow year-round, and thus do not have the alternating dark and light band pattern that allows us to read tree ring records.

Tree ring records can be combined to create climate records that span a timeframe longer than the life of a single tree. For example, the data from a living, 200-year old tree could be combined with a data from wood from a tree that was felled 150 years ago (after living a couple of centuries) to produce a composite dataset spanning several hundred years.

Trees, alive or dead, are not the only source of wood used to construct such extended records. Beams from old buildings or ruins, samples from wooden frames of old paintings, and slivers from violins have all been used to add wood samples from trees long dead to climate chronologies. In some cases, tree rings enshrined in petrified wood even give us some insights into climate conditions in truly ancient times.

The oldest trees on Earth, the bristlecone pines of western North America, can live for more than 4,000 years. Dead bristlecone trunks, often well-preserved in the dry terrain upon which bristle cones grow, can be as much as 9,000 years old.

The proxy climate record preserved by tree ring data spans a period of about 9,000 years. The resolution of tree ring data is one year. Tree ring records are amongst the highest resolution proxy climate data types, but they also have one of the shortest time spans over which they apply as compared to other proxies.

Scientists have used tree rings, whose width can reflect climate conditions experienced during each growing season, and they have used glaciers, which accumulate a new layer of ice with each year's snowfall. High-resolution ice cores from Greenland have shown multiple events during the past 100,000 years in which air temperatures abruptly rose and fell by as much as 10°C (18°F) within a decade. Scientists have found clues to past oceanic conditions preserved in sediment cores that accumulate in sequential layers on the seafloor.

Source:

- *Window to Universe*

  "http://www.windows2universe.org/earth/climate/CDcourses_treerings.html"

Leyden Jar; First storage device

Source:

- *John Jenkins SparkMuseum*
- *100 greatest science inventions of all time By Kendall F. Haven*
- *Electricity Its History and Development By William A Durgin*
- *How Stuff Works- "http://electronics.howstuffworks.com/capacitor3.htm"*

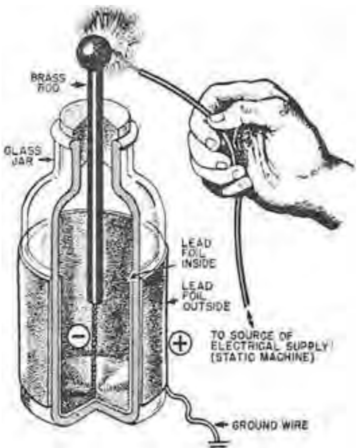
Till 17th century electricity depended upon the influence of rubbed glass rods or revolving globes were necessarily feeble because of the small size of the electric machines. Could not some way be devised of accumulating or storing the electricity-adding the product of the machine little by little until a considerable amount was obtained? Thus thought Von Kleist, Bishop of Pomerania, in 1745.

Glass was known to be a good insulator & water a good conductor, so, partly filling a glass bottle with water & arranging a nail to lead from the machine to the water, he held the bottle in one hand & worked his machine with the other. After some minutes he tried to disconnect the nail & was greatly terrified to "receive a shock which stuns his arms & shoulders." He had succeeded-the electricity had accumulated far beyond his expectations-and the Leyden jar was discovered.

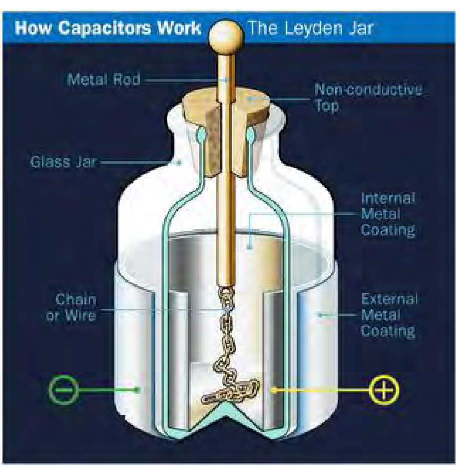
Pieter van Musschenbroek

As has so many times happened in the history of scientific discovery, it seems tolerably certain that this interesting device was hit upon by at least three persons, working independently of each other. One Cuneus, a monk named Kleist, & Professor Musschenbroek, of Leyden, are all accredited with the discovery; but the name of the city in which it was earliest exhibited & experimented with is that by which it has ever since been known. By its use, electricians were immediately able to work upon the mysterious "virtue" or "effluvia" in larger quantities, & to produce effects entirely unknown before.

Experiments soon showed that the hand outside the glass was just as important as the water within, later hand & water were replaced with tinfoil coatings as in the jars now used. This led at once to discovery that the outer coating must be connected to the rubber of the machine for the best action; & that larger the jar the greater was the accumulation.

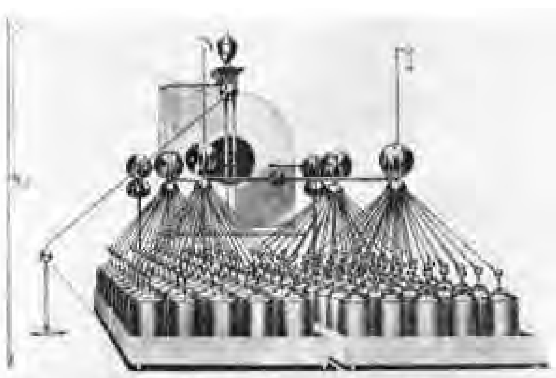


A Leyden jar consists of a glass jar with an outer and inner metal coating covering the bottom and sides nearly to the neck. A brass rod terminating in an external knob passes through a wooden stopper and is connected to the inner coating by a loose chain. When an electrical charge is applied to the external knob, positive and negative charges accumulate from the two metal coatings respectively, but they are unable to discharge due to the glass between them. The result is that the charges will hold each other in equilibrium until a discharge path is provided. Leyden jars were first used to store electricity in experiments, and later as a condenser in early wireless equipment. The Leyden jar was used to conduct many early experiments in electricity, and its discovery was of fundamental importance in the study of electricity. Previously, researchers had to resort to insulated conductors of large dimensions to store charge. The Leyden jar provided a much more compact alternative.



The original form of the device was just a glass bottle partially filled with water, with a metal wire passing through a cork closing it. The role of the outer plate was provided by the hand of the experimenter. Soon it was found that it was better to coat the exterior of the jar with metal foil (Watson, 1746), leaving the impure water inside acting as a conductor, connected by a chain or wire to an external terminal, a sphere to avoid losses by corona discharge. It was initially believed that the charge was stored in the water. Benjamin Franklin investigated the Leyden jar, and concluded that the charge was stored in the glass, not in the water, as others had assumed. In general the charge may be stored in the conductors, on the surface along the inward surfaces, or on the surface of the *dielectric if these are separated by a thin air gap. The charge leaks to the surface of the dielectric if contact is imperfect and the electric field is intense enough. Because of this, the fluid inside can be replaced with a metal foil lining. Early experimenters found that the thinner the dielectric, the closer the plates, and the greater the surface, the greater the charge that could be stored at a given voltage. Further developments in electrostatics revealed that the dielectric material was not essential, but increased the storage capability (capacitance) and prevented arcing between the plates. Two plates separated by a small distance also act as a capacitor, even in vacuum.*

Originally, the amount of capacitance was measured in number of 'jars' of a given size, or through the total coated area, assuming reasonably standard thickness and composition of the glass. A typical Leyden jar of one pint size has a capacitance of about 1 nF.



An advanced electrostatic battery in 1795

Frequently, several jars were connected in order to multiply the charge. Experimenting with this type of capacitors started to become pretty dangerous. In 1783, while trying to charge a battery during a thunderstorm, Prof. Richmann was killed by unintended getting too close to a conductor with his head. He is the first known victim of high voltage experiments in the history of physics.

St. Petersburg, 6 August 1783. Prof. Richman and his assistant being struck by lightning while charging capacitors. The assistant escaped almost unharmed, whereas Richman was dead immediately.

Here at last was sufficient electricity to produce a real stir in the world. Writing in 1795, Cavallo says: "In short nothing contributed to make Electricity the subject of the public attention & excite a general curiosity until the capital discovery of the vast accumulation of its power in what is commonly called the Leyden Jar, which was accidentally made in the year 1745. Then, & not till then, the study of electricity became general, surprised every beholder, & invited to the house of electricians a greater number of spectators than were ever assembled together to observe any philosophical experiments whatsoever."

Benjamin Franklin & Kite Experiment

Benjamin Franklin was one of the Founding Fathers of the United States. A noted polymath, Franklin was a leading author and printer, satirist, political theorist, politician, postmaster, scientist, inventor, civic activist, statesman, and diplomat. As a scientist, he was a major figure in the American Enlightenment and the history of physics for his discoveries and theories regarding electricity. He invented the lightning rod, bifocals, the Franklin stove, a carriage odometer, and the glass 'armonica'. He formed both the first public lending library in America and the first fire department in Pennsylvania.

Benjamin Franklin was born in Boston Massachusetts, on January 17, 1706. He was the seventh child in his family. Franklin started going to school when he was ten, and became an apprentice to his older brother who owned a printing firm in Philadelphia. Even though he did not attend school for a long time, Franklin began interested in science. He was particularly interested in Electricity. Even though there were already many experiments being conducted in this field, none of them had fully explained the phenomenon.

A list of Benjamin Franklin's inventions reveals a man of many talents and interests. It was the scientist in Ben that brought out the inventor. His natural curiosity about things and the way they work made him try to find ways to make them work better.

For example Ben had poor vision and needed glasses to read. He got tired of constantly taking them off and putting them back on, so he decided to figure out a way to make his glasses let him see both near and far. He had two pairs of spectacles cut in half and put half of each lens in a single frame. Today, we call them bifocals.

Benjamin Franklin developed a theory that every object had an "Electrical fluid". He believed that some objects had too much of this fluid, while others did not. Franklin proposed that "vitreous" and "resinous" electricity were not different types of "electrical fluid" (as electricity was called then), but the same electrical fluid under different pressures. He was the first to label them as positive and negative respectively, by putting his theories together, he invented the *electrical battery. It was made out of glass, lead plates, silk thread, and some wire.*

The individual Leyden jar, the early form of what is now called a capacitor, gathers an electrical charge and stores it until it is discharged. Franklin grouped a number of jars into what he described as a "battery" (using the military term for weapons functioning together). By multiplying the number of holding vessels, a stronger charge could be stored, and more power would be available on discharge.

Franklin realized that if a piece of silk were rubbed against a glass, the glass would have a positive charge. Other scientists at that time believed that rubbing produced electricity; however Franklin said that it was just the "Electric fluid" being transferred from the silk to the glass. This is known today as the law of conservation of change and it is one of the basic principles of physics.

Charge conservation is the principle that electric charge can neither be created nor destroyed. The quantity of electric charge, the amount of positive charge minus the amount of negative charge in the universe, is always conserved.

This was not a new idea, but Franklin was the first to perform an experiment on it. He said that if a metal rod was to be placed on top of a tower or a tall building, it would be struck by lightning & holds an electrical charge.

In 1752 Franklin devised another experiment to test whether or not lightning was an electric phenomenon. This seems fairly obvious to most of us today, but we must remember that in Franklin's day the largest sparks they could make were under an inch long! Since lightning is several miles long it is not so obvious that they can be the same.

Can you remember the first time you ever saw a lightning bolt in a dark, stormy sky? The awesome power of a lightning strike is etched into your memory. Without scientific understanding, lightning is frightening.

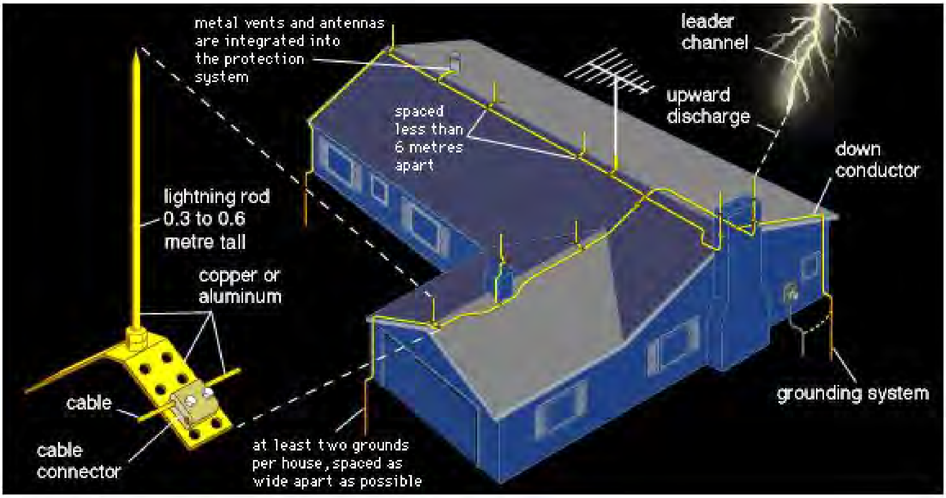
Early cultures relied on myth and magic to explain lightning and to ease their fears. The ancient Greeks, for example, believed that the king of all the gods, Zeus, threw lightning down from the heavens to show his anger at the people below. Lightning was his weapon.

As the study of weather science progressed, people stopped thinking of *lightning as a punishment from the gods. It wasn't until the 1700s, though, that science really began to understand lightning.*

Benjamin Franklin was one of the first lightning scientists. In 1752, he performed his legendary kite experiment.

He flied a kite carrying a pointed wire & attempted to test his theory that atmospheric lightning is an electrical phenomenon similar to the spark produced by an electrical frictional machine. To the kite Franklin attached a silk thread with a metal key. This was a very dangerous procedure, because if he failed to ground the wire he could have been easily killed by the electric current. His experiment was successful, & when ever lightning hit the key, it produced the spark just like Franklin theorized. By performing this experiment, he has demonstrated that electricity in atmosphere is same as that generated on earth.

An estimated 24,000 people are killed by lightning strikes around the world each year and about 240,000 are injured. So In addition to wanting to prove that lightning was electricity, Franklin began to think about protecting people, buildings, and other structures from lightning. This grew into his idea for the lightning rod. Franklin described an iron rod about 8 or 10 feet long that was sharpened to a point at the end. He wrote, "The electrical fire would, I think, be drawn out of a cloud silently, before it could come near enough to strike". Franklin's invention saved hundreds of lives, because house fires caused by lightning were big problem during his time.



The purpose of lightning rods is often misunderstood. Many people believe that lightning rods "attract" lightning. It is better stated to say that lightning rods provide a low-resistance path to ground that can be used to conduct the enormous electrical currents when lightning strikes occur. If lightning strikes, the system attempts to carry the harmful electrical current away from the structure and safely to ground. The system has the ability to handle the enormous electrical current associated with the strike. If the strike contacts a material that is not a good conductor, the material will suffer massive heat damage. The lightning-rod system is an excellent conductor and thus allows the current to flow to ground without causing any heat damage.

Did You Know?

Rubber tires aren't why you're safe in a car during a lightning storm. In strong electric fields, rubber tires actually become more conductive than insulating. You're safe in a car because the lightning will travel around the surface of the vehicle and then go to ground. This occurs because the vehicle acts like a Faraday cage. Michael Faraday, a British physicist, discovered that a metal cage would shield objects within the cage when a high potential discharge hit the cage. The metal, being a good conductor, would direct the current around the objects and discharge it safely to the ground. This process of shielding is widely used today to protect the electrostatic sensitive integrated circuits in the electronics world.

Franklin's Lightning Bells

Ben also developed another device to help him understand electricity. Called "lightning bells," the bells would jingle when lightning was in the air. To make these lightning bells work, Franklin used the lightning rod he had erected on his roof and ran a wire from it into his house. He divided the wire into two wires, which were attached to two small bells separated by 6 inches. Between the bells was a little brass ball, suspended by a silk thread. When storm clouds passed with electricity in them, the ball would go back and forth, ringing the bells.

This setup was used by Franklin to collect electric charge for use in other experiments. The amount of charge collected was sometimes so faint that after a spark between the bells it would take considerable time to charge up again. At other times a continuous stream of sparks could be obtained even at lengths of around 20cm. These sparks could very dangerous and a direct strike to the lightning rod could cause explosions and fire.

Franklin published his theories in a book titled "Experiments & observations on Electricity made at Philadelphia". It became best seller in Europe as well as in the colonies. The main topic of this book was Franklin's theory that lightning was electrical energy.

Franklin's Electric Stove:

Another well-known invention of Benjamin Franklin was the Open stove, often called the "Franklin Stove". In 1742, he created a stove which would provide better warming of rooms and at the same time save fuel. It was based on the models constructed by 'Robert Grace', one of Franklin's friends.

During Ben's lifetime, he made eight voyages across the Atlantic Ocean. These long journeys gave him a lot of time to learn about ships and how they worked. As early as 1784, Franklin suggested following the Chinese model of dividing ships' holds into watertight compartments so that if a leak occurred in one compartment, the water would not spread throughout and sink the ship.

Throughout his life Benjamin Franklin made many important discoveries & theories which greatly influenced future scientists & inventors. Later, other famous inventors, like Thomas A. Edison and Alexander Graham Bell, would follow in Ben's footsteps by trying to find ways to help people live better. Today's curious thinkers are keeping Ben's traditions alive by inventing new and improved ways to make things work.

Franklin wrote in his autobiography, "As we enjoy great advantages from the inventions of others, we should be glad of an opportunity to serve others by any invention of ours; & this we should do freely & generously".

Franklin's contributions to the science of electricity were numerous & comprehensive. His experiments were wisely planned & skilfully executed. His discussion of principles & his elaboration of hypotheses were characterized by that simplicity & clearness which made his writings upon all subjects the admiration of his own & future generations.

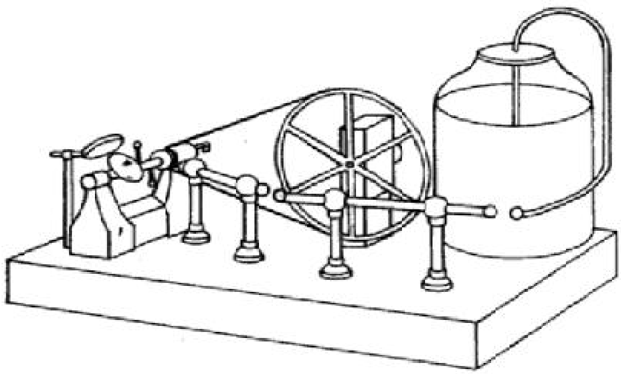
Source:

- The Franklin Institute
  "http://www.fi.edu/franklin/inventor/inventor.html"
- John Jenkins Spark Museum

What is the speed of electricity?

Have you ever thought; how fast does electricity travel? Does it travel more than speed of light or faster than sound? By the 1740s, William Watson had conducted several experiments to determine the speed of electricity. The general belief at the time was that electricity was faster than sound, but no accurate test been devised to measure the velocity of a current. Watson, in the fields north of London, laid out a line of wire supported by dry sticks and silk which ran for 12,276 feet (3.7 km). Even at this length, the velocity of electricity seemed instantaneous. Resistance in the wire was also noticed but apparently not fully understood, as Watson related that "we observed again, that although the electrical compositions were very severe to those who held the wires, the report of the Explosion at the prime Conductor was little, in comparison of that which is heard when the Circuit is short." Watson eventually decided not to pursue his electrical experiments, concentrating instead upon his medical career but he continued to support others in presenting evidence to the Royal Society

Then Charles Wheatstone an English scientist renown by a great experiment — the measurement of the velocity of electricity in a wire. He cut the wire at the middle, to form a gap which a spark might leap across, and connected its ends to the poles of a Leyden jar. Three sparks were thus produced, one at either end of the wire, and another at the middle. He mounted a tiny mirror on the works of a watch, so that it revolved at a high velocity, and observed the reflections of his three sparks in it. The points of the wire were so arranged that if the sparks were instantaneous, their reflections would appear in one straight line; but the middle one was seen to lag behind the others, because it was an instant later. The electricity had taken a certain time to travel from the ends of the wire to the middle. This time was found by measuring the amount of lag, and comparing it with the known velocity of the mirror. Having got the time, he had only to compare that with the length of half the *wire, and he could find the velocity of electricity. However experimental or calculation error led him to conclude that this velocity was 4,63,491 km per second, an impossible value as it is faster than the speed of light.*



Wheatstone' apparatus for measuring the velocity of electricity

Till then, many people had considered the electric discharge to be instantaneous; but it was afterwards found that its velocity depended on the nature of the conductor, its resistance, and its electro-static capacity. Michael Faraday showed, for example, that its velocity in a submarine wire, coated with insulator and surrounded with water, is only 144,000 miles per second (232,000 km/s), or still less. Wheat stone's device of the revolving mirror was afterwards employed by Leon Foucault and Hippolyte Fizeau to measure the velocity of light.

Source:

- *Wikipedia "http://en.wikipedia.org/wiki/Charles_Wheatstone"*
- *John Jenkins Spark Museum*

Discoveries Remained Undiscovered

Henry Cavendish, (October 10, 1731 - February 24, 1810) was a British scientist noted for early research into Electricity. Cavendish is also known for his "Measurement of the Earth's density" and his discovery of hydrogen or what he called "Inflammable Air". He described the density of inflammable air, which formed water on combustion, in a 1766 paper "On Factitious Airs". Antoine Lavoisier later reproduced Cavendish's experiment and gave the Element its name.

Because of his asocial and secretive behavior, Cavendish often avoided publishing his work and much of his findings were not even told to his fellow scientists. It wasn't until the late nineteenth century, long after his death, that James Clerk Maxwell looked through Cavendish's papers and found discoveries for which others had been given credit.

Among Cavendish's discoveries were the following:

- *The concept of Electric Potential, which he called the "Degree of Electrification".*
- *An early unit of Capacitance, that of a sphere one inch in diameter.*
- *The formula for the capacitance of a plate Capacitor.*
- *The concept of the Dielectric Constant of a material.*
- *The relationship between electric potential and current, now called Ohm's Law. (1781)*
- *Laws for the division of current in parallel circuits now attributed to Charles Wheatstone.*
- *Inverse square law of variation of electric force with distance now called Coulomb's Law.*

Electroscopes & Electrometers

The first Voltmeters

The term electroscope is given to instruments which serve two primary purposes: 1) to determine if a body is electrified, and 2) to determine the nature of the electrification. An electrometer, on the other hand, is a specialized form of electroscope that includes a calibrated scale for reading the strength of the charge.

*The first electroscope was a device called a Versorium, developed in 1600 by William Gilbert. The **Versorium** was simply a metal needle allowed to pivot freely on a pedestal. The metal would be attracted to charged bodies brought near. A simple hanging thread - called a **"Pendulous thread"** was introduced around 1731 by Stephen Gray. The thread would be attracted to any electrified body nearby.*

In 1753 John Canton improved the electroscope by adding two small pith balls suspended by fine linen thread. The upper ends of the threads were fastened inside a wooden box. When placed in the presence of a charged body, the two balls would become similarly charged, and since like charges repel, the balls would separate. The degree of separation was a rough indicator of the amount of charge.

In 1779 Tiberius Cavallo (1749-1809) designed an improved electroscope, his "pocket electrometer". The device included several improvements including, for the first time, enclosing the strings and corks inside a glass enclosure to reduce the effect of air currents.

Gold-leaf electroscope

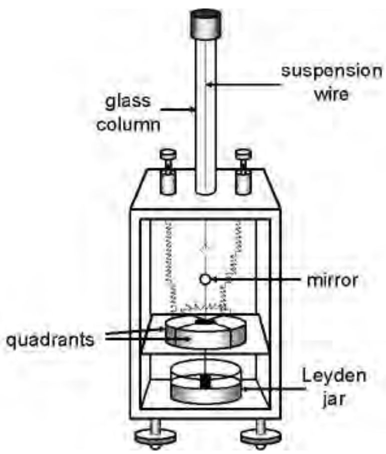
The gold-leaf electroscope was developed in 1787 by British clergyman and physicist Abraham Bennet, as a more sensitive instrument than pith ball or straw blade electroscopes then in use.

Electrometers

The first true electrometer came from Horace Benedict de Saussure (1740-1799) who placed the strings and balls inside an inverted glass jar and added a printed scale so that the distance or angle between the balls could be measured. It was de Saussure who discovered the distance between the balls was not linearly related to the amount of charge. However, the exact "inverse square" relationship would be left for Charles Coulomb to discover in 1784.

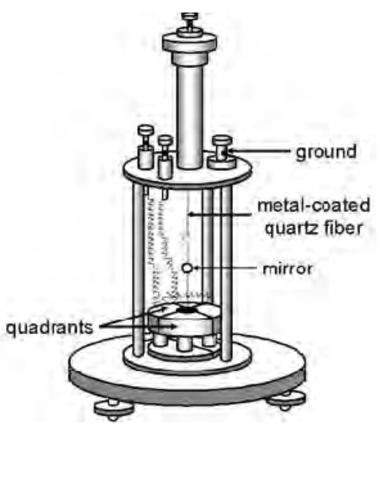
In 1770, William Henley developed the first portable quadrant electrometer. The date is sometimes referenced as 1772 since that was the first time the invention was published. The device consisted of an insulated stem with an ivory or brass quadrant scale attached. A light rod or straw extended from the center of the arc, terminating in a pith ball which hung touching the brass base of the electrometer. When the brass was electrified the ball would move away from the base, producing an angle which could be read off of the scale.

Early Quadrant Electrometers



The early bird cage and box-like quadrant electrometers maintained the vane at a constant potential while the potential/charge being measured was applied to one pair of quadrants.

Dolezalek Electrometer.



The Dolezalek electrometer, invented by the Hungarian, Friedrich Dolezalek (1873 - 1920), represented a significant improvement over earlier versions of quadrant electrometers by virtue of its increased sensitivity. It was invented in the same year that radioactivity was discovered (1896) and it quickly became a favorite of those investigating radioactive substances (e.g., Ernest Rutherford). Dolezalek spent most of his career in Germany and his research spanned a variety of fields: physics, chemistry, and electrical engineering.

Note that the quadrant electrometers of the 1800s did not provide the sensitivity or the reliability that was required for radioactive work.

In modern parlance, an electrometer is a highly sensitive electronic voltmeter whose input impedance is so high that the current flowing into it can be considered, for practical purposes, to be zero. Among other applications, they are of use in nuclear physics as they are able to measure the tiny charges left in matter by the passage of ionizing radiation. The most common use for modern electrometers is probably the measurement of radiation with ionization chambers, in instruments such as Geiger counters.

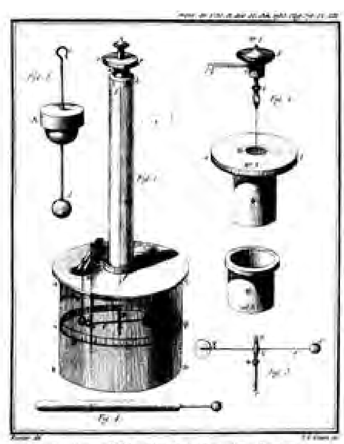
Source:

- Wikipedia "http://en.wikipedia.org/wiki/Electroscope"
- Wikipedia http://en.wikipedia.org/wiki/Electrometer
- John Jenkins Spark Museum

Laws Governing The Friction

After a breath taking experiments in electrostatics by many great scientist following his footsteps Charles-Augustin de Coulomb (14 June 1736 – 23 August 1806) was a French physicist. He is best known for developing Coulomb's law, the definition of the electrostatic force of attraction and repulsion.

Eighteenth-century experimenters dealt with electricity only in its static form; they studied charges, not currents. They had long known that opposite charges attract each other, while like charges repel, but the exact law governing electrical forces remained unclear until the French engineer Charles Coloumb tackled the problem in 1785.



Drawing of Coulomb's torsion balance.
From Plate 13 of his 1785 memoir.

In 1777 Coulomb invented the torsion balance, also called torsion pendulum, and is a scientific apparatus for measuring very weak forces. The torsion balance was an insulating rod with a metal-coated ball attached to one end, suspended by a silk thread. The ball was charged with a known charge of static electricity, and a second charged ball of the same polarity was brought near it. The two charged balls repelled one another, twisting the fibre through a certain angle, which could be read from a scale on the instrument. By knowing how much force it took to twist the fibre through a given angle, Coulomb was able to calculate the force between the balls. Determining the force for different charges and different separations between the balls, he showed that it followed "inverse square law".

Coulomb's 1779 memoir, The Theory of Simple Machines, is a compilation of his early experiments on statics and mechanics in which he makes the first formal statement of the laws governing friction. In 1784 he studied tensional elasticity, finding the relationship between the various factors involved in the small oscillations of a body subjected to torsion.

His most notable papers are the seven which Coulomb presented before the academy in 1785 and 1786. In the first he announced the measurement of the electrical forces of repulsion between electrical charges. He extended this work to the forces of attraction in his second memoir. This led to further quantitative work and his famous law of force for electrostatic charges (Coulomb's law). Coulomb explained the laws of attraction and repulsion between electric charges and magnetic poles, although he did not find any relationship between the two phenomena. He thought that the attraction and repulsion were due to different kinds of fluids.

Using a torsion balance, Coulomb was able to measure the electrostatic force between two electrically charged objects of small dimensions. His observations led him to discover a mathematical relationship that came to be called Coulomb's law. This law may be stated as follows: the magnitude of the electrostatic force between two point charges is directly proportional to the magnitudes of each charge and inversely proportional to the square of the distance between the charges. The formula to Coulomb's Law is of the same form as Newton's Gravitational Law: The electrical force of one body exerted on the second body is equal to the force exerted by the second body on the first. To calculate the magnitude of the force, it may be easiest to consider the simplified, scalar version of the law:

$$F = k_C \frac{|q_1||q_2|}{r^2}$$

where:

F is the magnitude of the force exerted,
q_1 is the charge on one body,
q_2 is the charge on the other body,
r is the distance between them,
$k_C = \frac{1}{4\pi\epsilon_0} \approx$ 8.988×10^9 N m^2 C^{-2} is the electrostatic constant or Coulomb force constant, and
$\epsilon_0 \approx$ 8.854×10^{-12} C^2 N^{-1} m^{-2} is the permittivity of free space, also called electric constant, an important physical constant.

Coloumb's experiments were open to criticism & are extremely difficult to replica. The idea of an inverse-square law of electrical or magnetic forces on the analogy of Newtonian gravity was not new, but Coloumb was the first to provide extensive experimental evidences. As a Newtonian he was more concerned with establishing the mathematical equations governing the actions of electrical forces than with discussing their cause. He used "two fluid" rather than a "one fluid" theory, but stated that this was simply because he found it more convenient.

The subsequent papers dealt with the loss of electricity of bodies and the distribution of electricity on conductors. He introduced the "proof plane" and by using it was able to demonstrate the relationship between charge density and the curvature of a conducting surface.

These papers on electricity and magnetism, although the most important of Coulomb's work over this period, were only a small part of the work he undertook. He presented twenty-five memoirs to the Academe des Sciences between 1781 and 1806. Coulomb worked closely with Bossut, Borda, de Prony, and Laplace over this period.

Measurement of surface density of electrification theory of the proof plane

In testing the results of the mathematical theory of the distribution of electricity on the surface of the conductors, it is necessary to be able to measure the surface-density at different points of conductor. For this purpose Coloumb employed a small disk of gilt paper fastened to an insulating stem of gumlac. He applied this disk to various points of the conductor by placing it so as to coincide as nearly as possible with the surface of the conductor. He then removed it by means of the insulating stem, & measured the charge of the disk by means of his electrometer.

Since the surface of the disk, when applied to the conductor, nearly coincide with that of the conductor, he concluded that the surface-density of the conductor at that place, & that the charge on the disk when removed was nearly equal to that on the area of the surface of the conductor equal to that on an area of the disk. A disk, when employed in this way, is called a Coloumb's proof plane.

The experiment to show charge resides on the surface of the conductor; Faraday's Bag

Faraday's bag is used to show that electric charge resides on the surface of a conductor. The example from Colby College above shows the original form: A muslin bag is attached to a metal hoop supported by an insulating glass rod. An electric charge is placed on the interior of the bag, and reappears on the outer surface of the bag. Its presence there can be demonstrated with a proof plane and electroscope. If the bag is then turned inside out by pulling on the strings, the charge appears on the new outside of the bag. This is clearly a version of the Faraday Ice Pail experiment.

Throughout his career, Coulomb espoused a characteristically eighteenth-century view of nature according to which material corpuscles were bound together by short-range forces such as cohesion and elasticity. Much of his groundbreaking research into friction, torsion, and the strength of materials were concerned with the limits of action of these forces. He was one of the chief architects of the "two-fluid" theories of electricity and magnetism that dominated these fields throughout the nineteenth century.

Let us end with quoting the tribute paid to him by Biot who wrote:-

It is to Borda and to Coulomb that one owes the renaissance of true physics in France, not a verbose and hypothetical physics, but that ingenious and exact physics which observes and compares all with rigour.

Source:

- Wikipedia "http://en.wikipedia.org/wiki/Charles-Augustin_de_Coulomb"
- A Treatise on Electricity and Magnetism By James Clerk Maxwell
- John Jenkins Spark Museum

Story of Invention of Waterwheel

Source:

- *100 greatest science inventions of all time By Kendall F. Haven*
- *Wikipedia "http://en.wikipedia.org/wiki/Water_turbine"*
- *Wikipedia "http://en.wikipedia.org/wiki/Water_wheel"*

Waterwheels were the first human machine in which a natural force was controlled & converted into mechanical motion to power human land-based activity. Waterpower, converted into mechanical energy by waterwheels, was the primary power source for grain mills, saw mills, leather works, textile mills & even blast furnaces for more than 1500 years. Waterwheels provided the major sources of civic & industrial power until the invention of the steam engine in the late 1700s.

What did people do before?

The power to grind grain, saw wood, spin lathes or turn potters wheels always came from human & animal labour- as did the power needed for any industrial or production process.

Wind power helped moved ships at sea. But even ships relied far more on oars & human power than on wind, until the ninth or tenth centuries.

As villages expanded into towns & cities, the demand for mechanical power increased. However, until the waterwheel was invented, no alternatives to human & animal power existed.

How Was the Waterwheels Invented

The waterwheel emerged to meet two vital needs of early societies: grind grain & lift water for irrigation. In 100 B.C., grain grinding was by far the more pressing need.

Grain was ground between stones. Handfuls of grain were dropped into a large, concave stone & ground into flour with a second handheld stone. By 150 B.C., Greek millers had flattened & enlarged both stones. Workers pushed the top, moving the stone back & forth across the stationary bottom stone to grind the grains trapped between.

Sometimes before 100 B.C., most Greek millers shifted from large square stones to circular grinding stones. Now the upper stone could be turned while lying on top of the stationary lower stone to grind grain. A vertical shaft & handles to push the stone in a circular motion. Then, sometimes between 95 B.C. & 85 B.C., some clever Greek realized that they could use the power of a flowing stream to turn the vertical shaft that spun his grinding stones.

They had to build his mill directly over a stream. A wooden shaft extended out of the floor of the mill down to water level. On that shaft, they secured a horizontal wheel. Onto the wheel, they fixed a number of cup-shaped paddles.

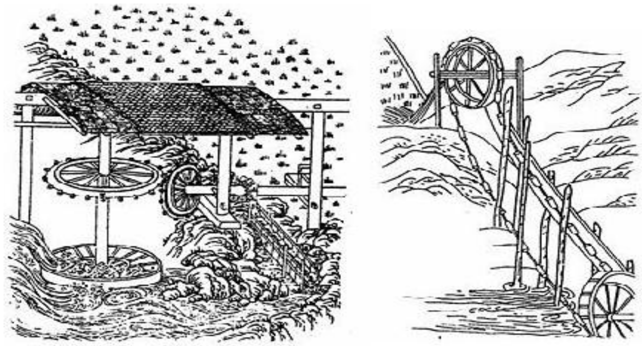
When the open side of the paddles faced upstream, they caught the current like a sail catching wind. That forced the wheel to turn. On the other side of the wheel, the backside of each curved paddle had to rotate back upstream. However, the curved backside created much less resistance in the water to turn in one direction. It's true that, the horizontal waterwheel lost some power because the backside of each paddle had to rotate back against the current. But the wheel still produced plenty of power to run a small mill.

Waterwheel technology quickly migrated to Rome. Roman millers & engineers made two significant improvements. First, they learned to dam a stream above a mill & channel water in a roaring torrent over the dam & down past their waterwheels. This greatly magnified the power their waterwheels produced.

Secondly, they realized that they could eliminate drag on their waterwheels by turning it on its side to create a vertical waterwheel. The engineer & author Vitruvius is given credit for this invention, & he described it in detail in one of his engineering design books, De Architectura dated to 25 B.C.

Now each paddle entered the water & was swept powerfully downstream. Then it lifted out of the water before it began its rotation back upstream. Resistance was eliminated & the waterwheels power was again multiplied. This Vitruvian waterwheel mills was the first efficient, powerful, general-purpose waterwheel design.

Vitruvius waterwheels were soon adapted to power lumber saws & to drive early spinning & weaving machines. This waterwheel was still the primary source of power 1700 years later when waterwheels powered the drive belts & conveyors of the early mills & factories of the Industrial Revolution.

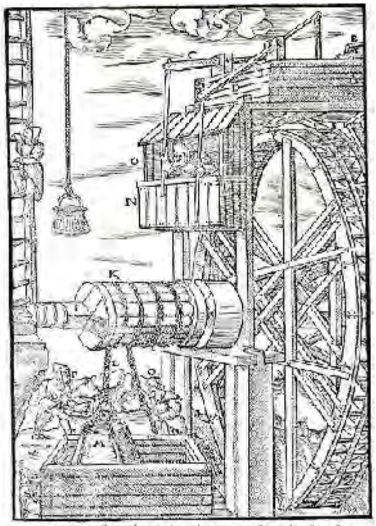


Two types of hydraulic-powered chain pumps from the Tiangong Kaiwu of 1637.

The Roman waterwheel at Bouches-du-Rhone (near Asrles in France) was built around 285 A.D. & is the greatest example of a Vitruvian waterwheel mill. Engineers built an aqueduct to divert the natural stream to a holding pond just above a steep slope. Two parallel channels were dug down the face of this slope. The mill complex sat on land between the two channels. Sixteen Vitruvian waterwheels (eight on each channel) were placed one above the other & frantically whirred to power the largest mill in the Roman Empire. The millers used a complex set of gears to allow shafts to turn at different speeds for different milling operations.

However, the inventions of the steam engine pushed water power out of major industrial uses. Steam engines produced more power & be located anywhere. Hence Waterwheels disappeared from industrial operations.

Water wheels have been used for thousands of years for industrial power. Their main shortcoming is size, which limits the flow rate and head that can be harnessed. The migration from water wheels to modern turbines took about one hundred years. Development occurred during the Industrial revolution, using scientific principles and methods. They also made extensive use of new materials and manufacturing methods developed at the time. Nineteenth-century efficiency improvements of water turbines allowed them to compete with steam engines.

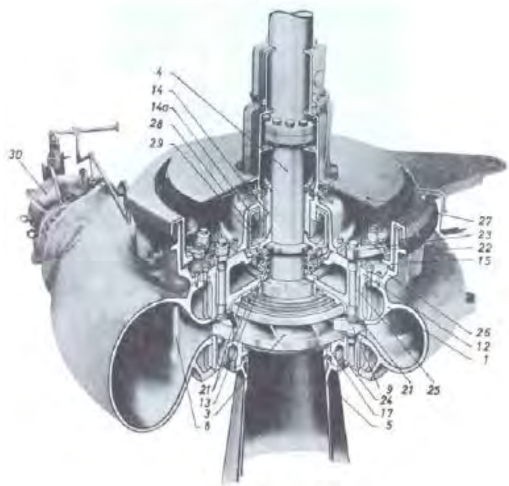


Water wheel powering a mine hoist in De re metallica (1566)

The word turbine was introduced by the French engineer Claude Bourdin in the early 19th century and is derived from the Latin word for "whirling" or a "vortex". The main difference between early water turbines and water wheels is a swirl component of the water which passes energy to a spinning rotor. This additional component of motion allowed the turbine to be smaller than a water wheel of the same power. They could process more water by spinning faster and could harness much greater heads. (Later, impulse turbines were developed which didn't use swirl).

In 1826 Benoit Fourneyron developed a high efficiency (80%) outward-flow water turbine. Water was directed tangentially through the turbine runner, causing it to spin. Jean-Victor Poncelet designed an inward-flow turbine in about 1820 that used the same principles.

In 1848 James B. Francis, while working as head engineer of the Locks and Canals company in the water-powered factory city of Lowell, Massachusetts, improved on these designs to create a turbine with 90% efficiency. He applied scientific principles and testing methods to produce a very efficient turbine design. More importantly, his mathematical and graphical calculation methods improved turbine design and engineering. His analytical methods allowed confident design of high efficiency turbines to exactly match a site's flow conditions. The Francis turbine, named for him, is the first modern water turbine. It is still the most widely used water turbine in the world today. The Francis turbine is also called a radial flow turbine, since water flows from the outer circumference towards the centre of runner.

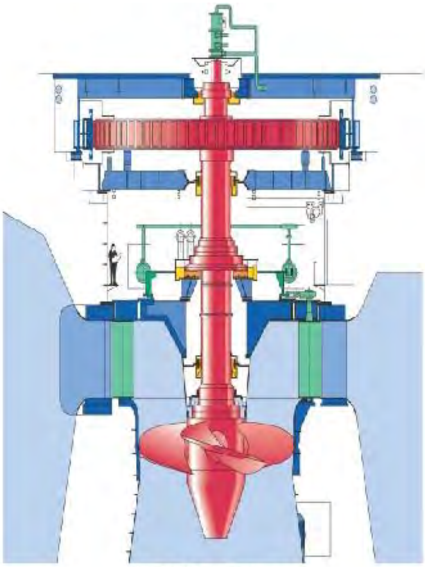


Francis turbine

1. The scroll casing
3. Runner
4. Shaft
5. Draft tube cone
8. Stay vanes
9. Guide vanes
12. Upper cover
13. Sealing box
14. Guide bearing
14a.Bracket for the bearing
15. Regulating ring
17. Lower cover
21.Replaceable wear and labyrinth rings
22. Link
23. Lever
24. Lower bearing for guide vane
25.Upper bearing for guide vane
26. Bearing for the regulating ring
27. Floor
28. Rotating oil cylinder
29. Oil scoop fastened to (14a) and (14) with the opening against the rotating oil in rotating oil cylinder (28)


A Francis turbine runner, rated at nearly one million hp (750 MW), being installed at the Grand Coulee Dam, United States.

Inward flow water turbines have a better mechanical arrangement and all modern reaction water turbines are of this design. As the water swirls inward, it accelerates, and transfers energy to the runner. Water pressure decreases to atmospheric, or in some cases subatmospheric, as the water passes through the turbine blades and loses energy.



Vertical Kaplan Turbine

Around 1913, Viktor Kaplan created the Kaplan turbine, a propeller-type machine. The Kaplan turbine is a propeller-type water turbine which has automatically-adjusted propeller blades with automatically-adjusted wicket gates to achieve efficiency over a wide range of flow and water level. The Kaplan turbine was an evolution of the Francis turbine. Its invention allowed efficient power production in low-head applications that was not possible with Francis turbines. Kaplan turbines are now widely used throughout the world in high-flow, low-head power production. It was an evolution of the Francis turbine but revolutionized the ability to develop low-head hydro sites.

All common water machines until the late 19th century (including water wheels) were basically reaction machines; water pressure head acted on the machine and produced work. A reaction turbine needs to fully contain the water during energy transfer.

Old Pelton wheel from Walchensee Power Plant, Germany

In 1866, California millwright Samuel Knight invented a machine that took the impulse system to a new level. Inspired by the high pressure jet systems used in hydraulic mining in the gold fields, Knight developed a bucketed wheel which captured the energy of a free jet, which had converted a high head (hundreds of vertical feet in a pipe or penstock) of water to kinetic energy. This is called an impulse or tangential turbine. The water's velocity, roughly twice the velocity of the bucket periphery, does a u-turn in the bucket and drops out of the runner at low velocity.

In 1879, Lester Pelton (1829-1908), experimenting with a Knight Wheel, developed a double bucket design, which exhausted the water to the side, eliminating some energy loss of the Knight wheel which exhausted some water back against the centre of the wheel. In about 1895, William Doble improved on Pelton's half-cylindrical bucket form with an elliptical bucket that included a cut in it to allow the jet a cleaner bucket entry. This is the modern form of the Pelton turbine which today achieves up to 92% efficiency.

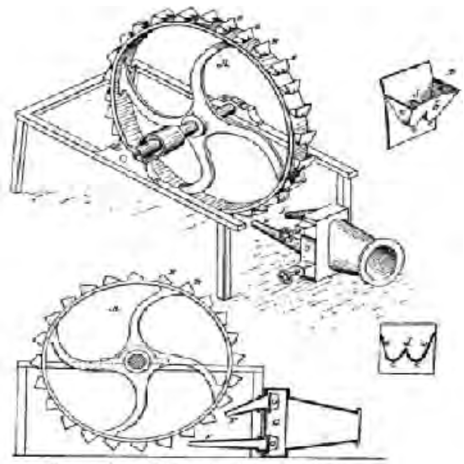


Figure from Pelton's original patent (October 1880)

Turgo and Crossflow turbines were later impulse designs. Today hydro electric dams exists in more than 150 countries around the world & are responsible for about 20% of the world's total electricity, and accounted for about 88% of electricity from renewable sources. Twenty-four countries get 90% of their electricity from hydropower. The largest dam in the world produces enough energy to light 200 million 100-watt bulbs at one time.

World's Largest Hydroelectric Power Plant

Source: *Wikipedia "http://en.wikipedia.org/wiki/Three_Gorges_Dam"*

The Three Gorges Dam is a hydroelectric dam that spans the Yangtze River by the town of Sandouping, located in the Yiling District of Yichang, in Hubei province, China. The Three Gorges Dam is the world's largest capacity hydroelectric power station with a total generating capacity of 18,200 MW.

The dam body was completed in 2006. Except for a ship lift, the originally planned components of the project were completed on October 30, 2008, when the 26th turbine in the shore plant began commercial operation. Each turbine has a capacity of 700 MW. Six additional turbines in the underground power plant are not expected to become fully operational until 2012. Coupling the dam's thirty-two main turbines with two smaller generators (50 MW each) to power the plant itself, the total electric generating capacity of the dam will eventually reach 22,500 MW.

Layout and scale

Made of concrete, the dam is 2,335 m (7,661 ft) long, and 185 metres (607 ft) high. The project used 200,000 cubic metres (300,000 cu yd) of concrete (mainly for the dam wall), 463,000 tonnes of steel (enough to build 63 Eiffel Towers) and moved about 102,600,000 cubic metres (134,200,000 cu yd) of earth.

When the water level is at its maximum of 175 metres (574 ft) above sea level (110 metres (361 ft) higher than the river level downstream), the dam reservoir is on average about 660 kilometres (410 mi) in length and 1.12 kilometres (0.70 mi) in width. It contains 39.3 km³ (31,900,000 acre·ft) of water and has a total surface area of 1,045 km². On completion, the reservoir flooded a total area of 632 km² of land, compared to the 1,350 km² of reservoir created by the Itaipu Dam.

Economics

The government estimates that the Three Gorges Dam project will cost 180 billion yuan (US$22.5 billion). By the end of 2008, spending had reached 148.365 billion yuan, among which 64.613 billion yuan was spent on construction, 68.557 billion yuan on relocating affected residents, and 15.195 billion yuan on financing. It is estimated that the construction cost will be recovered when the dam has generated 1,000 TWh of electricity, yielding 250 billion yuan. Full cost recovery is expected to occur ten years after the dam starts full operation.

Generating capacity

The Three Gorges Dam is the world's largest capacity hydroelectric power station with twenty-six 700 MW turbines and a total capacity of 18,200 MW. Eventually, it will have 32 generators: 30 main generators, each with a capacity of 700 MW, and two plant power generators, each with capacity of 50 MW, making a total capacity of 22,500 MW. Among those 32 generators, 14 are installed in the north side of the dam, 12 in the south side, and the remaining six in the underground power plant in the mountain south of the dam. The expected annual electricity generation will be over 100 TWh.

Panorama of the Three Gorges Dam

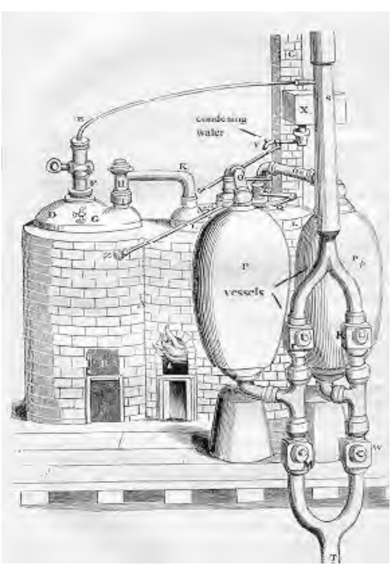
Brief History of the Steam Engine

Steam powered the Industrial Revolution. Steam powered England into world economic dominance in the eighteenth & nineteenth centuries & provided the energy to run industry, pumps, trains, & ships for 150 years. The Industrial Revolution, powered by steam, built on blast furnace iron & steel, radically changed the direction of human evolution. Without steam, it couldn't have happened.

The idea of the steam engine goes as far back as A.D.200. Hero of Alexandria observed that expanding water vapour could provide energy to make objects move or turn. But no one could imagine anything practical to do with it, & idea was dropped for 1500 years.

One of the most significant industrial challenges of the 1700's was the removal of water from mines. European coal mines had the nasty habit of flooding. Miners were desperate for pumps that could keep their mines dry.

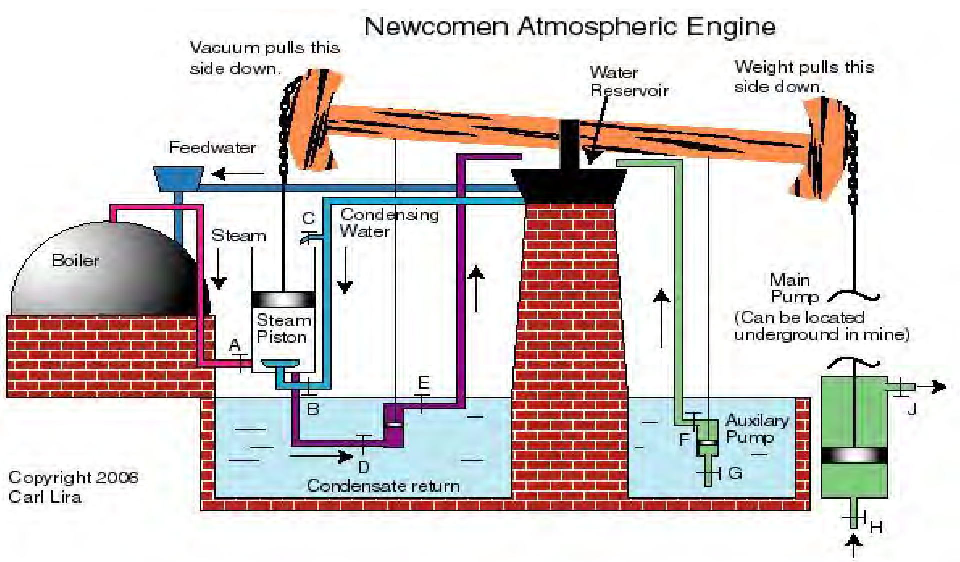
Savery Pump



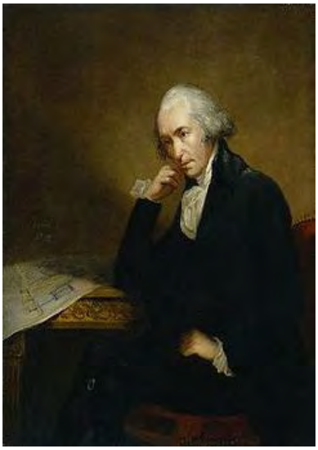
In the early days, one common way of removing the water was to use a series of buckets on a pulley system operated by horses. This was slow and expensive since the animals required feeding, veterinary care, and housing. The use of steam to pump water was patented by Thomas Savery in 1698, and in his words provided an "engine to raise water by fire". Savery's pump worked by heating water to vaporize it, filling a tank with steam, then creating a vacuum by isolating the tank from the steam source and condensing the steam. The vacuum was used to draw water up from the mines. However, the vacuum could only draw water from shallow depths. Another disadvantage of the pump was the use of steam pressure to expel the water that had been drawn into the tank. In principle, pressure could be used to force the water from the tank upwards 80 feet, but boiler explosions were common since the design of pressurized boilers was not very advanced.

Newcomen Atmospheric Engine

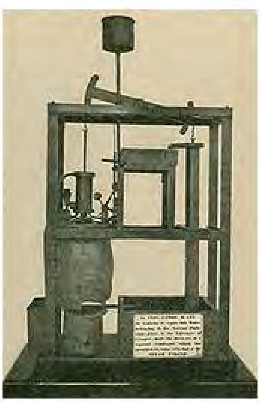
Thomas Newcomen (1663-1729), a blacksmith, experimented for 10 years to develop the first truly successful steam engine to drive a pump to remove water from mines. His ability to sell the engine was hampered by Savery's broad patent. He was forced to establish a firm with Savery, despite the improved performance of his engine, the significant mechanical differences, the elimination of the need for steam pressure, and the use of vacuum in a very different manner. A schematic of a Newcomen engine is shown in Figure. The engine is called an "atmospheric" engine because the greatest steam pressure used is near atmospheric pressure.



Newcomen engines were extremely inefficient. The users recognized how much energy was wasted. The steam cylinder was heated and cooled repeatedly, which wasted energy to reheat the steam, and also caused large thermal stresses. James Watt made a breakthrough development by using a separate condenser. Watt discovered the separate condenser in 1765. It took 11 years before he saw the device in practice!



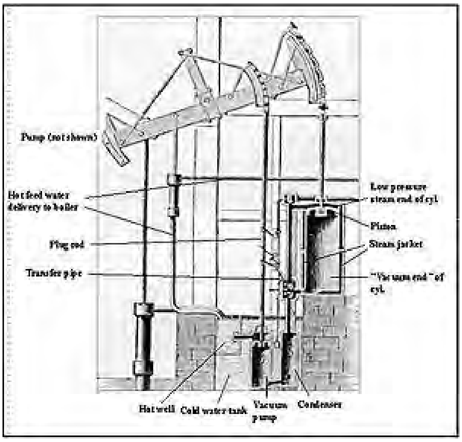
James Watt, (19 January 1736 – 25 August 1819) was a Scottish inventor and mechanical engineer whose improvements to the Newcomen steam engine were fundamental to the changes brought by the Industrial Revolution in both the Kingdom of Great Britain and the world. While working as an instrument maker at the University of Glasgow, Watt became interested in the technology of steam engines invented by the English engineers Thomas Savery and Thomas Newcomen, which were used at the time to pump water from mines. He realised that contemporary engine designs wasted a great deal of energy by repeatedly cooling and re-heating the cylinder. Watt introduced a design enhancement, the separate condenser, which avoided this waste of energy and radically improved the power, efficiency, and cost-effectiveness of steam engines. He also developed the concept of horsepower.



The model Newcomen engine upon which Watt experimented

James Watt soon discovered that it required a very small quantity of steam to heat a very large quantity of water, and immediately started to determine with precision the relative weights of steam and water in the steam cylinder when condensation took place at the down stroke of the engine. James Watt independently proved the existence of "latent heat", the discovery of another scientist, Doctor Black. Watt went to Black with his research, who shared his knowledge with Watt. Watt found that, at the boiling point, his condensing steam was capable of heating six times its weight of water used for producing condensation.

James Watt's Separate Condenser



Watt economized the boiler, and made boilers with wooden "shells" in order to prevent losses by conduction and radiation, and used a larger number of flues to secure more complete absorption of the heat from the furnace gases. He also covered his steam pipes with non-conducting materials, and took every precaution to secure the complete utilization of the heat of combustion. He soon discovered that the great source of loss was to be found in defects which he noted in the action of the steam in the cylinder. He soon concluded that the sources of loss of heat in the Newcomen engine which would be greatly exaggerated in a small model were:

- *First, the dissipation of heat by the cylinder itself, which was of brass, and was both a good conductor and a good radiator.*
- *Secondly, the loss of heat consequent upon the necessity of cooling down the cylinder at every stroke, in producing the vacuum.*
- *Thirdly, the loss of power due to the pressure of vapour beneath the piston, which was a consequence of the imperfect method of condensation.*

After his scientific investigations, James Watt worked on improving the steam engine with an intelligent understanding of its existing defects, and with knowledge of their cause. Watt soon saw that in order to reduce the losses in the working of the steam in the steam cylinder, it would be necessary to find a way to keep the cylinder always as hot as the steam that entered it.

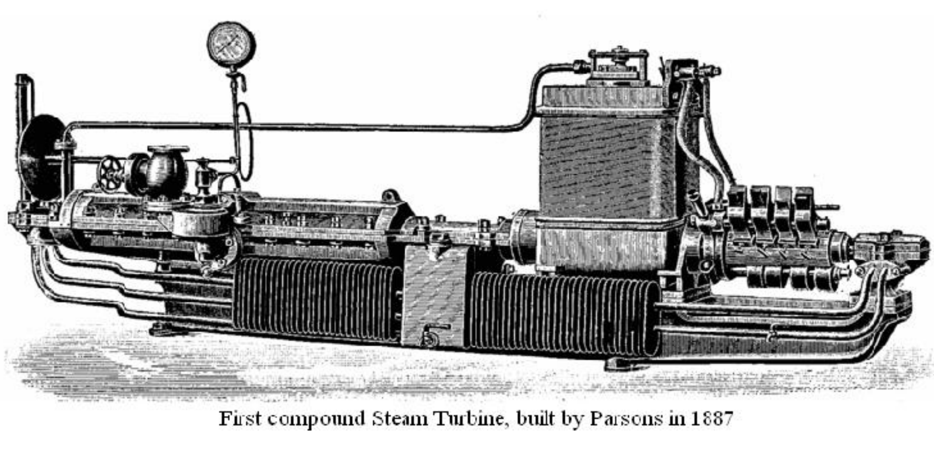
The history of the steam engine is from this time a history of the work of the firm of Boulton & Watt. Nearly every successful and important invention which marked the history of steam power for many years originated in the fertile brain of James Watt.

Today, it is appropriate to recognize Watt's contributions when we used the British (and American Engineering) units for power, hp, and the SI units for power, the Watt. Watt's steam engine provided the mechanical power to launch the Industrial Revolution. Soon after, steam engines were adapted to work on trains & ships.

In 1820, Jacob Leupold, working in Leipzig, Germany, designed a high-pressure steam engine. His engine allowed steam pressures of up to 30 psi (pounds of pressure per square inch). By 1850, better designs allowed pressure to raise to hundred of psi.

Electricity from Steam

The modern steam turbine was invented in 1884 by the Englishman Sir Charles Parsons, whose first model was connected to a dynamo that generated 7.5 kW (10 hp) of electricity. The invention of Parson's steam turbine made cheap and plentiful electricity possible and revolutionised marine transport and naval warfare. His patent was licensed and the turbine scaled-up shortly after by an American, George Westinghouse. The Parson's turbine also turned out to be easy to scale up. Parsons had the satisfaction of seeing his invention adopted for all major world power stations, and the size of generators had increased from his first 7.5 kW set up to units of 50,000 kW capacity. Within Parson's lifetime the generating capacity of a unit was scaled up by about 10,000 times, and the total output from turbo-generators constructed by his firm C. A. Parsons and Company and by their licensees, for land purposes alone, had exceeded thirty million horse-power.

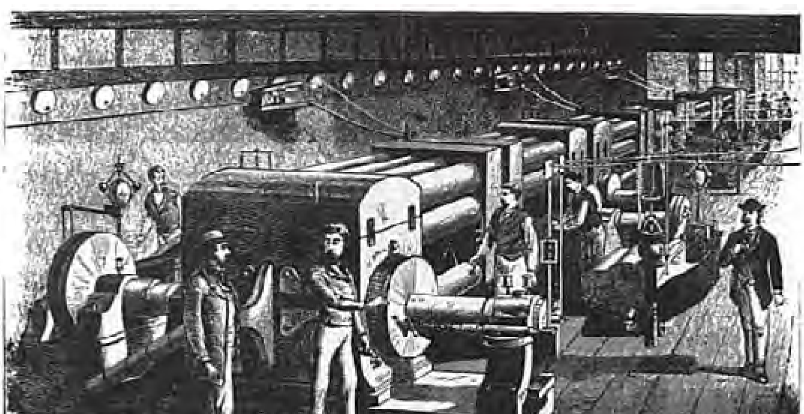


First compound Steam Turbine, built by Parsons in 1887

Laval turbine, 1883

A number of other variations of turbines have been developed that work effectively with steam. The de Laval turbine (invented by Gustaf de Laval) accelerated the steam to full speed before running it against a turbine blade. Hence the (impulse) turbine is simpler, less expensive and does not need to be pressure-proof. It can operate with any pressure of steam, but is considerably less efficient.

In nearly all the early power stations the prime mover were reciprocating steam engines. The technology was well established, & the electrical designers made generators to be driven by the available steam engines even though their rotational speed was less than ideal. Some stations used a belt drive to increase the speed, though Willans & Belliss & Morcom high speed engines were often directly coupled to the generator. The higher rational speed of the turbine made it the ideal prime mover for power stations.



Generator room of Pearl street station, New York(1882).

The very first commercial central electrical generating stations in the Pearl Street Station, New York and the Holborn Viaduct power station, London, in 1882, also used reciprocating steam engines. The development of the steam turbine allowed larger and more efficient central generating stations to be built.

By 1892 steam turbine was considered as an alternative to reciprocating engines. Turbines offered higher speeds, more compact machinery, and stable speed regulation allowing for parallel synchronous operation of generators on a common bus. Turbines entirely replaced reciprocating engines in large central stations after about 1905.

A continues steam of improvements & refinements of Watt's basic design peppered the decades of the nineteenth century-improved power output, improved speed of the engine, improved energy efficiency. But these were all just refinements of Watt's original design. For 150 years, the world ran on steam. By then the electric motor existed. Electric motors became more popular for factories. The internal combustion engine also emerged in the late nineteenth century. By the early twentieth century, the gasoline engine had pushed steam out of all transportation systems. Watt's engine was but a memory. But before it faded into history, that engine changed the world.

Source:

- *100 greatest science inventions of all time By Kendall F. Haven*
- *Wikipedia "http://en.wikipedia.org/wiki/Steam_turbine"*
- *Wikipedia "http://en.wikipedia.org/wiki/Steam_engine"*

Taichung Power Plant

The Taichung Power Plant is a large coal-fired power plant in Taiwan. With an installed capacity of 5,780 MW, it is the largest coal-fired power station in the world, and also the world's largest emitter of carbon dioxide.

The power plant consists of ten coal-fired units with nominal capacity of 550 MW each. Four original units were commissioned in 1992. In 1996–1997, four additional units were added. The eight older units have a total estimated coal requirement of around 12 million tonnes of bituminous and 2.5 million tonnes of sub-bituminous coal a year. In June 2005 and June 2006, 550 MW sub-critical pressure units 9 and 10 were installed. There is an expansion plan to build two new 800 MW units by 2016.

Taichung Power Plant

A survey by Carbon Monitoring for Action (CARMA) showed that the Taichung ranked No. 1 worldwide in terms of carbon dioxide emissions by power plants. The plant emits the most carbon dioxide per coal power plants in the world. What's pathetic is the fact that this country emits more in a year than 65 countries COMBINED. What's even more pathetic is the fact that the plant emits more than 144 individual countries. This single power plant almost emits as much in a year as does Ireland.

Source: Wikipedia *"http://en.wikipedia.org/wiki/Taichung_Power_Plant"*

Birth of Bioelectricity

A century and a half after Galileo's death, something of scientific importance was to develop in Italy. During the 1780's, biologist Luigi Galvani (September 9, 1737 – December 4, 1798) was an Italian physician who lived in Bologna discovered that the muscles of dead frog's legs twitched when struck by a spark. This was one of the first forays into the study of bioelectricity, a field that still today studies the electrical patterns and signals of the nervous system.

According to popular version of the story, Galvani dissected a frog at a table where he had been conducting experiments with static electricity. Galvani's assistant touched an exposed sciatic nerve of the frog with a metal scalpel, which had picked up a charge. At that moment, they saw sparks and the dead frog's leg kick as if in life. The observation made Galvani the first investigator to appreciate the relationship between electricity and life. This finding provided the basis for the current understanding that electrical energy (carried by ions), and not air or fluid as in earlier balloonist theories, is the impetus behind muscle movement.

Galvani called the term animal electricity to describe the force that activated the muscles of his specimens. Along with contemporaries, he regarded their activation as being generated by an electrical fluid that is carried to the muscles by the nerves.

Galvani was a professor at the University of Pavia in Italy; he had a very good reputation among chemists and scientists throughout Europe. Among his correspondents was Alessandro Volta, a fellow Italian scientist. Galvani sent Volta a copy of a pamphlet he had written detailing his latest experiments in 1792.

Galvani reported that when a partially dissected frog came into contact with two different metals that were grounded, its muscles flexed and legs twitched. He further reported that there was a relationship between the muscular contraction and the electrical stimulus, which he believed to be proof of the existence of "animal electricity."

Volta at first accepted Galvani's explanation of animal electricity as the reason for the frog's involuntary movements. But after carefully repeating Galvani's experiments, Volta became convinced that the contractions of the frog's legs did not result from animal electricity but were due to some external electricity caused by the two different metals in an arc coming into contact with the moist frog. He believed that the frog merely assumed the role of a simple and sensitive electroscope.

However, in another experiment, Galvani caused muscular contraction by touching the exposed muscle of one frog with the nerve of another and thus established for the first time that bioelectric forces exist within living tissue.

From the foregoing it will be seen that within each cup the current flows from the zinc to the copper plates, and exteriorly from the copper to the zinc plates through the conductors (B and E). With this inspiration a few years afterwards Volta devised what is known as the voltaic pile.

After eleven years of experimentation Galvani published his ideas in 1791 in an essay, De Viribus Electicitatis in Motu Musculari Commentarius (Commentary on the Effect of Electricity on Muscular Motion). Although his explanation of muscular movement induced by electricity was wrong, most scientists accepted his ideas, and his work stimulated science into new lines of investigation, both in physiology and in electricity.

Selected illustrations from Galvani's works

The following illustrations show some of Galvani's illustrations from his work "Commentary on the Effect of Electricity on Muscular Motion".

One of the principles of science is that experiments should be documented such that others can verify their result by repeating them. Galvani's illustrations are excellent examples of scientific documentation.

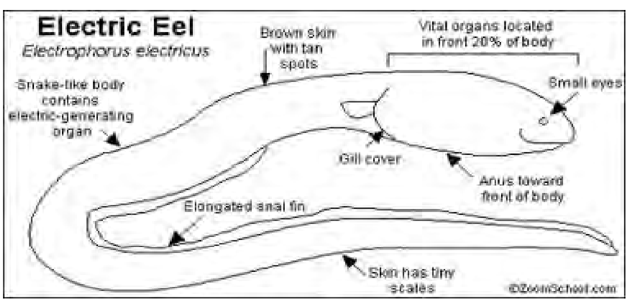
The last figure is an illustration of an experiment to investigate the effect of thunderstorms on muscle contraction. Galvani described his observations thus:

"Therefore having noticed that frog preparations which hung by copper hooks from the iron railings surrounding a balcony of our house contracted not only during thunder storms but also in fine weather, I decided to determine whether or not these contractions were due to the action of atmospheric electricity....Finally....I began to scrape and press the hook fastened to the back bone against the iron railing to see whether by such a procedure contractions might be excited, and whether instead of an alteration in the condition of the atmospheric electricity some other changes might be effective. I then noticed frequent contractions, none of which depended on the variations of the weather."

Galvani's discoveries opened the way to new research in the physiology of muscle and nerve and pioneered the subject of Electrophysiology -- the study of the connection between living organisms and Electricity. The name Galvanization is derived from Luigi Galvani, and was once used as the name for the administration of electric shocks, this stems from Galvani's induction of twitches in severed frog's legs, by his accidental generation of electricity.

The Electric eel (Electrophorus electricus), is an electric fish, and the only species of the genus Electrophorus. It is capable of generating powerful electric shocks, which it uses for both hunting and self-defence. It is an apex predator in its South American range.

The electric eel has three abdominal pairs of organs that produce electricity: the Main organ, the Hunter's organ, and the Sachs organ. These organs comprise four-fifths of its body, and are what give the electric eel the ability to generate two types of electric organ discharges (EODs), low voltage and high voltage. These organs are made of electrocytes, lined up so that the current flows through them and produces an electrical charge. When the eel locates its prey, the brain sends a signal through the nervous system to the electric cells. This opens the ion channel, allowing positively-charged sodium to flow through, reversing the charges momentarily. By causing a sudden difference in voltage, it generates a current.



The electric eel generates its characteristic electrical pulse in a manner similar to a battery, in which stacked plates produce an electrical charge. In the electric eel, some 5,000 to 6,000 stacked electro plaques are capable of producing a shock at up to 500 volts and 1 ampere of current (500 watts). Such a shock could be deadly for an adult human.

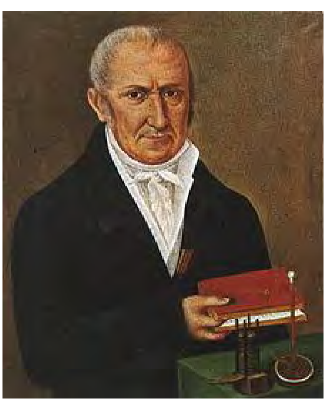
Electric eels have been widely used as a model in the study of bioelectrogenesis.

Invention of Voltaic Pile (Battery)

Until 1800 the production of electrical phenomena was linked essentially to the effects derived from the rubbing of different insulating substances. The age of amber sticks and of electroscopes with small balls of elder had passed by now, but the price of the newness consisted of a use of giant electrostatic machines, as those ones by Van Marum and Cuthberston still kept in Dutch Museums. Revolving vertically they produced voltages of 100.000 volts, jump sparks long a half meter and charged Leyden bottles that is rudimental condensers able to kill a man, as sometimes happened during the experiments. But they were not very practical and cumbersome systems that didn't facilitate the idea of a concrete use of electricity out of laboratories.

In this historical moment an Italian physicist Alessandro Volta announced a series of electrical phenomena huge for many points of view, generated with the simple help of a glass of water and two little thin metallic plates.

Alessandro Volta, born in Como, Italy, is best known for discovering current electricity and for developing the voltaic pile, which became an invaluable tool in electrochemistry.



Volta was interested in electricity early in his career. He published his first book on static electricity at the age of twenty-four. In 1775, Volta announced the discovery of the electrophorus, a new sort of instrument that could store static electricity.

Electrophorus from 1800s.

An electrophorus is a capacitive generator used to produce electrostatic charge via the process of electrostatic induction. The electrophorus consists of a dielectric plate (originally a 'cake' of resinous material like pitch or wax, but in modern versions plastic is used) and a metal plate with an insulating handle.

And in 1782, Volta invented another instrument, the condensing electroscope that was an extremely sensitive measuring device capable of detecting the existence of negative charge even in water vapour and in the smoke of burning coals.

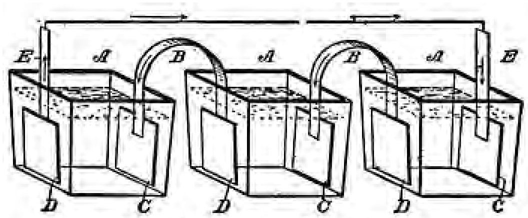
How was the battery invented?

After reading about Galvani's experiment, Volta began to wonder if an electric current could be created just by the presence of two different metals. He began a series of experiments to see if he could force an electric current to flow between two strips of two different metals. He laid them next to each other, nothing happened. He laid them across each other, nothing happened. He changed metals, nothing happened. He submerged them in water, and then also nothing happened.

However, when he submerged the metal strips in a strong acid, he found that he created a steady, strong electrical current flowing between the metal strips. He experimented with different metals & found that copper & zinc worked best.

Each time he created an electric current, however, it soon dwindled & ceased. Volta noted scaly deposits on one of his two metal strips & suspected that these somehow blocked the electric flow. Volta, however, was unable to identify the deposits or to prevent them from forming & throttling his electric current.

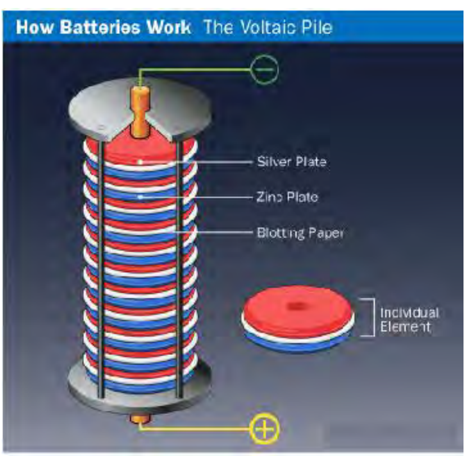
Volta wrote papers describing these experiments & put forth the idea that electric currents were created whenever two different metals were exposed to the same acid solution. After a few additional experiments over the next two years, Volta came to the conclusion that chemical reactions involving *strips of two different metals were what created an electric current. The metals & acid solutions created a chemical reaction that freed a flow of electricity. He began to call the acid solution an electrolyte, since it freed electricity from the metal strips placed in it.*



Galvanic Electricity. Crown of Cups

The first battery was called the "crown of cups," shown in fig, and consisting of a row of glass cups (A), containing salt water. These cups were electrically connected by means of bent metal strips (B), each strip having at one end a copper plate (C), and at the other end a zinc plate (D). The first plate in the cup at one end is connected with the last plate in the cup at the other end by a conductor (E) to make a complete circuit.

In 1800, Volta decided to build a battery using metal strips to prove his theory. He filled a series of blows with acidic brines & connected the blow with strips of copper & zinc. He was able to show that this arrangement created a steady current for almost an hour before it faded & trickled to a stop.



Volta found that a current was produced when two different metal disks such as silver and zinc were separated by a moist conductor, such as paper soaked in salt water, and brought into contact by a wire. By stacking a collection of silver-moist paper-zinc units, in effect forming a pile, Volta determined that the current intensified. If someone touched the top of such a "voltaic pile" (as this early battery was called) and put his or her other hand in a dish of salt water that was connected to the bottom metal disk by a strip of metal, that person would feel a continuous shock.

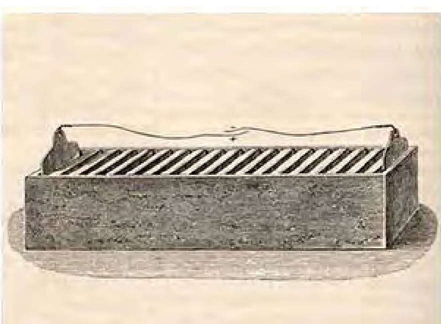
Volta demonstrating the Voltaic Pile to Napoleon Bonaparte

Volta made his discovery of the current electricity–generating voltaic pile known to the scientific community by 1800. In 1801 the French emperor, Napoleon, summoned Volta to demonstrate his battery. Napoleon was so impressed that he bestowed the Legion of Honour on Volta.

His invention gave rise to new fields of scientific inquiry, including electrochemistry, electromagnetism, and the modern applications of electricity.

William Cruickshank in 1802 invented Trough battery which was variant of Alessandro Volta's Voltaic Pile. Volta's battery consisted of brine-soaked pieces of cloth sandwiched between zinc and copper discs, piled in a stack. This resulted in electrolyte leakage as the weight of the discs squeezed the electrolyte out of the cloth.

Advantage of the Trough



A trough battery.

Cruickshank solved this problem by laying the battery on its side in a rectangular box. The inside of this box was lined with shellac for insulation, and pairs of welded-together zinc and copper plates were laid out in this box, evenly spaced. The spaces between the plates (the troughs) were filled with dilute sulphuric acid. So long as the box was not knocked about, there was no risk of electrolyte spillage.

The first chemists to use the voltaic pile were William Nicholson and Anthony Carlisle, who built a pile and used it to decompose water. Humphry Davy (1778–1829) used the voltaic pile to decompose many substances, such as potash and soda. Davy was also able to isolate for the first time several elements, including calcium and magnesium, using the voltaic pile.

The voltaic pile also had applications in other fields of science. William Cruikshank discovered the process of electroplating while working with a voltaic pile. Davy constructed the first crude electric light with the pile in 1820.

Early Batteries:

Although early batteries were of great value for experimental purposes, in practice their voltages fluctuated and they could not provide a large current for a sustained period. Later, starting with the Daniell cell in 1836, batteries provided more reliable currents and were adopted by industry for use in stationary devices, particularly in telegraph networks where they were the only practical source of electricity, since electrical distribution networks did not exist at the time. These wet cells used liquid electrolytes, which were prone to leakage and spillage if not handled correctly. Many used glass jars to hold their components, which made them fragile. These characteristics made wet cells unsuitable for portable appliances. Near the end of the nineteenth century, the invention of dry cell batteries, which replaced the liquid electrolyte with a paste, made portable electrical devices practical.

Volta Piles
1st Quarter, 19th Century

In 1859, French physicist Gaston Plante invented the rechargeable battery. By designing a lead-acid battery, he was able to force a current through it backwards & recharge the battery. In 1866, French chemist Georges Leclanche invented the dry cell battery. His battery was made of carbon & zinc electrodes in an ammonium chloride solution with a mixture of carbon grains & manganese dioxide to soak up any hydrogen produced at the electrodes. The common alkaline battery was invented in 1914 by Thomas Edison.

The battery or pile was Volta's great contribution to the science. For many years it afforded the only means of generating electricity in considerable & manageable quantities. By its use many of the remarkable discoveries were made. In various forms its practical applications have become so extensive & so common, that it is probably the best known of all electrical instruments.

When Volta died in 1827, the scientific community decided to honour him by using his name for the unit that measures electric potential - The volt.

Did You Know?

Japanese scientists have invented a new kind of battery. It uses seawater as its electrolyte. The batteries are manufactured & stored dry. Whenever you need battery power, just add sea water!

World's biggest battery

The world's biggest battery was plugged in to provide emergency power to one of the United States' most isolated cities. The rechargeable battery, which at 2,000 square meters is bigger than a football pitch and weighs 1,300 tones, was manufactured by power components specialist ABB to provide electricity to Fairbanks, Alaska's second-largest city, in the event of a blackout.

The earthquake-proof contraption contains 13,760 NiCad cells - bigger versions of those used in many portable electronic appliances including laptop computers and radios. Each cell measures 16inch by 21inch and weighs more than 12 stone.

Stored in a warehouse near the city, where temperatures plunge to -51 degrees Centigrade in winter, the battery will provide 40 megawatts of power - enough for around 12,000 people - for up to seven minutes. This is enough time, according to ABB, to start up diesel generators to restore power; an important safeguard since at such low temperatures, water pipes can freeze entirely in two hours.

History of Electrochemistry

Electrochemistry deals with the links between chemical reactions and electricity. This includes the study of chemical changes caused by the passage of an electric current across a medium, as well as the production of electric energy by chemical reactions. Electrochemistry also embraces the study of 'electrolyte solutions' and the chemical equilibrium that occur in them.

Almost three thousand years ago, the Greek philosopher Aristotle postulated that all matter is comprised of four basic elements: earth, water, air, and fire. The idea dominated science until the late 18th century, when revolutionaries from rival nations transformed chemistry from a jumble of medieval alchemy into a true science. The pace of discovery accelerated rapidly as chemists on the frontiers of knowledge established the theories and methodologies of modern science. Electrochemical systems have played a determinant role in the history of mankind. They are an intrinsic part of our evolution on this Planet.

The whole of electrical technologies is based on magnetic and electrical phenomena and no history of the subject can ignore the origins of these two groups, remote and sometimes uncertain as these origins may be. For many centuries man has observed magnetic effects in natural minerals found in the ground and electrical effects in lightning, the aurora borealis, St. Elmo's fire, the electric eel and the attraction of light objects by natural resins when rubbed.

Some of these observations have been put to practical use from the very earliest recorded times, the lodestone for navigation, the electric eel for medicinal purposes.

But the question now is when all it started? No one knows for sure but records reveal that despite the gain in knowledge of electrical properties and the building of generators, it wasn't until the late 18th century that Italian physician and anatomist Luigi Galvani marked the birth of electrochemistry by establishing a bridge between muscular contractions and electricity with his 1791 essay *De Viribus Electricitatis in Motu Musculari Commentarius*, where he proposed a "nerveo-electrical substance" in life forms.

After reading about Galvani's experiment, Volta began to wonder if an electric current could be created just by the presence of two different metals. He began a series of experiments to see if he could force an electric current to flow between two strips of two different metals.

Volta found that a current was produced when two different metal disks such as silver and zinc were separated by a moist conductor, such as paper soaked in salt water, and brought into contact by a wire. By stacking a collection of silver-moist paper-zinc units, in effect forming a pile, Volta determined that the current intensified.

The first important effect of the electric current to be discovered was its ability to break up chemical compounds into their elements, or electrolysis. At the beginning of the 18th century two English chemists, Carlisle and Nicolson connected the two ends of a Voltaic pile to two platinum wires in tubes containing dilute acid. Bubbles rose from the wires and it was found that those from one wire were composed of oxygen, while those at the other were hydrogen. The chemists concluded correctly that the water had been decomposed into the elements which built it up, by the electric current.

William Nicholson was English chemist, discoverer of the electrolysis of water, which has become a basic process in both chemical research and industry. Nicholson was at various times a hydraulic engineer, inventor, translator, and scientific publicist.

William Nicholson
1753-1815

He invented a hydrometer (an instrument for measuring the density of liquids) in 1790. In 1800, after he heard of the invention of the electric battery by the Italian physicist Alessandro Volta, he built one of his own. He then discovered that when leads from the battery are placed in water, the water breaks up into hydrogen and oxygen, which collect separately to form bubbles at the submerged ends of the wires. With this discovery Nicholson became the first man to produce a chemical reaction by electricity.

Johann Wilhelm Ritter
(1776-1810)

In 1800, only months after the English chemist William Nicholson succeeded in decomposing water into hydrogen and oxygen by electrolysis, Johann Ritter duplicated the experiment but arranged the electrodes so that he could collect the two gases separately, thus improving on the experiments of Carlisle and Nicholson. Soon thereafter he discovered the process of electroplating. He observed that he could get metal to attach to copper which was the first electroplating attempt. He also observed the amount of metal deposited and the amount of oxygen produced during an electrolytic process that depended on the distance between the electrodes. He learned that the closer the electrodes, the stronger the effects.

In 1802, he developed a dry cell battery from his efforts with electrolytic cells. He found that his new combination worked as well as the Volta pile to charge Leyden jars, and continued to function equally well for six days. Volta's pile worked only about 15 to 20 minutes before exhausting. Ritter again did not publish his work on the dry pile because he stated that his two months of very concentrated research would take him two years to write.

Johann Wilhelm Ritter discovered the ultraviolet end of the spectrum. Ritter was the first to establish an explicit connection between galvanism and chemical reactivity. He correlated the electrical effects produced by various metal couples on the muscle with differences in the metals' ease of oxidation. His suggestion that current was due to a chemical interaction between the metals was the first electrochemical explanation of this phenomenon.

Ritter had a difficult writing style, a marked tendency to speculate to excess, and procrastinated heavily when it came to publishing detailed accounts of his investigations and discoveries. For these reasons, many of his findings went unnoticed, only to be soon independently rediscovered by other scientists. In the last years of his life, his scientific credibility was also damaged by his interest in occult phenomena, and more importantly by the inability of other scientists to reproduce his experiments in this area. Thus dismissed by most of his scientific peers, facing severe financial difficulties and family illnesses, Ritter died few weeks after his thirty-third birthday. It took over a century before his scientific work was given due credit.

Humphry Davy (1778-1829) too began to examine the chemical effects of electricity in 1800. He soon found that when he passed electrical current through some substances, these substances decomposed, (a process later called electrolysis). In 1813, Sir Humphry Davy concocted a giant battery in the basement of Britain's Royal Society. It was made of 2,000 pairs of plates and took up 889 *square feet.*

The intensity of its effect (the voltage generated) was directly related to the reactivity of the electrolyte with the metal. Evidently, Davy understood that the actions of electrolysis and of the voltaic pile were the same. His work led him to propose that the elements of a chemical compound are held together by electrical forces.

Through electrolysis, Davy eventually discovered magnesium, calcium, strontium, and barium in 1808. For all these discoveries, much groundwork had of course been done by others.

In 1832, Michael Faraday's experiments led him to state his two laws of electrochemistry.

First law of electrolysis

In 1832, Michael Faraday reported that the quantity of elements separated by passing an electric current through a molten or dissolved salt is proportional to the quantity of electric charge passed through the circuit. This became the basis of the first law of electrolysis:

$$m = k \cdot q$$

Second law of electrolysis

Faraday also discovered that the mass of the resulting separated elements is directly proportional to the atomic masses of the elements when an appropriate integral divisor is applied. This provided strong evidence that discrete particles of matter exist as parts of the atoms of elements.

The work that led to these two laws also resulted in many of the modern electrochemical terms — electrode, electrolyte, and ion, to name a few — all coined by Faraday.

It is hard to overstate the importance of electrochemistry in the modern world: the ramifications of the subject extend into areas as diverse as batteries, fuel cells, effluent remediation & recycling, clean technology, electro-synthesis of organic & inorganic compounds, conversion & storage of solar energy, semiconductor processing, material corrosion, biological electron transfer process & a wide range of highly specific analytical techniques. The impact of electrochemistry on the lives of all of us has increased immeasurably, even in recent years.

Biotechnology in gold extraction

Bioleaching is the extraction of specific metals from their ores through the use of living organisms. This is much cleaner than the traditional heap leaching using cyanide. Bioleaching is one of several applications within biohydrometallurgy and several methods are used to recover copper, zinc, lead, arsenic, antimony, nickel, molybdenum, gold, silver, and cobalt.


Thiobacillus ferrooxidans

The most important player in the bioleaching process is Acidithiobacillus ferrooxidans. It is a chemoautotrophic acidophile, meaning that it obtains its energy from inorganic sources and fixes its own carbon while growing in an acidic medium. Its unique ability to oxidise ferrous to ferric, and sulphur and reduced sulphur compounds to sulphuric acid, leads to leaching of metals from their oxide and sulphide ores. Among the group of Thiobacilli, Thiobacillus ferrooxidans has emerged as an economically significant bacterium in the field of leaching of sulfide ores.

Bioleaching technology, originally developed by BacTech Mining Corporation. Historically, liberation of metals has been achieved by smelting, or burning, of sulphide ores or concentrates. Concentration of metal sulphides into a smaller mass is often performed prior to smelting or bioleaching, as these are the more expensive parts of an overall operation, and it is cheaper to treat smaller tonnages of material. Although economically efficient, smelting produces noxious SO_2 emissions that create acid rain and/or arsenic trioxide. Bioleaching produces no offensive gases as it is a hydrometallurgical form of treatment.

There are often many deleterious elements such as arsenic associated with sulphide minerals and these often report to the flue gases in smelting. Bioleaching has a further environmental attribute by effectively stabilizing any arsenic present and producing a stable end product for tailings disposal.

Bioleaching uses naturally-occurring bacteria in reactors (tanks) to oxidize sulphides. The key is that by providing the bacteria with optimal operating and living conditions in reactors, they are capable of oxidizing metal encapsulated *in sulphides in as little as 5-6 days, as opposed to many years in their natural habitat. This is a common residence time in a commercial bioleach plant and the control of this and other parameters, such as the particle size of feed, are relatively simple and readily managed by operators with the correct training.*

Bioreactor technology for gold processing is being commercially practised in South Africa, Australia, Ghana and Brazil.

Dream Still Remained As a Dream

Source: *Documentary on Universe by PBS NOVA titled "The Elegant Universe"*

Albert Einstein greatest scientist ever born, we all know that he ruled the world for more than a century with his theory of "General Relativity", but what many people don't know is, he had a dream. He dreamt of solving a mystery, the mystery so profound that today thousands of scientists on the cutting edge of physics are still trying to solve it. Even as he near the end of his life Einstein kept a note pad close at him furiously tried many equations, theories. Many people believed that he was at the verge of achieving his dream. Now the question is what was he dreamt about? Does he succeed in achieving it?

Albert Einstein got the Nobel Prize in 1921 "for his services to Theoretical Physics and especially for his discovery of the law of the photoelectric effect". Despite all that he had achieved Einstein wasn't satisfied; he immediately set his sides on an even grander goal. Einstein had a vision of 'unification' a vision that encompasses all the laws of the physics. A single theory that explains all the workings of the universe, Einstein clearly believes that the universe has overall grand & beautiful patterns to the way it works.

And long before Einstein the quest for unification began with most famous accident in the history of science. As a story goes one day in 1665 a young man was sitting under a tree when all the sudden he saw an apple fall from above & with the fall of that apple Isaac Newton revolutionized our picture of the universe in an audacious proposal for his time Newton proclaimed that the force pulling an apple to the ground & force keeping the moon in orbiting around the earth were actually one & the same, so Newton for the first time unified the heavens & the earth's in a single theory called 'gravity'.

In mid 18th century electricity & magnetism were sparking scientist's interest; these two forces seem to share a curious relationship that inventers like Samuel Morse were taking advantage of it by inventing telegraph. Electricity & magnetism is so obvious in nature that it demanded unification. In 1864 Maxwell devised a set of 4 elegant mathematical equations that unified electricity & magnetism in a single force called Electro-magnetism. Einstein thought *that this was one of the triumphant moments of all the physics & admired Maxwell hugely for what he had done.*

About 50 years after Maxwell unified electricity & magnetism Einstein was confident that he could unify his new theory of gravity "General Relativity" with Maxwell's electromagnetism he will be able to formulate a master equation that could describe everything, the entire universe.

Einstein found that the difference in strengths between these two forces would outweigh their similarities. Compared to electromagnetism, force of gravity is very feeble. It would be an uphill battle for Einstein to unify these two forces of widely different strengths. Einstein had achieved so much in 1920 that he naturally expected that he could go on by achieving the great things. But Einstein ran out of time, unfortunately he died on April 18th 1955 & his dream unfulfilled.

This was the frequently asked question, why was he looking for unification? & the answer is very simple Einstein is one of those physicists who really want to know the mind of God, which means the entire picture.

Now scientists are trying a new theory called "string theory" which could help in achieving Einstein dream.

An Observation That Has Changed The World

Apparatus to Demonstrate Oersted's Discovery

Hans Christen Oersted (1775-1851), while making a demonstration during a lecture in 1820, accidentally placed a wire to lie on top of a compass. Oersted noticed a deflection of the compass needle when an electric current started flowing through the wire. Philosophically, scientists had speculated that electricity & magnetism must be related. Oersted was the first to demonstrate the relationship.

Oersted was superb teacher & an outstanding scientist who elevated science in Denmark to the equal of that in any other country. He was also an enthusiastic populariser of science, writing articles & reviews for popular journals. Much of Oersted scientific work involved chemistry, electrochemistry, & the physics of gases & liquids. These fields were experiencing the same kinds of groping that were apparent in electricity & magnetism at the time.

Oersted experiment to prove there is a relation between Electricity & Magnetism.

Oersted work in electricity & magnetism, however, produced a discovery which excited scientists throughout the world. Orthodox corpuscular theories before 1820 did not predict that the two were related. Coulomb had felt that electricity & magnetism were fundamentally different, & he could find no commonality between them in his researches from 1785 to 1790, although both had the same relationship between force & the reciprocal square of the separations between charges & poles. Oersted, believing in the unity of nature, felt that there was such a relationship, & set about finding the proper conditions for its taking place.

During a lecture demonstration, on April 21, 1820, while setting up his apparatus, Oersted noticed that when he turned on an electric current by connecting the wire to both ends of the battery, a compass needle held nearby deflected away from magnetic north, where it normally pointed. The compass needle moved only slightly, so slightly that the audience didn't even notice. But it was clear to Oersted that something significant was happening.

Whether completely accidental or at least somewhat expected, Oersted was intrigued by his observation. He didn't immediately find a mathematical explanation, but he thought it over for the next three months, and then continued to experiment, until he was quite certain that an electric current could produce a magnetic field (which he called an "electric conflict").

His battery, a voltaic pile using 20 copper rectangles, probably produced an emf of about 15-20 volts. He tried various types of wires, and still found the compass needle deflected. When he reversed the current, he found the needle deflected in the opposite direction. He experimented with various orientations of the needle and wire. He also noticed that the effect couldn't be shielded by placing wood or glass between the compass and the electric current.

On July 21, 1820, Oersted published his results in a pamphlet, which was circulated privately to physicists and scientific societies. His results were mainly qualitative, but the effect was clear–an electric current generates a magnetic force.

The publication caused an immediate sensation, and raised Oersted's status as a scientist. Others began investigating the newly found connection between electricity and magnetism. Scientists all over Europe were fascinated with the new discovery. Ampere in France, Schweigger & Poggendorff in Germany, & Cumming in England quickly built Oersted's findings & made significant contributions to the science of electricity & magnetism.

Oersted's discovery not only showed how a magnet could be produced by an electric current, but also, for the first time in the history of science, afforded the means of reversing at will the direction of magnetism and thus obtaining a continuous rotary motion.

Magnetic Field Around a Current-Carrying Wire

This early twentieth-century apparatus by Max Kohl of Chemnitz, Germany, was used to show the magnetic field line configurations around current-carrying wires. Iron filings scattered on the upper surface aligned themselves along the magnetic field lines set up by currents in the wires. Various combinations of parallel and anti-parallel currents were possible by connecting the leads from the current source to the various binding posts.

The apparatus is in the collection at the University of Cincinnati physics department.

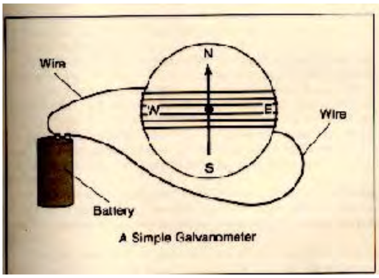
The Foundations For Electrodynamics

Electrodynamics is the phenomena associated with moving electric charges, and their interaction with electric and magnetic fields. On the 11th of September, 1820, Andre Marie Ampere first learned of the Oersted experiment, in which a magnetic needle was deflected by the electric current. On the 18th of the same month, in a paper presented to the academy, he announced the fundamental principles of the science of "electrodynamics." In the almost incredibly short time of one week he had worked over Oersted's discovery both theoretically & experimentally he had made the capital discovery that magnetic effects could be produced from the currents were flowing in the same direction.

The history of electrodynamics can be roughly divided into a pre-scientific period of time, an era of magetostatics & electrostatics, a period when it was a success to create permanent flowing electric currents, & epoch of combining all electric & magnetic phenomena into electrodynamics. The last epoch brought the conceptual clarification.

A reproduction of Ampere's apparatus for studying the interaction between two current-carrying parallel conductors.

He formulated a law of electromagnetism (commonly called Ampere's law) that describes mathematically the magnetic force between two electric currents. He also performed many experiments, the results of which served to develop a mathematical theory that not only explained electromagnetic phenomena already reported but predicted new ones as well. Among his laws of electrodynamics are: 1) parallel conductors currying currents in the same direction are attracted to each other and 2) parallel conductors carrying currents in the opposite directions are repelled from each other. He also suggests that electromagnetism could be used in telegraphy.



Ampere was also the first person to develop measuring techniques for electricity; Ampere built an instrument utilizing a free-moving needle to measure the flow of electricity. Its later refinement was known as the galvanometer. He used a highly sensitive galvanometer to make his measurements. A galvanometer is a device used to detect and measure the flow of electricity. A simple galvanometer is a compass with a wire wrapped around it. Connect either end of the wire to whatever you want to test (such as a battery) if the needle is deflected then a current has been created. The stronger the current the great the needle will be deflated. Ampere invented the astatic needle, which made possible the modern astatic galvanometer.

Ampere is also responsible for developing the mathematical theory, which he called "electrodynamics" to distinguish it from electrostatics, describing the interaction between electricity & magnetism. This theory was published in the same 1826 book.

This is an early model of the same apparatus constructed by Ampere for his famous experiments on the relationship between magnetic fields and electric current.

Ampere's Law allows physicists to determine the magnitude and direction of the magnetic field induced by an electric current. Ampere's law is a mathematical relationship between the amount of magnetic field around a closed loop and the total amount of electric current enclosed by the loop. It is somewhat analogous to Gauss's law, relating the total electric flux over a closed surface to the total charge enclosed by the surface

Original Ampere's Circuital law

In its original form, Ampere's Circuital law relates the magnetic field B to its source, the current density J:

$$\oint_C \mathbf{H} \cdot \mathrm{d}\mathbf{l} = \iint_S \mathbf{J} \cdot \mathrm{d}\mathbf{S} = I_{\mathrm{enc}}$$

Where

- $\oint_C$ *is the closed line integral around contour (closed curve) C.*
- $\mathbf{H}$ *is the magnetic field in amperes per metre.*
- $\mathrm{d}\mathbf{l}$ *is an infinitesimal element (differential) of the contour C,*
- $\mathbf{J}$ *is the current density (in amperes per square meter) through the surface S enclosed by contour C*
- $\mathrm{d}\mathbf{S}$ *is a differential vector area element of surface S, with infinitesimally small magnitude and direction normal to surface S,*
- I_{enc} *is the current enclosed by the curve C, or strictly, the current that penetrates surface S.*

Equivalently, the original equation in differential form is

$$\nabla \times \mathbf{H} = \mathbf{J}$$

On this joint work of Oersted & Ampere the whole structure of modern electricity may be said to rest, & with the establishment of this, it's almost ample foundation, their names will ever be inseparably connected.

The theoretical foundation presented by Ampere served as the basis for other ideas of the 19th century regarding electricity and magnetism. It helped to inspire research and discoveries by scientists including Faraday, Weber, Thomson, and Maxwell. The ampere – the unit for measuring electric current – was named in honour of Ampere.

In the two hundred years from the mid nineteenth century to the mid twentieth century, physics underwent a remarkable revolution in its mathematics.

No doubt that, through his work in earth magnetism, Carl Friedrich Gauss (1777-1855) started a revolution in electrodynamics and in physics. Throughout 1832 Gauss worked to develop and test a method for measuring the quantity and direction of the earth's magnetic intensity, independently of the characteristics of the measuring compass.

In fact, the methods used until then were largely unreliable mainly because the measures were dependent on the particular magnetic moment of the compass employed and were variable in time due to variations in this moment.

Due to both features (independence of instrument and independence of location), Gauss called the units "absolute". Wilhelm Eduard Weber (1804-1891) was, for a major part of his life, a collaborator and a friend of Gauss at the University of Göttingen. The path to Weber's electrical researches lay through Gauss's magnetism at Göttingen. In fact, Gauss's and Weber's magnetic interests soon extended to the exploitation of the magnetic techniques in the new field opened by Faraday's recently discovered electromagnetic induction. In 1843, Weber had become particularly concerned with Ampere's electrodynamics.

Weber's research culminated in his discovery of a fundamental law of electrodynamic action, which he presented in his influential 1846 paper "Electrodynamic Measures on a General Fundamental Law of the Electric Action". The law was fundamental in the sense that the electric action applied to electric "masses" themselves rather than to their ponderable carriers, the conducting wires.

A definition of electrodynamics and electromagnetic units of current intensity, independently from Gauss's method of current-magnet interaction, was included among the results of Weber's works, thus providing a simpler basis for the absolute measure of electric current in terms of fundamental mechanical units.

Following there footsteps, James Clerk Maxwell (13 June 1831 – 5 November 1879) was a Scottish physicist and mathematician. His most prominent achievement was formulating classical electromagnetic theory. This united all previously unrelated observations, experiments and equations of electricity, magnetism and even optics into a consistent theory. Maxwell's equations demonstrated that electricity, magnetism and even light are all manifestations of the same phenomenon, namely the electromagnetic field. Subsequently, all other classic laws or equations of these disciplines became simplified cases of Maxwell's equations. Maxwell's achievements concerning electromagnetism have been called the "second great unification in physics", after the first one realised by Isaac Newton. He was the first cousin of notable 19th century artist Jemima Blackburn.

Maxwell demonstrated that electric and magnetic fields travel through space in the form of waves, and at the constant speed of light. In 1865 Maxwell published A Dynamical Theory of the Electromagnetic Field. It was with this that he first proposed that light was in fact undulations in the same medium that is the cause of electric and magnetic phenomena. His work in producing a unified model of electromagnetism is one of the greatest advances in physics.

Maxwell is considered by many physicists to be the 19th-century scientist who had the greatest influence on 20th-century physics. His contributions to the science are considered by many to be of the same magnitude as those of Isaac Newton and Albert Einstein. In the millennium poll—a survey of the 100 most prominent physicists—Maxwell was voted the third greatest physicist of all time, behind only Newton and Einstein.

His famous equations, in their modern form of four partial differential equations, first appeared in fully developed form in his textbook A Treatise on Electricity and Magnetism in 1873. Maxwell's equations are a set of partial differential equations that, together with the Lorentz force law, form the foundation of classical electrodynamics, classical optics, and electric circuits. These in turn underlie modern electrical and communications technologies.

Maxwell's Equations in the classical forms

Name	Differential form	Integral form
Gauss' law:	$\nabla \cdot \mathbf{D} = \rho$	$\oint_S \mathbf{D} \cdot d\mathbf{A} = \int_V \rho \cdot dV$
Gauss' law for magnetism (absence of magnetic monopoles):	$\nabla \cdot \mathbf{B} = 0$	$\oint_S \mathbf{B} \cdot d\mathbf{A} = 0$
Faraday's law of induction	$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$	$\oint_C \mathbf{E} \cdot d\mathbf{l} - \oint_C \mathbf{B} \times \mathbf{v} \cdot d\mathbf{l} = -\frac{d}{dt} \int_S \mathbf{B} \cdot d\mathbf{A}$
Ampère's law (with Maxwell's extension):	$\nabla \times \mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t}$	$\oint_C \mathbf{H} \cdot d\mathbf{l} = \int_S \mathbf{J} \cdot d\mathbf{A} + \int_S \frac{\partial \mathbf{D}}{\partial t} \cdot d\mathbf{A}$

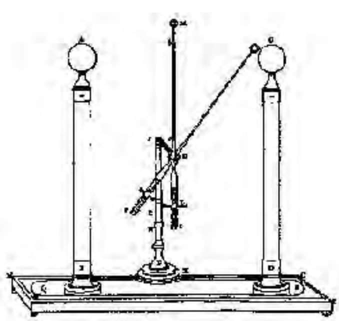
A history of the evolution of electric clocks

Relatively very little is known about electrostatic clocks and literature on this subject is difficult to obtain. Ever since the motive power of static electricity was realized efforts were made to make full use of this property. So probably as early as the late eighteen hundreds efforts were made to use static electricity to drive a pendulum for the purpose of keeping time.

Johann Wilhelm Ritter (1776-1810) of Germany is believed to be the first to have made a dry pile as early as 1802 showing identical effects to those of an electrostatic machine.

In the beginning of the 19th century, the abbot Zamboni, an Italian physicist, developed a method of making Volta Piles (Early batteries) by using very thin metal foil and paper. Using this method he was able to create piles of over 2000 layers that stood less than 12" tall.

Zamboni is known to students of physics for an improved version of the dry pile (an electric battery which does not use an electrolyte) which he invented in 1812. It consists of a number of paper discs coated with zinc foil on one side and manganese dioxide on the other; the moisture of the paper serves as a conductor.

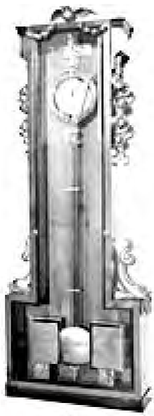


Scheme of electric pendulum that constituted the first perpetual electromotive

By pressing a large number of such discs together in a glass tube, an electromotive force can be obtained that is sufficient enough to deflect the leaves of an ordinary electroscope. By bringing the terminal knobs of the pile near each other and suspending a light brass ball between them, Zamboni devised what was called an electrostatic clock. The device is so named because the ball oscillating between the knobs looks like a pendulum.

Some say these machines worked non-stop for more than 100 years, hence they are called Perpetual Motion Machines. The piles are by now exhausted, and it's possible to take one out from the tube. These very rare pieces formed the earliest research on very high voltage batteries and today only a few examples survive.

PILES, PENDULUMS AND CLOCKS STILL PRESERVED



(1)

(2)

(3)

(4)

Pendulum clock (1) realized by Antonio Camerlengo working with Zamboni's piles and certified for the Agriculture, Commerce and Arts Academy in 1827, property of Mr. Paul Forlati.

Pendulum mechanical clocks (2) moved by the Zamboni's piles preserved at Liceo Classico "Scipione Maffei" in Verona.

Zamboni's Pendulum electromotive (3) and Perpetual Motion (4), treated from volume "Duecento anni di elettricità", catalogue of the Museum of Physics History in Padua.

Invention of the first electric arc lamp

"Light is the most beautiful of materials, it connects us to the natural world, as this world becomes more artificial its purity becomes even more powerful"

-David Chipperfield

"The existence of light allows us to walk along the tightrope between translucency and transparency"

-Nicholas Grimshaw

Mankind has made use of light for thousands of years. From the primitive use of fire to simple oil lamps then to the more sophisticated gas and electric lights that are more familiar to our lifetimes.

Before electricity was made available as a means of lighting one's home the most common method was either by candlelight or by gas. Candles were made of tallow which is the solid part of animal fat and was the cheapest material to use. Although cheaper they were very smelly and produced a lot of dirty smoke. Oil lamps were an improvement but still suffered from the smell and needed constant cleaning, refueling and adjusting.

Gas lighting offered some improvement. The gas light of the nineteenth century was simply the light of a naked gas flame and looked much like a large candle flame. Its introduction made a big difference to the lives of many- light became readily available without the need to continually clean and trim the wicks of oil lamps, or the constant need to replace candles and clean up the mess of spilt wax. However, it had the disadvantage of making rooms very hot and stuffy by taking oxygen from the air.

These illustrations show a selection of gas lamps from Fredrick Accum's book A Practical Treatise on Gas-Light, London, 1818. Early electric lights used similar designs to appeal to customers.

All the lights before electricity relied on a flame, which caused problems such as bad smells, uncomfortable heat, dirt or the taking of oxygen from the air. Electricity on the other hand opened up new opportunities. A major practical problem with the development of electric lighting was the need to find a suitable source of electricity that was not expensive.

Arc Lighting

The arc lamp was the first widely-used type of electric light and the first commercially successful form of electric lamp. It uses two carbon rods with an electric arc or "spark" between. It was the earliest form of electric street lighting. The arc light's development coincided with basic power generation developments. To improve one, they had to improve the other.

The principle is that two pieces of carbon, connected to an electricity supply, are touched together and then pulled apart. A spark or 'arc' is drawn across the gap and a white hot heat is produced. The concept was first demonstrated by Sir Humphry Davy in the early 19th century, using charcoal sticks and a 2000-cell battery to create an arc across a 4-inch gap. He mounted his electrodes horizontally and noted that, because of the strong convection flow of air, the arc formed the shape of an arch. He coined the term "arch lamp", which was contracted to "arc lamp" when the devices came into common usage. The lamp called firedamp or mine damp, allowed for the mining of deep seams despite the presence of methane and other flammable gases. There were attempts to produce the lamps commercially after 1850 but the lack of a constant electricity supply thwarted efforts.

CLANNY LAMP. DAVY LAMP

Although there is a dispute to who invented the "first" miner's flame lamp that was safe to use in fiery mines, the success of the flame safety lamp was a culmination of the principles discovered by Dr. William R. Clanny, Sir Humphrey Davy, and George Stephenson. All three men worked independently on the problem at about the same time, and all had some knowledge of the other's work.

From 1840 to 1859, many patents were taken out on arc lamps, most of them operated by clockwork, but these were not successful, due chiefly to the lack of a suitable source of current, since all depended on primary cells for their power. The interest in this form of light died down about 1859, & nothing further was attempted until the advent of the Gramme dynamo.

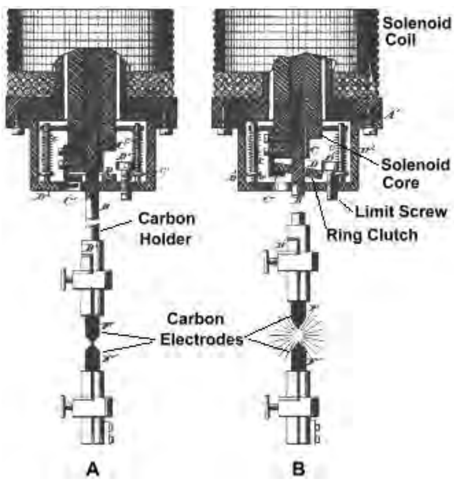
Further improvements made by Charles F. Brush

During his childhood, Brush read about the first arc light experiments performed by Sir Humphrey Davy in the early years of the nineteenth century. At the time of Davy's experiments, the battery was very new to science. Volta had developed the first one only a few years earlier, in 1800. These early batteries were inefficient and very expensive to construct. The lack of an economic source of electricity confined the arc light of the time to the laboratory.

Improvements in batteries by the middle of the century stimulated further development of the arc light. Regulation of the gap between the electrodes was a primary design challenge in producing a practical lamp. During operation, the carbon electrodes are consumed at their tips, resulting in a widening of the gap between them. Left unattended, the lamp will cease to operate when the gap becomes too wide to allow current flow between the electrodes. The problem can be solved by providing a mechanism to adjust the gap during operation.

In developing an arc lighting system, Brush initially concentrated on finding an economical source of electric power. His vision was to light America on a grand scale and this would not be possible with expensive batteries. At the time, the only alternative for producing electricity was the dynamo. Brush realized that the dynamo was the key to a successful lighting system and it would represent a great challenge to his inventive skill. Using sound logic, Brush developed a viable *dynamo before working on the arc lamp itself. By 1877 he had enough confidence in his dynamo to start work on the arc lamp.*

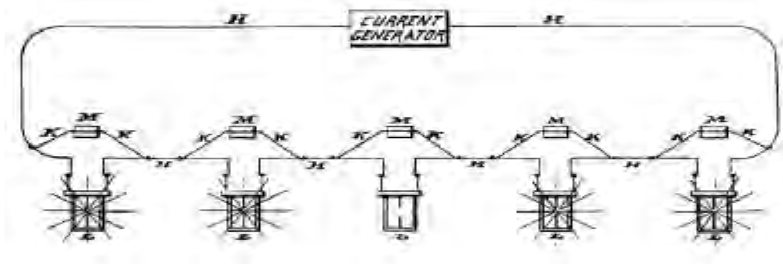
Brush set forth the following design criteria for his lamp: simplicity, reliability, durability, and automatic regulation. These where the characteristics that would insure wide-scale adoption of the lamp, initially he experimented with electromagnetic control devices for maintenance of the arc gap. This was not a new idea; several inventors had produced lamps with electromagnetic regulators prior to Brush. However, Brush found that he could not obtain the desired regulation with an electromagnetic device alone. Better control was achieved when Brush combined electromagnetic and mechanical means to control the arc.



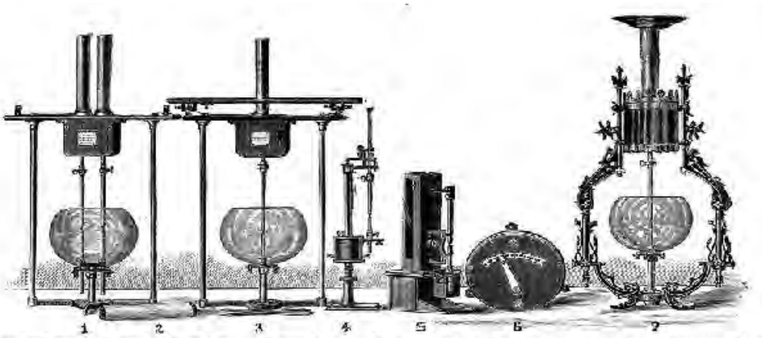
The illustrations to the left were derived from Brush's US patent no. 203 411, Improvement in Electric Lamps, dated May 7, 1878. They illustrate a control mechanism that Brush developed for maintaining the arc gap. The lamp electrodes and solenoid are wired in series so that electric current always flows through the solenoid coil while the lamp is operating. The solenoid contains an iron core which is free to move up and down inside the coil.

By utilizing this scheme, Brush was able to create an arc lamp with good regulation characteristics. The light output was fairly stable and of high intensity.

The lamp designs described above were suitable for single-lamp systems, where one dynamo was used to power one lamp. However, these lamps were not optimal for use in series where one dynamo powered multiple lamps. Brush knew that this was a critical limitation in his system. If the arc was extinguished in one lamp due to a malfunction, all lamps in a series circuit would cease to operate.



The problem could be overcome by adding another control device that would allow current to bypass a malfunctioning lamp. Brush developed a shunt that he could add to each lamp for multiple-lamp systems. The system is diagrammed in the above figure. In this system, each lamp is equipped with a cut-out device, labelled M in the illustration. If a lamp should fail to sustain its arc during operation, a shunt would close, providing a bypass route for current.



1. Double Lamp.—2. Carbons.—3. Single Lamp.—4. Focusing Lamp.—5. Head-light Lamp.—6. Dial Attachment to Machine.—7. Ornamental Lamp.

BRUSH ELECTRIC LAMPS.

Serrin Electric Arc Lamp(1857)

What you see here is the only known example of the first self-starting and self-regulating arc lamp invented by Victor Serrin of Paris, and built in 1857 by the great French instrument maker, Breguet. This beautiful lamp represents an important step in the evolution of the electric light. During the 1850's many people had devised electromagnetic regulators to maintain the arc as the carbon electrodes burnt down. However, in order to start the arc, the carbon rods had to be touched together briefly and then separated. Existing mechanisms required that the lamp be started manually. This was a big problem especially if the lamp was in a hard to reach *area or if it went out once it had been started. Serrin's design proved popular and was soon adopted as the main choice for French light houses where it served for many years. All of this took place 22 years before Thomas Edison perfected his incandescent lamp!*

The Electric Light's first commercial success and happier whales.

The history of electric lightning as a commercial proposition begins with the invention of the Gramme dynamo by Z.J.Gramme, in 1870, together with the introduction Jahlochkoff candle, which was first announced to the public in 1876. In 1880 authorities in Wabash, Indiana discover that the Brush electric arc light system for it's streets would cost $800 less per year than gas lighting. Also they stated that they would get greater volume of illumination. This was the beginning of the revolution across the world to switch to the electric light. By proving to be economically better than oil and gas the future was set. This also stopped the complete eradication of certain whale species that provided the oil, these whales were already close to extinction in the 1880's due to over-hunting.

And also gas used for lighting in those days was made from coal. The coal was shipped to cities, and cooked in a crucible, a gas resulted that supplied the town's light systems. This process was very dirty, it produced massive amounts of carbon monoxide and a coke remains that was then shipped out for other uses as dirty combustible fuel. The electric arc light eliminated the need for plants that produced urban localized pollution.

In 1890 there were more than 130,000 arc lamps in use in the United States. Arc lamps were soon superseded by more efficient and longer-lasting filament lamps in most roles, remaining in only certain niche applications such as cinema projection and searchlights, but even in these applications conventional carbon arc lamps are being pushed into obsolescence by xenon arc lamps.

Source:

- Wikipedia "http://en.wikipedia.org/wiki/Arc_lamp"

History of the Incandescent light bulb

Source:

- *Spark Museum* *"http://www.sparkmuseum.com/LIGHTING.HTM"*
- *Wikipedia* *" http://en.wikipedia.org/wiki/Incandescent_light_bulb"*
- *An Encyclopedia of the History of Technology By Ian McNeil*
- *www.donsbulbs.com*

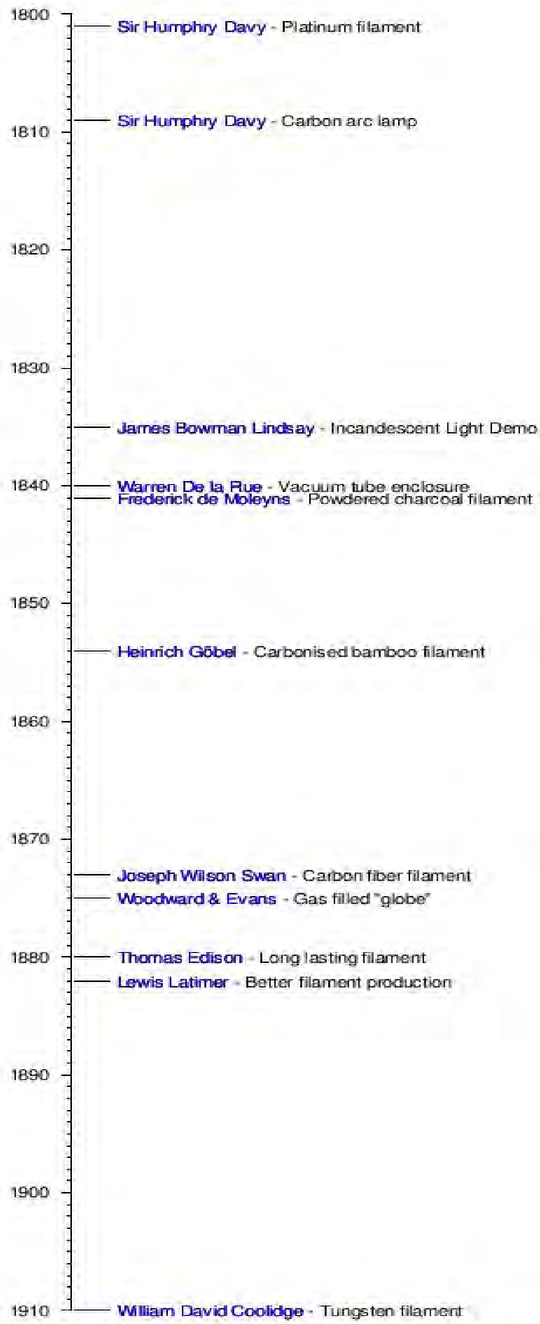
The Arc Lamp produced a very bright light so was better suited for illuminating large areas such as railway stations and street lighting. For domestic use, a smaller light was required. The dazzling light of the arc needed to be 'sub-divided' into smaller lights. This was achieved with the development of incandescent filament lamps.

In an incandescent filament lamp the heated wire was first made of carbon and heated until white hot ('incandescent') by passing an electric current through it. Early experiments show that it was not a simple procedure as a filament material that could be heated to white hot temperatures and then cooled without breaking was required. A means of sealing the connections in a glass bulb without the heat cracking it and a vacuum pump to remove sufficient air to prevent oxidation also needed to be found.

Experiments with metal filaments demonstrated that they could run at a higher temperature than carbon. Platinum was used in early tests but was far too expensive for general use. Metals with very high melting points were tried and tungsten was found to be the most successful with the highest melting point than any other metal.

In addressing the question of who invented the incandescent lamp, historians Robert Friedel and Paul Israel list 22 inventors of incandescent lamps prior to Joseph Wilson Swan and Thomas Edison. They conclude that Edison's version was able to outstrip the others because of a combination of three factors: an effective incandescent material, a higher vacuum than others were able to achieve (by use of the Sprengel pump) and a high resistance that made power distribution from a centralized source economically viable.

Stages of Evolution of Electric lamp

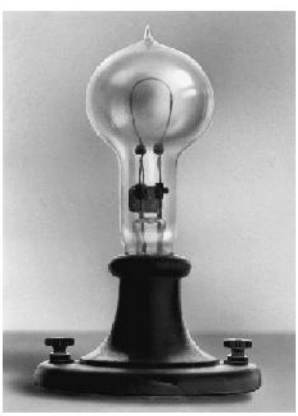


Over the first three-quarters of the 19th century many experimenters worked with various combinations of platinum or iridium wires, carbon rods, and evacuated or semi-evacuated enclosures. Many of these devices were demonstrated and some were patented.

Carbon filament lamp (E27 socket, 220 volts, approx. 30 watts, left side: running with 100 volts)

Joseph Wilson Swan (1828–1914) was a British physicist and chemist. In 1850, he began working with carbonized paper filaments in an evacuated glass bulb. By 1860 he was able to demonstrate a working device but the lack of a good vacuum and an adequate supply of electricity resulted in a short lifetime for the bulb and an inefficient source of light. By the mid-1870s better pumps became available, and Swan returned to his experiments.

With the help of Charles Stearn, an expert on vacuum pumps, in 1878 Swan developed a method of processing that avoided the early bulb blackening.

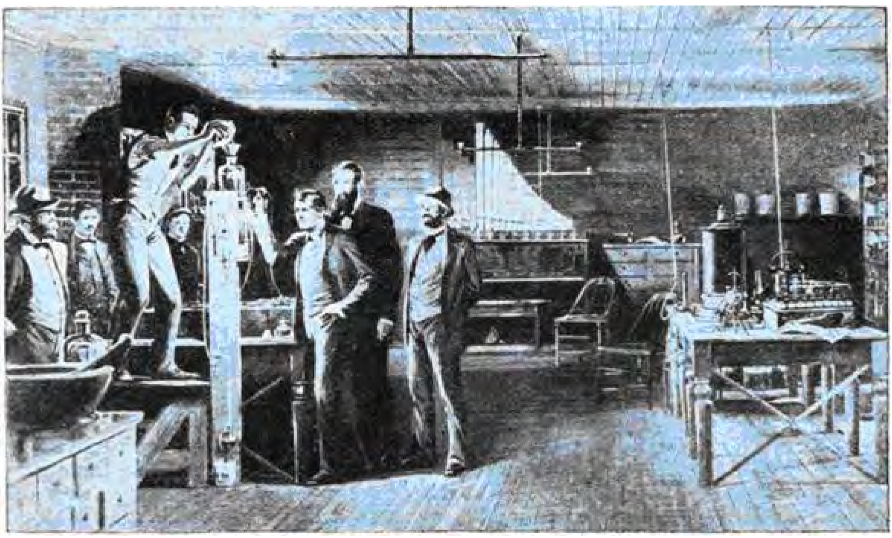


Thomas Edison's electric lamp, patented January 27, 1880.

Incandescent lamp was but a piece of laboratory apparatus up to 1878 then Thomas Edison began serious research into developing a practical incandescent lamp. Edison filed his first patent application for "Improvement in Electric Lights" on October 14, 1878. After many experiments with platinum and other metal filaments, Edison returned to a carbon filament. The first successful test was on October 22, 1879, and lasted 13.5 hours. Edison continued to improve this design and by Nov 4, 1879, filed for a U.S. patent for an electric lamp using "a carbon filament or strip coiled and connected ... to platinum contact wires." Although the patent described several ways of creating the carbon filament including using "cotton and linen thread, wood splints, papers coiled in various ways," it was not until several months after the patent was granted that Edison and his team discovered that a carbonized bamboo filament could last over 1200 hours.

A DRAMATIC moment in the history of modern illuminating science is pictured in the photograph below, showing Thomas A. Edison and his assistants testing the first incandescent lamp bulb at Menlo Park, N. J., on October 19, 1879. The lamp burned continuously for 40 hours before the filament parted. Its life was less than one- tenth that of modern bulbs whose filaments of special alloys burn in an atmosphere of inert gases instead of in a vacuum, as in the original lamp.

Edison is shown in the foreground driving the last of the gases from the bulb with a battery. The picture was taken in Edison's old laboratory.



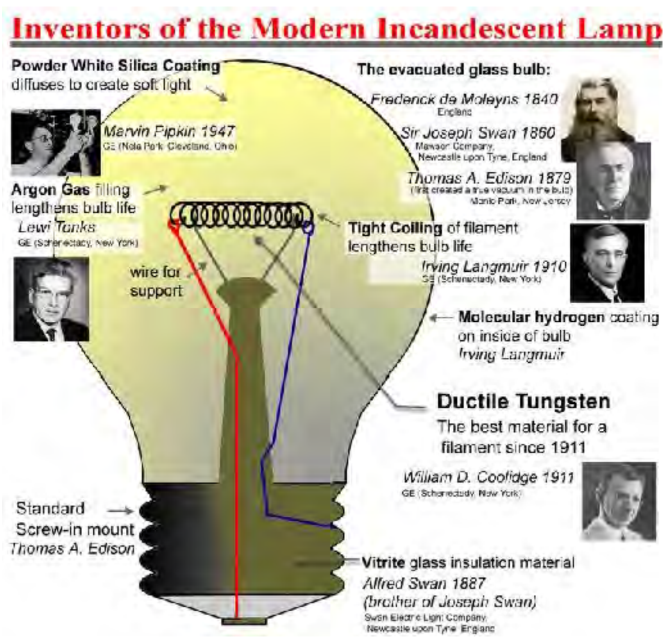
In 1882, the first recorded set of miniature incandescent lamps for lighting a Christmas tree was installed. These did not become common in homes for many years.

In 1897, German physicist and chemist Walther Nernst developed the Nernst lamp, a form of incandescent lamp that used a ceramic globar and did not require enclosure in a vacuum or inert gas. Twice as efficient as carbon filament lamps, Nernst lamps were briefly popular until overtaken by lamps using metal filaments.

On December 13, 1904, Hungarian Sandor Just and Croatian Franjo Hanaman were granted a Hungarian patent for a tungsten filament lamp, which lasted longer and gave a brighter light than the carbon filament. Tungsten filament lamps were first marketed by the Hungarian company Tungsram in 1905.

The initial spread of electricity in Britain was slow and as it was so much more expensive than gas the ordinary person could not afford it. It was not until about 1911, when metal filament lamps had been perfected, that electric lighting became more widely available.

From this time on, the development of electric lighting has been very rapid, & the consumption of incandescent lamps alone has reached several million each year. When we compare the small amount of lighting done by means of electricity twenty-five years ago with the enormous extent of lighting systems & numerous applications of electric illumination as they are today, the growth & development of the art is seen to be very enormous.



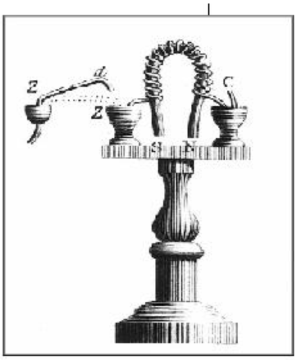
Despite the slow start, electric lighting soon became very popular. Once the incandescent light was developed by Edison & his team, lighting became something very, very different. Suddenly our lives were longer, our productivity increased, our life style changed totally because of that incandescent light.

Development of the Electromagnet

Sailors long ago noticed that, when there was constant lightning, the needle of a compass danced about in all directions. The same dancing of the needle was observed when a magnet was brought near a compass. These & other facts, like knives being made into magnets when a house was struck by lightning, developed curiosity among scientists who were interested in finding out what connection there was between magnetism & electricity.

In 1819, Hans Oersted (1777-1851) found that an electrical current, when passed through a straight piece of wire, deflected the needle on a compass. He published his findings in a small pamphlet in 1820, probably one of the last great scientific discoveries to be published entirely in Latin.

His discovery showed there was a connection between electricity and magnetism and prompted a whirlwind of further investigation by others. In 1825 William Sturgeon developed the first practical electromagnet by loosely winding a coil of un-insulated wire around a horseshoe-shaped piece of iron. To prevent the wire from shorting Sturgeon coated the iron in varnish. The seven-ounce magnet was able to support nine pounds of iron using the current from a single cell.



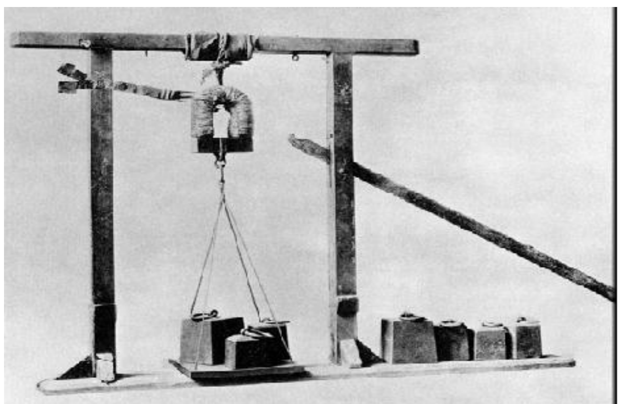
The first artificial electromagnet, invented by Sturgeon in 1824 Sturgeon's original drawing from his 1824 paper to the British Royal Society of Arts, Manufactures, and Commerce. The magnet was made of 18 turns of bare copper wire (insulated wire had not yet been invented)

Sturgeon could regulate his electromagnet; this was the beginning of using electrical energy for making useful and controllable machines and laid the foundations for large-scale electronic communications.

Sturgeon was surprised at the way the electromagnet worked. It was considerably stronger than a natural or permanent magnet of the same size. However, the most surprising element was that instant the current was turned on; the iron core became a magnet. When the current was turned off, the core practically ceased to be a magnet. People at that time thought this peculiar action of electromagnet would make it useless invention, but it is this very action that makes it so useful. If a needle or other object is picked up with a permanent magnet is to scrape or pull it off. To get it off an electromagnet, it is necessary only to break the electric current.

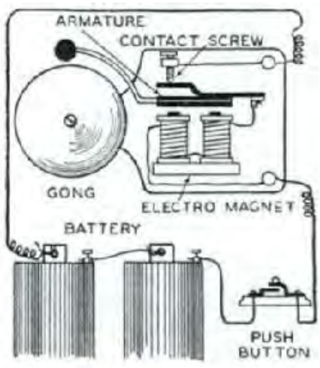
Joseph Henry
(1797-1878)

The electromagnet is, therefore, under our control. We can also control the power of the electromagnet; that is, the size of the load it will lift. The man who taught us how to do this was Joseph Henry (1797-1878) a Scottish-American scientist. Instead of varnishing the iron core as Sturgeon had done, to keep the electricity from flowing off, Henry insulated the copper wire by covering it with wrapping of silk. Instead of putting a single turn of wire round the iron core, he put many turns. On his first electromagnet, he put thirty-five feet of wire, making about 400 turns. These additional turns increased the strength of the magnet very much.



Henry's Yale magnet, mounted in frame constructed under Silliman's direction. N.M.A.H. Cat. No. 181,343.Smithsonian neg. no. 13,346.

Henry found that the magnet was stronger when wound with several separate coils of wire, the ends of each coil being connected with the battery. With a small battery, one of Henry's electromagnet lifted eight-five pounds; and, in 1831, he exhibited a magnet that lifted 36,000 pound. Thus by using a small or large battery, small or large iron cores, a few or many coils of wire, electromagnet of different strength can be made.



Electric Doorbell

Henry was also the first to make the electromagnet do work at a distance, & to show us how it could be made useful. Henry explained his plan like this: "I arranged around one of upper rooms in the Albany Academy a wire more than a mile in length, through which I was enabled to make signals by sounding a bell." When the current was passed through the electromagnet, this caused the bar magnet to swing & strike the bell.

Small electromagnets by the millions are now in use. In connection with the electric battery, they ring our door bells, sound alarms, move signals, & do other work. Enormous lifting magnets are now employed to handle iron & steel. Some of these will lift as much as 100,000 pound. One of the world's largest electromagnet is the Walker magnet, which can lift up 270 tons. Electromagnets do all kinds of work for us. In addition, they are an essential part of the telegraph, the telephone, & the dynamo.

Source: "Wikipedia"

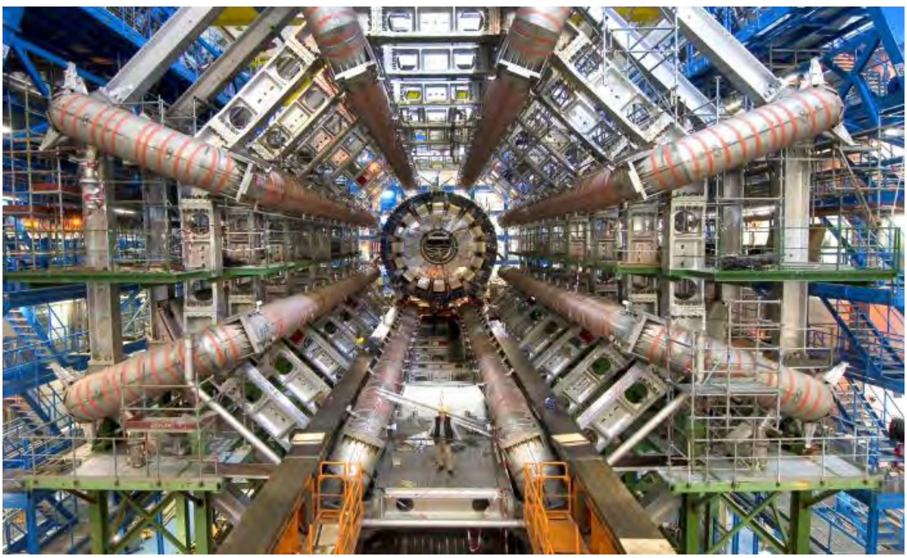
- *http://en.wikipedia.org/wiki/Electromagnet*
- *http://en.wikipedia.org/wiki/Joseph_Henry*

"Spark Museum"

- *http://www.sparkmuseum.com/MAGNET.HTM*

World's Largest Superconducting Magnet

The world's largest superconducting magnet has been successfully powered up on its first try and is ready to test some of the most fundamental questions of science, advancing the understanding of the deepest laws of nature.



Weighing 110 tons (100 metric tons), the Barrel Toroid—seen here with all eight of its superconducting coils clearly visible in a photo released November 20—is 16 feet (5 meters) wide and 82 feet (25 meters) long, dwarfing the lone technician seen bottom center. The Toroid is able to create a magnetic field of about 4 T (tesla) while an electrical current of more than 21,000 amperes pass through its eight gigantic coils.

The instrument is a vital component of ATLAS, one of the particle detectors housed at the European Organization for Nuclear Research's (CERN's) Large Hadron Collider (LHC), a new, internationally funded particle accelerator scheduled to begin operation late next year in Geneva, Switzerland. Particle *accelerators create and collide beams of speeding, highly energetic atomic or subatomic particles.*

The LHC will smash two beams of protons together in some of the most energetic collisions ever created. The goal, physicists say, is to explore the fundamental nature of matter and energy by creating conditions similar to those of the early universe.

At stake are some of science's most difficult puzzles. What is dark matter? Why do things have mass? Why is there so little antimatter? The LHC could provide answers to them all.

Source: National Geographic News

"http://news.nationalgeographic.com/news/2006/11/061121-giant-magnet.html"

Michael Faraday

Source:

- *Documentary on Faraday by PBS-NOVA titled 'Einstein's Big Idea'*
- *The history of science in the eighteenth century by Ray Spangenburg, Diane Moser*

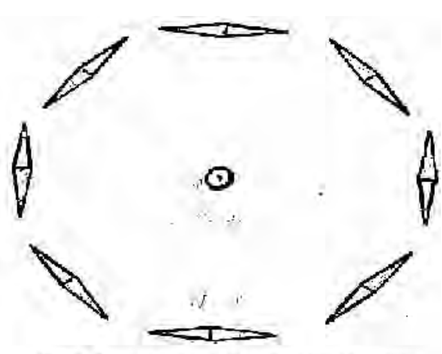
In the early 19th century scientists didn't think in terms of energy, they thought in terms of individual powers or forces. These were obviously objects connected unrelated things the power of wind, the force of door closing, the crack of lightning. The idea that there might be some sort of over arching unifying energy, which lay before all these forces had yet to be revealed. One poor hungry man's drive to understand the hidden mysteries of nature would begin to change all that.

One of the 10 children, the son of blacksmith in England, Michael Faraday (1791-1867) started life with no hope of going to school beyond learning to read & write, much less obtaining a university education. At the age of 12, he'd begun earning his share of rent, & his school days were finished. But some people have such a curious minds that nothing ca stop them from trying to find out what the world is made of, or why people act the way they do, or what makes things work. And Michael Faraday had one of those tirelessly curious minds. He also had a bit of luck. He found a job as an apprentice to a bookbinder, & as he bound the outside of the books, he avidly devoured words inside. He read the articles on electricity in the Encyclopaedia Britannica & Lavoisier's Elements of chemistry.

Then another piece of luck came Faraday's way. One day a customer of the bookbinder gave young Faraday tickets to four lectures by Humphry Davy; one of the prominent chemist of that age. Faraday was elated & took scrupulous notes at all four lectures, which he later bound & sent to Davy, with an application for a position as assistant at the institution. A few months later, when an opening came up, Davy offered the job to Faraday. "Let him wash bottles," one of Davy's colleagues said. "If he is any good, he will accept the work, if he refuses, he is not good for anything." The job paid less than his bookbinding job, but Faraday jumped at the chance. Shortly thereafter, in 1813, Davy set off for Europe with Faraday at his side as secretary & scientific assistant. Though Davy's wife treated Faraday as a servant, the young man never complained, instead taking advantage of the opportunity to meet the key figures of science, including Volta, Ampere, Gay-Lussac, Arago, Humboldt & Cuvier. As they travelled from laboratory to laboratory across Europe, performing experiments & attending lectures, Faraday received the education he had never had.

The academic establishment of that time thought that electricity was like a fluid flowing in a pipe pushing its way along. But in 1821 a Dennish researcher Oersted showed that when we pass an electric current through a wire & place a compass near, it reflects the needle at right angles, this was the first time researchers had seen electricity affecting magnetism. The first glimpse of two forces which have previously seen entirely separate now unified in some inexplicable way.

One day Humphry Davy & his co-scientist tried to repeat the same experiment, for this they set up an arrangement & when the apparatus turned on, the magnetic needle deflected at right angles. Then they placed the compass on other side of the wire, the result was same. One among them said "if electric current flows through the wire, why not the needle moves in the same direction parallel to the wire." Then Michael Faraday, who is an assistant to Davy says "perhaps electricity is throwing out some invisible force outwards from the wire may be some sort of electric force". But his idea was rejected since they believed that electricity only flows through a wire not side ways to it. Why the compass deflects at right angles? Why the electricity affecting the compass at all? Didn't found it by Davy & many others.



Alignment of compass needles around a current carrying conductor

To prove his idea Faraday placed compass all around an electrified wire & he started to notice a pattern as shown in the fig left. When everyone else at that time thought electric force travelling straight ways but Faraday imagined that invisible lines of force flowed around an electric wire.

Original Copper Printing Plate from "Description of Electro-magnetic Apparatus for the Exhibition of Rotatory Motion" 1820

Faraday set up a simple experiment of his own. In September 1821 he demonstrated "electromagnetic rotation," showing that a wire could be made to move around a fixed magnet through the use of electric current, & that a magnet could be made to move a fixed wire. It was the first primitive electric motor (see page no. 147 for detailed explanation).

Unfortunately, Davy became angry with over his experiment, claiming that Faraday had overhead a discussion between Davy & William Wollaston describing a similar experiment. Admitted he may have gotten a start from the conversation, but his apparatus was substantially different, & both Wollaston & history seem to agree on this point.

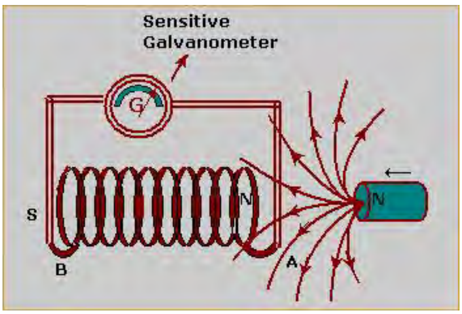
Diagram showing the basic set-up of Faraday experiment.

On 29th August 1831, Michael Faraday conducted an experiment with an iron ring, some copper wire and a big 4 inch plate battery. He was investigating the phenomenon known as electro-magnetism. Faraday began with an iron ring, wrapping one segment of it with a coil of wire. He could introduce an electric current into the wire by closing with a key. He then wrapped another segment of the ring wire & connected it to a galvanometer. He thought that the current in the first coil of wire might cause a current in the second coil. The galvanometer would measure the presence of the second current & tell the story.

Photo of one of Michael Faraday's original wire-coiled iron rings, courtesy of the Royal Institution, where Faraday did his experiments

This idea did work- it was the first transformer-but the results contained a surprise. Despite the steady magnetic force set up in the iron ring, no steady electric current ran through the second coil. Instead, a flash of current ran through the second coil when Faraday closes the circuit- with a jump on the galvanometer. Then when he opened the circuit again, another flash of current, marked by a second galvanometer jump.

Since Faraday knew no mathematics, he used visualization to explain this phenomenon- and came up with the idea of lines of magnetic force. He had noticed that if we sprinkled a paper with iron fillings, held it over a strong magnet & tapped it, the fillings would arrange themselves in distinct patterns, along what Faraday concluded were the magnet's lines of force. He saw how he could work out what the lines of force would look like for a bar magnet, for spherical magnet such as the earth, for an electric wire. And for the first time since Galileo & Newton had conceived of the mechanistic universe, now a new & even more productive way to look universe-field theory-was in the making.



In 1831 Faraday demonstrated the lines of force in another way. He took a coil of wire & moved a magnet into the coil. The needle of the galvanometer attached to the wire swung, it stopped when the movement of the magnet stopped. When he moved the magnet out of the coil, again the galvanometer swung but this time in opposite direction. But if he let the magnet just sit motionless inside the coil of wire, no action registered on the galvanometer; there was no current. Faraday had discovered the principle of electromagnetic induction. That is, he had found that by combining mechanical motion with magnetism he could produce electric current. This was the basic principle of the electric generator or Dynamo.

Faraday's next step, of course, was to build a generator, producing a continuous source of electricity instead of the jerky, on-off variety he had induced in his experiment. This he did by setting up a copper wheel so that its edge passed between the poles of a permanent magnet. As long as the wheel turned, an electric current was set up in it, and the current could be led off and set to work. By adding a water wheel or steam engine to turn the wheel, the kinetic energy of falling water or the combustive energy of burning fuel could be transformed to electrical power. Electrical generators today don't look much like Faraday's original model, & it took some 50 years for practical application to be found, but it was unquestionably the most important electrical discovery ever made.

Description: The Royal Institution, London, England. Michael Faraday's assistant, Sergeant Anderson, stands behind him on the platform. Seated in the first row to Michael Faraday's right are John Barlow and Henry Bence-Jones.
Date: 1855
Credit: Photograph by R. B. Fleming and Company, LTD., Copyright The Royal Institution

English chemists John Daniell (left) and Michael Faraday (right), credited as founders of electrochemistry today.

In 1839, he completed a series of experiments aimed at investigating the fundamental nature of electricity. Faraday used "static", batteries, and "animal electricity" to produce the phenomena of electrostatic attraction, electrolysis, magnetism, etc. He concluded that, contrary to scientific opinion of the time, the divisions between the various "kinds" of electricity were illusory. Faraday instead proposed that only a single "electricity" exists, and the changing values of quantity and intensity (current and voltage) would produce different groups of phenomena.

In 1845, Faraday discovered that many materials exhibit a weak repulsion from a magnetic field, a phenomenon he named diamagnetism. Diamagnetism is the property of an object which causes it to create a magnetic field in opposition to an externally applied magnetic field, thus causing a repulsive effect. Specifically, an external magnetic field alters the orbital velocity of electrons around their nuclei, thus changing the magnetic dipole moment. According to Lenz's law, this opposes the external field. Diamagnets are materials with a magnetic permeability less than μ_0 (a relative permeability less than 1).

Consequently, diamagnetism is a form of magnetism that is only exhibited by a substance in the presence of an externally applied magnetic field. It is generally quite a weak effect in most materials, although superconductors exhibit a strong effect.

Faraday also found that the plane of polarisation of linearly polarised light can be rotated by the application of an external magnetic field aligned in the direction the light is moving. This is now termed the Faraday Effect. He wrote in his notebook, "I have at last succeeded in illuminating a magnetic curve or line of force and in magnetising a ray of light".

In his work on static electricity, Faraday demonstrated that the charge resided only on the exterior of a charged conductor, and exterior charge had no influence on anything enclosed within a conductor. This is because the exterior charges redistribute such that the interior fields due to them cancel. This shielding effect is what now known as a Faraday cage.

Faraday in his Laboratory

The story of Michael Faraday's life is one of the most romantic stories in the annals of science. It will continue to inspire in countless ways. Faraday rose from a book- binder's apprentice to become one of the greatest scientists of all time. He is acknowledged as one of the greatest thinkers of his time. He was a true pioneer of scientific discoveries. His discoveries had a spectacular effect on successive scientific and technological developments.

The more we study the work of Faraday with the perspective of time, the more we are impressed by his unrivalled genius as an experimenter and a natural philosopher. When we consider the magnitude and extent of his discoveries and their influence on the progress of science and industry, there is no honour too great to pay to the memory of Michael Faraday - one of the greatest discoverers of all time.

-Ernest Rutherford

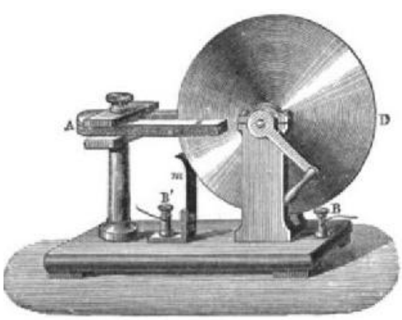
History of Electric Generator

Improvements in electrical machines have, as might well be expected, kept pace with improvements in the science of electricity. While in the early 18th century nothing more than electrical attraction & repulsion were known, everything that was known might be exhibited by means of piece of amber, sealing wax or glass; which the philosopher rubbed against his coat, & presented to bits of paper, feathers, & other light bodies that came in his way, and cost him nothing.

To give a greater degree of friction to electrical substances Otto Von Guericke & Mr. Hawksbee contrived to whirl sulphur & glass in a spherical form; but their limited knowledge of electricity did not suggest, or require more complex structure of a modern electrical machine: Mr. Hawksbee contrivances indeed, were excellent, & the apparatus for many of his experiments well adapted to the purpose for which they were intended.

When no further use could be made of globes, philosophers had recourse to the easier & cheaper apparatus of glass tubes, & sticks of sulphur or sealing wax; & the first conductors they made use of were nothing more than hempen cords supported by silken lines. Before the connection between magnetism and electricity was discovered, electrostatic generators were invented that used electrostatic principles. These generated very high voltages and low currents. They operated by using moving electrically charged belts, plates and disks to carry charge to a high potential electrode. The charge was generated using either of two mechanisms:

- *Electrostatic induction*
- *The triboelectric effect, where the contact between two insulators leaves them charged.*



Faraday disk, the first electric generator

Because of their inefficiency and the difficulty of insulating machines producing very high voltages, electrostatic generators had low power ratings and were never used for generation of commercially-significant quantities of electric power. The Wimshurst machine and Van de Graaff generator are examples of these machines that have survived.

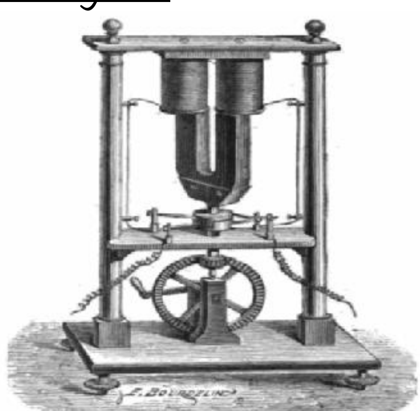
In the years of 1831-1832 Michael Faraday discovered the operating principle of electromagnetic generators. The principle, later called Faraday's law, is that a potential difference is generated between the ends of an electrical conductor that has a varying magnetic flux. He also built the first electromagnetic generator, called the 'Faraday disk', a type of homopolar generator, using a copper disc rotating between the poles of a horseshoe magnet. It produced a small DC voltage.

This design was inefficient due to self-cancelling counter flows of current in regions not under the influence of the magnetic field. While current was induced directly underneath the magnet, the current would circulate backwards in regions outside the influence of the magnetic field. This counter flow limits the power output to the pickup wires, and induces waste heating of the copper disc. Later homo polar generators solved this problem by using an array of magnets arranged around the disc perimeter to maintain a steady field effect in one current-flow direction.

Another disadvantage was that the output voltage was very low, due to the single current path through the magnetic flux. Experimenters found that using multiple turns of wire in a coil could produce higher more useful voltages. Since the output voltage is proportional to the number of turns, generators could be easily designed to produce any desired voltage by varying the number of turns. Wire windings became a basic feature of all subsequent generator designs.

Electrical generators today don't look much like Faraday's original model, & it took some 50 years for practical application to be found, but it was unquestionably the most important electrical discovery ever made.

Pixii's dynamo

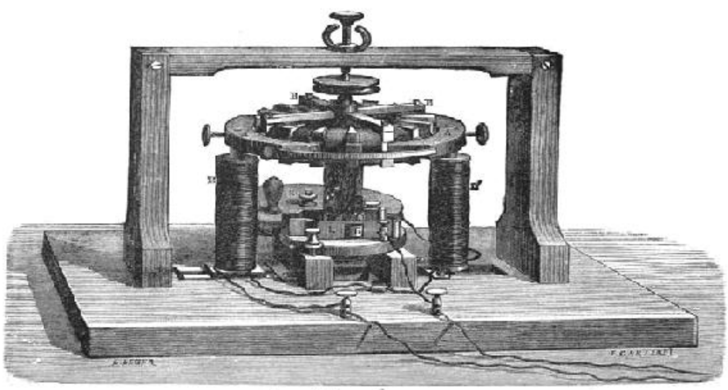


Pixii's dynamo. The commutator is located on the shaft below the spinning magnet.

The first dynamo based on Faraday's principles was built in 1832 by Hippolyte Pixii, a French instrument maker. It used a permanent magnet which was rotated by a crank. The spinning magnet was positioned so that its north and south poles passed by a piece of iron wrapped with wire. Pixii found that the spinning magnet produced a pulse of current in the wire each time a pole passed the coil. However, the north and south poles of the magnet induced *currents in opposite directions. To convert the alternating current to DC, Pixii used a commutator, a split metal cylinder on the shaft, with two springy metal contacts that pressed against it.*

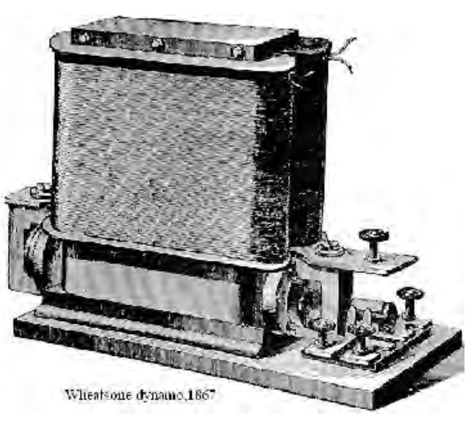
Pacinotti dynamo

The early dynamo designs had a problem: the electric current they produced consisted of a series of "spikes" or pulses of current separated by none at all, resulting in a low average power output. Antonio Pacinotti, an Italian physics professor, solved this problem around 1860 by replacing the spinning two-pole axial coil with a multi-pole toroidal one, which he created by wrapping an iron ring with a continuous winding, connected to the commutator at many equally spaced points around the ring; the commutator being divided into many segments. This meant that some part of the coil was continually passing by the magnets, smoothing out the current.



Pacinotti dynamo, 1860

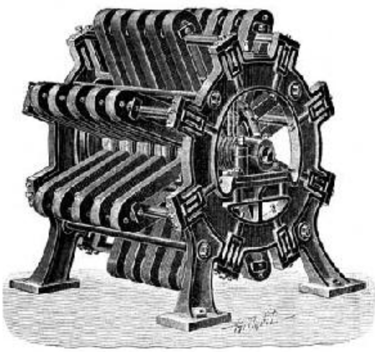
Siemens and Wheatstone dynamo (1867)



Wheatsone dynamo,1867

The first practical designs for a dynamo were announced independently and simultaneously by Dr. Werner Siemens and Charles Wheatstone. On January 17, 1867, Siemens announced to the Berlin academy a "dynamo-electric machine" (first use of the term) which employed self-powering electromagnetic field coils rather than permanent magnets to create the stator field. On the same day Charles Wheatstone announced to the Royal Society a paper describing a similar design with the difference that in the Siemens design the stator electromagnets were in series with the rotor, but in Wheatstone's design they were in parallel. The use of electromagnets rather than permanent magnets greatly increases the power output of a dynamo and enabled high power generation for the first time. This invention led directly to the first major industrial uses of electricity. For example, in the 1870s Siemens used electromagnetic dynamos to power electric arc furnaces for the production of metals and other materials.

Alliance dynamo

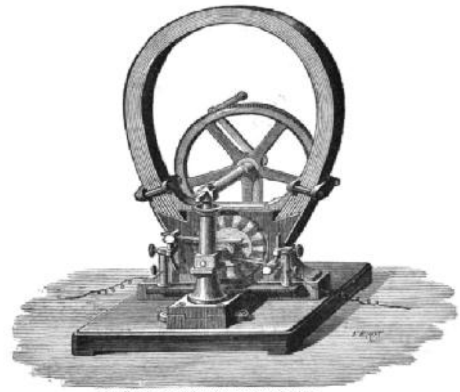


Alliance Dynamo

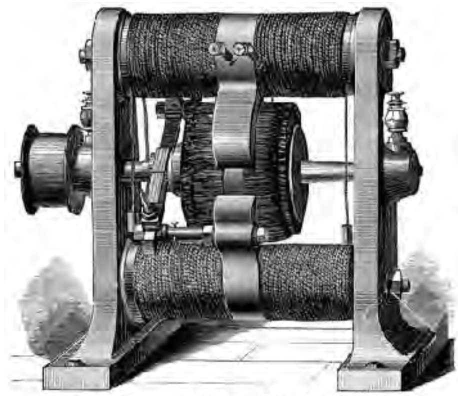
This machine was designed by Nollet for the commercial manufacture of illuminating gas by decomposing water electrically. This project failed, but in 1862 the machine was used to supply current to the first commercial use of an electric light, an arc lamp in the Dungeness Lighthouse in England.

Gramme ring dynamo

Zenobe Gramme reinvented Pacinotti's design in 1871 when designing the first commercial power plants, which operated in Paris in the 1870s. The advantage of Gramme's design was a better path for the magnetic flux, by filling the space occupied by the magnetic field with heavy iron cores and minimizing the air gaps between the stationary and rotating parts. The Gramme dynamo was the first machine to generate commercial quantities of power for industry. Further improvements were made on the Gramme ring, but the basic concept of a spinning endless loop of wire remains at the heart of all modern dynamos.



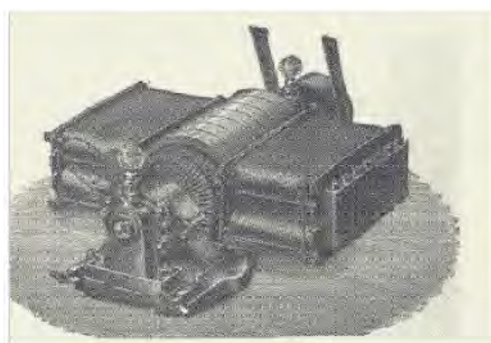
Small Gramme dynamo, around 1878



Gramme machine for Electroplating

The very rapid commercial development of the Gramme machine has given rise to a large number of similar machines, which are presented sometimes with a certain difference in the bobbins, sometimes with some new shapes of frames or of electro-magnets, & even sometimes with no other alterations than those resulting from a change in the sizes of parts.

The most important of these machines is, without doubt, that invented by Mr.Hefner Von Alteneck, & which is generally known under the name of Siemens machine. Its success, which nearly equals that of the Gramme machine, is derived from its intrinsic merits, the care with which it is manufactured.

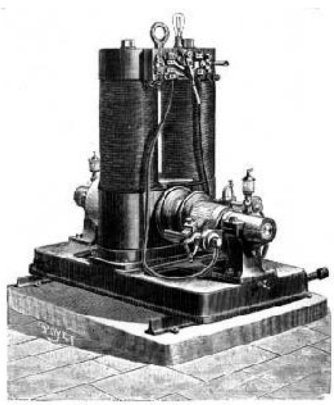


Alteneck's dynamo, 1872

The armature was 'drum' wound that is; the wires were wound on the surface of the armature. This construction is used in all dynamos made till today.

Edison's dynamo

In the fall of 1878, after experiments indicated that existing arc light generators were inefficient for incandescent lighting Edison and his chief assistants, Charles Batchelor and Francis Upton, investigated generator design and the principles of electromagnetism. During the first months of 1879, Edison designed a dynamo that differed in important ways from contemporary designs. Many contemporary electrical experts thought a generator would work best when its internal electrical resistance was equal to the external resistance of the circuit. This view was based on the understanding that the maximum power output for any given battery occurred when its internal resistance matched that of the rest of the circuit. Generators with equal internal and external resistance generated maximum current, but because Edison considered the economic efficiency of his system to be related to the number of lamps per horsepower, he determined that a generator with a small internal resistance would produce more efficient power output.

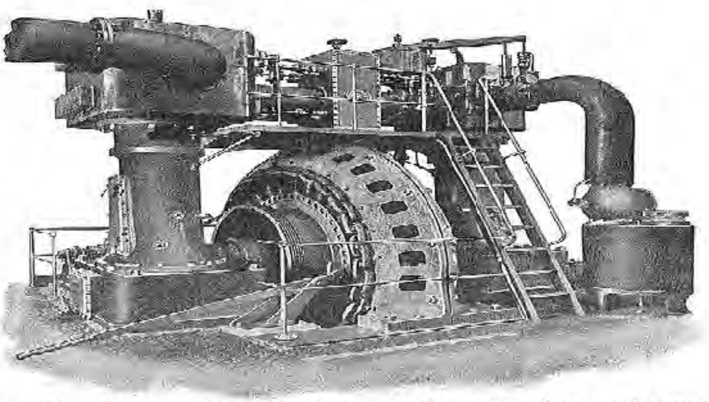


Edison "long-legged Mary-Ann" Dynamo of 1884, later renamed the "long-waisted" Mary-Ann out of modesty

The other key feature of the Edison dynamo was its large bipolar magnets, which gave the generator its nickname, the "long-legged Mary-Ann". Understanding that the more lines of force crossed in the most direct manner, the more productive the generator, Edison apparently conceived his large magnets as a concentrated source of Faraday's lines of magnetic force. However, John Hopkinson later demonstrated that such large electromagnets were inefficient.

The dynamo was the first electrical generator capable of delivering power for industry. Through a series of accidental discoveries, the dynamo became the source of many later inventions, including the DC electric motor, the AC alternator, the AC synchronous motor, and the rotary converter. Large power generation dynamos are now rarely seen due to the now nearly universal use of alternating current for power distribution and solid state electronic AC to DC power conversion. But before the principles of AC were discovered, very large direct-current dynamos were the only means of power generation and distribution.

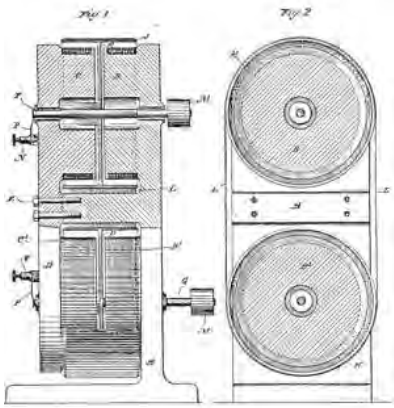
The first public demonstration of a more robust "alternator system" took place in 1886. Large two-phase alternating current generators were built by a British electrician, J.E.H. Gordon, in 1882. Lord Kelvin and Sebastian Ferranti also developed early alternators, producing frequencies between 100 and 300 Hz. In 1891, Nikola Tesla patented a practical "high-frequency" alternator (which operated around 15 kHz).



Ferranti two phase generator set (Rankin Kennedy, Electrical Installations, Vol III, 1903)

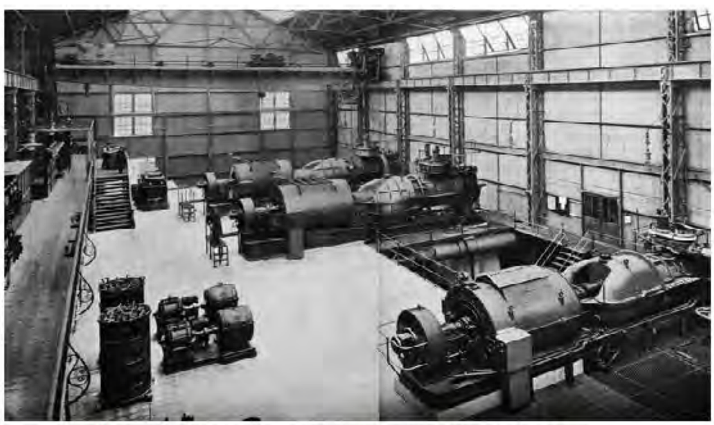
Tesla's Polyphase AC 500 Generator

Tesla pointed out the inefficiency of Edison's direct current electrical powerhouses that have been building up and down the Atlantic seaboard. Edison's lamps were weak and inefficient when supplied by direct current. This system had a severe disadvantage in that it could not be transported more than two miles due to its inability to step up to high voltage levels necessary for long distance transmission. Consequently, a direct current power station was required at two mile intervals.



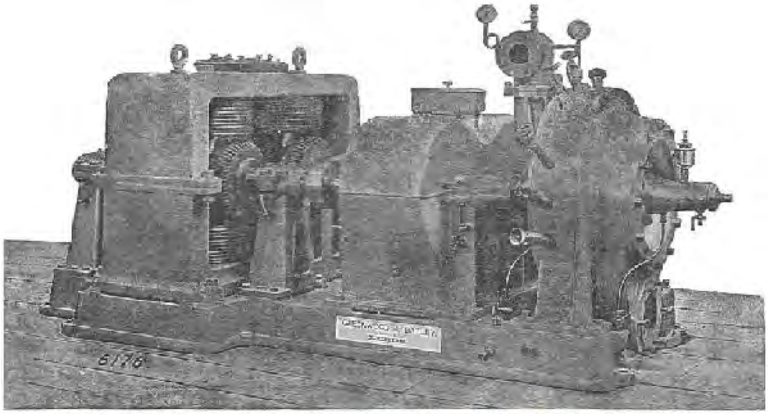
US Patent 406,968
Dynamo Electric Machine
Nikola Tesla • July 16, 1889

Tesla patented a device to induce electrical current in a piece of iron (a rotor) spinning between two electrified coils of wire. This rotating magnetic field device generates AC current when it is made to rotate by using some form mechanical energy, like steam or hydropower. When the generated current reaches its user and is fed into another rotating magnetic field device, this second device becomes an AC induction motor that produces mechanical energy. Induction motors run household appliances like clothes washers and dryers. Development of these devices led to widespread industrial and manufacturing uses for electricity.

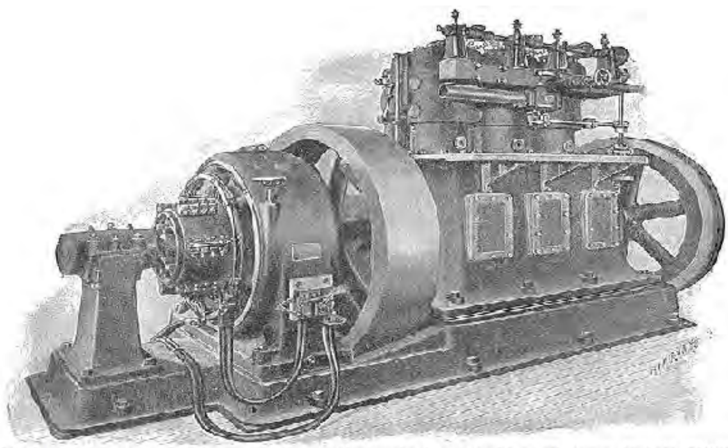


Carville power station on Tyneside, 1904, designed by Charles Merz and William McLellan. High-speed Parsons steam turbines drive alternators.

In the early days Generators for use with steam turbines have usually only a single pair of field poles, rather than the multi-polar machines used with reciprocating drives. Initially the armature windings, in which the current was generated, were the rotating member & the field poles were static. As machines became larger, it became difficult to make brushes & slip rings or commutator adequate to take current. The solution was to invert the machine, having the armature static & the field rotating. The brushes then had to carry only the magnetising current for the field. The last largest rotating armature machine was a 1500kw set for Neptune Bank power station on Tyneside in 1901.



100hp De Laval turbine-dynamo (Rankin Kennedy, Electrical Installations, Vol III, 1903)



125hp gas engine and dynamo (Rankin Kennedy, Electrical Installations, Vol III, 1903)

For a while think of where our society would be without the invention of electrical generators. Many of our other inventions and discoveries wouldn't exist. Computers? Television and Radio? Phones? Modern refrigeration? The internet? None of it, including many of the other items on this list. To appreciate modern technology, one must first appreciate its lifeblood and the heart that provides it, electricity and the electrical generator.

Source:

- "Wikipedia" http://en.wikipedia.org/wiki/Electrical_generator
- "Spark Museum" http://www.sparkmuseum.com/LIGHTING.HTM
- *The book of electrical installations by* Rankin Kennedy

Electric Motor

Source:

- *100 greatest science inventions of all time* By *Kendall F. Haven*
- *Wikipedia "http://en.wikipedia.org/wiki/Electric_motor"*
- *John Jenkins Spark Museum*

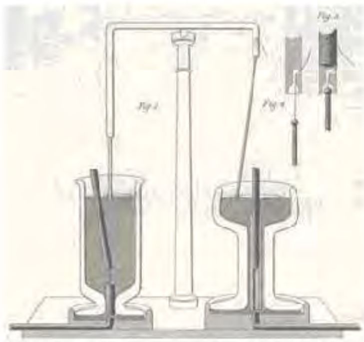
Probably one of the most valuable gifts of electromagnetic science to the industrial world is that of the electromagnetic motor. Like other great achievements, the electric motor has not been the product of any single Man or nation, but is rather the embodiment of the life work of many able workers, from many countries, through many years. As Emerson has aptly expressed it:" Not in a week, or a month, or a year, but by the lives of many souls, a beautiful thing must be done."

What did people do before?

Humans used manual labour, animal power, & water power to move equipment, run mills & machines, & power agriculture. They burned wood & coal to power forges & stoves & provide heat. When James Watt invented the steam engine, industry & transportation shifted to steam. However, no engine existed for small uses.

Since the electromagnetic motor consists essentially of means whereby a continuous rotary motion is produced, by the combined agency of an electric current & a magnet. It was through a process of development and discovery beginning with Hans Oersted's discovery of electromagnetism in 1820 and involving additional work by William Sturgeon, Joseph Henry, Andre Marie Ampere, Michael Faraday, Thomas Davenport and a few others.

Using a broad definition of "motor" as meaning any apparatus that converts electrical energy into motion, most sources cite Faraday as developing the first electric motors, in 1821. They were useful as demonstration devices, but that is about all, and most people wouldn't recognize them as anything resembling a modern electric motor.



The first electric motors - Michael Faraday, 1821
From the Quarterly Journal of Science, Vol XII, 1821

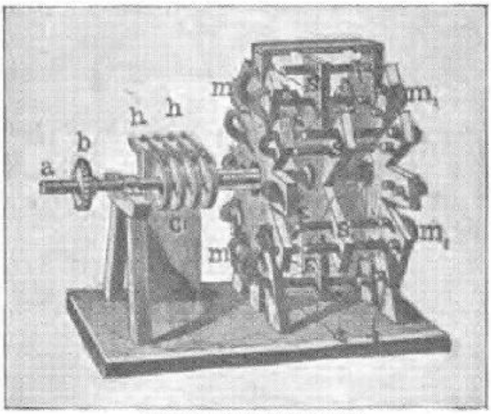
Faraday motors were constructed of a metal wire suspended in a cup of mercury. Protruding up from the bottom of the cup was a permanent magnet. In the left cup the magnet was attached to the bottom with a piece of thread and left free to move, while the metal wire was immobile. On the right side, the magnet was held immobile and the suspended wire was free to move.

When current from a Volta pile was applied to the wire, the circuit was completed via the mercury (a good conductor of electricity) and the resulting current flowing through the wire produced a magnetic field. The electromagnetic field interacted with the existing magnetic field from the permanent magnet, causing rotation of the magnet on the left, or of the wire on the right.

Once Faraday revealed the principles of electric motors & generators, progress toward large, practical versions of each was rapid.

A later refinement is the Barlow's Wheel. The Barlow wheel was first built in 1822 by the English mathematician and physicist Peter Barlow (1776-1862).Mercury is poured into the trough located on the base of the apparatus. The wheel is lowered until a spoke just dips into the mercury. Voltage applied to the binding posts will cause rotation of the wheel.

These were demonstration devices only, unsuited to practical applications due to their primitive construction. The first commutator-type direct current electric motor capable of turning machinery was invented by the British scientist William Sturgeon in 1832. Following Sturgeon's work, a commutator-type direct-current electric motor made with the intention of commercial use was built by Americans Emily and Thomas Davenport and patented in 1837. Their motors ran at up to 600 revolutions per minute and powered machine tools and a printing press. Due to the high cost of the zinc electrodes required by primary battery power, the motors were commercially unsuccessful. Several inventors followed Sturgeon in the development of DC motors but all encountered the same cost issues with primary battery power. No electricity distribution had been developed at the time. Like Sturgeon's motor, there was no practical commercial market for these motors.

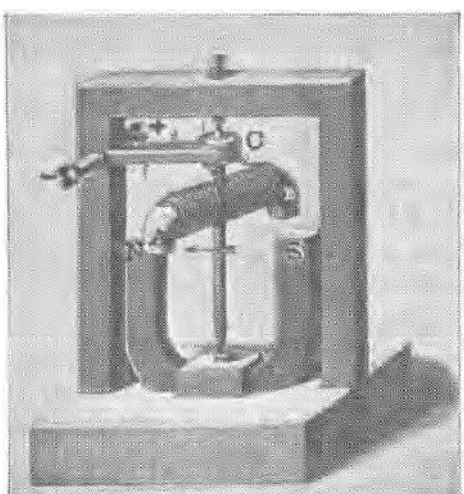


Jacobi's Electric Motor (1838)

One of the earliest practical motors was produced by Jacobi in 1834, & perfected in 1838. This motor is interesting from a historical standpoint, from the fact that in its improved form it was employed for the propulsion of a boat on the river Neva, in 1838. In this case the motor was driven by a voltaic battery.

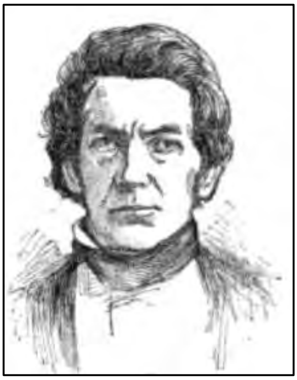
Ritchie Motor

The principle of the operation of Jacobi may, perhaps, be better understood by an examination of a motor designed by Ritchie, Here a movable electromagnet AB, is caused to continuously rotate under the mutual interaction of its flux & the flux produced by a permanent magnet NS.

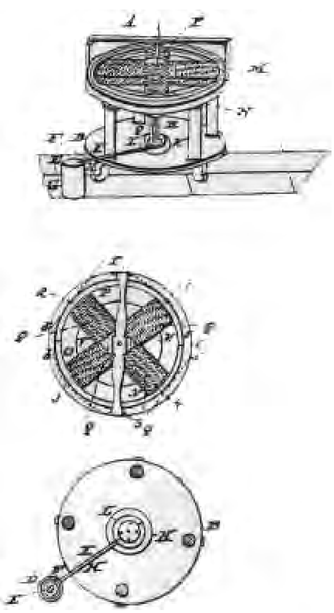


Ritchie's Motor

Thomas Davenport' Motor



The first person to obtain patents for electromagnetic engine was Thomas Davenport. Thomas Davenport, who in 1837, designed an electromagnetic motor in which permanent magnets, placed on a fixed frame, & was attracted by electromagnets placed on a moving frame. Davenport perfected his motor to an extent which enabled him to apply it to the driving of a small model of a circular railway, which he exhibited at Springfield.



Davenport mounted one magnet on a wheel; the other magnet was fixed to a stationary frame. The interaction between the two magnets caused the rotor to turn half a revolution. He learned that by reversing the wires to one of the magnets he could get the rotor to complete another half-turn. Davenport then devised what we now call a brush and commutator. Fixed wires from the frame supplied current to a segmented conductor that supplied current to the rotor-mounted electromagnet. This provided an automatic reversal of the polarity of the rotor-mounted magnet twice per rotation, resulting in continuous rotation.

The motor had the potential to drive some of the equipment in Davenport's shop, but he had even bigger ideas. The era of the steam locomotive and railroads was just beginning, but already boiler failures and explosions were becoming frequent, tragic occurrences. Davenport's solution was the electric locomotive. He built a model electric train that operated on a circular track; power was supplied from a stationary battery to the moving electric locomotive using the rails as conductors to transmit the electricity.

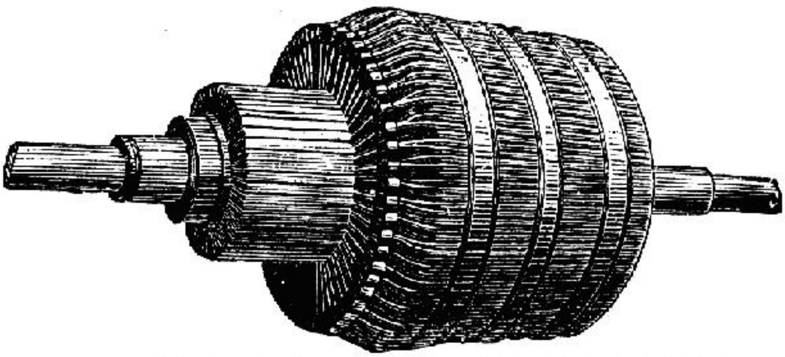
During the 30 years between 1830 and 1860 many attempts were made to use electro-magnetism to produce engines that could be used instead of steam and one group of experimenters converted the linear motions of their inventions to rotary motion via linkages similar to those found in steam engines of the time. The early engines of Charles Grafton Page took this form. Dr Page was perhaps one of the most prolific inventors of his time and developed many electro-magnetic engines both reciprocating and rotary as well as other early electrical apparatus many of which were built and sold by Daniel Davis of Boston, the leading manufacturer of electro-magnetic machines of the time.

Story of invention of modern electric motor

In 1873, an industrial exhibition in Vienna, Austria, displayed a number of dynamos. One day, an absent-minded workman connected the wires of Gramme dynamo that was running to one that was standing still. To his surprise, the armature began to spin around. It was thus discovered by accident that the dynamo, invented to produce electricity, could be used also to change electricity into Mechanical power. The dynamo soon became a useful motor. Dynamos & Motors are now built almost alike, but motors do not have to be as large & heavy as dynamos. Therefore, the men who perfected the dynamo also perfected the electric motor.

The Gramme machine was the first powerful electric motor useful as more than a toy or laboratory curiosity. Today the design forms the basis of nearly all DC electric motors. Gramme's use of multiple commutator contacts with multiple overlapped coils, and his innovation of using a ring armature, was an improvement on earlier dynamos and helped usher in development of large-scale electrical devices.

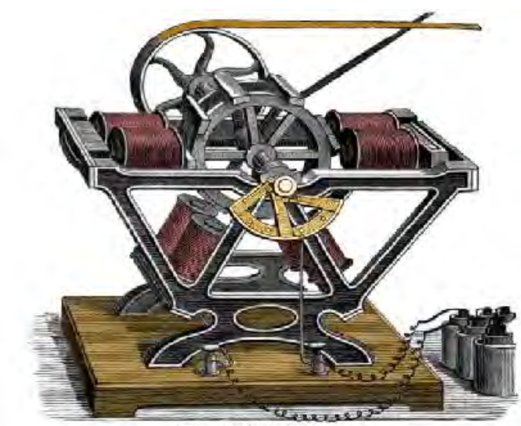
Earlier designs of electric motors were notoriously inefficient because they had large, or very large, air gaps throughout much of the rotation of their rotors. Long air gaps create weak forces, resulting in low torque. It took a number of decades in the 19th century for electrical engineers to learn the importance of small air gaps. The Gramme ring, however, has a comparatively small air gap, which enhances its efficiency.



Modern design of the Gramme ring, wrapped only around the exterior of the core

Several exhibitors at the first International Electric Exhibition, held at Paris in 1881, demonstrated motors. Marcel Deprez, for example, had a motor driven sewing machine, lathes, a drill & a printing press. Siemens exhibited a lift within the building & a tram running towards it along the Champs-Elysées.

One of the first Gramme machines to be sold as a motor was used to drive a conveyor for sugar beet in a factory at Sermaize, France. It was so successful that in May 1879 the factory owners decide to try electric ploughing.



Froment's Electric Motor

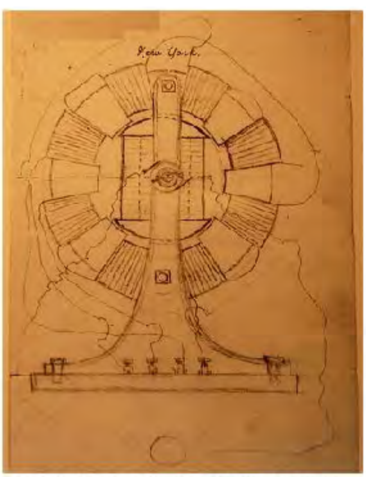
Froment in his workshops had an electromotive engine of one-horse power. But, though an interesting application of the transformation of energy, these machines will never be practically applied on the large scale in manufactures, for the expense of the acids and the zinc which they use very far exceeds that of the coal in steam-engines of the same force motors worked by electricity.

The first company to exploit electric motors on a large scale was Siemens, & their first major customer was the Prussian state mines. Electric motors proved to be very good for driving rolling mills, where the combination of power & precise control was valuable. Thereafter electric motors were gradually introduced for driving machine tools, & the advantage of individual drives over line-shaft systems was readily appreciated.

In 1886 Frank Julian Sprague invented the first practical DC motor, a non-sparking motor capable of constant speed under variable loads. Other Sprague electric inventions about this time greatly improved grid electric distribution (prior work done while employed by Thomas Edison), allowed power from electric motors to be returned to the electric grid, provided for electric distribution to trolleys via overhead wires and the trolley pole, and provided controls systems for electric operations.

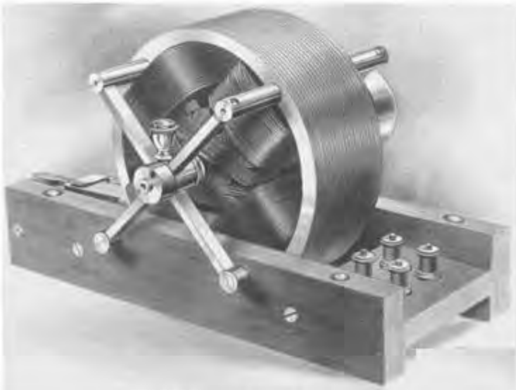
Glorious moment in electrical: The birth of Induction Motor

In 1882, Nikola Tesla discovered the rotating magnetic field, a fundamental principle in physics and one of the greatest discoveries of all times. In February, 1882, Nikola Tesla was walking with his friend through a city park in Budapest, Hungary. Tesla was reciting stanzas from Goethe's Faust; the sun was just setting, when suddenly the elusive solution to the rotating magnetic field, which he had been seeking for a long time, flashed through his mind. At this very moment, he saw clearly in his mind an iron rotor spinning rapidly in a rotating magnetic field, produced by the interaction of two alternating currents out of step with each other. One of the ten greatest discoveries of all times was born at this glorious moment. Tesla was gifted with the intense power of visualization and exceptional memory from early youth on.



Nikola Tesla Induction Motor Drawing

Tesla was able to fully construct, develop and perfect his inventions completely in his mind before committing them to paper. From his memory he constructed the first induction motor. In the summer of 1883, Tesla was working in Strasburg, France, where he built his first actual induction motor model and saw it run. Tesla's A-C induction motor is widely used throughout the world in industry and household appliances. It started the Industrial Revolution at the turn of the century.



Tesla's Electric Motor.
Courtesy the Tesla Memorial Society of New York.

The development of electric motors of acceptable efficiency was delayed for several decades by failure to recognize the extreme importance of a relatively small air gap between rotor and stator. Early motors, for some rotor positions, had comparatively huge air gaps which constituted a very high reluctance magnetic circuit. They produced far-lower torque than an equivalent amount of power would produce with efficient designs. The cause of the lack of understanding seems to be that early designs were based on familiarity of distant attraction between a magnet and a piece of ferromagnetic material, or between two electromagnets. Efficient designs, are based on a rotor with a comparatively small air gap, and flux patterns that create torque.

Simple Armature Motors

Revolving Armature Engine 1848

Upright Reciprocating Engine Probably Daniel Davis 1842

Revolving Armature Engine Daniel Davis 1848

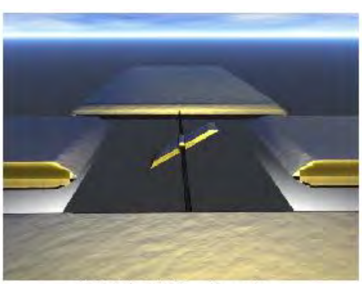
Unusual Electric Motor
English 1860

Electrodynamic Revolving Ring
Probably Daniel Davis 1848

Magnetic Motor
French 1870

Application of electric motors revolutionized industry. Industrial processes were no longer limited by power transmission using shaft, belts, compressed air or hydraulic pressure. Instead every machine could be equipped with its own electric motor, providing easy control at the point of use, and improving power transmission efficiency. Electric motors applied in agriculture eliminated human and animal muscle power from such tasks as handling grain or pumping water. Household uses of electric motors reduced heavy labour in the home and made higher standards of convenience, comfort and safety possible. Today, electric motors consume more than half of all electric energy produced.

Did You Know?



UC Berkeley World's smallest motor

Early electric motors were heavy & bulky. However, in 2003 the UC Berkeley Nanotechnology department built an entire electric motor so small that it measures only 500 nanometres across. That's only 200-thousandths of an inch!

History of Transformer

The invention of the Power Transformer towards the end of the nineteenth century made possible the development of the modern constant voltage AC supply system, with power stations often many miles from centers of electrical load. Before that, in the early days of public electricity supplies, these were DC systems with the source of generation, of necessity, close to the point of loading.

Pioneers of electric supply industry were quick to recognize the benefits of a device which could take the high current relatively low voltage output of an electrical generator & transforms this to a voltage level which would enable it to be transmitted in a cable of practical dimensions to consumers who, at that time, might be many miles away.

As we wish to write of those discoveries which led up to the invention of the transformer, we must go back to a time, old as compared with the modern development of electrotechnics. For the starting point of our observations we shall take Faraday, who, like Newton in mechanics, led the way in the domain of electricity, & whose name stands in the most intimate relation with all inventions for the mechanical production of the electric current, & therefore with the later development of electrotechnics.

The most important discovery for which we have to think of Faraday is that of induction. This discovery was made by him in the year 1831, & intimated to the philosophical world in a paper read on the 24th November 1831, appearing in the Transactions of the Philosophical Society in the year 1832.

Faraday's first induction apparatus consisted of two coils of wire, the one being slid over the other. As he was passing the current from a battery through one of these, he made the discovery that each time the circuit of the coil was opened or closed an electromotive force was created in the second coil, which caused a short gush of current or induction current to flow, provided the circuit of this coil was closed, as might be through a galvanometer.

The peculiarity of this induced current was that it only flowed in the second coil during the time the current in the first coil took to reach its normal strength after closing the circuit, or on breaking the circuit during the time the current took to decrease from its normal strength to zero.

This discovery undoubtedly belongs to the domain of the transformer, induction being the physical precedent upon which the transformer is based; indeed, a transformer is in principle an induction apparatus.

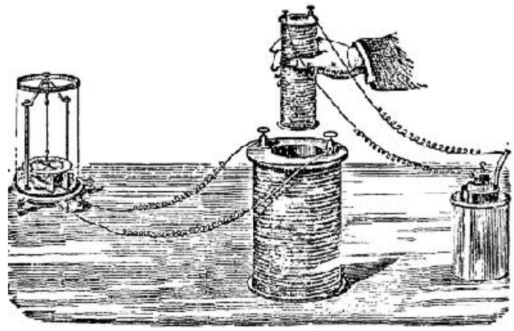


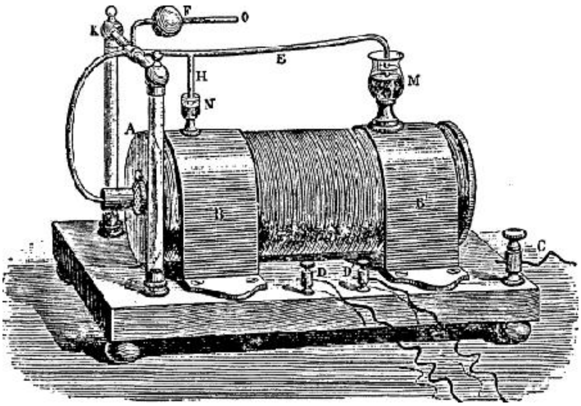
Fig above represents the arrangement of this fundamental experiment. The primary coil is connected with the battery, the secondary with the galvanometer. The primary coil, in order to obtain the best effect, is placed inside the secondary, & on opening & closing its circuit the needle of the galvanometer is thrown to the one or the other side respectively.

Induction coils evolved from scientists' and inventors' efforts to get higher voltages from batteries. Since batteries produce direct current (DC) rather than alternating current (AC), induction coils relied upon vibrating electrical contacts that regularly interrupted the current in the primary to create the flux changes necessary for induction. Between the 1830s and the 1870s, efforts to build better induction coils, mostly by trial and error, slowly revealed the basic principles of transformers.

Transformers as at present understood were first known in Europe as the Ruhmkorff's induction coil. Before we take up this invention we shall mention a much earlier & like invention, which had already been made in the United States in the year 1838. This was the induction coil of Charles Page, & was the outcome of another invention by Joseph Henry, whose apparatus was only a single induction coil. The first public notice of page's apparatus appeared in the Silliman-Journal of 12th May, 1836, under the title, "Methods & trails of obtaining physiological phenomena & sparks from a heat engine by means of Henry's apparatus."

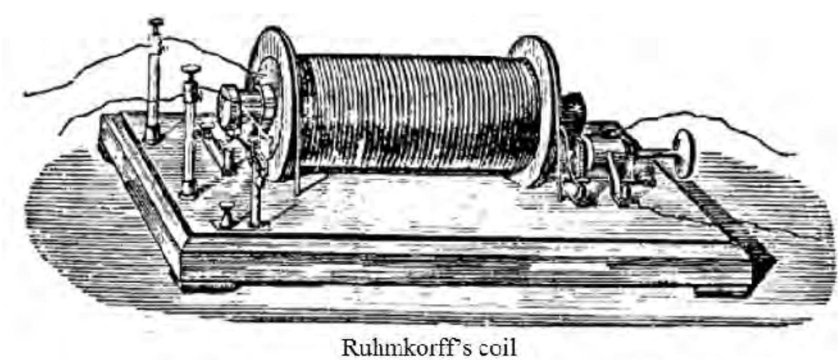
In May, 1837, Sturgeon published, in the "Annals of Electricity," in London, a description of the apparatus of Henry & Charles Page. Callan, an

English student of physics in Minnoth, showed first, in the year 1837, that if high tension was wanted, it was necessary to employ thick wire for the primary & thin for the secondary coil. Before this time wires indeed of different lengths, but of equal cross sections, had always been employed. His apparatus was not as bad as those before known, but still stood far behind that of Charles Page.



The arrangement of Charles Page's apparatus, which is shown in fig left, was as follows: Two coils of wire well insulated from one another were wound on to a bundle of iron wires. A self-acting contact-breaker was put into the primary to make & break the circuit.

Ruhmkorff's constructed, in the year 1848, the so called spark-induced named after him, the object of which was also to convert currents of low tension into those of very high tension.With this coil & like coils of larger dimensions effects were produced, but only such as were afforded by the common forms of frictional electrical machines. All things considered, it is not a little surprising that while the invention of Ruhmkorff's coil was still in its infancy, the wonderful output of Charles page apparatus was still, even in the year 1851, quite unknown in Europe.



Ruhmkorff's coil

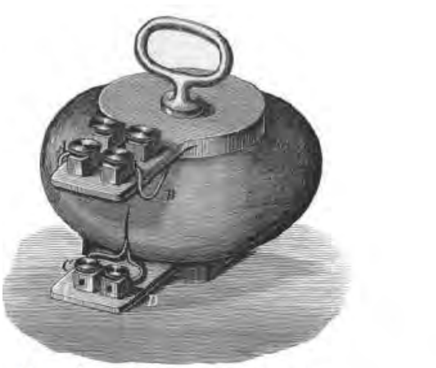
There were no transformers in those days which, in the present sense of the word "transformer," convert high electromotive force to low to suit the consumers. On the contrary the apparatus, which was then used in electric lightning plant, was such as converted low into high electromotive force, or such that the ratio was 1:1, or nearly so, according as it was determined by the connection in series of the primary coils, & the difference of potential at the consumption devices; for example, the induction coils of B.Ruhmkorff, Jablochkoff, & Gordon.

Lucien Gaulard and John Dixon Gibbs first exhibited a device with an open iron core called a "secondary generator" in London in 1882, then sold the idea to the Westinghouse company in the United States. They also exhibited the invention in Turin, Italy in 1884, where it was adopted for an electric lighting system. However, the efficiency of their open-core bipolar apparatus remained very low.

Induction coils with open magnetic circuits are inefficient for transfer of power to loads. Until about 1880, the paradigm for AC power transmission from a high voltage supply to a low voltage load was a series circuit. Open-core transformers with a ratio near 1:1 were connected with their primaries in series to allow use of a high voltage for transmission while presenting a low voltage to the lamps. The inherent flaw in this method was that turning off a single lamp affected the voltage supplied to all others on the same circuit. Many adjustable transformer designs were introduced to compensate for this problematic characteristic of the series circuit, including those employing methods of adjusting the core or bypassing the magnetic flux around part of a coil.

Efficient, practical transformer designs did not appear until the 1880s, but within a decade the transformer would be instrumental in the "War of Currents", and in seeing AC distribution systems triumph over their DC counterparts, a position in which they have remained dominant ever since.

Closed-core lighting transformers



Drawing of Ganz Company's 1885 prototype.
Capacity: 1400 VA, frequency: 40 Hz, voltage ratio: 120/72 V

In the autumn of 1884, Ganz Company engineers Károly Zipernowsky, Ottó Bláthy and Miksa Déri had determined that open-core devices were impracticable, as they were incapable of reliably regulating voltage. In their joint patent application for the "Z.B.D." transformers, they described two designs with closed magnetic circuits: the "closed-core" and "shell-core" transformers. In the closed-core, the primary and secondary windings were wound around a closed iron ring; in the shell-core, the windings were passed through the iron core.

In both designs, the magnetic flux linking the primary and secondary windings traveled almost entirely within the iron core, with no intentional path through air. The new Z.B.D. transformers reached the 98 percent efficiency, which was 3.4 times higher than the open core bipolar devices of Gaulard and Gibs. When employed in parallel connected electric distribution systems, closed-core transformers finally made it technically and economically feasible to provide electric power for lighting in homes, businesses and public spaces. Bláthy had suggested the use of closed-cores, Zipernowsky the use of shunt connections, and Déri had performed the experiments; Bláthy also discovered the transformer formula, Vs/Vp = Ns/Np.

The vast majority of transformers in use today rely on the basic principles discovered by the three engineers. They also reportedly popularized the word "transformer" to describe a device for altering the EMF of an electric current, although the term had already been in use by 1882. In 1886, the Ganz Company installed the world's first power station that used AC generators to power a parallel-connected common electrical network, the steam-powered Rome-Cerchi power plant.

Prototypes of the world's first high-efficiency transformers.
They were built by the Z.B.D. team on 16th September 1884.

William Stanley's First Transformer built in 1885

In 1885 William Stanley makes the transformer more practical due to some design changes: "Stanley's first patented design was for induction coils with single cores of soft iron and adjustable gaps to regulate the EMF present in the secondary winding. This design was first used commercially in the USA in 1886".

George Westinghouse and William Stanley created a transformer that is practical to produce (easy to machine and wind in a square shape, making a core of E shaped plates) and comes in both step up and step down variations.
In 1886 William Stanley uses his transformers in the electrification of downtown Great Barrington, MA. This was the first demonstration of a full AC power distribution system using step up and step down transformers.

William Stanley was the mastermind behind the first AC distribution system in North America and the Stanley Transformer which changed the world. The transformer has been called "the heart of the alternating-current system" His system at Great Barrington is very similar to modern electric distribution systems. Engineers before 1886 knew that AC voltage could be controlled using transformers but no one had built a full working system. Stanley was the first person to understand the behavior of the magnetic core of a transformer, and he was the first to understand the concept of counter electromotive force. Later on Albert Schmid improved Stanley's design, extending the E shaped plates to meet a central projection.

In 1889, Russian-born engineer Mikhail Dolivo-Dobrovolsky developed the first three-phase transformer at the "General Electricity Company" in Germany.

Transformer used on the Lauffen to Frankfurt demonstration line. 3 phase alternating current, 40 hz Oerlikon Company 8 kV and 25 kV transmission in 1891

This transformer was created for the longest power transmission to date: 109 miles from Lauffen am Neckar to Frankfurt, Germany.

Photo courtesy of Historisches Museum Frankfurt

Early three phase transformer (circular core type) Siemens and Halske company 5.7 kVA 1000/100 V in 1891

This transformer was created at the beginning of the modern electrical grid, the same year as the Frankfurt Electrical Exhibition which demonstrated long distance transmission of power.
The artifact in this photo is on display at the Deutsches Museum: www.deutsches-museum.de

Alternating current could be transmitted over long distances at high voltages, with lower current, and thus lower energy loss and greater transmission efficiency, and then conveniently stepped down to low voltages for use in homes and factories, it became clear that AC was the future of electric power distribution; all it was possible only because of the invention of Transformer.

Source:

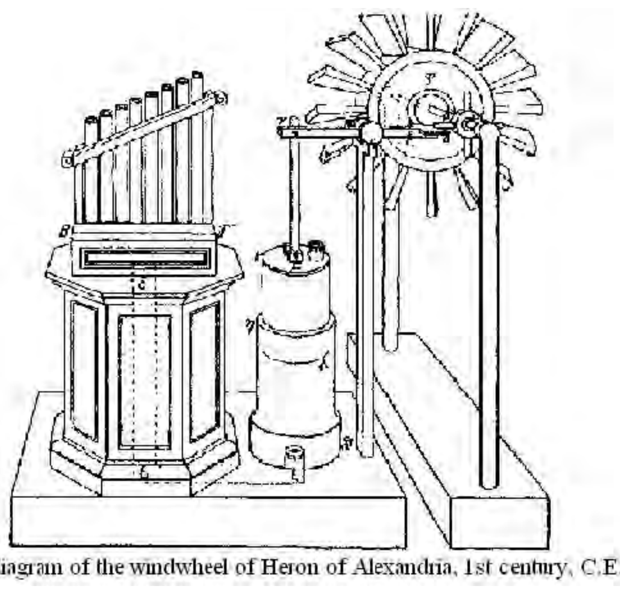
- *"History of Transformer, by Friedrich Uppenborn"*
- *"Edison tech centre" www.edisontechcentre.org*
- *"Wikipedia" http://en.wikipedia.org/wiki/Transformer*

History of wind power

The unequal heating of land and water by sun is the main cause of wind generation on the earth's surface. The global installed capacity of wind farm is 175 GW and Energy production was 340 TWh, which is about 2% of worldwide electricity usage in 2009.Wind energy is one of the forms of energy made available by the nature and is available at free of cost.

People have used technology to transform the power of wind into useful mechanical energy since antiquity. Along with the use of water power through water wheels, wind energy represents one of the world's oldest forms of mechanised energy. Though solid historical evidence of wind power use does not extend much beyond the last thousand years, anecdotal evidence suggests that the harnessing of mechanised wind energy pre-dates the Christian era.

The use of wind power is said to have its origin in the Asian civilisation of China, Tibet, India, Afghanistan & Persia. The first written evidence of the use of wind turbines is from Hero of Alexandria, who in the third or second century BC described a simple horizontal-axis wind turbine. Another early example of a wind-driven wheel was the prayer wheel, which was used in ancient Tibet and China since the 4th century.



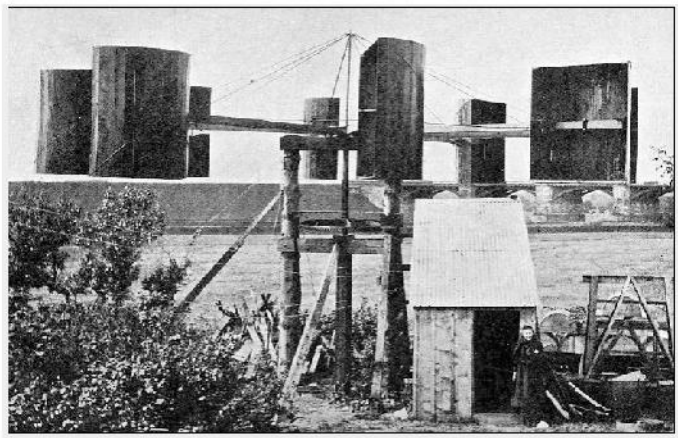
A diagram of the windwheel of Heron of Alexandria, 1st century, C.E

The first practical windmills were built in Sistan, a region between Iran and Afghanistan, possibly earlier in the 7th century. These were vertical-axle windmills, which had long vertical drive shafts with rectangle shaped blades. Made of six to twelve sails covered in reed matting or cloth material, these windmills were used to grind corn and pump water, and were used in the grist milling and sugarcane industries. Windmills were in widespread use across the Middle East and Central Asia, and later spread to China and India from there. Horizontal-axle windmills were later used extensively in North-western Europe to grind flour beginning in the 1180s, and many Dutch horizontal-axle windmills still exist. By 1000 AD, windmills were used to pump seawater for salt-making in China and Sicily. By the 14th century, Dutch windmills were in use to drain areas of the Rhine River delta.

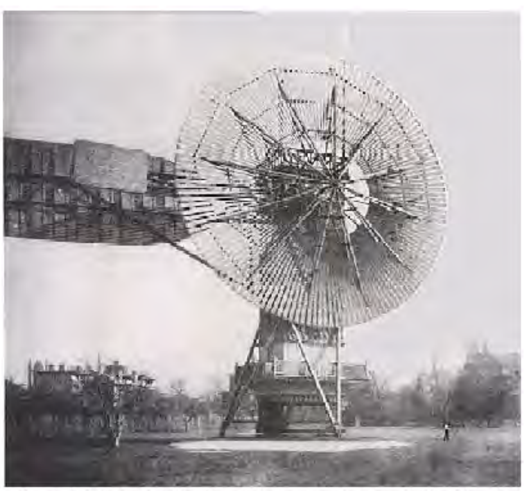
European Windmills

With the advent of the steam engine in the eighteenth century the world's demand for power gradually shifted to techniques & machines based on thermodynamic processes. The advantages of these machines over wind became particularly evident with the introduction of fossil fuels such as coal, oil & gas. The advantages of steam engine & steam & gas turbines were threefold. First, the new machines were more compact & able to deliver power on a much larger scale than necessary for just water pumping & grinding, allowing a whole new level of industrial development. Secondly, the engines & turbines could be located virtually any where, unlike windmills & water wheels which were dependent on the availability of good sites. And third, the new machines provided more reliable power than the wind, whose availability was vulnerable to changing weather conditions.

Research in wind power utilisation did not die because of compilation from fossil fuels, but rather made steady progress over the past 100 years.In Denmark by 1900, there were about 2500 windmills for mechanical loads such as pumps and mills, producing an estimated combined peak power of about 30 MW. The first electricity generating wind turbine, was a battery charging machine installed in July 1887 by Scottish academic, James Blyth to light his holiday home in Marykirk, Scotland.



James Blyth's electricity generating wind turbine photographed in 1891



The world's first automatically operated wind turbine was built in Cleveland in 1888 by Charles F. Brush. It was 60 feet (18 m) tall, weighed 4 tons (3.6 metric tonnes) and powered a 12kW generator.

The first use of a large windmill to generate electricity was a system built in Cleveland, Ohio, in 1888 by Charles F. Brush. The Brush machine (shown at left) was a postmill with a multiple-bladed "picket-fence" rotor 17 meters in diameter, featuring a large tail hinged to turn the rotor out of the wind. It was the first windmill to incorporate a step-up gearbox (with a ratio of 50:1) in order to turn a direct current generator at its required operational speed (in this case, 500 RPM.)

Despite its relative success in operating for 20 years, the Brush windmill demonstrated the limitations of the low-speed, high-solidity rotor for electricity production applications. The 12 kilowatts produced by its 17-meter rotor pales beside the 70-100 kilowatts produced by a comparably-sized, modern, lift-type rotor. In 1891, the Dane Poul La Cour developed the first electrical output wind machine to incorporate the aerodynamic design principles (low-solidity, four-bladed rotors incorporating primitive airfoil shapes) used in the best European tower mills. The higher speed of the La Cour rotor made these mills quite practical for electricity generation. By the close of World War I, the use of 25 kilowatt electrical output machines had spread throughout Denmark, but cheaper and larger fossil-fuel steam plants soon put the operators of these mills out of business.

By 1920, the two dominant rotor configurations (fan-type and sail) had both been tried and found to be inadequate for generating appreciable amounts of electricity. The further development of wind generator electrical systems in the United States was inspired by the design of airplane propellers and monoplane wings.

By the 1930s, windmills for electricity were common on farms, mostly in the United States where distribution systems had not yet been installed. In this period, high-tensile steel was cheap, and windmills were placed atop prefabricated open steel lattice towers.

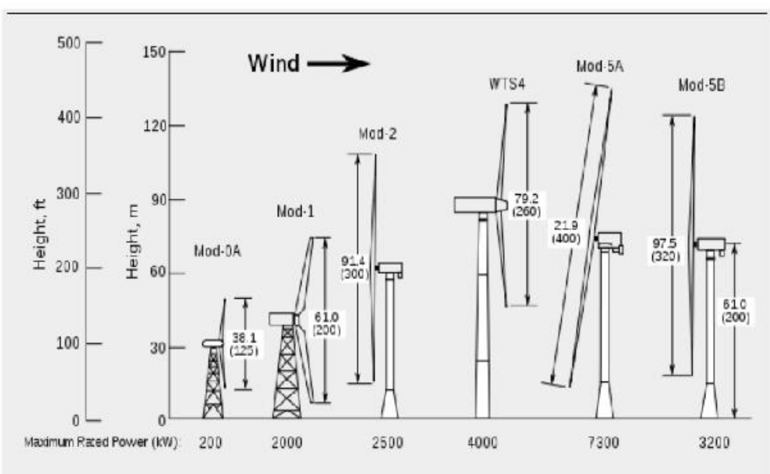
Bulk" Power from Wind"

The world's first megawatt-size wind turbine near Grandpa's Knob Summit, Castleton, Vermont.

The development of bulk-power, utility-scale wind energy conversion systems was first undertaken in Russia in 1931 with the 100kW Balaclava wind generator. This machine operated for about two years on the shore of the Caspian Sea, generating 200,000 kWh of electricity. Subsequent experimental wind plants in the United States, Denmark, France, Germany, and Great Britain during the period 1935-1970 showed that large-scale wind turbines would work, but failed to result in a practical large electrical wind turbine.

Experimental wind turbine at Nogent-le-Roi, France, 1955.

From the mid 1970's through the mid 1980's the United States government worked with industry to advance the technology and enable large commercial wind turbines. This effort was led by NASA at the Lewis Research Centre in Cleveland, Ohio and was an extraordinarily successful government research and development activity. With funding from the National Science Foundation and later the United States Department of Energy (DOE), a total of 13 experimental wind turbines were put into operation including four major wind turbine designs. This research and development program pioneered many of the multi-megawatt turbine technologies in use today, including: steel tube towers, variable-speed generators, composite blade materials, partial-span pitch control, as well as aerodynamic, structural, and acoustic engineering design capabilities. The large wind turbines developed under this effort set several world records for diameter and power output.



Comparison of NASA wind turbines

By the time the new era of wind energy began in 1970s & 1980s, new materials & technologies had also become available. As composite materials such as fibreglass proved highly suitable for wind turbine rotor blades, blade design become increasingly sophisticated; & electronic controls for wind turbines also continue to advance.

Changing World of Energy

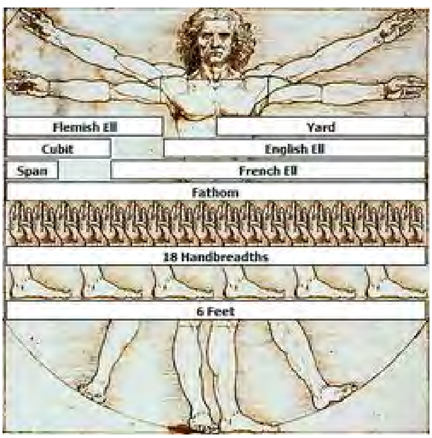
For over a century, our world has been powered primarily by carbon fuels. In recent years, concern about global warming and the harmful effects of fuel emissions has created new demand for cleaner and sustainable energy sources, like wind. In many areas around the globe, the energy market is also being driven by a dual new dynamic: deregulation and privatization. As more and more consumers choose who produces their power, the market for renewable resources is forecast to expand at an even greater pace.

Today, more than 175 gigawatts of wind energy are installed throughout the world, and forecasts for wind power continue to be favorable with more than 200 cumulative gigawatts predicted worldwide by 2010. With a cost of energy of approximately 3.5 to 4 cents per kilowatt hour and declining, wind is a low-cost renewable energy source that is less expensive than coal, oil, nuclear and most natural gas-fired generation, and is becoming attractive to utilities and electric cooperatives.

The Story of Measurements

Over 4 billion years ago, the earth formed. More than 3 million years ago, primitive people walked on earth. About 10,000 years ago, people began to supplement their hunting of animals by cultivating grain-bearing grasses.

By around 3000BC historians agree that cities had been established in Mesopotamia, Egypt, China. The management of land, construction of buildings, & other group projects required that standards of measurement be established for lengths, areas, volumes, & weights. Each was important in barter, trade, work, government, & religion. Specimens of agreed-upon units were preserved as reference standards of primary authority of the city-state. These standards were inscribed with the king's name & deposited in the principal temples of the kingdom.



The cubit was a commonly used unit of length in many kingdoms; its story illustrates how units developed & were used in ancient times. The Egyptian hieroglyphic symbol for the cubit is a picture of the forearm, indicating its derivation from human body. It was the distance from the peak of the elbow to the tip of the middle finger, & was the basis of units based on the human body. The digit was the width of a thumb, & a palm was the width of a hand. In most lands, four digits made a palm, & five palms made a cubit. In time, fractions of a cubit were used extensively. The length of a foot was also used.

The Science Museum in London has a collection of Egyptian wood & stone cubit standards dating from 2400 BC to the first century AD; over that long period of time, the Egyptian cubit varied less than 5%. The cubit had an extremely long life, & was used in some countries as late as the 1960s before being replaced by metric measures. The foot is still in use today in the United States.

Volume standards were used for measuring grain & liquids, & were based on convenient, arbitrary containers. Weights were probably first used for trade in precious metals, & their standards were initially stones, then a set of carved stones, & later metal castings.

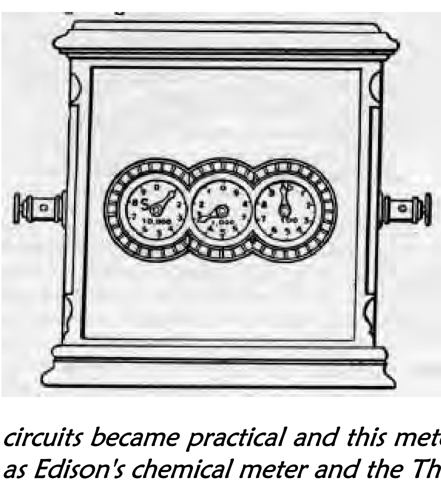
Time is an abstract concept, & measurements of time developed slowly in civilizations. Initially, life was thought to be a succession of recurring cycles, & there was no concept of history. The cycles were based on correlations of natural events: when certain plants bloom, when the heavy rains occur, or when the cry of the migrating cranes is heard. The changes of the moon provided another basis for measuring time: nine moons for the duration of pregnancy, or six moons between sowing & harvest. In sunlight, observing the position of the sun's shadow around a vertical stick indicated the time of the day. As centuries passed, more elaborate solar observations developed. About 2600BC Stonehenge was built in England, & less elaborate observatories were constructed in France.

History of Electrical Measurement

Up to the 1870s, electricity had little use beyond the telephone and telegraph. The earliest use of electricity for power was to operate strings of arc lamps connected in series. Since the current was constant and the voltage required for each lamp was known, and all of the lamps were controlled by one switch, it was adequate to measure only the time current flowed in the circuit (lamp-hours).

As commercial use of electric power spread in the 1880s, it became increasingly important that an electrical energy meter, similar to the then existing gas meters, was required to properly bill customers for the cost of energy, instead of billing for a fixed number of lamps per month. Many experimental types of meter were developed.

Samuel Gardiner's lamp-hour meter

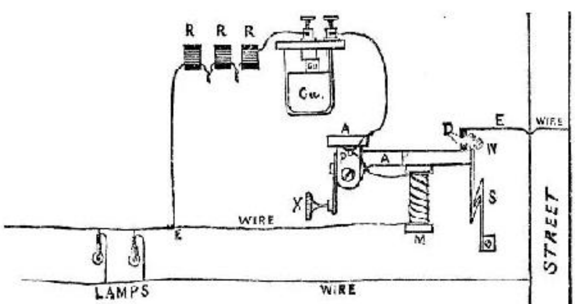


This was one of the earliest meters and the first known model to be patented. It was used with the earliest DC arc-lamp systems and only measured the time energy was supplied to the load as all the lamps connected to this meter was controlled by one switch. The internal workings were nothing more than a clock that was started and stopped by an electromagnet that was connected in series with the load. With the introduction of Edison's light bulb, subdividing lighting circuits became practical and this meter became obsolete, replaced by meters such as Edison's chemical meter and the Thomson Recording Wattmeter.

Edison Chemical Meter

Edison Chemical Meter 1883

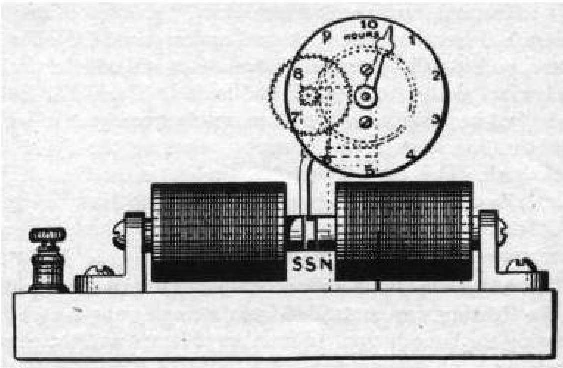
Inside the Edison Chemical Meter.
Note the small jar containing the electrodes and electrolyte solution.



Wiring diagram of the chemical meter

Edison developed the first meter that measured the amount of electricity instead of how long the circuit was energized. This meter was connected across the load and consisted of several jars with zinc plates and a chemical solution. One set of jars was intended for the main reading while the second set was operated off a smaller shunt and was intended for comparison purposes (a primitive check on the meter's accuracy). The monthly reading was made by removing the plates from the jars and weighing them with a laboratory balance. The change in the plates' weight between readings was a measure of electricity consumption. *This meter was very inconvenient to use, and in a couple cases mishandling of the plates resulted in large billing errors. Also, as there was no ready way to indicate the usage to the customer, this also made it hard for them to trust its accuracy. These disadvantages and the fact that this meter itself had high internal losses made it unpopular enough that these meters were rapidly replaced by more reliable meters in the late 1880's, including the Thomson Recording Wattmeter.*

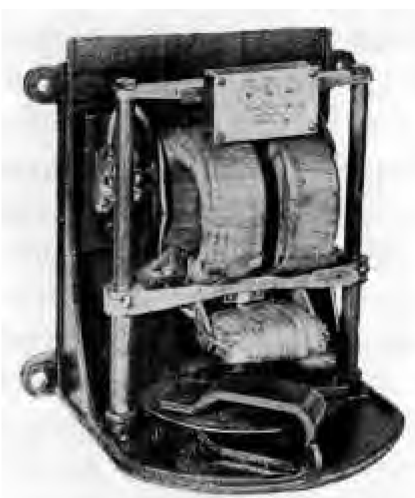
J.B. Fuller's lamp-hour meter



Westinghouse Handbook on Watthour Meters

This meter was the first known AC meter to be patented, and like the Gardiner DC lamp-hour meter that preceded it, it only measured the time energy was supplied to the load. The meter was simply a clock operated by the alternating fields of the two coils. Lamp-hour meters were soon abandoned as customers started adding other electrical appliances and the need arose for meters that meters that measured energy, like Shallenberger's ampere-hour meter.

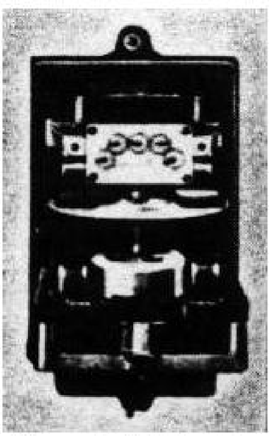
Thomson-Houston Recording Wattmeter



After Thomas Edison came up with his chemical meter in the late 1870s, Elihu Thomson came up with the idea for a motor-type meter. This meter was designed to work on both alternating and direct current and was much more rugged and accurate than other meters available at the time. Shortly after the merger of Edison General Electric and Thomson-Houston Electric, the Thomson Recording Wattmeter was redesigned slightly and continued with a few changes along the way over the next few years. The T.R.W. was a commercial success, many of the early electric utilities quickly standardizing on this model. Initially, this meter was available in numerous styles covering the whole spectrum of applications from 3-amp models for smaller residential loads to models rated up to 1200 amps for heavy DC power circuits. There were also high-voltage versions made for metering the output of DC and AC arc-lamp generators. For AC applications, some were made for use with current and potential transformers to meter high-voltage / current circuits and (with appropriate resistance or reactance *boxes) on balanced polyphase circuits. With the introduction and rapid acceptance of induction-type meters in the late 1890s (starting with Westinghouse's Shallenberger watthour meter and GE's Form C Induction Wattmeter), the T.R.W. was quickly relegated to use on DC circuits. In fact, the T.R.W. was the only commercially available DC meter for a few years until other manufacturers started making DC meters in the early 1900s.*

Modern Induction-Type Wattmeters

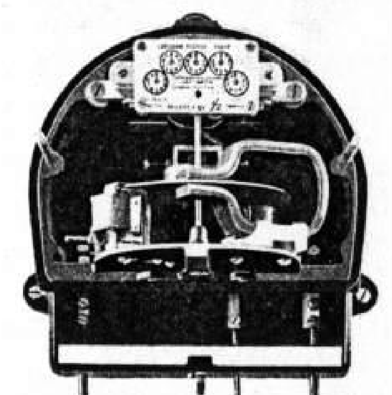
The first induction-type wattmeter was introduced by the Fort Wayne Electric Company in 1892. This type of meter was cheaper, more reliable and easier to use than Thompson's and was quickly adopted. The wattmeter became an indispensable part of the watthour meter, which allowed power companies to measure electrical usage at a particular location and accurately bill for power consumption.



Form C Wattmeter

This model was the first induction meter made by GE.

This meter had separate magnetic structures for voltage and current coils and used an aluminium cylinder for the rotor. A disk with permanent magnets was used for braking as in the T.R.W. meters. This meter was replaced the following year by the Form C-4.



The Form C-4 was an improved version of the previous Form C, but was still quite primitive. The voltage circuit in this meter used an external reactance coil mounted behind the register (similar to the reactance coil as used in the early Ft. Wayne and Westinghouse meters). The coils and brake magnet were mounted on a platform underneath the disk (as opposed to the later practice of using a vertical frame).

Although the induction meter would only work on alternating current, it eliminated the delicate and troublesome commutator of the Thomson design.

With increase in the use of electricity its complexity also increased, which necessitated the need for more efficient & reliable energy meters. With the invention of Electronic meters which display the energy used on an LCD or LED display, can also transmit readings to remote places. In addition to measuring energy used, electronic meters can also record other parameters of the load and supply such as maximum demand, power factor and reactive power used etc. They can also support time-of-day billing, for example, recording the amount of energy used during on-peak and off-peak hours. With all these options it has given new insight to measuring system.

DO YOU KNOW

In Netherland, for instance, an average household encountered only 35 minutes interruption to their supply in the year 2006 out of a total 8760 hours, resulting in an availability of 99.99%.

History of Electric Locomotive

Source: *Some Early Traction History By Thorburn Reid*

Electric locomotives are the epitome of efficiency. Even today, no other locomotive type can match the low operating costs, high tractive effort, and swift acceleration speeds of electrics. The development of steam locomotive in the first decades of the nineteenth century made possible the railways boom that began in the early 1820s, & which spreads across the Atlantic within a few years. Steam power was synonymous with railway. Over the years, gradual refinement of locomotive design allowed for the operation of longer, heavier, & faster trains. Yet, the inherent limitations of steam locomotive design were long recognized by inventors & railway operators. Steam locomotive were dirty, inefficient, difficult to start, & costly to maintain & operate. From the 1830s onwards, scientists & inventors experimented with electric motive power, often using battery- Powered miniature locomotives. Harnessing electricity was a new form of power with great potential, but it was still undeveloped & impractical for large-scale experimentation.

At that time, and for many years afterwards, the primary battery was the only available source from which electric energy could be obtained for driving motors. The initial cost of the primary battery was very high, and the cost of the chemicals consumed in it was about sixteen times that of the coal required to produce the same amount of electrical energy through the medium of the steam engine and the modern dynamo. This great expense, combined with the difficulty in handling the liquids and more or less fragile materials used in the construction of the battery, constituted an insurmountable obstacle to the commercial use of the electric motor for traction purposes.

Notwithstanding this, however, many inventors worked at the problem during the period from 1835 to about 1873, when the power-driven dynamo commenced to take shape as to make it commercially available as a source of electrical energy for driving motors. During these years many of the details were worked out and methods employed which are still used in the best modern practice.

Davonport's Electric Railway Model, 1835

The invention of the electric vehicle is attributed to various people. In 1828, Anyos Jedlik, a Hungarian who invented an early type of electric motor, created a tiny model car powered by his new motor. In 1834, Vermont blacksmith Thomas Davenport, the inventor of the first American DC electrical motor, installed his motor in a small model car, which he operated on a short circular electrified track.

The first known electric locomotive was built by a Scotsman, Robert Davidson of Aberdeen in 1837 and was powered by galvanic cells ('batteries'), it attained a speed of four miles an hour. Davidson later built a larger locomotive named Galvani which was exhibited at the Royal Scottish Society of Arts Exhibition in 1841. But the limited electric power available from batteries prevented its general use.

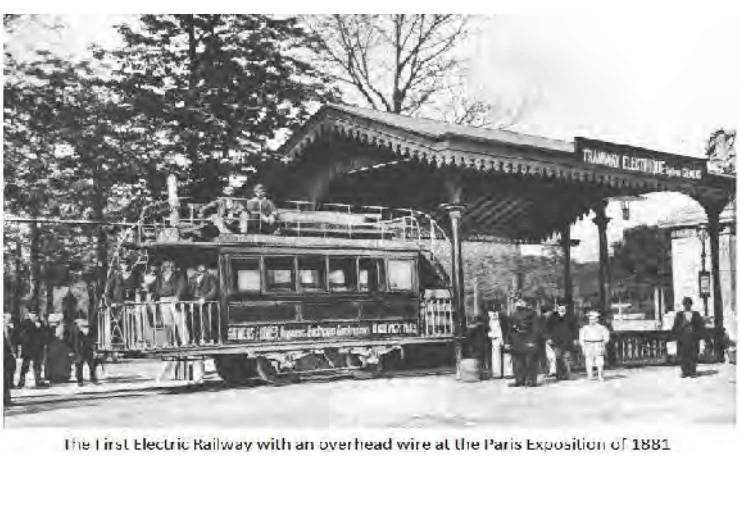
In 1864 the modern dynamo was born, but no one dreamed then, or for many years afterwards, how large a part it was destined to play in the industrial progress of the world. Earlier inventors, discouraged by their lack of success, had turned their powers into other fields, and did not realise that the one great obstacle to the commercial development of electric traction, the prohibitive expense of a battery as a source of power, had been removed with the advent of the far more economical dynamo.

In 1879, Werner Von Siemens exhibited a small electric railway in Berlin. The event is often heralded as the first practical public demonstration of electric motive power using mechanically generated electricity. The first electric passenger train was presented by Werner von Siemens at Berlin in 1879. The locomotive was driven by a 2.2 kW motor and the train, consisting of the locomotive and three cars, reached a maximum speed of 13 km/h. During four months, the train carried 90,000 passengers on a 300 meter long circular track. The electricity was supplied through a third, insulated rail situated between the tracks. A stationary dynamo nearby provided the electricity.

First electric locomotive by Werner von Siemens

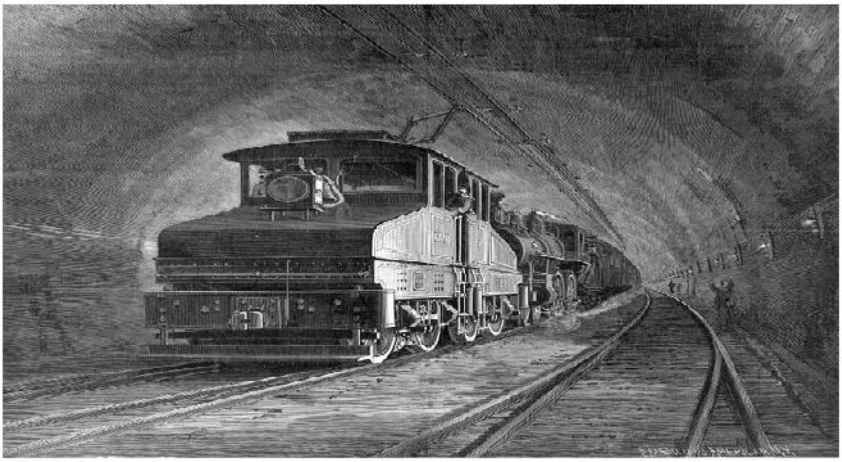
The success of Siemens's road in Berlin incited many inventors to work at the same problem. In the succeeding year Egger showed a model electric railway in which the current was conducted to the motors through one of the rails upon which the car ran, and returned through the other; but this was a step backward, since this would have meant a shock to a horse or man who might happen to touch both rails at once. In 1880 Edison came into the field, but he does not appear to have made any radical improvements.

In Europe, Siemens was driving ahead with tremendous energy and enthusiasm, being engaged in the development of various schemes, including an elevated road with the working rails as conductors. He proposed running the speed up to forty miles an hour, and for this purpose was the first to suggest placing the armature of the motor directly on the axle of the locomotive. In May, 1881, the first commercial electric road, as distinguished from the previous experimental roads, was opened to the public at Lichterfeld, Germany.



The First Electric Railway with an overhead wire at the Paris Exposition of 1881

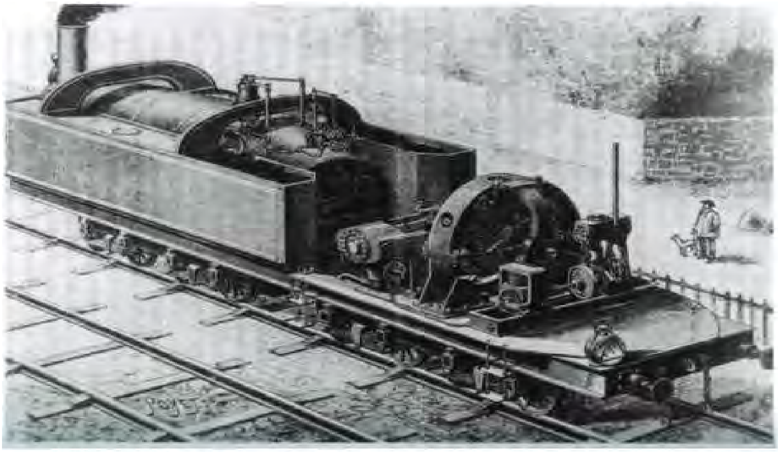
However, main line electric locomotives did not appear until 1895 when the Baltimore & Ohio Railroad opened a three mile stretch of electrified territory in Baltimore that operated on a 600-volt direct current system with four gearless, 360 horsepower, locomotives (or "motors") for power.



Electric locomotive of the Baltimore Belt Line, 1895. The steam locomotive was not detached for passage through the tunnel. The overhead conductor was a ∩ section bar at the highest point in the roof, so a flexible, flat pantograph was used

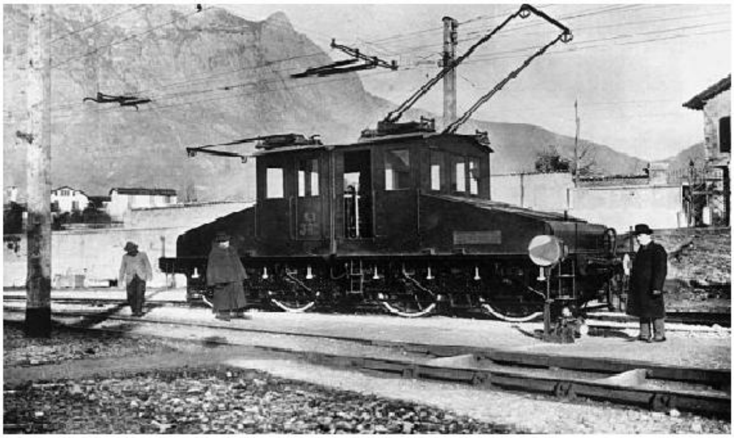
The primary reason for the B&O's electrification was to solve a safety issue with its 1.25-mile long tunnel situated under residential neighbourhoods in Baltimore where smoke would become a health issue. However, by this time steam locomotive smoke in large urban areas, in general, was becoming a serious health and safety issue and by the early 20th century, particularly after a New York Central passenger train collided with a New Haven suburban train in January of 1902 in New York City (because of a smoke-obscured signal), many cities began passing ordinances banning steam from their city limits.

The result of the steam locomotive ban forced railroads, which had widespread operations in large urban areas like the New York Central and Pennsylvania Railroad, to employ electric operations, using the B&O's Baltimore project as a starting point.



The "Fusée Electrique" of 1893, cab removed. Compounded pistons drove a Gramme-style dynamo powering electric motors on all axles. The small engine, right, was the exciter for the dynamo windings.

The first practical AC electric locomotive was designed by Charles Brown, then working for Oerlikon, Zürich. In 1891, Brown had demonstrated long-distance power transmission, using three-phase AC, between a hydro-electric plant at Lauffen am Neckar and Frankfurt am Main West railway station, a distance of 280 km. Brown, using the experience he had gained while working for Jean Heilmann on steam-electric locomotive designs, had observed that three-phase motors had a higher power-to-weight ratio than DC motors and, because of the absence of a commutator, were simpler to manufacture and maintain. However, they were much larger than the DC motors of the time and could not be mounted in under floor bogies: they could only be carried within locomotive bodies. In 1896, Oerlikon installed the first commercial example of the system on the Lugano Tramway. Three-phase motors, which run at constant speed and provide regenerative braking, are well suited to steeply graded routes and the first mainline three-phase locomotives were installed by Brown.



AC locomotive in Valtellina (1898-1902). Power supply: 3-phase 15 Hz AC, 3000 V. Designed by Kálmán Kandó in Ganz Company, Hungary and supplied by Westinghouse.

A development by Kálmán Kandó of the Ganz works, working with Westinghouse of Italy, introduced an electro-mechanical converter, allowing the use of three-phase motors powered from single-phase alternating current, thus eliminating the need for two overhead conductor wires. The first implementation of industrial frequency single-phase AC supply for locomotives came from Oerlikon in 1901, using the designs of Hans Behn-Eschenburg and Emil Huber-Stockar; installation on the Seebach-Wettingen line of the Swiss Federal Railways was completed in 1904. The 15 kV, 50 Hz 345 kilowatts (460 hp), 48 tonne locomotives used transformers and rotary converters to power DC traction motors.

One of the first countries to use electric traction for main-line operations was Italy, where a system was inaugurated as early as 1902. By World War I a number of electrified lines were operating both in Europe and in the United States. Major electrification programs were undertaken after that war in such countries as Sweden, Switzerland, Norway, Germany, and Austria. A number of metropolitan terminals and suburban services were electrified between 1900 and 1938 in the United States, and there were a few main-line electrifications.

Thomas Alva Edison

Source:

- *Story of Thomas Alva Edison by Jules Levey & Lester Cooper*
  http://www.youtube.com/watch?v=hZe3ErwbJpE&feature=related
- *A video on Thomas Alva Edison by "Rothman institute of entrepreneurial studies"*
  http://www.youtube.com/watch?v=qHPh8Q1uALI

Thomas Alva Edison (February 11, 1847 – October 18, 1931) did not invent the modern world. But he was more responsible than any one else for creating the modern world. No one did more to shape the physical/cultural makeup of present day civilization. He was a significant figure in the organization & growth of communication & power systems, & entertainment industries. One hundred & sixty three years after his birth & 79 years after death-his name stands for inventive creativity. His electric bulb is the symbol of a bright idea. His list of 1093 U.S. Patents remain unchallenged by any other inventor. Accordingly he was the most influential figure of the millennium.

"He led no armies into battle, he conquered no countries, and he enslaved no peoples... Nonetheless, he exerted a degree of power the magnitude of which no warrior ever dreamed. His name still commands a respect as sweeping in scope and as world-wide as that of any other mortal - a devotion rooted deep in human gratitude and untainted by the bias that is often associated with race, color, politics, and religion."

Thomas Alva Edison, whose development of a practical electric light bulb, electric generating system, sound-recording device, and motion picture projector had profound effects on the shaping of modern society. His greatest invention may not have been his products but the funding and impotence he placed on his company's research and development efforts.

Surprisingly, little "Al" Edison, who was the last of seven children in his family, did not learn to talk until he was almost four years of age. Immediately thereafter, he began pleading with every adult he met to explain the workings of just about everything he encountered. If they said they didn't know, he would look them straight in the eye with his deeply set and vibrant blue-green eyes and ask them "Why?"

At age seven - after spending 12 weeks in a noisy one-room schoolhouse with 38 other students Tom's overworked and short tempered teacher finally lost his patience with the child's persistent questioning and seemingly self centered behavior. Noting that Tom's forehead was unusually broad and his head was considerably larger than average, he made no secret of his belief that the hyperactive youngster's brains were "addled" or scrambled.

If modern psychology had existed back then, Tom would have probably been deemed a victim of ADHD (attention deficit hyperactivity disorder) and proscribed a hefty dose of the "miracle drug" Ritalin. Instead, when his beloved mother - whom he recalled "was the making of me...[because] she was always so true and so sure of me...And always made me feel I had someone to live for and must not disappoint." - became aware of the situation, she promptly withdrew him from school and began to "home-teach" him. Not surprisingly, she was convinced her son's slightly unusual demeanor and physical appearance were merely outward signs of his remarkable intelligence.

At age 16, after working in a variety of telegraph offices, where he performed numerous "moonlight" experiments, he finally came up with his first authentic invention. Called an "automatic repeater," it transmitted telegraph signals between unmanned stations, allowing virtually anyone to easily and accurately translate code at their own speed and convenience. Curiously, he never patented the initial version of this idea.

Phonograph – History

Edison cylinder phonograph ca. 1899

The Phonograph, record player, or gramophone is a device that was most commonly used from the late 1870s through the 1980s for playing sound recordings. The recordings played on such a device generally consist of groups of wavy lines that are scratched, engraved, or grooved onto a rotating cylinder or disc. As the cylinder or disc rotates, a needle or other similar object on the *device traces the wavy lines and vibrates, reproducing sound waves.*

The first great invention developed by Edison in Menlo Park was the tin foil phonograph. How it was developed was an interesting story;
It actually deals with something called the automatic telegraph repeater which was a device to capture the indentation of incoming telegraph messages. He discovered if the needles rubbed against the dots & dashes of that recording it would create almost voice like qualities.

Also while working with the telephone mouth piece, he discovered that speaking into mouth piece, it caused vibrations that you could actually feel. In fact the needle holding the diaphragm in place, in the telephone mouth piece would prick finger when he would yell into it. This started Edison thinking about possibly taking sound & trying to capture it.

Edison theorized that perhaps one could speak into such a diaphragm with a needle onto surface & by speaking indent that surface with vibrations of sound & take those vibrations & recreate sound. It was an amazing concept.

On December 6 1877 Edison makes first official recording which is "Marry had a little lamb, its fleece was white as snow" onto what we call the tin foil phonograph. It was an amazing moment in history. One might say, perhaps one of the greatest moments of Edison's life. Because he had done something that was considered impossible. People theorized it was impossible, people didn't believe you could capture sound because it was of the ether, it was of the air, it wasn't something tangible.

If you are going to innovate, invent, create a very very important thing has to be done is publicity. To get people to know about it, one has to educate the public as to what you are creating. Edison always knew that publicity is as important as invention itself.

So next day Edison went to the office of scientific America, plopped the Phonograph on the editor's desk, turned the crank & the phonograph introduced itself to the editor. Asked to the editor about his health, told the editor it was feeling fine & bid the editor a fond good day. What a great way to introduce a machine that talks by letting the machine that talks introduce itself. That's the genius of Edison; the editor writes about it, people came to see Edison. Edison becomes an international celebrity. In fact, Edison becomes known as the wizard of Menlo Park, because of the Phonograph.

Light Bulb

We lose track in this day & age of how amazing that development was. What was lightning in the 19th century? We had candles, kerosene, whale oil & gas. Once the incandescent light was developed by Edison & his team, lighting became something very very different. Suddenly our days were longer, our productivity increased, our life style changed totally because of that incandescent lamp.

The first thing that Edison did was learn everything he could about the subject; he came to the crux of the problem

1. If you heat certain materials by electricity they give off light
2. If you heat these materials in vacuum they lost much longer

So he told his glass factory to make some glass bulbs.

He started thinking, what would glow of that light continuously bright & easy on the eye? Now the laboratory became his home. Day, night time itself went nothing to him, he tried everything & in search of the proper thing to heat in the vacuum. After trying metals, he started on the world of organic matter, anything everything within reach human hair, wood, leather.

Finally one day he took a piece of common carbon plate & placed it in a furnace, out of furnace came a thin thread of a pure carbon, he attached this filament to electric wire inside the bulb, he pumped the air out of the bulb, he turned on the electric current, this was the light he wanted. The lamp burned for two days & two nights. He invited the world, a world still lit by candle & gas light came to Menlo Park to see on New Year 1879. New light to the new world on New Year evening. The news papers called it "miracle of the 19th century"

lightning up the Menlo Park its only stun for new years evening, the real test came when Edison announced he would illuminate on square mile of heart of the Newyork city with the new electric light.

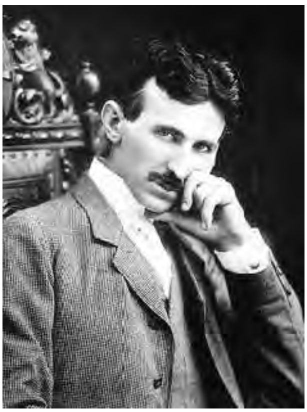
The bulb that gave miracle light was only beginning, the end component of thousand component parts, generators, meters, sockets, switches, cables & conductors needed to make it work. The incandescent bulb was not one but 360 different inventions all welded together. To make power you need power. He took a building in Pearl's street & turned it into first power plant in the United States. It was on September 4, 1882, that Edison switched on his Pearl Street generating station's electrical power distribution system, which provided 110 volts direct current (DC) to 59 customers in lower Manhattan.

Nikola Tesla

The Life & Times of Forgotten Genius

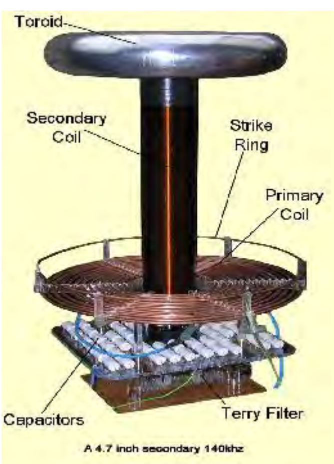
Source:

- *A documentary on Nikola Tesla by History channel titled "Mad Electricity"*



For the power to change night into day thank Nikola Tesla. There are so many aspects of modern life, everyday life directly influence by the world created by Nikola Tesla. But tragically in later years, his brilliance responsible for more than 200 patents was over shadowed by what some consider madness. Because of Tesla a turn of a switch brings power to our finger tips.

Never the less FBI has created a secret file on Nikola Tesla & when he died U.S. government took charge on his scientific papers. What were the powerful & terrifying ideas that have threatened National Security; are they mad man's ranting or works of a genius.



Many people believed that he was onto something & may its time to look back & reinvestigate what Tesla really up to. We know one thing Tesla up to 'Wireless Energy" that can be transmitted around the world. The wireless transmission of power would appear over & over again even in Tesla's most exotic vision. The key to understand this remarkable idea was this peculiar yet powerful invention, first patented in 1871 by Tesla at age 35 called the 'Tesla Coil'. Nothing like it had ever been done before, think of a Tesla Coil as a giant electrical pump, this Tesla Coil steps up voltage from standard 120 volts to more than 5,00,000 volts.

Imagine electricity flowing in a wire same way as water pumped through pipes, the current is like a flow of water & voltage like a water pressure. If nozzle is connected to pipe the force of the water pressure is dramatically increased while the flow of water decreased. The Tesla Coil acts in the same way, by passing the current through a small primary coil to secondary much larger coil it steps up voltage tremendously & reduces the current, this makes the Tesla Coil the transformer. Using the enormous coil Tesla wanted to pump the earth atmosphere full electrical energy. He believed that he could use earth as a natural conductor of electricity & send power around the world in the essence the earth would become a giant electrical outlet.

To prove his widely original theory Tesla left his home in Newyork city & began experimenting with wireless power in 1899 the age of 43 on the Colorado. He constructed a laboratory & tower that showed 80 feet into the air. Inside the bond like structure was enormous Tesla coil. By tapping into the local electrical power from Colorado Tesla coil produced more than 12 million volts. He often demonstrated his wireless concept by illuminating the phosphorous bulb by holding it in his hand.

The Tesla coil outputs electrical energy without harming humans. Similar to the way the transmission towers bombard us with radio waves. Tesla wanted to transmit power globally so that people only have to receive power to use it. Tesla claimed his experiments in Colorado a success & he had achieved wireless transmission of power illuminating light bulbs which are one mile away.

Tesla's Wardenclyffe Tower

In 1901 based on Colorado experiment Tesla began to build his visionary wireless power, he called it wardenclyffe. It was comprised of laboratory & power plant adjacent to it was a 187 feet tower. Power from the coil was set to a giant Tesla coil in the tower. Underneath the tower the inventor shrunk huge shafts 120 feet into the soil to transmit electrical current into the earth. This was to be the first of many transmitters in a system that encircles the world with wireless energy. The vast amount of electricity necessary would come from huge hydroelectric projects.

Lot of people thought he was crazy because they couldn't understand what he was seeing. He was able to see the things which others worried it visionary. But even visionaries need money, so Tesla convinced J.P. Morgan to invest 150 thousand dollars to build wardenclyffe. Tesla promised financier that the tower would make millions by broadcasting messages, news, music & even pictures to any part of the world.

In fact the timing that ultimately doomed wardenclyffe, on December 12th 1901 as Tesla was working at his wireless network Marconi met him to the patch & successfully transmitted a radio signal across the Atlantic. Well Marconi achievements were indeed the first; in reality he used 17 of Tesla patents to accomplish these feet. Tesla was not only forgotten as a father of radio Marconi's transmission sealed the fade of wardenclyffe. Morgan was no longer interested in supporting Tesla's work so in 1905 well still under construction & after some amazing electrical display the wardenclyffe project was abanded & later destroyed.

"The world is not prepared for it. It was too ahead of his time. But the same laws will prevail in the end & make it a triumphal success."

-Nikola Tesla

How can it be for the century after the failure of wardenclyffe Tesla's ideas still so passionately considered? Perhaps long before wardenclyffe Tesla already changed the world.

According to legends man who invented the twentieth century was born in 1856 at the stroke of midnight during thunderstorm. Tesla began his carrier as an electrical engineer with the telephone company in Budapest. He also developed a device that, according to some, was a telephone repeater or amplifier, but according to others could have been the first loudspeaker.

One day as he was walking in a park with his friend, Tesla suddenly vision a ground braking concept for a new electrical motor & drew it out in dirt, this simple illustration became patent for 'Induction Motor' which would go on to be the standard electric motor for the world. It's used for everything tools, appliances, hybrid cars & industrial plants.

In 1884 at age 28 Tesla moved to America with little money & only a letter from his boss Charles Batchelor to Thomas Edison. It is claimed that Batchelor wrote, 'I know two great men and you are one of them; the other is this young man'. Edison haired a brilliant young engineer & eventually asked him to redesign his companies' electric generators for a 50 thousand dollar bonus. .After Tesla developed a number of profitable patents he asked Edison for his bonus Edison replied, "Tesla, you don't understand our American humour," thus breaking his word & Tesla resigned. So began a life long battle between the upstart young engineer & established inventor. Tesla leaves Edison & he was digging ditches in Newyork city.

In 1886, Tesla formed his own company, Tesla Electric Light & Manufacturing. The initial financial investors disagreed with Tesla on his plan for an alternating current motor and eventually relieved him of his duties at the company. Tesla worked in New York as a labourer from 1886 to 1887 to feed himself and raise capital for his next project. In 1887, he constructed the initial brushless alternating current induction motor, which he demonstrated to the American Institute of Electrical Engineers (now IEEE) in 1888. In the same year, he developed the principles of his Tesla coil, and began working with George Westinghouse at Westinghouse.

In 1898, Tesla demonstrated his radio-controlled boat, which he was able to control remotely. He presented it as the first of a future race of robots, which would be able to perform labour safely and effectively, and many credit the event as being the birth of robotics.

In 1934 Tesla conceived a 'Death Ray', his idea was to blast a concentrated beams of particles charged with millions of volts of electricity through the air which could down fleets of the enemy air craft at a distance about 250 miles.

Tesla spent his later years in two small rooms in the Newyorker hotel, but when his death at age 86 was discovered. The United States government took control of his scientific papers. There was a great deal of concern at the time of his death as to what was there in his papers. The government claims that after inspecting Tesla papers they were released in 1952 & later sent to Belgrade where they now remain at the Nikola Tesla museum. However many believed some of his papers still missing, who knows what were in his papers. May be they are very sensitive or may be they are plans to death ray, we may never know what all these papers contain but we do know as his work is being re-evaluated; some of his ideas were century ahead of his time.

Do you think you know his name, every time you switch on your light or turn on radio his contributions as far as reaching Albert Einstein, Isaac Newton or even his enemy Thomas Edison? This mysteries tall dark Serbian invented Alternating current, wireless communication, modern electric motor, basic laser, radar technology, X-ray, Neon lamp, robotics & remote control all over 100 years ago. Yet today how many have heard of Nikola Tesla? How can history overlook such an incredible legacy?

"Our virtues & our failings are inseparable, like force & matter. When they separate, man is no more."

-Nikola Tesla

Interesting Facts on Nikola Tesla

- *On June 21 1943, the United States Supreme Court reversed itself granting patent rights to Tesla, not Marconi, for the invention of radio.*
- *In 1898, Tesla invented the "Electrical Igniters for Gas Engines". Today it is used in more than 600million cars worldwide & is best known as automobile ignition system.*
- *In 1917, Tesla proposed the concept of radio waves reflecting off objects to determine position & speed. That was 17 years before the invention of Radar.*
- *In 1887, Tesla experimented with X-ray radiation. That was eight years before Wilhelm Rontgen documented his own X-ray discovery, which won Rontgen the Nobel Prize in physics.*

When I read about Tesla I remember few lines from a movie Prestige From the character Tesla "Society tolerates one change at a time, first time I tried to change the world, I was hailed as a visionary. Second time.... I was asked politely to retire."

The War of Currents

Two mentalities come to a clash. One relies on the systematic proofs of trial and error. The other uses mathematical principles and theory to derive results.

During the initial years of electricity distribution, Edison's direct current was the standard for the United States and Edison did not want to lose all his patent royalties. Direct current worked well with incandescent lamps that were the principal load of the day, and with motors. Direct-current systems could be directly used with storage batteries, providing valuable load-levelling and backup power during interruptions of generator operation. Direct-current generators could be easily paralleled, allowing economical operation by using smaller machines during periods of light load and improving reliability. At the introduction of Edison's system, no practical AC motor was available. Edison had invented a meter to allow customers to be billed for energy proportional to consumption, but this meter only worked with direct current. As of 1882 these were all significant technical advantages of direct current.

From his work with rotary magnetic fields, Tesla devised a system for generation, transmission, and use of AC power. He partnered with George Westinghouse to commercialize this system. Westinghouse had previously bought the rights to Tesla's polyphase system patents and other patents for AC transformers from Lucien Gaulard and John Dixon Gibbs.

Edison's DC distribution system consisted of generating plants feeding heavy distribution conductors, with customer loads (lighting and motors) tapped off them. The system operated at the same voltage level throughout; for example, 100 volt lamps at the customer's location would be connected to a generator supplying 110 volts, to allow for some voltage drop in the wires between the generator and load. The voltage level was chosen for convenience in lamp manufacture; high-resistance carbon filament lamps could be constructed to withstand 100 volts, and to provide lighting performance economically competitive with gas lighting. At the time it was felt that 100 volts was not likely to present a severe hazard of fatal electric shock.

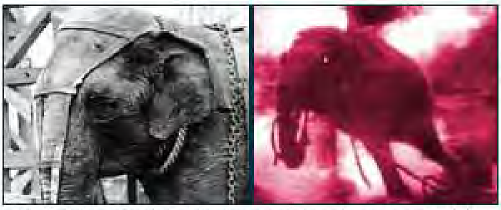
To save on the cost of copper conductors, a three-wire distribution system was used. The three wires were at +110 volts, 0 volts and −110 volts relative potential. 100-volt lamps could be operated between either the +110 or −110 volt legs of the system and the 0-volt "neutral" conductor, which only carried the unbalanced current between the + and − sources. The resulting three-wire system used less copper wire for a given quantity of electric power transmitted, while still maintaining (relatively) low voltages. However, even with this innovation, the voltage drop due to the resistance of the system conductors was so high that generating plants had to be located within a mile (1–2 km) or so of the load. Higher voltages could not so easily be used with the DC system because there was no efficient low-cost technology that would allow reduction of a high transmission voltage to a low utilization voltage.

In the alternating current system, a transformer was used between the (relatively) high voltage distribution system and the customer loads. Lamps and small motors could still be operated at some convenient low voltage. However, the transformer would allow power to be transmitted at much higher voltages, say; ten times that of the loads. For a given quantity of power transmitted, the wire diameter would be inversely proportional to the voltage used. Alternatively, the allowable length of a circuit, given a wire size and allowable voltage drop, would increase approximately as the square of the distribution voltage. This had the practical significance that fewer, larger generating plants could serve the load in a given area. Large loads, such as industrial motors or converters for electric railway power, could be served by the same distribution network that fed lighting, by using a transformer with a suitable secondary voltage.

Edison's response to the limitations of direct current was to generate power close to where it was consumed (today called distributed generation) and install large conductors to handle the growing demand for electricity, but this solution proved to be costly (especially for rural areas which could not afford to build a local station or to pay for massive amounts of very thick copper wire), impractical (including, but not limited to, inefficient voltage conversion) and unmanageable. Edison and his company, though, would have profited extensively from the construction of the multitude of power plants required to make electricity available in many areas.

Direct current could not easily be converted to higher or lower voltages. This meant that separate electrical lines had to be installed to supply power to appliances that used different voltages, for example, lighting and electric motors. This required more wires to lay and maintain, wasting money and introducing unnecessary hazards. A number of deaths in the Great Blizzard of 1888 were attributed to collapsing overhead power lines in New York City.

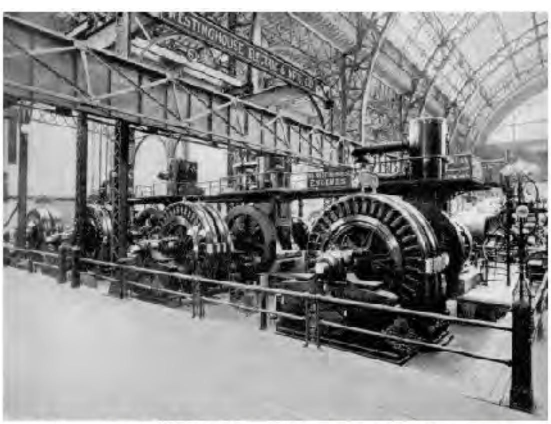
Alternating current could be transmitted over long distances at high voltages, using lower current, and thus lower energy loss and greater transmission efficiency, and then conveniently stepped down to low voltages for use in homes and factories. When Tesla introduced a system for alternating current generators, transformers, motors, wires and lights in November and December 1887, it became clear that AC was the future of electric power distribution.



Poor Topsy the elephant was electrocuted by Edison to prove that Tesla's AC current was dangerous. But Tesla's superior AC survived.

Edison carried out a campaign to discourage the use of alternating current, including spreading disinformation on fatal AC accidents, publicly killing animals, and lobbying against the use of AC in state legislatures. Edison directed his technicians, primarily Arthur Kennelly and Harold P. Brown, to preside over several AC-driven killings of animals, primarily stray cats and dogs but also unwanted cattle and horses. Acting on these directives, they were to demonstrate to the press that alternating current was more dangerous than Edison's system of direct current.

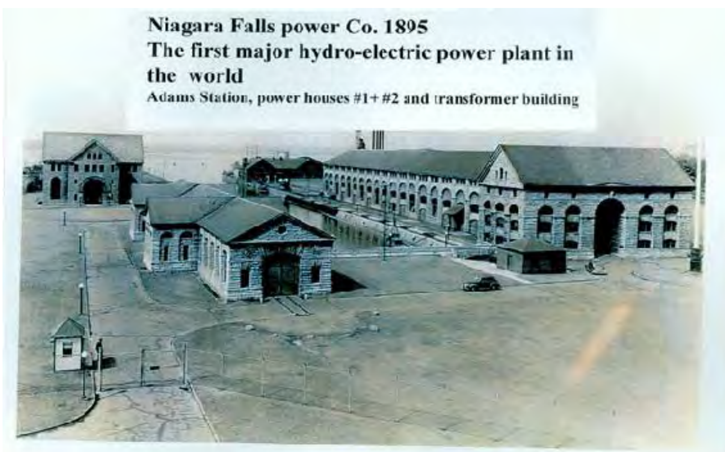
On the occasion of the 400th anniversary of Columbus' discovery of America, in Chicago in 1893, the first all-electric exhibition was organized. Two companies applied for the task of lighting the event – General Electric Company, which in the meantime took over Edison's company, and Westinghouse's company. The offer General Electric made was one million dollars. The largest expanse was related to the copper lines used for transporting direct current. Their offer was buried by Westinghouse's, which was two times lower.



Chicago's World Fair lit by alternating electric current

On May 1st 1893, the world exhibition was festively opened by the American President Grover Cleveland. By turning on a hundred thousand bright lamps, he lighted the entire fairgrounds, and the spectacle clearly conveyed to the visitors that the future of electricity lies in alternate current. "The City of Light" was the work of Tesla and Westinghouse, and it was generated by about nine *megawatts of electricity from a generator also housed on the fairgrounds. In the Large Hall of Electricity, Tesla proudly presented his multi-phase system of generation and transport of alternate current. The fair was visited by 27 million people who witnessed the victory of Tesla's inventions in the "War of Currents."*

Nikola Tesla and George Westinghouse built the first hydro-electric power plant in Niagara Falls in 1895 and started the electrification of the world. The successful Niagara Falls system was a turning point in the acceptance of alternating current. AC replaced DC for central station power generation and power distribution, enormously extending the range and improving the safety and efficiency of power distribution. Edison's low-voltage distribution system using DC was superseded by AC devices proposed by others: primarily Tesla's polyphase systems, and also other contributors, such as Charles Proteus Steinmetz (in 1888, he was working in Pittsburgh for Westinghouse).



Power house 1, Niagara falls.

Section of cable over which current over Niagara station was conducted. April 16, 1895

With this we end our journey: Hope you enjoyed your Ride. It's an effort to pay a tribute to all unsung heroes who made our life as it is now. Many people have been generous with their time, Talent & Expertise in helping us with this book. We are very thankful for everyone for their support & A special thanks to you "The Reader".