PHYSICS

Electricity in the Nineteenth Century

"A Classic of Science"

Elihu Thomson Tells the Achievements of Electricity's First Century and Forecasts More Modern Developments

ELECTRICITY DURING THE NINETEENTH CENTURY. By Prof. Elihu Thomson. In Annual Report of the Board of Regents of the Smithsonian Institution for the year ending June 30, 1900. *Washington: Government Printing Office,* 1901. *This is an exact reprint of extracts from the original publication.*

HAS SCIENCE any answer to make to the question, What is electricity? We think not; nor has it any answer to make to the question, What is energy? The most that science can possibly expect to do is to extend our horizon and permit us to acquire a deeper knowledge of the intimate relations of things. We speak of the ether as the electrical medium, and we acquire more and more knowledge of its properties and actions as the years go by. Facts are gradually being accumulated by workers in all departments of science, and there must follow generalizations which will bring into harmony the present discordancies where they appear. It will probably be found that the electrical properties of the ether are the fundamental ones on which the universe is built and that the properties of matter, which we speak of as mass, weight, inertia, cohesion, elasticity, etc., are dependent upon or have their origin in the ether properties. Perhaps just as light and radiant heat have been shown to be electrical vibrations, gravitation and the other properties may follow. True it is that electrical laws are most simple, most definite. Electrical measurements can be made with the utmost accuracy and delicacy. Indications these are of its fundamental and universal character.

In order to account for the passage of light, radiant heat, magnetism, and other forces through space science has need of what is called the ether, a medium filling all space and propagating waves of heat and light, as well as magnetic disturbances and gravitation. The sun radiates to the earth luminous waves and heat waves. Moreover, it has been shown that whenever there is a great cyclonic storm upon the sun the earth sympathizes or receives influences which disturb the compass needle. There is reason to believe that the eleven-year sun spot periods find their expression upon the earth in the greater frequency of displays of aurora borealis, magnetic storms, and even thunderstorms following the more active storm period of the sun, when the sun spots are most numerous.

What, then, is the nature of this ether of space? To this question no complete answer can as yet be given, except to say that it is the electro-magnetic medium. It is the ether and not the air which enables a magnet to attract or repel, for the action occurs in the best vacuum, undiminished. It is the ether and not the air which enables an electrified body to act upon surrounding bodies in attracting or repelling them. When we sit in front of an open fire, it is the ether which brings the light and also the heat radiated to us. Early in the century the theory that light consisted of ether vibrations of a particular character became the commonly accepted theory. It remained for Clerk Maxwell, a mathematical physicist of the highest eminence, to put forward, about the middle of the century, the idea that light waves were really electrical waves. Light would, then, become one form of the manifestation of electrical force; and the same would be true of radiant heat. This theory, however, lacked experimental confirmation until the researches of the late Dr. Hertz, too early lost to science. We see references to what are called "Hertzian waves." These are waves identical in nature with light waves, but of much lower pitch or period. Red light consists of about four hundred millions of millions of electrical waves in the ether per second; blue or violet light about double that number. Hertz showed in his experiments that electric sparks between polished balls, under proper conditions, were attended by ether waves of the same nature as those of light, but having a pitch represented by some millions of vibrations per second. These waves, however, could be reflected, could be refracted, could be polarized, and be dealt with as if they were light waves. Ordinary alternating-current waves are, in fact, closely akin to these waves, only their speed is from 25 to 200 or 300 per second. Their "frequency" is low.

When we speak of "high-frequency waves" we usually mean waves of great rapidity as compared with ordinary alternating-current waves. When a Leyden jar is discharged through a short wire, or coil of wire, there is momentarily generated a set of high-frequency waves. This was shown by Henry in the early half of the century. The brilliant effects which have been produced within recent years by Mr. Tesla, as well as by the present writer, in the use of high-frequency discharges or

CELEBRATING

Dr. Thomson (left) on his eightieth birthday, shows Dr. Karl T. Compton, president of Massachusetts Institute of Technology, his first electrical device, a wine-bottle friction machine, built when he was eleven years old. Dr. Thomson's first dynamo stands on the table. Applied electricity has developed during his life-time, and almost every branch of it has felt the impress of his work.

waves are well known. Electric sparks many feet in length are easily generated. Astonishing luminous effects accompany high-frequency experiments. Conductors glow in the dark with a bluish luminosity. Vacuum tubes are caused to give out light many feet away from the apparatus in which the high-frequency discharges are generated.

Most curious perhaps of all, to the lay mind, is the possibility of passing through the body current enough at high frequency to light lamps in circuit with the body, without producing any harmful effects, and, in fact, without producing any sensation whatever. Spark discharges from the apparatus which would seem to have the power to kill instantly are received harmlessly. Indeed, when currents have a frequency more than a certain amount—say 10,000 per second—the physiological effects seem to be in abeyance, as if the rapid reversals of the current could not leave any permanent effect.

Certain forms of moderately high frequency currents give promise of actually producing insensibility to pain without interfering with consciousness, and it is possible that the future may see surgical operations performed with the protection of the subject from painful sensations by the passage of these currents. Up to the present, however, there has been no use actually made in the practice of high-frequency effects, unless we class with such effects those of transmission without wires.

Wireless telegraphy of today is, however, a direct outcome of Hertz's experiments on electric waves. It is but little more than ten years since Hertz announced his results to the world. His work, supplemented by that of Branly, Lodge, and more recently Marconi, has made wireless telegraphy a possibility, and there are indications that enormous distance may yet be covered by this ethereal transmission. Just here we may refer to the fact—for it is a fact—that the electrical energy transmitted over a line, which may be many miles in length, really does not travel by the wire connecting the two points. It travels in the ether surrounding the wire. The wire itself is, in fact, the guiding core of the disturbances in the ether which proceed outward in all directions to unlimited distances. The guiding core or conducting wire is needed to focalize or direct the delivery of the energy. This curious conclusion of science, then, that the power from the power-station travels in the space around the wires led from the station is one of the results of recent electrical studies, just as with light those studies begun by Maxwell and Hertz have led to the inevitable conclusion that the light of the candle, the light of a kerosene lamp, and the light of a gas burner are all in essence electrical phenomena as are all forms of radiation in the ether.

The wireless telegraph of today utilizes a sudden electrical disturbance made at one point, which travels by the surrounding ether in all directions and is picked up in feeble fashion, it may well be, by very sensitive receiving instruments. The shock or disturbance to the ether is thus recognized, and by a preconcerted system of signals the slight disturbances are sent out in a sequence such as to convey intelligible messages. Distances of upward of 100 miles are thus covered with what must be regarded as an extremely feeble means so far as the scale of the apparatus is concerned, and there would seem to be no reason why the scale of operations greatly increased may not in the near future widely extend the range over which wireless telegraphy can work.

The wonderful X ray and the rich scientific harvest which has followed the discovery by Röntgen of invisible radiation from a vacuum tube were preceded by much investigation of the effects of electric discharges in vacuum tubes, and Hittorf, followed by Crookes, had given special study to the effects in very high or nearly perfect vacua. Crookes, though specially enriching science by his work, missed the peculiar X ray, which nevertheless must have been emitted from his vacuum tubes, not only in his hands, but in those of subsequent students. It was as late as 1896 that Röntgen announced his discovery. Since that time several other sources of invisible radiation have been discovered, more or less similar in effect to the radiations from a vacuum tube, but emitted, singular as the fact is, from rare substances extracted from certain minerals. Leaving out of consideration the great value of the X ray to physicians and surgeons, its effect in stimulating scientific inquiry has al-

ANTHROPOLOGY

Many Colors Found In Eyes of Newborn Babies

THE TRADITION that all babies' eyes are blue at birth has been shattered. Taught by physicians, physiologists, and geneticists for many years, this "fact" has been proved a fallacy by the simple means of actually examining under good illumination the eyes of nearly five hundred newborn infants in the hospital of the Johns Hopkins University. Dr. W. C. Beasley, instructor in psychology at the university, made the examination.

Not only were other colors than blue found in the newborn babies' eyes, but brown was found in 79.5 per cent. of the white infants' eyes and 99.3 per cent. of the Negroes'. Many eyes held several colors. Yellowish and reddish browns were seen, and greens, violet, gray and lavender, as well as flecks and streaks of as many as 187 different hues. Only 28 of the 455 infants examined had plain blue eyes.

But there is a reason for the tradition that all white infants have blue eyes. For the eyes at birth have a clouded appearance, due perhaps to lack of clearness in the fluid between the front of the iris and the cornea. This cloudiness acts as a veil to hide the true colors of the eye from the casual observer. The resulting appearance is a murky look which could well be described as dark blue or gray.

If you look at the young baby's eyes closely, however, with bright illumination and some optical aid such as that afforded by a reading glass or pocket microscope, you will be rewarded by seeing the real eye color shine through.

And you will probably notice many things about the eyes that you have never seen before. You may see streaks radiating from the center like the spokes of a wheel. Or you may find a ragged patch, either large or small, surrounding the pupil. Or a narrow ring around the pupil. Or all sorts of flecks, spots, and streaks. Altogether 200 different combinations of these patterns were found to be possible in human eyes.

inquiry has almost been incalculable. The renewed study of effects of electric discharge in vacuum tubes has already, in the work of such investigators as Lenard, J. J. Thomson, and others, apparently carried the subdivision of matter far beyond the time-honored chemical atom, and has gone far toward showing the essential unity of all the chemical elements. It is as unlikely that the mystery of the material universe will ever be completely solved as it is that we can gain an adequate conception of infinite space or time. But we can at least extend the range of our mental vision of the processes of nature as we do our real vision into space depths by the telescope and the spectroscope. There can now be no question that electric conditions and actions are more fundamental than many hitherto so regarded.

The nineteenth century closes with many important problems in electrical science as yet unsolved. What great or far-reaching discoveries are yet in store, who can tell? What valuable practical developments are to come, who can predict? The electrical progress has been great—very great—but after all only a part of that grander advance in so many other fields. The hands of man are strengthened by the control of mighty forces. His electric lines traverse the mountain passes as well as the plains. His electric railway scales the Jungfrau. But he still spends his best effort, and has always done so, in the construction and equipment of his engines of destruction, and now exhausts the mines of the world of valuable metals for ships of war, whose ultimate goal is the bottom of the sea. In this, also, electricity is made to play an increasingly important part. It trains the guns, loads them, fires them. It works the signals and searchlights. It ventilates the ship, blows the fires, and lights the dark spaces. Perhaps all this is necessary now, and, if so, well. But if a fraction of the vast expenditure entailed were turned to the encouragement of advance in the arts and employments of peace in the coming century, can it be doubted that, at the close, the nineteenth century might come to be regarded, in spite of its achievements, as a rather wasteful, semibarbarous transition period?

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GENETICS

Control of Sex in Rabbits Attempted By Electricity

AN ATTEMPT to control the sex of rabbits is reported by Prof. N. K. Koltzov and V. N. Shröder of the Moscow Institute of Animal Breeding in a note to *Nature*. The method involves the use of an electric current and artificial impregnation.

The general theory of geneticists is that spermatozoa carrying the x-chromosomes produce females while those carrying y-chromosomes produce males. The ova all have the x-chromosomes. The Russian investigators reasoned that a method which would separate the spermatozoa carrying x-chromosomes from those carrying y-chromosomes would give a method by which male or female mammals could be bred as desired.

The Russian investigators further believed that the spermatozoa carrying x-chromosomes might carry an electrical charge of opposite sign to those spermatozoa carrying y-chromosomes. Accordingly they tried to separate them by passing an electric current through the sperm suspended in a salt solution. They found that part of the spermatozoa did go to the positive pole, part to the negative pole while the rest remained in the middle of the apparatus.

The Russian investigators artificially impregnated three female rabbits with the different portions of the sperm that had been separated by electricity.

"The female impregnated with the anode spermatozoa produced six young, all of the female sex," they reported; "the second, impregnated with cathode spermatozoa, produced four males and one female; the third, impregnated with the central fraction left between the two poles of the Michaelis apparatus, bore two males and two females."

While the separation of spermatozoa by an electric charge is of interest to scientists, practical application of this method even with lower animals, is considered extremely remote.

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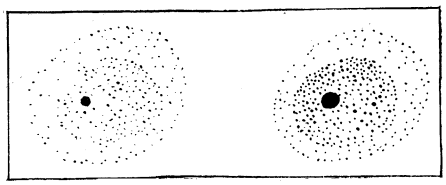

NORMAL CANCEROUS

The dark spot near the center of each cell represents the nucleolus. The larger nucleolus of the cancer cell is suggested as a means of distinguishing it from normal cells with which it might be confused.

MEDICINE

Way Found to Distinguish Cancer Cells From Normal

THE SIZE of the cell nucleolus is the distinguishing feature by which a cancer cell may be told from normal cells, Drs. William Carpenter MacCarty and Eva Haumeder of the Mayo Clinic told members of the American Association for Cancer Research at their meeting in Washington this week.

Medical scientists have long been searching for a method of distinguishing between normal and cancer cells. It is not always possible to tell from its gross appearance whether or not a tumor is malignant.

Surgeons about to remove a tumor generally send a small piece of it down to the hospital laboratory for diagnosis. The pathologist must, within two or three minutes, cut a paper-thin sliver from the piece of tumor tissue, fix it on a glass slide, stain it, examine it under the microscope, and report to the surgical team waiting in the operating room whether or not the tissue is cancerous.

But even when examined in this way, cancer cells sometimes look so much like certain types of normal, non-malignant cells that it is extremely difficult to make an accurate diagnosis.

Drs. MacCarty and Haumeder have found that the area of the nucleolus in the cancer cell is much greater than the area of normal cell nucleoli. They conclude that the cancer cell has at least one differential characteristic and that this must be used by those who expect to reduce the tremendous mortality from cancer.

The nucleolus is a very small but important part of a cell. For their investigations, the Rochester scientists had to devise a special method of measuring this small area, which they described at the meeting.

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