Electromagnetism
A New Dimension

by Creighton Cody Jones

The discovery of the principles of electromagnetism is a provocative slice of the history of human evolution. For man, the process of evolution is not expressed as some biological change, but rather as a willful change in his relationship to the universe, as a function of the discovery of new universal principles. In other words, man intentionally evolves himself through the discovery, transmission, and assimilation of principles of science, to the effect of gaining greater control over the world around him, creating new states of order that had not previously existed. This is most certainly the case with the successive self-feeding process of discovery and application of the many aspects of electromagnetism.

The discovery of electricity was not, as some initially thought, the discovery of some new motive fluid, but was rather a discovery of a hidden fundamental characteristic of all the elements of the periodic table. Today it is understood that electricity is the propagation of a specific form of action that requires a material carrier, and is intimately associated with a fundamental and inherent property of all matter, called *charge*.

This understanding, that chemical elements are composed of fundamental charge carriers, was not fully realized until after 150 years of modern experimentation with, and economic application of, electricity. This understanding came with the discovery of the electron by J.J. Thompson in 1897, where already at that time the electrical field concept was under full development, the fruit of the labors of such scientific luminaries as Ampère, Gauss, and Weber. And it is from these foundations that mankind has progressed to having the ability today of near-instantaneous communication across oceans, and to set foot on the moon.

It was, and continues to be, a discovery of a new type of Promethean fire, sparked by an investigation into the deeper fabric of physical chemistry. Whereas the fire of metallurgy was seated in burning embers, the fire of electromagnetism starts with the rubbing of amber.

The Evolutionary History of Man

On Earth, the different acts of producing, harnessing, moving, and using electricity call upon different electrical characteristics of materials. Some produce electricity by being rubbed, vibrated, or heated, like the static charge built up on rubbed amber. Some are excellent transporters of electricity, like copper, while others prevent its motion, as seen with glass.

These general properties, however, can be changed when materials are exposed to extreme or rare conditions.[1] For example, among ceramics, which normally act as insulators that restrict the flow of electricity, some express the opposite property at extremely low temperatures, becoming superconductive. Carbon, which, in a diamond crystal lattice is completely non-conductive, also becomes superconductive when its structural configuration is changed, in the form of graphene—a one atom thick lattice of carbon.

In essence, how we choose to use electricity, or how we can use electricity, is a function of the varied responses of different elements under different conditions to the interactions with moving charge and charged substances. Thus, the study of electromagnetism is very much an investigation into the deeper domains of physical chemistry.

All elements are composed of charge, but we often find them in states where charges are balanced between oppositely charged electrons and protons, and therefore they do not express, on the macroscopic scale, any immediately measurable electric effect, as with a typical piece of wood or plastic. However, there are numerous conditions where many elements and their composites do express electrical effects, as we will see.

Before we get to the more modern development of the battery and the discovery and application of flowing current, it is important to briefly discuss the form of electricity as it was explored by Ben Franklin and others in the early to mid-18th century.

At this time, man was investigating a phenomenon that had been known as far back as the ancient Greeks. It was found, that when a substance such as amber was rubbed with fur, it could be made to attract pieces of lint or hair.[2] Other substances were found that exhibited this prop-

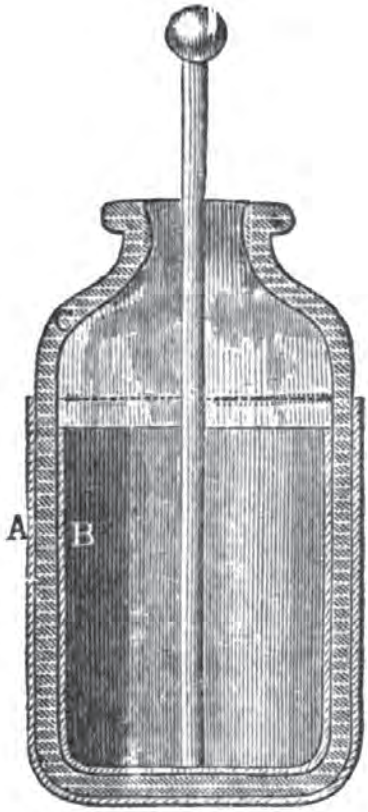
1. More often than not these "rare" conditions are man-made conditions.

2. The term *electricity* comes from the Greek word for amber (*elektron*).

erty when rubbed, and it was discovered that there were two different and opposite kinds of electricity: that produced from rubbing amber (*resinous* electricity) and that produced by rubbing substances such as glass (*vitreous* electricity). Either amber or glass would attract small bits of metal, but once a piece of metal had touched charged glass, it would be repelled by it, but would be *attracted* to the amber.

It was the buildup of static charge and its discharge that was at the core of many of Franklin's experiments, and is most famously displayed by his use of Leyden jars. These devices were essentially closed glass jars with a metal rod poking out of one end of the lid while in the other direction the rod extended into the open space of the jar. A charge would build up inside the jar when the exposed end of the rod was rubbed with a charged piece of amber, glass, or other material, as if to wipe the charge onto the metal rod. Franklin considered the two types of electric charge not to be two different fluids, but rather an overabundance or a lack of a common electrical fluid. His terminology for "positive" and "negative" electricity is still used today.[3]

It is now understood that in one case there is a buildup of excess electrons on the surface of the substance, producing what Franklin had arbitrarily dubbed "negative" charge, or in the other case a "positive" charge is built up through the removal of electrons. What is created is a static charge, whose intensity is a function of the amount of charge built up and contained by a given region. It is akin to the buildup of pressure which results from pumping more and more gas into a rigid container. The full charge which has been built up is then discharged when the metal rod is brought into contact with a conductive body, such as a finger or a wire.



A Leyden jar, similar to those used by Franklin. These devices served to store electrostatic charge, and were common laboratory instruments in the late 1700s.

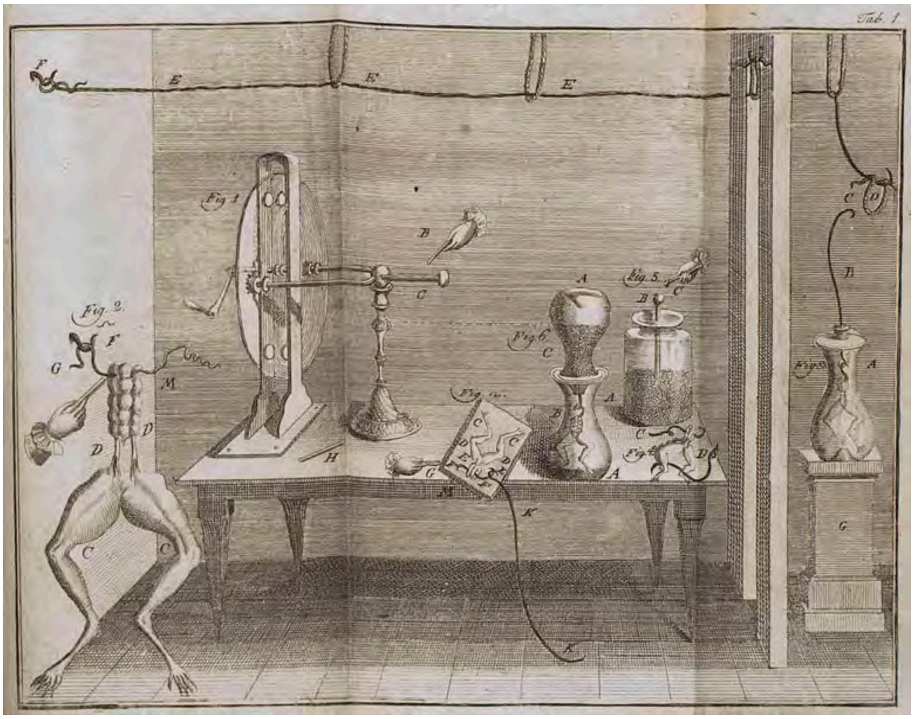
Various technologies were developed to exploit the new understanding of this phenomenon, including attempts at a telegraph, but the difficulty in making a signaling device with static electricity, and the amount of effort required to produce the electricity, made the technology impractical. The Leyden jar and the various electrostatic devices did, however, provide for the means for experimenting with electricity in a variety of contexts, including in biological experiments, which then gave way to the development of the battery and the sustained flowing current of electricity.

Galvani and Frogged Determination

The first modern development of the battery is credited to a 1749 discovery by Luigi Galvani, an Italian biologist who was studying how action is propagated in a living organism. Galvani's lab had a Leyden jar and an electrostatic machine, which Galvani would use to send charges into the muscles of frog legs, which he found would produce movement. Often this was done by touching the nerves of muscles with electrostatically charged medical utensils. History was changed when in one particular circumstance he had some long frog legs hanging from copper hooks in his lab, and as the story goes, he touched a region of nerve bundles with an *uncharged* metal instrument and caused the same twitching movement in the dismembered frog. Galvani realized that an electric charge was generated, and was stimulating the leg muscles of the frog, but in a way that did not require a charged utensil.

The chemical configuration that had been assembled by Galvani in this circumstance, between the two different metals (copper and iron) and the biological gel of the frog's fluids, are in general form the assemblage that we now know as the chemical battery. It is worth noting that the chemical process that produces the flow of electrical current that Galvani stumbled onto, as it was later discovered, is that which life utilizes for signal propagation throughout the body, but at a much smaller scale. In this sense, the battery really was a biochemical discovery, though not the discovery of some new distinct form of "animal electricity" as Galvani had thought. Also, as a historical cultural note, the widely popularized phenomenon of causing dead and dismembered animal parts to become animated by the application of electrical charge is said to

3. If Franklin had given the opposite names (calling resinous, rather than vitreous electricity *positive*), then we would not today have the odd circumstance where current is the flow of *positive* charge, while the electrons which actually do the flowing have *negative* charge.



An engraving of Luigi Galvani's laboratory. Galvani's research into electricity and anatomy led to his serendipitous creation of the first electric cell.

be the inspiration for the Mary Shelley novel *Frankenstein*.[4]

In 1800, Alessandro Volta distilled and refined the process discovered by Galvani, reducing it down to a relationship between two different metals separated by an ionized solution, such as salt water, with the metals then connected to each other by a conductive material. This was found to produce the flow of electricity. Volta constructed what became known as the *voltaic pile*, a stack of alternating discs of copper and zinc, separated in turn by a piece of cloth saturated with salt water. It was found that when the briny cloth was removed from the pile, the amount of electric discharge was reduced to that of a single copper-zinc disc pair, whereas when the cloth was inserted within each pair in the stack, the charge was greatly magnified, increasing with each additional cloth-separated copper-zinc disc pair.

What we now understand is occurring is that the two metals, now called electrodes, are reacting chemically with the ionized solution. When atoms of the metal are induced to bond with atoms in the solution, which are more chemically attractive to them, they leave some of their electrons behind. The result is that the abandonment of the metal by the positively charged nuclei that go on to form new compounds with the solution, leaves behind negatively charged residual electrons, which build up to form an overall negatively charged state for that metal. A similar effect is occurring at the site of the other metal as well, the difference being that the developed charged is relatively positive in comparison with the first. This results is a potential difference between the two metals (voltage), which when connected to each other by a conductive material (one that allows for the easy flow of electric current), results in a flow of electrons from a place of high negative charge to one of less negative or relatively positive charge. The amount of flow is known as the current. It is like connecting a pipe from a mountaintop lake to a desert valley below and opening up the spigot.

It is again worth noting that this process is very chemical-specific, as you need the appropriate type of metals that will chemically react in a specific way with the proper solution to produce the necessary charge difference between them, which then will allow for the flow of electricity when the two are connected by a material whose specific atomic structure and macroscopic form allow for the relatively free flow of electrons. One of the earliest and most important experimental uses of electricity from batteries was the application of battery-supplied current to water to dissociate hydrogen and oxygen. Already in 1802, the chemist Humphry Davy was utilizing electrolysis to isolate a whole set of new metals from ores, including potassium, sodium, barium, strontium, and magnesium. Thus, the new science of electricity was opening up new potentials and insights in the older science of elemental chemistry.

Batteries continued to evolve over time as our understanding of the most efficient and effective elements to be used developed, but the fundamental concepts stayed the same. This includes rechargeable batteries, where the chemical reactions are induced to run in the opposite direction during the recharge phase, as for example, the lithium ion batteries that are at the heart of many of our most used electronic devices, such as computers, phones, and battery-powered cars.

It is extremely important to recognize that one of the first uses of this new power of controlled and sustained current was for the technology of the telegraph, though the concept remained mostly novel and conceptual until the next wave of electrical innovations and discoveries. With the telegraph, mankind now had the ability to carry

4. Mary Shelley's subtitle was "The Modern Prometheus." Considering the disasters that attend the use of science in the novel, what does this suggest about her view of the conflict between Prometheus and Zeus?

Wikipedia contributor GuidoB

A voltaic pile of Alessandro Volta's design. This battery of electric cells (also known as elements) produced current by the interaction of the copper and zinc electrodes with brine-soaked spacers between the electrodes of each element.

out long-distance, nearly instantaneous communication, creating a new level of connectivity among the minds and thoughts of the human species. The first trans-Atlantic electronic communication was established in 1866, between Britain and the United States. Ten years later saw the patenting of the telephone by Alexander Graham Bell, and 25 years after that Guglielmo Marconi sent a wireless communication across the Atlantic, based on the discovery and experiments with electric waves made by Heinrich Hertz.

At the beginning of the 19th century, along with the parlor trick and novelty uses, the battery was the basis for conducting a whole new set of investigations and experiments into the nature of electricity, and eventually lead to the development of the theory of electromagnetism, where electricity and magnetism were unified under one banner, which led to the development of a great liberator of mankind, the electromagnetic motor.

Ampère: Beyond the Battery

With the ability to have sustained current, thanks to the development of the battery, André-Marie Ampère set up a group of experiments that looked at the relationships of different currents, flowing in different directions and configurations relative to each other. He showed that parallel currents moving in opposite directions repel each other while those moving in the same direction attract. Overlapping perpendicular current elements had no effect on each other at all. Ampère established the experimental and theoretical foundations for the development of the science of moving electric charge, which he called electrodynamics, even forecasting the existence of what we now know as the electron and deriving the relationship of electricity to the speed of light. To this day, one of the principal discoveries of Ampère, that of the "angular force," is a point of controversy, and has to a large extent been left out of textbooks, though some prominent scientists think it may hold the key to a more thorough understanding of atomic and subatomic processes.[5] A key to Ampère's work was his introduction to a principle discovered by Hans Christian Oersted, of the relationship between electricity and magnetism.

In 1820, Oersted observed that a compass needle, which responds to magnets and the magnetic field of the Earth, would move when brought close to an electric current. Moving electricity produced a magnetic effect. The inverse property of inducing current in a conductive material by the relative motion of a conductor and a magnetic field, was developed by Michael Faraday in the early 1830s.

This relationship between electric current and magnetism became, through the motor, the basis for the second industrial revolution, as the electric generator became the primary technology at all sides of the productive process. This is a result of the fact that magnetic and electric fields exist with a perpendicular relationship to each other, and the change of one produces the other. Take, for example, the generation of electricity at a dam with a hydroelectric generator which rotates a magnetic field through a bundle of conductive wire, which then transmits electricity across conductive lines where it is then transformed back into some form of mechanical action in an inverse way, as with a motor in an electric drill.

The electromagnet, which has replaced permanent magnets at the core of most generators and motors, has its roots in Ampère's work: creating a magnetic field by

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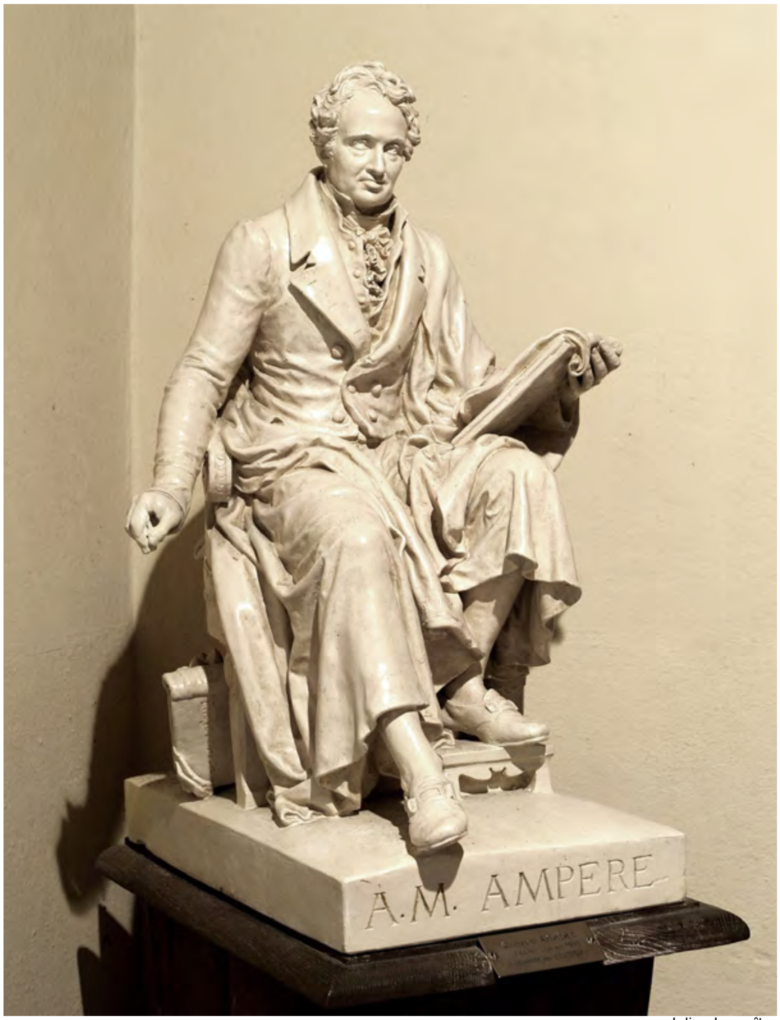
5. Ampère's angular force is a result of his longitudinal force, whereby two collinear, opposite current elements attract each other and those moving in the same direction repel. This effect is denied and left out of most modern electrodynamics. For more, see "The Atomic Science Textbooks Don't Teach" in *21st Century Science and Technology*, Fall 1996.

running current through a circularly wound wire. He found that the strength of the magnetic field was directly proportional to the current and the number of windings of wire. The first generators were put into use by the mid-1830s, with the largest alternating current (AC) power generator of its era set up at Niagara Falls in 1895, producing a great deal of electricity from its hydroelectric generators. Hydroelectric power generation and transmission was fully exploited as a civilization-changing application under the guidance of the Franklin Roosevelt Presidency through the combination of a massive hydroelectric buildup and a rural electrification initiative, which saw electricity lighting up homes and chicken coops and powering the water pumps of farms across the country.

No longer was electricity a local urban resource, but with projects such as the Grand Coulee Dam and the Tennessee Valley Authority generating abundant amounts of new electricity, the vision of the Rural Electrification Administration could be realized. Farmers and other rural residents alike were now given access to the benefits of electricity which lead to not only an increase in the productivity of the farm, but also to cultural changes such as increased literacy and educational opportunity. Through the power of electricity, more people were liberated from the demands of farming as productivity increased, and could pursue other productive activities, further increasing the dynamic complexity of society. The United States as a whole was now operating in the field of electromagnetic potential, and was equipped with the power to not only stop global fascism, but to extend the field of progress on a global scale. Unfortunately, the untimely death of Roosevelt brought that momentum to a grinding halt, and in the main, that potential has been placed under the yoke of an oligarchical agenda.



Julien Lemaître

Statue of André-Marie Ampère at the Museum of Electricity—the Maison d'Ampère—in Poleymieux, France. Ampère introduced the first detailed understanding of electrodynamics, and began to unify the principles of electricity and magnetism.

The Motor of Human Progress

The first commercially developed electromagnetic motor was patented in 1837, though the practical and economically sound use of the motor did not take hold until the 1870s and ’80s. From that point the motor became the principal technology for modern manufacturing processes, moving from the machine tool sector to the household consumer, from precision lathes, to conveyor belts, to the vacuum cleaner. The electric motor also found early use in transportation with the first electric trolley cars going into action in the late 1880s. With the electric motor electricity could now be transformed into mechanical action, and as the electrical transmission grid spread, so did the productive potential. This was equally true for areas that already had manufacturing, where machines were all run by a complex of pulleys and axles connected to belts which were in turn connected to other pulleys and a larger gear system, which was all powered by an on-site steam engine.

Now, with electrification, all that was needed was a power line running in from a distant area, and individual machines could be much more easily plugged in, turned on, moved around, and changed out. The move away from belt-driven and on-site steam-powered production towards electromotive action began in the early 1900s. No place benefitted more from the use of wire-pumped electricity than deep mines, where combustion would be noxious and potentially dangerous, and pumped steam power was cumbersome and often impractical. Wires could now be snaked to otherwise hard to access areas. Ultimately this meant an increased density of machine power per capita as electrically powered motorized machines expanded and played an increasing role in more facets of the economy, from sawmills to blenders. Today, electricity is again being applied more widely to mass transportation, with electric cars and high-speed trains, where, depending on the case, the energy is either derived from an onboard chemical battery, or is drawn off the electrical grid. To this day, when it comes to the electrical grid, the source of the electricity is a mechanical electromagnetic generator, driven by either one, or a combination of gravitational, chemical combustion, or thermal exchange forms of work transfer.[6] Still in the design phase is the use of what is called "direct conversion" where the motion of charged particles is converted directly into voltage.

The Grand Coulee Dam, one of FDR's "Four Corners" projects. Grand Coulee's cheap and abundant electricity made the Pacific Northwest a center for aluminum and aerospace production, critical for winning World War II.

It's Not All About Machines

Besides the commercial use of the motor, electricity was exploited for its resistive interaction with certain materials, where the action of the retarded flow of the electrons is expressed as thermal and light energy. This resistive property of some materials is used in everything from a light bulb, where in many cases a resistive tungsten filament radiates energy in the form of bright white light, to an electric coil top stove where the primary amount of energy released is in the thermal range.[7] By the 1880s, light bulbs were gaining widespread use, thanks to the labors of such inventors as Thomas Edison and Joseph Swan, who made successive breakthroughs in understanding what materials would most effectively radiate light, as well as creating the proper vacuum conditions for the bulbs, which was necessary so that the filaments would not catch fire due to the presence of the highly combustive gas, oxygen. The lives of an increasing number of the world's people were transformed by the ability to have nighttime illumination on a grand scale, extending the productive hours in a day, whether it be at the farmhouse or the central city library.

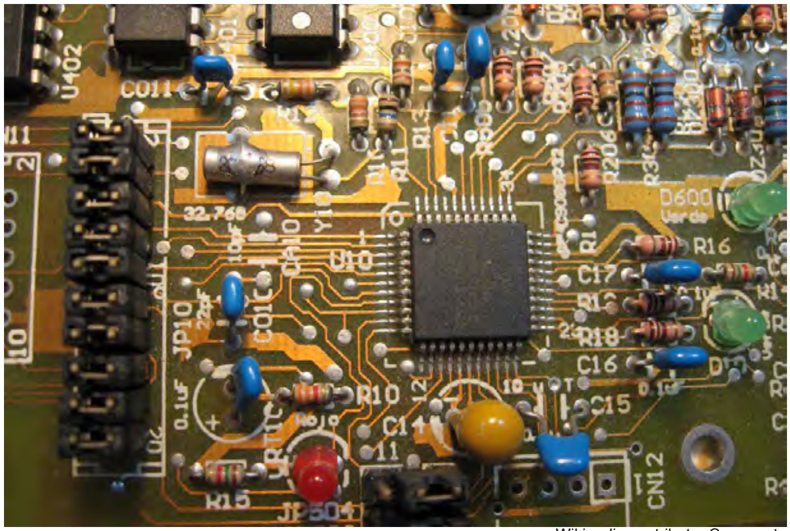
Resistive materials, as, for example, the filament in a light bulb, have a somewhat inverse character to conductive materials. The theory is, that while conductive materials, such as the metals copper and gold, have a crystal lattice arrangement of their atoms which allows for a relative free drift of electrons, silicon-based resistors, on the other hand, have an impeding effect on the flow of electrons, creating a kind of friction to the flow. This type of friction energy is then radiated out from the surface of the material often as light or heat. Some materials, such as quartz crystals, translate the resistive action into vibrational action, which can be tuned and amplified by the amount of current and voltage that runs through it. This is the concept behind the quartz radio and watch.

Vibrating action is another key element in the technologies that utilize electricity, particularly ones that relay and transmit audio. By having a modulated oscillation of a magnet, a modulated flow of electricity can be induced, which can in turn be transformed into radio or other electromagnetic signals which can be captured and re-radiated as sound, effectively following the same steps back.

6. Excepting the insignificant (and foolishly wasteful) use of solar power.

7. The light produced by a regular tungsten incandescent light bulb is only a few percent of the energy it consumes.

The Power of Regulation

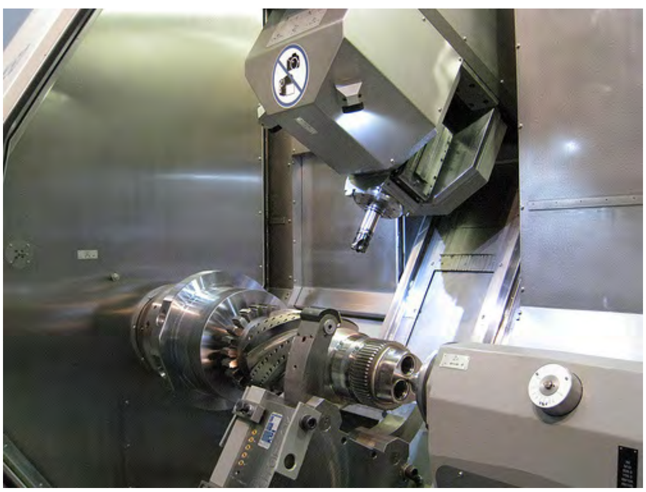


Wikipedia contributor Cmarcante

A printed circuit board, showing integrated semiconductor circuits (e.g., the central black square), capacitors (labeled with Cs), resistors (labeled with Rs), and other components. Semiconductor technology allows control systems to be orders of magnitude smaller.

The property of resistance now plays a very critical regulatory role in all electronics, where resistors restrict the flow of current, in various degrees, to different elements of a circuit. This allows for the use of a variety of different components, which have varying degrees of sensitivity to current amount, to all be used in the same circuit. Without resistors, many of the components would require their own individual power source specified to their voltage and current requirements. Here again, the particular chemical composition and arrangement play a determinant role in how the properties of electricity will be expressed. For example, the resistors that are used in modern electronic circuits are often made of carbon mixed with some sort of ceramic, but as resistors these are best when used at small scales.

The semiconductor is an excellent regulator of current and voltage moving through electrical devices. These are most commonly made of silicon or germanium, and doped with trace amounts of other elements to produce materials with a slightly positive or negative disposition. This doping transforms an otherwise non-conductive material into one that can now facilitate a flow of current by changing the electron configuration of the material. Semiconductors are in effect turned on and off in a process known as gating; the application of an electric field turns the material into a channel for the passage of current. Transistors are a type of semiconductive component that act as incredibly small electrical switches, replacing, in many cases, the mechanical relays and electromagnetic vacuum tubes used for this purpose earlier. This is crucial for being able to change and regulate the amount of current and voltage that enters the various components of an electronic device, allowing for increasingly more complex and diverse operations.



A CNC machine tool. Such automated devices can automatically change cutting tools and reposition work objects, allowing for high automation of part-machining.

Semiconductor integrated circuits are the basis of those electronics that are so dominant in today's world, where through the use of computers, we have created a much more refined use of electricity for the storage, transmission, and utilization of information, for communication and control of machinery. For example, the use of computers to mediate the control of airplanes and machine tools, translates the intentions of the programmer and user into complex and complicated precision actions. Computers express a remarkable utilization of the essential properties of moving charge, i.e., voltage, current, and resistance, and the specific material relationships to those properties. They represent, when applied properly, a significant extension of the physical power of man.

With the discovery and application of the principles of electromagnetism, mankind has tapped a fundamental dimension of the universe and opened up a new power. With all moves from a lower to a higher platform, society takes on a more multiply-connected nature, in terms of the number of interdependent connections that make up an individual's environment. Each individual has more power to transform the universe, but that power is a function of, and dependent on, an ever increasing array of technologies, institutions, and people. This is the natural tendency of mankind, to increase his power to act in the universe, through the increase in density of applicable fire, as a function of an increased knowledge of physical chemistry.