Trail Blazers to Radionics and Reference Guide to Ultra High Frequencies

Compiled by
E. KELSEY, Engineering Correlator
ZENITH RADIO CORPORATION
CHICAGO, ILLINOIS

TRAIL BLAZERS

TO

RADIONICS

and

REFERENCE GUIDE TO ULTRA HIGH FREQUENCIES

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PREFACE

Trail Blazers to Radionics and *Reference Guide to Ultra High Frequencies* have been prepared to fill a need recognized by those in the communications divisions of our armed forces, by radio engineers, science teachers, and college and high school students, as well as by the layman. In writing *Trail Blazers to Radionics* (Part 1) every effort was made to present in a concise form important data that would not otherwise be obtainable without considerable research in a large library. The purpose of this work is to present biographies of great men of science and their research, and tell where such contributions are now used in the progress of science. We hope that its contents will stimulate a desire for the pursuit and advancement of knowledge by students, therefore preparing the way to the Radionic Age into which man is now entering.

The first edition of *Reference Guide to Ultra High Frequencies* was published months ago and widely distributed. It provided much of the academic background for Radar research and is regarded as a definite contribution in the field. This third edition of *Reference Guide to Ultra High Frequencies* (Part 2) has been brought up to date and includes much new material. We hope that it will continue to aid those developing Radionic military equipment, especially the men in our Army and Navy research laboratories who long before war was declared did the original work on that most valuable weapon, Radar.

Miss Elizabeth Kelsey of Zenith Radio Corporation's engineering division has spent many patient months in compiling and editing this book. She is a Fellow of the Royal Society of Arts and Sciences, member of American Association for the Advancement of Science, and an associate member of the Institute of Radio Engineers and of the International Television Society.

We present to you the results of Miss Kelsey's efforts, with the compliments of Zenith Radio Corporation, in the interests of the victory program.

G. E. GUSTAFSON, *Vice President in Charge of Engineering*

E. F. MCDONALD, JR., *President Zenith Radio Corporation*

Part 1

TRAIL BLAZERS TO RADIONICS

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FOREWORD TO PART 1

RADIO engineers, physicists in their laboratories on the home front, men in the Signal Corps, Navy Radar, and Air Corps Communications, as well as laymen, realize one fact: there are new frontiers in Radionics, the great industry whose subdivisions are Radar, Radio, and Electronics.

Important as a background for future developments are the lives and works of those great men who, in years gone by, blazed trails through a scientific wilderness to new "Promised Lands."

Mathematics has often been spoken of as the corner-stone of civilization. Its influence on scientific development, philosophy, and the arts is so great that most cultural as well as intellectual development can be traced directly or indirectly to this source. For example, consider the prediction by J. Clerk Maxwell, famous 19th century mathematician, that electromagnetic waves would be found to travel through space at the speed of light, approximately 186,000 miles per second. Heinrich Hertz, along with other experimenters (after they had read Maxwell's mathematical development), then started a search for these waves and techniques to generate them. Wireless telegraphy and radio soon followed. Today Maxwell's equations are often used in designing ultra high frequency radio equipment, so vital for final victory. To give mathematics its proper place and honor, *Trail Blazers to Radionics* opens with the biography of a mathematician.

PYTHAGORAS • 540-510 B. C. • Greek

Pythagoras, mathematician and philosopher, was the first to give the world the abstract idea of a number, as distinguished from the counting process. This was, in one sense of the word, an invention, and made possible the development of a practical system of mathematics. To Pythagoras also goes credit for the first deductive proof that the square on the hypotenuse of a right angled triangle is equal to the sum of the squares on the other two sides. How does this apply to electricity? Suppose one wishes to know the impedance, or opposition to the flow of current, in an a-c circuit. Engineers have found that impedance can be determined mathematically by use of the above, expressed in electrical terminology as $Z = \sqrt{R^2 + X^2}$, where Z = impedance, R = resistance, and X = reactance.

Pythagoras, with a limited background probably received from Egyptian priests, was the first to approach music from a scientific viewpoint. He realized that when strings of various lengths, but of identical material and stretched to the same tension, were used to give the perfect harmony of the octave, fifth, and fourth, their lengths must be in the ratios of 1 to 2, 2 to 3 or 3 to 4, respectively. Here, therefore, originated the science of musical tone.

J. GOW.......................................*A Short History of Greek Mathematics*
T. DANTZIG.......................................*Number: The Language of Science*
W. L. EVERITT.......................................*Fundamentals of Radio*
T. GOMPERZ.......................................*Greek Thinkers*

THALES • 640-546 B. C. • Greek

Historical evidence seems to justify the statement that Thales of Miletus, another mathematician and philosopher, may be called the "father of electricity." He found that when the brownish-yellow stone we know as amber was rubbed, it took on a new property, attracting straw and hair. To Thales this was real magic. The Greek word for amber was "elektron" and from such an origin come the words electricity and electronics. Aside from this discovery of amber's "magic power," little was learned of the properties or the causes for magnetic attraction until 1600 A.D.

Perhaps the first person to use geometry for indirect measurement was Thales. While studying mathematics and physical sciences with the Egyptian priests, he impressed them by calculating the height of a pyramid. Thales selected a stick, drove it into the ground and determined its length. Next he measured the length of a shadow cast by this stick as well as the length of the pyramid's shadow. By use of these measurements and a familiar theorem of plane geometry he calculated the height of a pyramid.

Theorem: "If two right triangles are similar, the ratio of a pair of sides in one triangle is equal to the ratio of the pair of corresponding sides in the other triangle."

Thales added astronomy to his interests and predicted a date for the sun's total eclipse. On May 28, 585 B.C., two Grecian states were at war and when fighting was at its worst the sun disappeared. All involved knew of Thales' prediction and consequently they sought his counsel. He persuaded the leaders, on the strength of this prophecy, to stop the battle.

Today we are told the country that is superior in communications and

Radionics will be victorious. Let us not forget Thales, the first disciple of Radionics.

F. CAJORI..*History of Mathematics*
F. CAJORI..............................*Notes on the History of Geometry and Algebra*
D. FIEDEMANN................*Griechenlands erste Philosophen, oder Leben und Systeme des Orpheus, Pherecydes, Thales und Pythagoras* (THALES, p. 101; PYTHAGORAS, p. 187.)

ROGER BACON • 1214-1294 • English

Bacon stands out as one of the most distinguished, though misunderstood, scientists and philosophers of the Middle Ages. He entered the Franciscan Order at a rather early age, but understanding friends provided funds for books and materials to build apparatus, thus facilitating experimentation. Centuries ahead of the day in thought, he was suspected of black magic by contemporaries. Bacon's *Opus Majus,* published in 1267, is a scientific encyclopedia covering mathematics, physics, philosophy, and experimental research.

Optics was another subject that attracted Bacon. He described the construction, as well as the behavior, of convex and concave lenses, and mentioned their use to improve vision.

The calendar of that time contained many errors. Bacon proceeded to make the necessary corrections, and successfully completed the task in 1263. A copy of this work may still be seen in the library of University College, Oxford.

J. H. BRIDGES..................................*The Opus Majus of Roger Bacon*
A. G. LITTLE..*Roger Bacon*

LEONARDO DA VINCI • 1452-1519 • Italian

Leonardo Da Vinci devoted his life to research in almost every field of knowledge. Here in one man we find scientist, inventor, painter, astronomer, philosopher, sculptor, architect, geographer, musician—said to be, "perhaps the most richly gifted by nature among all the sons of men." The impact of Leonardo's inventive genius is felt in practically every branch of science and art. The following subjects are only a few out of a long impressive list given in his *Notebooks:* description of a machine-gun, armoured car, alarm clock, mechanical oilpress, boring machine, soldering stove for roofing, camera obscura, wind gauge, first magnetic needle on horizontal axis, spinning-machine, centrifugal pump for draining marshes, airplane, telescope tube, experiments with metal alloys, anatomical studies, botanical discoveries, and masterpieces in oil painting, such as *The Last Supper* and *Mona Lisa.*

The original manuscript, written by hand, *Notebooks of Leonardo Da Vinci,* numbered approximately 5,000 pages. A translation brings to life the record of a great mind that was blazing new trails of thought during the Renaissance.

E. MACCURDY................................*The Notebooks of Leonardo Da Vinci*
I. B. HART.......................*The Mechanical Investigations of Leonardo Da Vinci*
SIR K. CLARK........*Leonardo Da Vinci (An Account of His Development as an Artist)*
A. VALLENTIN..*Leonardo Da Vinci*
D. MEREJKOWSKI...................................*Romance of Leonardo Da Vinci*

WILLIAM GILBERT • 1540-1603 • English

The curtain of mysticism that had surrounded the attracting properties of amber and lodestone since the days of Thales was lifted by Gilbert. With his research, electricity and magnetism took their proper places in the world of science.

Gilbert received the appointment of Court Physician to Queen Elizabeth, as well as to James I who succeeded her. The Queen, appreciating genius, set aside a pension for him. This assured the leisure time he needed to carry on experimentation and to prepare manuscripts.

Gilbert's book *De Magnete* is a collection of all the information then available on magnetism, to which he appended the results of his own experimental investigations. This gave him sufficient evidence from which to conclude that the strength and distance of magnetic attraction from a lodestone or magnet of uniform size are proportional to its mass.

Engaged in extensive experiments using terrellas made of lodestone, Gilbert noticed that the magnetic needle changed position when it was moved around the sphere. Such variations are called the magnetic dip. A magnetic needle points to the magnetic poles of the earth, not to the geographic. The north magnetic pole is actually about 1300 miles from the geographic north pole, at 71° N. latitude, 96° W. longitude. The south magnetic pole is at 72-73° S. latitude, 156° E. longitude. From such findings of a bipolar distribution of magnetism came the important announcement that the earth may be considered as one enormous magnet. Gilbert's research is the second landmark along the road of magnetism. The first was made by Peregrinus in 1269 with a treatise on lodestone.

P. F. MOTTELAY............................*De Magnete by W. Gilbert* (TRANSLATION)
W. F. MAGIE..*A Source Book in Physics*
C. E. BENHAM...*William Gilbert of Colchester*

GALILEO GALILEI • 1564-1642 • Italian

Galileo is often regarded in the scientific world as the first of the moderns. His work incorporated methods still employed by investigators of physical science.

When only 19 years old he observed the regular motions of a lamp swinging from the ceiling of a cathedral in Pisa and applied the principle of its motion (isochronous pendulum) to the measurement of time.

Perhaps Galileo's cardinal and unique contribution was the founding of a new science called dynamics, which accounts experimentally and mathematically for the relation between the motions of bodies as well as the forces that act on them.

He constructed the first thermoscope, an instrument which may be considered a forerunner of the present thermometer. It was fundamentally much like a barometer, but was sensitive to changes of temperature.

Galileo's investigations in astronomy led to further analysis of the motions of both terrestrial and celestial objects. On January 7, 1610, looking through a telescope of his own construction, he made the first observation of Jupiter's satellites. By watching the regular movement from east to west of the sun spots he described the sun's rotation.

Galileo's method of attack was to determine what occurred, if possible, by direct investigation of nature's mysteries, augment this with experimentation, and then evolve an explanation for that which was observed.

H. B. LEMON...*From Galileo to Cosmic Rays*
H. CREW and A. DE SALVIO............*Dialogues Concerning Two New Sciences by Galileo* (TRANSLATION)
SIR D. BREWSTER..*The Martyrs of Science*
J. J. FAHIE..*Galileo: His Life and Work*
H. CREW...............“GALILEO: PIONEER IN PHYSICS,” *Scientific Monthly*, p. 440; 1943
G. MCCOLLEY.............*The Defense of Galileo of Thomas Campanella* (TRANSLATION)

CHRISTIAN HUYGENS • 1629-1695 • Dutch

Huygens began his career as an astronomer, building and designing telescopes. His treatise on light, *Traité de la Lumière,* published in 1690, gave the undulation theory of light, but due to the acceptance of the Newtonian theory it was neglected at that time. Later years have shown this work to be the foundation of modern geometrical optics.

His famous treatise, *Horologium Oscillatorium,* describes the control of clocks with a pendulum, and also contains a theoretical discussion on centrifugal force.

While studying wave motion he made many interesting observations that resulted in the Huygens' Principle. Simply stated, each point on an ever advancing wave front acts as a source from which secondary waves spread out into the surrounding medium. Using this principle, he explained the phenomena of reflection, refraction, double refraction, and polarization of light by double refraction. The discoverer of polarized light, he could offer no explanation for its behavior, because he believed that light vibrations were longitudinal instead of transverse. Scientists today recognize the value of "Huygens' Principle" when solving problems dealing with wave motion.

S. P. THOMPSON...............................*Treatise on Light* (TRANSLATION)
H. CREW..*Scientific Memoirs*, VOL. 10

SIR ISAAC NEWTON • 1642-1727 • English

"Nature and Nature's laws lay hid in night:
God said, 'Let Newton be!' and all was light."
Alexander Pope.

Proper evaluation of Newton's greatness has come with time, and tributes to him have been voluminous. Three hundred years have passed since Newton's birth, yet he lives on, having given to physics the idea of universal gravitation, as well as a theory of light and colors. Mathematics received from him the calculus, the method of infinite series, and the binomial theorem for negative and fractional exponents.

Newton might never have written *Philosophiae Naturalis Principia Mathematica (Mathematical Principles of Natural Philosophy)* had he not quarreled with Hooke on scientific matters, and later have been encouraged by Halley, who realized the *Principia's* significance. So broad and profound is this work that it has served as a starting point for subsequent developments in the study of moving bodies.

Another of Newton's favorite subjects was optics. To this branch of science, he gave a second masterpiece, *Optics*. The opening statement of the book in a way forecasts what followed: "My design in this book is not to explain the properties of light by hypotheses, but to prepare and prove them by reason and experiments." By using prisms he discovered and set up fundamental concepts of light.

Newton's estimate of himself was modest. He said, "I don't know what I may seem to the world, but as to myself, I seem to have been only as a boy playing on the seashore diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, while the great ocean of truth lay all undiscovered before me."

A. J. SNOW.........................*Matter and Gravity in Newton's Physical Philosophy*

S. BRODETSKY..........."NEWTON: SCIENTIST AND MAN," *Nature*, VOL. 150, DEC. 19, 1942

E. N. DAC. ANDRADE........."NEWTON AND THE SCIENCE OF HIS AGE," *Nature*, VOL. 150, DEC. 19, 1942

LORD RAYLEIGH........."NEWTON AS AN EXPERIMENTER," *Nature*, VOL. 150, DEC. 19, 1942

SIR J. JEANS......."NEWTON AND THE SCIENCE OF TODAY," *Nature*, VOL. 150, DEC. 19, 1942

SIR D. BREWSTER...*The Life of Sir Isaac Newton*

SIR D. BREWSTER......*Memoirs of the Life, Writings and Discoveries of Sir Isaac Newton*

R. DE VILLAMIL...*Newton: The Man*

W. STUKELEY...*Memoirs of Sir Isaac Newton's Life*

F. ALGAROTTI..*Newton's Theory of Light and Colors*

P. FROST...*Newton's Principia*

L. T. MORE...."NEWTON'S PHILOSOPHY OF NATURE," *Scientific Monthly*, p. 491, JUNE 1943

W. A. GRANVILLE, P. F. SMITH and W. R. LONGLEY.......*Elements of the Differential and Integral Calculus*

GOTTFRIED LEIBNIZ • 1646-1716 • German

Leibniz, courtier, diplomat, scholar, mathematician and philosopher, has been proclaimed one of the greatest system-builders in philosophical history. The invention of a calculating machine which would add, subtract, multiply, and divide brings further evidence of his versatility.

In a letter to Marquis de L'Hospital he presented the fundamental idea of determinants, which was a major contribution to algebra. This particular piece of work by Leibniz occurred some fifty years before G. Cramer gained fame by aiding the development of a determinant theory.

Leibniz shares honors with Newton as inventor of the calculus, a branch of mathematics which deals with change and rate of change of a quantity. Everywhere in nature there is what appears to be manifestation of continuous change. In science, for example, one is confronted with the rate of change of an electric current, or the rate of change in a chemical reaction. The calculus in its two forms, differential calculus and integral calculus, expresses these ideas of change by use of symbols that can be manipulated in a precise way. Leibniz consequently becomes another "Trail Blazer to Radionics," for without the calculus a large part of modern science would be lacking proper interpretation.

C. E. LOVE...*Differential and Integral Calculus*

A. N. WHITEHEAD.....................................*An Introduction to Mathematics*

M. I. LONGSDON...*A Mathematician Explains*

R. COURANT...*Differential and Integral Calculus*

B. RUSSELL...*The Philosophy of Leibniz*

D. E. SMITH..*A Source Book in Mathematics*

G. JAMES...*Mathematics Dictionary*

BENJAMIN FRANKLIN • 1706-1790 • American

Franklin, destined to become one of America's greatest men, started to work making candles in his father's shop at the age of ten.

About 1721, Franklin's older brother founded the second American newspaper, the *New England Courant*. Benjamin was employed as a member of the paper's staff and there gained his first knowledge of journalism.

From 1733 to 1758, Franklin edited and published *Poor Richard's Almanac*. This contribution to literature, and the fact that his signature appears on the Declaration of Independence, would in themselves place him among famous Americans.

How did Franklin become interested in electricity? Historians tell us that he saw a "Dr. Spence" do a number of electrical experiments that fascinated him. There has been much discussion as to who this "Dr. Spence" was. Recent information tells us that he was Dr. Adam Spencer and that Franklin first met him in Boston in 1743. After this meeting Franklin spent more and more time in scientific research.

The famous kite experiment by Franklin gave experimental proof for his belief that lightning was an electrical phenomenon. He watched his kite, after a successful take off, fly higher and higher until it disappeared into a cloud. The string fastened to the kite became wet and was a fairly good conductor. Attached to this wet line was a dry silk cord which Franklin held tightly in his hand. As he brought the knuckles of his hand near a key that was tied to the end of the wet string, a spark leaped from this key with the same snapping sound as the discharge from a static machine in the laboratory. Franklin then lowered the key into contact with a Leyden jar. Further examination showed that his thinking had been correct, because the jar was charged. Thus came about one of the greatest discoveries in scientific history.

Let us not forget that Franklin's observations, written to Alexander Small in 1760, establish him as the founder of a modern science called meteorology.

J. Bigelow.................... *The Complete Works of Benjamin Franklin* (10 Volumes)

I. Cohen.. *Benjamin Franklin's Experiments*

B. Franklin.............. *Poor Richard's Almanac* (Barse and Hopkins—New York)

C. Abbe................................. "Benjamin Franklin as a Meteorologist," *(Proceedings of American Philosophical Society,* Vol. XLV, p. 117)

L. B. Cohen .... "Benjamin Franklin and the Mysterious 'Dr. Spence' " *(Journal of the Franklin Institute,* Vol. 235, p. 1, Jan. 1943)

C. T. R. Wilson........ "Franklin's Experiments and Observations on Electricity," *Nature,* Vol. 151, p. 430; April 17, 1943

R. E. Spiller............................... "Benjamin Franklin: Student of Life" *(Journal of the Franklin Institute,* Vol. 233, p. 309; April 1942)

HENRY CAVENDISH • 1731-1810 • English

Cavendish, grandson of the second Duke of Devonshire, inherited a large fortune from an uncle. With financial security provided, chemistry became the major interest of this so-called laboratory hermit. He seldom took part in social activities, but devoted himself untiringly to scientific research.

An outstanding chemist in his day, he claimed the discovery of water's two chemical components and the characteristics of hydrogen as well.

Cavendish was first to make reasonably accurate measurements of the earth's weight. He obtained, by experiment, the numerical value of K, called the constant of gravitation, in the equation $F = K\frac{m_1 m_2}{d^2}$. Here m_1 and m_2 are the masses of two bodies, d is the distance between them, and F a measure of their mutual gravitational attraction. Since the usual method of measuring mass is by weighing, Cavendish may be said to have weighed the earth.

G. WILSON.......................... *Life and Works of the Honorable Henry Cavendish*
SIR T. E. THORPE................................... *Essays in Historical Chemistry*

CHARLES COULOMB • 1736-1806 • French

Coulomb served in Martinique, West Indies, with the French Engineering Corps. A serious illness resulted in his return to Paris where he spent the remainder of his life in scientific endeavors.

The French Academy awarded Coulomb a prize in 1779 upon receiving his *Théorie des Machines Simples,* which contained a law of torsion and the laws of friction. He also invented the torsion balance by which one can measure the attraction of electricity and magnetism.

Coulomb's fame as a great trail blazer is based upon his Fundamental Law of Electricity. It is stated thus: *The force between two bodies charged with electricity is in the inverse ratio of the square of the distance between the two, and directly proportional to the product of the charges.*

The unit of charge called the coulomb, in honor of this illustrious Frenchman, is the quantity of electrical charge carried by 6,280,000,000,000,000,000 (6.28×10^{18}) electrons.

W. F. MAGIE.. *A Source Book in Physics*
GAUTHIER-VILLARS.......... "MEMOIRS DE COULOMB" in *Memoirs Relatifs a La Physique,* TOME I—1884

ALESSANDRO VOLTA • 1745-1827 • Italian

Volta began electrical research where Luigi Galvani left off, by developing what is called a voltaic cell or "Volta's pile." This may be considered the primitive primary battery. It was built by stacking small discs of zinc and silver on top of each other alternately; then paper moistened with salt water was placed between the metals. Each pair of discs—zinc and silver—separated by the paper is called a cell. A series of these gave a rather large difference of potential. From this humble origin comes our modern battery. In 1801 he was summoned to Paris, where before the Institute of France he demonstrated a number of experiments. Napoleon honored Volta by conferring on him the titles of Count and Senator.

Included among his chemical contributions is the discovery of the organic nature of marsh gas. Another invention of Volta's which must not be overlooked is an electroscope with condenser attachment whose value as a laboratory tool is well known.

C. BROCKMAN................................ "PRIMARY CELLS: A HISTORICAL SKETCH" *The Journal of Chemical Education,* VOL. 4, p. 770; 1927
ALESSANDRO VOLTA.......................... *Collezion Dell' Opere* (TOME III—1816)

WILLIAM NICOL • 1768-1851 • Scotch

Nicol's position among "Trail Blazers to Radionics" is unique, because it was he who constructed the prism that provided a successful means of polarizing light.

Ordinary light waves are transverse waves. The vibrations constituting the transverse wave motion take place in all directions, in a plane perpendicular to the direction in which the light is traveling.

Nicol made a prism from Iceland spar shaped like a rhomboid, sliced diagonally into two sections. After the surfaces of the two parts had been polished, Canada balsam was used to cement them together. When a beam of light or incident ray passes through a crystal, it is divided into two beams called the ordinary and the extraordinary rays. Because the index of refraction of Canada balsam is larger than the index of refraction of Iceland spar, total reflection of the extraordinary ray cannot occur as it does with the ordinary ray. The extraordinary ray emerges from the rhomboid as a plane polarized beam of light, that is, the direction of the vibrations is in a single plane.

In modern usage, Nicol's prisms may be found in some television apparatus and other equipment using polarized light. His share in opening new frontiers is consequently recognized.

F. J. CHESHIRE..."THE POLARIZATION OF LIGHT,"
Journal of the Television Society, p. 201; DEC. 1932

ANDRE AMPERE • 1775-1836 • French

Ampère, after hearing about Oersted's experiments from colleagues, proceeded to make further investigations. His findings showed that a magnetic field surrounds a wire carrying electric current. Then came his electro-dynamic theory, published and presented in the treatise *Théorie des phénomènes électrodynamiques uniquement déduite de l'expérience*. Unfortunately, approbation did not follow immediately, because Ampère's explanations about these phenomena were highly mathematical, to a degree beyond the understanding of his contemporaries. However, succeeding years brought recognition, and in his honor the word "ampere" is used to designate the rate of current flow.

Ampère was unquestionably affected by the chaotic conditions prevalent in France during his lifetime. Actually he never quite recovered from the shock caused by his father's death upon the guillotine in 1793.

H. CHEUVREUX...*André Marie Ampère*
R. APPLEYARD..................................*Pioneers of Electrical Communication*

HANS OERSTED • 1777-1851 • Danish

Oersted received his degree as Doctor of Philosophy in 1799 from the University of Copenhagen.

On several occasions we have seen that an accident occurring in experimental procedures precipitates a discovery. Oersted's finding of the long sought connection between magnetism and electricity was one of those accidents.

One day while demonstrating and lecturing to his class, he observed that a magnetic needle was deflected whenever current flowed through a wire placed near the needle. To him, this magnetic needle was behaving very peculiarly, because it was not repelled or attracted but assumed a position perpendicular to the current-carrying wire. Here was a new phenomenon which seemed to violate an accepted principle; namely, that forces, between magnets or electrified objects, acted along lines connecting them. Oersted's experiment immediately showed the error in this theory. Recognition followed when the Royal Society of London gave him the Copley Medal, and the Institute of Paris awarded him a prize for his contribution to electricity.

W. F. MAGIE..*A Source Book in Physics*
H. WILLIAMS..............................."THE CENTURY'S PROGRESS IN PHYSICS" (*Harper's Magazine*, VOL. XIV, p. 254, 1894)
H. C. OERSTED..............................."CHEMICO—GALVANIC OBSERVATION" (*Philosophical Magazine*, VOL. 23, p. 129, 1805)
H. C. OERSTED........"NATURVIDENSKABELIGE SKRIFTER" (*Scientific Papers*, VOL. 3, 1820)
H. C. OERSTED....................*The Soul in Nature with Supplementary Contributions* (TRANSLATION BY J. B. HORNER and L. HORNER)

GEORGE OHM • 1787-1854 • German

Ohm was eager to obtain a university professorship. In those days, a position of this kind could be attained only by the presentation and acceptance of a scientific treatise. Ohm chose electricity as a subject with possibilities for such a work. Laboratory equipment, even wire, had to be made by the experimenter, but these handicaps did not daunt him. Ohm's father had been a locksmith who taught his son a trade which now proved to be a real asset. The technic of wire-drawing was not common knowledge, but Ohm mastered it, and began his studies by comparing the current conducting characteristics of wire in various sizes and materials.

Ohm made a discovery that resulted in formulating the famous law which bears his name. Ohm's Law is $E = IR$, $I = \frac{E}{R}$, or $R = \frac{E}{I}$, where $E =$ voltage, $I =$ current, and $R =$ resistance. The unit of resistance called the ohm is the resistance of a conductor that allows one ampere of current to flow at a potential difference of one volt.

George Ohm announced his findings and anxiously awaited the honors due him, but they were not forthcoming. Instead, the German Minister of Education criticized him, and Ohm was forced to resign his position as teacher in a secondary school. Finally his research became known in scientific circles outside of Germany. This acceptance from abroad ultimately brought recognition by authorities of his native country.

Just twenty-two years later, in 1849, he received the coveted professorship at the University of Munich. In 1854, after five happy years, Ohm died, the possessor of an honor that had been a motivating force to him.

W. F. MAGIE..*A Source Book in Physics*
G. S. OHM..........................*The Galvanic Circuit Investigated Mathematically* (TRANSLATED BY W. FRANCIS)

JOSEPH FRAUNHOFER • 1787-1826 • Bavarian

Fraunhofer, an optician by training, specialized in grinding lenses. He invented a machine for polishing parabolic surfaces, and was the first to polish lenses, as well as mirrors, without altering their curvature. He also was responsible for the first heliometer, the achromatic microscope, and the great refracting telescope at Dorpat.

While observing the spectrum of a candle flame he noticed a pair of very narrow isolated yellow lines. Next he investigated the sun's spectrum. Lo and behold, instead of a pair of yellow lines (emission line spectra) he found a large number of dark lines—some intense, some faint. Fired with an explorer's desire to chart the unknown, he turned his telescope, equipped with a prism and a device for measuring angles, toward the moon, planets, and stars. The dark lines (absorption line spectra) were still visible, but diversely placed. Physicists and astronomers now call such dark lines "Fraunhofer Lines." These lines are used to help determine the elements present in the celestial bodies. Helium was discovered by this method of sun spectrum analysis before it was found on earth.

Fraunhofer followed in the footsteps of Newton and Wollaston, pursuing further the investigations of light. By his keen observations and their proper interpretation he gave new insight to the problems of spectrum analysis.

A. W. Smith .... *The Elements of Physics*
J. S. Ames .... *Prismatic and Diffraction Spectra (Memoirs of J. Fraunhofer)*

MICHAEL FARADAY • 1791-1867 • English

Faraday's early life was humble indeed. His father, a blacksmith and book binder, had little with which to endow a son. As a young man, profound interest in science led him to apply for a post as an assistant at the Royal Institution under Sir Humphrey Davy. Fortune smiled, and the year 1813 found him working with Davy.

Faraday's discoveries of the laws of electrolysis and induction form a notable part in the underlying structure of modern electro-chemistry, atomic science, and radionics. Induction is the property of an electric circuit, or two neighboring circuits, which determines the electromotive force induced in one of the circuits by a change of current and magnetic field in either. Without a knowledge of induction the science of radionics could never have been born, and we would not have even the dynamo, without which our present civilization could not be.

While studying light, he showed that its plane of polarization can be rotated by a magnetic field. From this came his conclusion that light had both electric and magnetic properties. Faraday was also aware of electromagnetic radiation nearly half a century before Hertz; therefore, to some degree, he may be considered a precursor of radio. In honor of Faraday, the unit of capacity in electrical and radio engineering is called the farad.

Faraday could have amassed a fortune by commercial exploitation of his numerous discoveries, but he consistently and resolutely waived all patents. To genius there are things of inestimably greater value than money.

F. Ferndall .... *Faraday as a Discoverer*
Michael Faraday .... *Faraday's Diary*
Michael Faraday .... *Experimental Research in Electricity*
J. Gladstone .... *Michael Faraday*
S. P. Thompson .... *Michael Faraday, His Life and Works*
B. Jones .... *Life and Letters of Faraday*

JOSEPH HENRY • 1797-1878 • American

Henry was the first American after Benjamin Franklin to make a major contribution to electrical science. He focused his attention on electromagnetism, and in 1831 demonstrated a practical telegraph to students at Princeton University. Morse, who receives the honors for this invention, did not apply for a patent until 1837. He obtained information and help from Henry, and incorporated some of these suggestions in the first Morse telegraph apparatus.

Henry was actually first to observe the phenomena of mutual inductance, but he did not formally go on record, and lost priority to Faraday, then experimenting independently in England.

However, prompt publication gave him an incontestable first in the discovery of self inductance, the property of an electric circuit which determines for a given rate of change of current in the circuit the electromotive force induced in the same circuit.

Henry was appointed first secretary of the Smithsonian Institution in 1846, and thereafter did everything within his power to develop it as a source of scientific knowledge.

W. TAYLOR............ *Scientific Work of Joseph Henry*

W. F. MAGIE............ "JOSEPH HENRY, PIONEER IN SPACE COMMUNICATION," *Proceedings of the I.R.E.*, VOL. 30, p. 261, JUNE 1942

W. F. SNYDER....... "ACOUSTICAL INVESTIGATIONS OF JOSEPH HENRY AS VIEWED IN 1940," *Journal of Acoustical Society of America*, p. 58, JULY 1940
Smithsonian Scientific Series (12 VOLUMES)

H. S. OSBORNE............ "JOSEPH HENRY, PIONEER IN ELECTRICAL SCIENCE," *Electrical Engineering*, VOL. 61, p. 550, NOV. 1942

JAMES JOULE • 1818-1889 • English

Joule was the son of a wealthy Manchester brewer. At an early age he began studying electric motors and wrote numerous papers on this subject.

He sent a report to the Royal Society on December 17, 1840, that contained the experimental evidence from which was evolved his law that heat produced by the passage of an electric current through a conductor is directly proportional to the current squared times the resistance.

Joule's collaboration with Lord Kelvin (William Thomson) was fortunate, and their work stimulated rapid advances in the science of thermodynamics.

Joule devoted much of his life and experimentation to the measurement of the mechanical equivalent of heat. Further examination of his memoirs brings convincing proof that he belongs among the formulators of the well-known Principle of Conservation of Energy.

J. G. CROWTHER............ *Men of Science*

A. WOOD............ *Joule and the Study of Energy*

J. JOULE............ *Scientific Papers* (PUBLISHED BY THE PHYSICAL SOCIETY OF LONDON, VOL. 1 and VOL. 2)

HERMANN VON HELMHOLTZ • 1821-1894 • German

Helmholtz attended medical school, and later entered the Prussian army as a surgeon. Delving into the subject of physiological optics, his brilliant thinking and experiments ended in the writing of a classic *Handbuch der Physiologischen Optik*. This treatise contains basic knowledge on color vision and sight sensation.

Helmholtz became interested in the Principle of the Conservation of Energy. After thorough investigation, he set up convincing and valid arguments in support of this principle.

Helmholtz applied his searching mind to acoustics and then wrote another masterpiece *Tonempfindungen* or *Sensations of Tone*. The Law of Acoustics (law of tone quality) was first stated by Ohm in 1843. About thirty years later Helmholtz added a missing link, which may be simply expressed as follows: the quality of any musical tone depends entirely on the relative strength and number of the partial simple tones, and not upon their phase differences.

Few men have possessed greater appreciation for the true value of music than Helmholtz. His comments on music as an art are inspiring to musician and scientist alike.

H. von Helmholtz.........*Handbuch der Physiologischen Optik—Physiological Optics* (Translation by J. P. C. Southall)
H. von Helmholtz...........................*Tonempfindungen—Sensations of Tone* (Translation by A. J. Ellis)
C. Ladd-Franklin..*Color and Color Theories*
E. H. Barton...*Text Book of Sound*
D. C. Miller...*Science of Musical Sounds*
L. Koenigsberger..*Hermann von Helmholtz*
H. von Helmholtz.......*Beschreibung eines Augenspiegels* (Translation by Shastid)

WILLIAM THOMSON (Lord Kelvin) • 1824-1907 • Irish

William Thomson graduated from Cambridge University in 1845. A year later he accepted a professorship at University of Glasgow. He was knighted in 1866 and received the title "Lord Kelvin of Largs" during 1892.

At the age of twenty-three he wrote a mathematical treatise that gave Maxwell information from which to evolve his electromagnetic Theory of Light. Lord Kelvin is also recognized as one of the originators of the Theory of Thermodynamics, which may be traced to his exchange of ideas and friendship with Joule.

Lord Kelvin spent his life as a citizen of Glasgow and made a large fortune in industry there. He showed how physics might be practically applied to communications and transportation. This is illustrated by the fact that he was consulting engineer for the company which laid the first successful Atlantic telegraph cable. Through the influence of Lord Kelvin some British universities made changes in their science courses to meet the needs of industry.

He also capitalized on studies in navigation, and invented a sounding device which could be used to make measurements from aboard ship while underway. Another invention of his, important as laboratory equipment, is the mirror galvanometer.

One major reason for Lord Kelvin's lasting fame is the dualism of his contributions as a scientist and industrialist.

A. Gray......................*Lord Kelvin, An Account of His Scientific Life and Work*
A. King...*Kelvin, The Man*
S. P. Thompson.....................................*The Life of William Thomson*

GUSTAV KIRCHHOFF • 1824-1887 • German

Kirchhoff carried on extensive experiments in analysis of both light and electricity. Together with R. W. Bunsen he studied the spectra of flames into which were introduced vaporized substances. They observed that such spectra, instead of being a continuous band of colors ranging from red to violet, were made up of individual lines scattered throughout the entire spectral band. Each line was the same color as that part of the spectrum in which it was found. These lines are called "emission line spectra" to distinguish them from the Wollaston-Fraunhofer "absorption line spectra." Since each chemical element possesses its own individual spectrum, Kirchhoff had found, by using these line spectra, a technic for analyzing unknown chemical substances.

Should we look for the antecedent of the Quantum Theory of Radiation (Planck) 1899, it would be found in Kirchhoff's Law of Black Body Radiation. A "black body" is defined as that body the surface of which will absorb all incident radiation upon it. Kirchhoff showed that this body is a good source of uniform radiant energy. No such body actually exists, but a surface covered with lampblack does approach the required condition. For experimental work a cavity of unique design with a lampblack interior and a hole in one side is often used. Radiant energy is emitted from every point on the surface of the inside wall of the cavity. These radiations will strike other points on the inner surface where part of the radiant energy will be absorbed and part again reflected. This process will continue, resulting in the presence of radiations of uniform density as well as of all wave lengths. Should the temperature of the wall be raised, there will be an increase in the amount of radiation per cubic centimeter. Radiation passing out of the hole in the wall of the cavity can be examined with a spectroscope and its nature determined. Physicists are thus able to determine the emissive power of a "black body" experimentally by measuring the surface brightness of a small opening in the side of a uniformly heated cavity.

Another reason for Kirchhoff's place as a "Trail Blazer to Radionics" are the laws that bear his name. Kirchhoff's Laws are important in solving complicated problems dealt with in electric circuits, and are stated thus: (1) the sum of the currents flowing into any junction of an electric circuit is equal to the sum of the currents flowing out of that junction; (2) with due regard to polarities, the sum of the products of the current, times the resistance made around a closed circuit, is just equal to the sum of the electromotive forces which one finds in following the closed circuit.

Physicists and radio engineers in their all out effort to help win the war are continually reminded of this distinguished scientist and his work.

J. BRAINERD, G. KOEHLER, J. REICH, and I. WOODRUFF... *Ultra High Frequency Techniques*

L. WARE and H. REED.... *Communication Circuits*

PHYSICS STAFF, UNIVERSITY OF PITTSBURGH.... *An Outline of Atomic Physics*

M. I. T. STAFF.... *Applied Electronics*

H. B. LEMON and M. FERENCE, JR.... *Analytical Experimental Physics*

R. VON HELMHOLTZ, "A MEMOIR OF GUSTAV ROBERT KIRCHHOFF" (TRANSLATION BY J. DE PEROTT), *Annual Report of the Smithsonian Institution for 1889;* p. 527.

A. W. LOWAN and G. BLANCH, "TABLES OF PLANCK'S RADIATION AND PHOTON FUNCTIONS," *Journal Optical Society of America,* VOL. 30, p. 70; FEB. 1940.

H. DJOUDAT, "ESTABLISHMENT OF SCALE OF COLOR TEMPERATURE," *Revue d' Optique Theorique et Instrumentale,* VOL. 16, p. 401; DEC. 1937.

MICHAEL PUPIN • 1858-1935 • Serbian

Pupin came to the United States as a penniless and ambitious young immigrant. With his death the world lost one of its most brilliant and amiable scientists.

When a youth attending school in Panchevo, he heard of Benjamin Franklin and the kite experiment. Stories told him about Lincoln made this other great American his hero also.

At an early age, sound and light became to him divine means of communication. Throughout his life he sought to interpret and apply the two in a manner that would aid his fellow men.

Hard work in the land of opportunity was rewarded by recognition and a degree from Columbia. Still striving to find out more about the phenomenon of light, he went to Cambridge. Since he wished to study with Helmholtz, England to Germany was the next rung on the ladder of progress. By this time nothing was more important to the young scientist than electromagnetic theory. Faraday, Maxwell, and Helmholtz had become his gods.

Pupin was present at the Physical Society meeting in Berlin on that memorable day in 1887 when Helmholtz announced the discovery of electromagnetic waves by his illustrious pupil, Heinrich Hertz.

Returning to Columbia, he took over the newly founded Department of Electrical Engineering. Pupin brought with him a message from the scientific giants in Europe. Today, we find two of his students, Major E. H. Armstrong and Robert Millikan, great contributors to an ever expanding world of science.

Pupin invented what he called an electrical resonator for the selective detection of alternating currents at a definite frequency.

No one appreciates more than the American Telephone and Telegraph Company the advance made and money saved by the Pupin Coil, as well as the technic developed for its use.

Immortality has many interpretations, but there is perhaps no more concrete example of it than when a scientist like Pupin lives on in the works of those who received and applied his teachings.

M. Pupin...*From Emigrant to Inventor*
M. Pupin...*Romance of the Machine*

JAMES CLERK MAXWELL • 1831-1879 • Scotch

Maxwell is often proclaimed throughout the world as the nineteenth century's greatest theoretical physicist. As a young boy his inquiring mind exhibited itself by the persistent question, "What's the go o' that?" A magnificent memory was another of his blessings, and at the age of eight he was able to recite long passages from the Bible. The fact that Maxwell was deeply religious throughout his life is possibly one reason he did not fall into the erroneous philosophical thinking prevalent in his day.

Maxwell's father, well aware of his son's intellectual capacity, personally directed his education and took him, as a lad of fifteen, to meetings at the Royal Society of Edinburgh.

About this time the boy became interested in light, particularly its polarization and the Newton rings. An understanding uncle gave young Maxwell the opportunity of meeting Nicol, whose fame for research on polarized light is well known. With such inspiration, Maxwell began a long chain of experiments which ultimately placed him with Newton, Young, and Helmholtz in the development of a theory of color vision.

One of his most outstanding papers dealing with electrical subjects was *On Faraday's Lines of Force;* another was *A Treatise on Electricity and Magnetism.* Modern physicists also applaud him for *Illustrations of the Dynamical Theory of Gases.*

The impact of Maxwell's thinking on 20th century physics is obvious when we realize that his Theory of Electricity and Magnetism was the forerunner of the Relative Theory; and his Dynamical Theory of Gases, a direct contribution to the Quantum Theory.

Last but not least, let us not forget that he is helping indirectly to win the present world conflict. He has the gratitude of engineers designing and studying ultra high frequency radio equipment, vital to victory, because they realize the value of Maxwell's equations.

J. Brainerd, G. Koehler, J. Reich, and I. Woodruff... *Ultra High Frequency Techniques*
H. Skilling.......... *Fundamentals of Electric Waves*
J. Slater.......... *Microwave Transmission*
J. Crowther.......... *Men of Science*
R. Glazebrook.......... *James Clerk Maxwell and Modern Physics*
L. Campbell and W. Garnett.......... *Life of James Clerk Maxwell*
W. Niven.......... *The Scientific Papers of James Clerk Maxwell*

THOMAS A. EDISON • 1847-1931 • American

Edison, the "Wizard of Menlo Park," not only brought incandescent lamps to man, but illuminated many other dark paths in the scientific wilderness he explored.

Edison began his brilliant career as a telegraph operator and at twenty-one invented the first double telegraph transmitter. By the time his sensationally productive life came to an end, the patent office listed some 1,300 patents under his name. The most important of these disclosures dealt with electric lights, telephone receivers, certain motion-picture equipment, phonographs, microphones, and storage batteries.

Edison is heralded as the father of the vacuum tube, the heart of all radionic equipment. While experimenting with the first electric light, Edison noticed a black deposit inside the bulb which, curiously enough, was not continuous. There appeared on it a marking that resembled the shadow from one of the filament's legs. He observed that the leg which cast the shadow was connected to the positive side of the electrical circuit. Then, reasoning that the negative leg of the filament was emitting minute carbon granules, he put plates between the two legs and ran wires from them. Connecting a galvanometer to the positive leg, he found a current flow that did not appear when the galvanometer was attached to the negative side. This was the Edison Effect, but he failed to recognize its further applications and possibilities. It remained for J. A. Fleming to utilize the phenomenon in radio's first vacuum tube.

M. Childs.......... *Edison, Modern Olympian*
F. Wheeler.......... *Thomas Alva Edison*
W. Simonds.......... *Edison*
F. Miller.......... *Thomas A. Edison*
F. Dyer and T. Martin.......... *Edison, His Life and Inventions*
G. Bryan.......... *Edison, The Man and His Work*

WILHELM RÖNTGEN • 1845-1923 • German

Röntgen's name appeared in the headlines of newspapers throughout the world on January 5, 1896. The discoverer of the X-ray had just announced his great find. He claimed that these mysterious rays would pass through opaque substances.

Röntgen had been investigating cathode rays with a Crookes' tube. The presence of cathode rays was exhibited by fluorescence, but to be aware of even the slightest flow he had darkened the room in which he was experimenting, and placed a piece of black cardboard over the Crookes' tube. All at once things started to happen. Whenever a discharge took place through the tube, a near-by screen coated with barium platinocyanide became fluorescent. One experiment followed another; then emerged the forerunner of present day X-ray technic, when a "shadow picture" of bones in the hand became a reality. Thus Röntgen opened up for further exploration a new section of the electromagnetic spectrum beyond visible light. The many applications of X-rays to medical and industrial laboratory problems have made them one of man's greatest benefactors.

O. GLASSER........................*W. C. Röntgen and the Early History of Röntgen Rays*

G. F. BARKER...*Röntgen Rays*

H. P. ROOKSBY, "APPLICATIONS OF X-RAY TECHNIQUE TO INDUSTRIAL LABORATORY PROBLEMS," *Journal of Royal Society of Arts*, FEB. 16, 1940.

ALBERT MICHELSON • 1852-1931 • American

Michelson came to this country from his native Germany, and in 1873 graduated from the United States Naval Academy. He taught at the Naval Academy for four years, then accepted a professorship at Case School of Applied Science. From here he went to the physics department at Clarke University. The year 1892 brought an offer to become Professor of Physics at the University of Chicago, which he accepted and held until his death.

Michelson built an ingenious piece of equipment with which to demonstrate and measure the speed of light (about 186,000 miles per second) in the laboratory. His investigations on the speed of light and interference phenomena were recognized when he became the first American physicist to receive the Nobel Prize.

Michelson, collaborating with his friend E. Morley, set out to discover, if possible, the relative motion of the earth and that mysterious something called the ether, the presence of which seemed a necessity to the transmission of wave motions. In order to test for this effect Michelson invented the interferometer. The results of their experiments were negative; however, the efforts were not wasted; years later they became the starting point for Einstein's Theory of Relativity.

A. A. MICHELSON..*Light Waves and Their Uses*

J. LOVERING..............................*A. A. Michelson's Recent Researches on Light*

F. R. MOULTON, "A. A. MICHELSON" *(Popular Astronomy*, VOL. 39, p. 307, JUNE AND JULY 1931)

A. A. MICHELSON..*Studies in Optics*

A. A. MICHELSON, "THE ECHELON SPECTROSCOPE" *(Proceedings of the American Academy of Arts and Sciences*, VOL. 35, p. 109; 1899)

HENRI BECQUEREL • 1852-1908 • French

Becquerel attended École Polytechnique, and in 1895 accepted a professorship there. Soon after Röntgen's discovery of the X-ray, Becquerel set out in search of a possible connection between X-rays and phosphorescence. A substance which retains its luminescence after the exciting source (radiant energy) has been removed is said to be phosphorescent. Becquerel thought perhaps such materials might also give off X-rays. He went about analyzing various ores by placing them on photographic plates to see if they emitted radiation. Fortunately a bit of uranium salt was included in the experiments. Upon developing and examining the plate that was used to test uranium he found a silhouette produced by radiations from the crystal. Substances having such characteristics are now called radioactive.

News of this kind spreads fast in scientific circles, and other investigators became interested. It was from Becquerel's work that Marie and Pierre Curie found the clue which resulted in their isolating a new element, radium.

H. BECQUEREL, "ON THE RADIOACTIVITY OF MATTER" *(Annual Report of the Smithsonian Institution*, p. 197; 1902)

W. F. MAGIE...*A Source Book in Physics*

PHYSICS STAFF, UNIVERSITY OF PITTSBURGH................*An Outline of Atomic Physics*

SIR JOSEPH J. THOMSON • 1856-1940 • English

Thomson has a position all his own in the development of modern physics. Awards were conferred upon him by the Royal Society of London and Smithsonian Institution, and in 1906 he received the Nobel Prize in physics. England honored a favorite son with knighthood, and conferred upon him the Order of Merit.

The sesquicentennial celebration at Princeton in 1896 was an occasion for Thomson to visit the United States. While at the university he gave a series of lectures on the "Discharge of Electricity Through Gases."

Returning to England, he became Professor of Physics in the Royal Institution. Some of his brilliant, epochal papers are: *Application of Dynamics to Physics and Chemistry, Electricity and Matter, Thermochemistry,* and *Corpuscular Theory of Matter.*

Thomson will be remembered as one of the greatest contributors to the modern Ionic Theory of Electricity and The Electrical Theory of Inertia of Matter.

J. J. THOMSON...*Recollections and Reflections*

J. J. THOMSON.............*Corpuscular Theory of Matter* (C. SCRIBNER AND SONS, 1907)

F. W. ASTON...*Mass Spectra and Isotopes*

HEINRICH HERTZ • 1857-1894 • German

Hertz' sensational career was ended at the age of thirty-seven when he died of blood poisoning. His interest and progress in science was rapid, and he succeeded in verifying experimentally the theoretical predictions of Maxwell concerning electromagnetic waves.

The following experiment performed by Hertz proved that electromagnetic radiations pass through space between transmitting and receiving apparatus: As "transmitter" he used the secondary of an induction coil with a spark gap between the two terminals. Whenever a spark occurred, an oscillatory discharge was radiated into the surrounding space, producing electromagnetic waves. The "receiving" equipment consisted of a rectangular metal conductor with two wires leading from it, leaving a spark gap between them. Across these wires he placed a bar and carefully moved it along the line. Suddenly a spark jumped across the gap, showing that the second circuit was tuned to resonate with the first, and was picking up the electromagnetic radiations.

Hertz found that a sheet of metal reflected these waves and by employing the light from a spark gap in the resonator he located the maximum and minimum (loops and nodes) of the waves. In this manner he determined the wavelength of these radiations. Thus Hertzian, or radio waves, first generated in the ultra short wave region, became known to the world. From his day on radio waves began to serve us daily in many ways.

D. E. JONES................*Electric Waves;* and *Preface to Collected Papers of H. Hertz*

CHARLES STEINMETZ • 1865-1923 • German

Steinmetz was cursed with an hereditary deformity, but magnificent intellectual powers overshadowed any physical disadvantages he possessed. Steinmetz' father, a railroad lithographer, and himself a cripple, well understood the trials that would be his son's. At every turn he encouraged the boy's mathematical and scientific yearnings.

Young Steinmetz' scholastic record was one of obvious superiority. Finally, after getting into difficulties over political issues in Germany, he set out for the United States. Another youthful immigrant boy was called to the "Land of Opportunity."

Steinmetz first worked for R. Eichemeyer, manufacturer of hat machinery and electrical devices. Later, when General Electric bought the Eichemeyer factory, they insisted that Steinmetz be included in the transaction. An appointment as consulting engineer followed and the mathematical engineering wizard soon became the "Supreme Judge" at General Electric.

Steinmetz was not an inventor. He, like Einstein, Newton and Leibniz, through abstract reasoning established formulas and broad principles that could be put to practical use as needed by engineers. At the age of twenty-eight, he won his place among great mathematicians with the Law of Hysteresis.

Steinmetz on Alternating Current is another classic in electricity. Complex, but complete, the treatise deals with almost every conceivable problem in this particular branch of electricity, and answers many perplexing questions. Electrical engineering would not be where it is today but for Steinmetz, his paper, his pencil, and his cigar.

C. P. STEINMETZ...*Relativity and Space*
C. P. STEINMETZ............................*General Lectures on Electrical Engineering*
J. BRODERICK...*Steinmetz and His Discoverer*
J. HAYDEN.................*Lectures on Radiation, Light and Illumination by Steinmetz*
J. HAMMOND..*Charles Proteus Steinmetz*
J. LEONARD..*Loki, The Life of Steinmetz*

MARIE SKLODOVSKA CURIE • 1867-1934 • Polish

Madam Curie, daughter of a Polish professor, lived to see the day when she would be twice a Nobel Prize winner and acclaimed the world's greatest woman scientist. Fame was never her goal, for what she cherished most was scientific research, test tubes, and the laboratory. Marie Curie gave herself and her work to aid mankind.

The Curies read about Becquerel's discovery of radioactivity in 1896 and instantly realized the necessity for further investigation. Pierre Curie stopped his research in piezoelectricity to help Marie. After arduous hours of endless experimentation, their first success was announced in July, 1898. They had found, by an analysis of pitchblende, a new metal some 400 times more active than uranium. Madam Curie named the new metal Polonium in honor of her native Poland.

Then in December, 1898, came the major discovery, when the Curies made their far-reaching report that they had unearthed another new element called Radium. Medical investigations soon showed that radium was a new weapon that could be used to battle certain dreaded diseases. Consequently, more frontiers in physics and medicine were opened.

Marie knew the meaning of poverty and sorrow, first felt in her youth. For a time after her marriage to Pierre Curie, famous French physicist, happiness prevailed as they worked together. Then, one day Pierre was killed in a street accident. Left with two young children to care for, Madam Curie carried on gloriously, to the end of her life, the research in radioactivity whose inception she and Pierre had seen together.

M. Curie, "Modern Theories of Electricity and Matter," *Smithsonian Institution Annual Report*, p. 103; 1906.
M. Curie, "Radio-Active Substances," *Chemical News*, Aug. 2, 1903 to Dec. 1903, pp. 85, 97, 134, 145, 159, 169, 175, 187, 199, 211, 233, 235, 247, 259, 271.
Eve Curie..*Madam Curie*

ROBERT A. MILLIKAN • 1868– American

Millikan's brilliant career as a physicist began when his Professor of Greek at Oberlin requested that he teach a class in physics. He thought his previous training was inadequate, so he spent the following summer preparing. The next fall he accepted the position. He later studied with Pupin and Nernst. Then he took his place on the physics staff at the University of Chicago and from there went to California Institute of Technology.

By means of his famous "oil-drop" experiment, Millikan was successful in determining the charge on a single electron. The quantity of electricity carried by the electron is given as approximately 1.602×10^{-19} coulomb.

The effects of Millikan's oil-drop experiment are so far reaching that a description of his apparatus and technic is of great interest. By means of an atomizer, an oil fog was blown into a chamber containing two plates oppositely charged by a battery. The oil fog particles drifted slowly downward, and a few found their way into the space between the plates. These droplets were strongly illuminated by an arc lamp and could then be seen through a low-powered microscope, on which there was a scale to determine the elevation of the oil-drop. When one horizontal plate was made positive with respect to the other it was noted that some of the droplets fell faster than others. This indicated that some of the oil drops were positively charged, others made negative. Now a careful adjustment of the potential on the upper plate was made, and a droplet remained practically motionless in the space (electric field) between the two charged plates.

Stokes' law was used to find the mass of the droplet. This law describes the motion of a sphere through a homogenous medium. The size of the droplets is small compared to the distance between molecules; this caused an error in calculation. Millikan introduced a corrective factor to gain further accuracy. When a strong electric field was applied, the oil drop was lifted. Then the field was removed. The length of time that the droplet took to fall through a known distance was determined. With the radius and velocity of the oil droplet known, the mass, as well as the charge carried, could be calculated, giving the elementary electrical charge "e" of an electron. Any charge carried would always be an integral multiple of 1.602×10^{-19} coulomb.

Also famous for his cosmic ray research, Millikan continues the tireless quest for evidence that will solve one of nature's greatest mysteries.

R. A. MILLIKAN.................*Electrons, Protons, Photons, Neutrons and Cosmic Rays*
K. K. DARROW...*Contemporary Physics*
R. A. MILLIKAN...*Cosmic Rays*
R. A. MILLIKAN.............................*Science and the New Civilization*
J. B. HOAG...*Electron and Nuclear Physics*
R. A. MILLIKAN, "HIGH FREQUENCY RAYS OF COSMIC ORIGIN," *Annual Report Smithsonian Institution*, p. 193; 1926.
R. A. MILLIKAN, "EXTENDED COSMIC-RAY IONISATION DEPTH CURVE AND EVIDENCE FOR ATOM BUILDING," *Physics Review*, VOL. 37, p. 235; FEB. 1931.
R. A. MILLIKAN, "ENERGY DISTRIBUTION OF INCOMING COSMIC-RAY PARTICLES," *Proceedings of the American Philosophical Society*, VOL. 83, p. 409; 1940.
R. A. MILLIKAN, H. V. NEHER and W. H. PICKERING, "ORIGIN OF COSMIC RAYS," *Nature*, JUNE 12, 1943, p. 663.

CHESTER H. THORDARSON • 1868– Icelandic

Thordarson, world famous inventor and manufacturer of transformers, began his questioning of natural phenomena when a very small boy.

It was early spring in Iceland, young Thordarson and his sister were driving home a flock of sheep, when suddenly streamers of light floated across the sky. The two youngsters watched the aurora borealis. Then the questioning mind of the young lad took possession, as he asked, "What makes them?" "Why do they dance like that?"

A few years later the family came to Wisconsin. When eighteen, he went to Chicago to attend public school and at twenty started to work. Electricity fascinated him, and he read whatever he could get his hands on that dealt with the subject. His first position was with a company manufacturing arc lamps, dynamos, and other electrical equipment. Just seven years later Thordarson started a business of his own making electrical apparatus.

One group of customers whose needs he solicited was the leading universities in the country. In 1904, he built for Purdue University the first million volt 25 cycle transformer. It was displayed at the St. Louis World's Fair and later used for experimental work at the University. Eleven years later he constructed another million volt transformer to be displayed at the Panama-Pacific International Exposition.

Thordarson has to his credit patents on long distance radio transmitting apparatus, ignition coils for automobiles, and transformer constructions. Here is another pioneer whose questioning of Nature has brought answers that place him among the greatest living "Trail Blazers to Radionics."

Technical information may be obtained from the Engineering Department of Thordarson Transformer Co., Chicago, Illinois.

LEE DE FOREST • 1873– American

De Forest's genius has been challenged many times, but viewed in proper perspective, his unique position in the radio world is recognized.

De Forest was among America's pioneers in wireless telegraphy, radio telephony, talking movies, and the development of vacuum tubes.

In 1906, he introduced the grid as a third element placed between the filament and plate of a vacuum tube. This provided the missing link for controlling electron flow in a tube. De Forest called his first radio tube the "Audion." From then on radio progressed by leaps and bounds.

De Forest's latest brain child is a new radionic terrain altimeter, with which pilots can tell how high they are flying above the ground. He, like other American inventors, is now concentrating all personal efforts to help win the war.

G. CARNEAL............................*Conqueror of Space* (AUTHORITATIVE BIOGRAPHY OF THE LIFE AND WORK OF LEE DE FOREST).

M. I. T. STAFF..*Applied Electronics*

L. DE FOREST, "AN AUDION, A NEW RECEIVER FOR WIRELESS TELEGRAPHY," *American Institute of Electrical Engineers Proceedings*, VOL. 25, p. 719; OCT. 1906.

L. DE FOREST, "AUDION AS AMPLIFIER AND DETECTOR," *Proceedings of the I.R.E.*, VOL. 2, p. 15; JAN. 1914.

GUGLIELMO MARCONI • 1874-1937 • Italian

Marconi, endowed with imagination, persistency, refinement of character, and initiative, achieved fame as the "Father of Wireless Communication."

He was the son of a wealthy Italian family who took full advantage of all that environment had to offer. From his mother Marconi received inspiration that greatly influenced his entire life.

In the summer of 1894, Marconi, then only twenty years old, happened to read of the work Hertz had done with electromagnetic waves. From this the young Italian got the idea of using these waves for communication. He reasoned that if such electromagnetic radiations could be intensified and controlled they might be used for transmitting messages through space.

On December 12, 1901, Marconi's dream came true, when he received the first transatlantic signal, the letter "S" sent in code from Poldhu to Cabot Tower, St. John's, Newfoundland.

One triumph followed another as he pushed on, always advancing to a position from which new horizons were visible. When he passed away in 1937 the world mourned the loss of another fearless "Trail Blazer of Radionics."

O. E. DUNLAP....................................*Marconi: The Man and His Wireless*

W. K. TOWERS..*Masters of Space*

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ALBERT EINSTEIN • 1879– German

Einstein's boyhood days were spent in Munich where his father carried on a business in electrical goods. Science won him at an early age; when only about fourteen he was studying the calculus and analytical geometry. Financial reverses resulted in the family moving to Milan. Einstein then went to Switzerland where he studied at Zurich Technical Academy, and later took his Ph.D. degree from the University of Zurich. Then followed a number of appointments as professor of physics in other universities abroad. Later he came to America and is now at the Institute for Advanced Study, Princeton, New Jersey.

Einstein becomes a "Trail Blazer to Radionics" through his research in photoelectricity and the development of the Photoelectric Equation. His ideas on the subject were to some degree radical, but fundamental.

When this illustrious scientist is thought of, it is generally in connection with his Theory of Relativity. At present he is following this up with a search for a Unified Field Theory to bridge the gap between relativity and quantum mechanics. Should he be successful, human knowledge will feel the results of another advance into the great unknown.

H. G. GARBEDIAN.................................*Albert Einstein, Maker of Universes*

A. EINSTEIN...*The Meaning of Relativity*

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A. EINSTEIN and L. INFELD.................................*The Evolution of Physics*

H. REICHENBACH..*Copernicus to Einstein*

P. G. BERGMANN.........................*An Introduction to the Theory of Relativity*

VLADIMIR K. ZWORYKIN • 1889– Russian

Zworykin's research in electron optics places him among the leaders in this new branch of science which seems at the present to have unlimited possibilities.

He graduated from Petrograd Institute of Technology with a degree in Electrical Engineering. While studying physics under Professor Boris Rosing, he began the first television experiments. A number of years later these resulted in his development of the Iconoscope or "electronic eye" of the television camera, and the Kinescope or "picture tube" that makes possible the change of electrical impulses into an image at the television receiver.

In 1912 Dr. Zworykin did X-ray research at the College of France in Paris, and during World War I served as an officer in the radio corps of the Russian Army. He received his Ph.D. from University of Pittsburgh in 1926, and D.Sc. from Brooklyn Polytechnic Institute in 1938.

Dr. Zworykin added another thrilling page to the history of science when he applied his knowledge of electron optics to the problem of microscope construction. Light microscopes are limited to magnifications of about 2,000, but the new electron microscope will magnify as high as 100,000 times. The Leeuwenhoeks and Pasteurs of the future, working with electron microscopes, will bring to man visual knowledge of the fundamentals of matter and of life itself.

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R. W. HUBBELL..*4000 Years of Television*

EDWIN H. ARMSTRONG • 1890– American

Perhaps no other living man has done more, as an individual, toward the advancement of radio than Armstrong.

At Columbia University, as pupil and friend of Michael Pupin, he found guidance that was to be of great benefit as years passed. He graduated in 1913 with a degree in electrical engineering, and served in France during World War I, as a Major in the Signal Corps. Today, we find him again contributing greatly to victory for the Allies, but a detailed description of his work must be withheld until the war is over.

·Armstrong's contributions to radio are fundamental and far reaching. His invention of a regenerative circuit brought increased sensitivity of the vacuum tube as a detector. The use of this circuit was prominent in early radio receiver design, and still continues to have practical applications. This was followed in 1917 by another invention, the superheterodyne circuit, which is used in the majority of modern radio receivers. A third outstanding contribution was the superregenerative circuit that made possible two way police communication on ultra-short waves.

In 1933, Armstrong scored another triumph with the announcement of wide band frequency modulation, which brought, at last, static-free radio reception and high-fidelity tone quality such as had not been heard before.

The peace time progress of FM was halted by the war, but in the Radionic world of tomorrow Major Armstrong's most recent invention, Frequency Modulation, will bring to the public new standards of radio performance.

A. HUND..*Frequency Modulation*
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ARTHUR H. COMPTON • 1892– American

Compton, the great American physicist, and cosmic rays are inseparable. The magnitude of his contributions will be felt by generations to come.

Like other illustrious scientists in the past, his talents and interests were apparent at an early age. Compton's father was Professor of Philosophy at Wooster College. When his son wanted to experiment and photograph stars through a telescope, encouragement was forthcoming.

He graduated from Princeton University in 1916 with a degree in physics. Cavendish Laboratory in England beckoned and Compton answered, continuing research in radiation phenomena. Now after teaching positions at the University of Minnesota and Washington University, we find him Dean of the Physical Sciences at the University of Chicago. Radiation and atomic physics are his major interests.

His early laurels were in recognition of outstanding work with X-rays, namely the "Compton Effect." He was a Nobel prize winner in 1927.

In 1931, cosmic rays received international attention when Compton organized a world wide survey to learn more about the character of these "mysterious intruders" from, as far as is known at the present, interstellar space. What are cosmic rays? The answer is still to be learned, but it is known that they have the shortest wavelength of any radiation found to date, being from .01 (A) to .0001 (A) as compared to light from 4,000 (A) to 8,000 (A). In scientific literature we often find the Angstrom unit (A) used to measure wavelengths. It is equal to .000,000,001 centimeter.

Cosmic radiation is detected and studied by the use of such apparatus as Geiger-Muller counters, cloud-expansion chambers, and ionization chambers. Scientists found a residual conductivity in the air that could not be explained by the effects of any known radioactivity of the earth's crust, and which was probably due to the presence of some very penetrating radiation. It may be possible that this residual ionization is due to atomic particles of enormous penetrating power coming into the earth's atmosphere from some source outside the solar system.

Experiments made in the past show that at 30 kilometers above the surface of the earth, where the pressure of the atmosphere is only about one per cent of that at sea level, there is an intensity of cosmic radiation about 200 times as great as on the ground. Ionization was also measured down to depths of 280 meters below the surface of Lake Constance, where it was found that cosmic ray intensity is only one per cent of that at sea level.

Exactly what these particles are, where they come from, how they are formed, or where, is not definitely known. One can understand therefore why this branch of physics challenges the intellect and imagination of the greatest modern physicists.

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A. H. COMPTON..*X-rays in Theory and Experiment*

SIR WATSON WATT • 1892– Scotch

Sir Watson Watt has gained recognition for his contribution in design of equipment for radiolocation (English Radar). Educated at University College, Dundee, Scotland, he was appointed assistant to the Professor of Physics in 1912. During the last war he was Meteorologist-in-Charge at a Royal Aircraft Establishment, holding that post from 1917 until 1921, when he joined the Radio Research Station of the Department of Scientific and Industrial Research as an assistant superintendent. He remained there until 1933, when he was appointed Superintendent of the Radio Department, National Physical Laboratory, and in 1936, Superintendent of the Bawdsey Research Station. In May 1938, he became Director of Communication Development. On September 13, 1942, he was selected Vice Controller of Communication Equipment in the Ministry of Aircraft Production, and at the same time retained another post as Scientific Adviser in Telecommunications at the Air Ministry.

Sir Watson Watt is known for his work on radio direction finding and for his investigations in atmospherics. The research on which he and his assistants have been engaged is a closely guarded military secret. When peace comes we will hear a great deal more about their findings, the place it will occupy in Radionics, and how it saved England during World War II.

SIR R. A. W. WATT, *Through the Weather House;* and *Application of the Cathode Ray Oscillograph in Radio Research*

E. O. LAWRENCE • 1901– American

Lawrence is America's illustrious "atom smasher." In order to evaluate his work we must know something about atomic structure.

Matter is composed of atoms or combinations of atoms called molecules. Number and arrangement of the minute components of an atom—the electron, proton, and neutron—determines the character of the atoms of the ninety-two known elements, used as "building stones" to create matter in all its forms.

For many years atoms were regarded as immutable and indestructible. The investigations by Lord Rutherford led the way to refutation of such thinking. The atom consists of a central nucleus (positive in charge) surrounded by electrons (negative in charge) revolving in orbits something like planets around the sun.

Lord Rutherford showed how nitrogen could be transformed into oxygen, and aluminum into phosphorus, by bombarding the original element with high speed "atomic bullets."

Ernest Lawrence went to work on the problem of atom smashing. His answer was the invention of the Cyclotron, a magnetic resonance accelerator, built into a vacuum container in such a manner as to impart very high velocities to electrified particles like the proton or helium nucleus. These particles are released at the center of a large cylindrical box separated into two sections called "dees"—so called from their resemblance to the letter D—with an insulating space between the two straight edges. A high-frequency alternating voltage (10 to 20 kv) at a frequency of 15,000,000 cycles per second is developed by a suitable generator and applied to the dees, where it sets up an oscillating electric field between the straight edges. A strong magnetic field, from an electromagnet weighing nearly 100 tons, is applied perpendicular to the flat surfaces of the dees. The electric field of the oscillator pulls the particle inside of one dee, where it is forced to move in a circular path by the magnetic field. The magnetic field is adjusted so that each time the particle reaches the gap between the dees, the electric field has reversed and gives it additional speed by forcing it across the gap. This causes the particle to travel through an arc each trip with ever increasing speed and energy.

A good example of practical application of the Cyclotron is the production of radio-active sodium from sodium salts, that gives off a gamma ray more powerful than radium at less cost. This radio-active substance then has possibility for treating malignant growths, such as cancer.

Neutrons may also be produced by the bombardment of beryllium with alpha particles. These neutrons can then be used for more atom smashing, and become a weapon for the physicists to use in their never ending search for truth.

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PHILO T. FARNSWORTH • 1906– American

Farnsworth began to study radio and to think about television while still going to high school.

Since those early days, research and experimentation in his chosen field have brought this young scientist from a position as electrician in a roundhouse to that of one of America's recognized inventors of television apparatus.

He realized the limitations of early mechanical scanning systems, and determined to do the job by some electronic method. In August, 1934, Farnsworth demonstrated his new television camera, using electronic scanning, at the Franklin Institute. A unique and outstanding feature of this camera is a tube called the "image dissector" which was invented by Farnsworth. Lenses are used to collect the light radiated from a scene to be photographed and the image is brought to focus on a photo-electric plate or "photo-cathode" in the "image dissector." Employing this method, an electron image is produced at the photo-cathode by the optical image upon which the camera is focussed. After the "electron image" is formed it is drawn from the cathode to an anode located in the same tube. Next the "electron image" is moved bodily, backward and forward, past a small aperture at a speed of 15,750 times per second. While this motion is taking place the image is also pulled up and down vertically 60 times per second. The result is a 525 line "electron image" with a repetition speed of 30 frames per second. Each tiny element (367,500 in number) that goes to make up the picture or image delivers its own signal impulse since the electrons composing it enter the aperture and strike the "electron multiplier."

The purpose of this "electron multiplier" is to increase the number of electrons making up the original tiny picture element, therefore, improving sensitivity so that outdoor scenes and motion picture film can be reproduced. The output from the "electron multiplier" is then passed through a suitable amplifier and used to modulate the high frequency carrier wave sent out from the television station.

Farnsworth, by his fundamental contribution to television, has established himself among the pioneers in the art.

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D. G. FINK...*Television Engineering*

O. E. DUNLOP...*The Future of Television*

RADIONICS
"THE PROMISED LAND"

WE have followed the trails blazed by the daring frontiersmen of science, and at last find ourselves entering "The Promised Land." It is a new world in which developments have already begun. The great Radionics industry with its subdivisions, Radio, Radar, and Electronics, is creating modern miracles.

The term *radionics* has an interesting origin, being a combination of Latin and Greek. *Ray, radiation, radiate* and the English word *radius* all spring from a Latin root which comprises the first syllable of radionics. Radiate appears in the Latin form as *radiatus,* which is the past participle of the Latin *radiare,* meaning "to emit rays from" and in turn is derived from the Latin *radius,* meaning *rod* or *ray*. The word *ion* comes from the Greek *ion,* neuter of *iōn,* present participle of *ienai,* to wander, or go. The literal translation of the word radionics is wandering, or traveling radiations.

Remember, the early physicists believed atoms consisted only of protons and electrons. They were not aware of the possibility of wave mechanics. Now scientists have found in nuclear physics a number of other entities such as the positron, neutron, deuteron, etc. In the future, when atomic disintegration and ultra-high frequency techniques come out from behind closed doors, perhaps there will be other particles that may be used as building blocks, and controlled as electrons are now.

Now let us consider the implied scientific meaning of the word "radionics." "Ion" is used to indicate a charged particle and its use here combined with radiation is self-explanatory. It is a broad term which in view of the present state of the art, covers current and future developments.

Radionics may be defined as that domain of science which deals with electromagnetic radiations, charged particles, and their associated phenomena, along with ultimate useful applications, as well as the research necessary to bring about their possible utilization in such forms.

World War II accelerated the research and construction of Radionic apparatus whose practical applications are closely guarded military secrets. One outstanding example is Radar (Radio detecting and ranging). There are however many other uses that do not come under this heading, and among these we find the following examples.

Radio tubes and associated equipment are used in modern industry for color matching, resistance welding, protection of property by alarm systems, automatic operation of conveyors, and induction heating that has brought new methods for hardening metals, brazing bombs, and bonding plywood.

Aviation also receives the benefits of radionic devices which enable the pilot to determine his geographic position along with altitude when in flight, make blind landings, and carry on two way conversation.

Medicine and biology, too, received new tools in the "electric knife," X-ray, diathermy, electrocardiograph, electron microscope, and the apparatus for measuring electroencephalographic potentials in the brain.

Under the head of equipment for measurements are the cathode-ray oscilloscope and vacuum tube volt meters; in addition, there are the X-ray diffraction camera, accelerometer, spectrophotometer, devices that will determine rotational speed, and other apparatus to measure the thickness of materials.

In the field of communication further advances are being made in the development of Frequency Modulation transmitters and receivers, standard radio broadcast equipment, F-M police radio, television, sound movies, facsimile, phonographs, and hearing aids.

With this quick survey of the Radionic World as it is today there can be little question as to potentialities when peace is ours once more.

PART 2

ULTRA HIGH FREQUENCY BIBLIOGRAPHY

Contents

ULTRA-HIGH-FREQUENCY TECHNIQUE

Many physical differences separate u.h.f. technique from that of "standard radio." Oscillator, transmitter and receiver circuits are similar to those with which engineers are familiar, but the components required to build u.h.f. equipment have changed. For example, coils and condensers needed in tuned circuits may be replaced by sections of copper tubing. Vacuum tube design has also been affected as can be seen by comparing the small "acorn" tube or the magnetron with any previous radio tubes.

The u.h.f. spectrum is generally thought of as all frequencies above about 30 M.C. (10 meters). The wave-lengths become so small at the higher frequencies that they are expressed in centimeters. More noticeable as the wave-lengths get shorter is their possession of other characteristics of light, in addition to its rate of travel. At these ultrahigh frequencies it is possible to direct, reflect, diffract and refract the waves.

The service area, in which satisfactory signal strength is available, is a function of the height of the transmitting and receiving antennas as well as transmitter power. Of course receiver sensitivity and location must also be taken into consideration.

The directional antenna arrays often used are numerous and fascinating in design. One type of directive antenna uses a parabolic reflector with a dipole mounted in the center. Another means of getting directivity is to stack a number of loop aerials, one above the other. This arrangement is called a binomial array. Also horizontal or vertical radiators (rods) can be used to project a wave in a definite direction by placing other rods behind them. Electromagnetic horns or wave-guides flared at the open end, give a highly directional radiation having different field patterns for various flare angles.

As frequencies get higher and higher capacitances and inductances needed to tune the circuits get smaller and smaller. Above about 100 M.C. it becomes increasingly difficult to obtain a satisfactory amount of selectivity and impedance from ordinary coils and condensers. In other words, electrical characteristics are determined less by lumped constants than by distributed constants.

How are we then to tune circuits? The answer appears to be the use of approximately quarter wave-length sections of parallel conductors (copper tubing) or concentric lines. The lines may be other than quarter wave-length but will then require considerable reactance to give resonance. Capacity can be reduced by using a line of higher surge impedance.

For greatest selectivity and oscillator control, conductor radius should be about a quarter of the center-to-center line spacing with parallel open wire lines. If using a coaxial line, the inner conductor is about a quarter of the diameter of the outer section.

At u.h.f. another important problem appears and this is electron transit time. The small fraction of a second taken for an electron to travel from element to element, called grid-cathode and grid-anode transit time, became appreciable causing trouble. The reason for this is that transit time of the electron from one element to the other, as small as it is, becomes the same order of magnitude as the period of oscillation. Dividing the average electron velocity between cathode and grid into the distance (d_{gf}) separating the elements gives the grid-cathode transit time. Since the effect of space charge must be considered, the actual expression used is

$$\text{Grid-cathode transit time } t_g = \frac{3d_{gf}}{6 \times 10^{-7}\sqrt{E_g}}$$

If total transit time, T, is less than one-tenth of a cycle, the tube will operate satisfactorily and if it approaches a quarter of a period of the oscillation cycle, the tube usually will stop oscillating.

New demands for tubes and generators of ultrahigh frequencies are being met by engineers. Among the most outstanding examples to date are the "acorn" tube numbered 955, the "door-knob tube numbered 368A as well as the magnetron and klystron. In each tube type there is variation in physical characteristics and electrical operation.

Among other important factors to remember is that at these higher frequencies current travels on an ever increasingly thin layer or "skin" of the conductors. Resistance can be kept down by using conductors with large surface areas. Also, all connecting wire leads must be as short as possible to reduce radiation from open lines.

Receiver circuit requirements are often met by application of super-regeneration and superheterodyne technique. Again Major Armstrong comes to the rescue. For extremely high frequencies (say those above 600 M.C.) special crystal rectifiers have been used.

Although secrecy surrounds their military uses, we can be certain that here are potent silent weapons that will once more help bring freedom on land, sea and in the air. What their peace time activities will be is hard to predict but again there are new frontiers in radio.

E. Kelsey.

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For Information on Crystal Research Write Mr. G. Striker,
Engineering Dept. Zenith Radio Corp., Chicago, Ill.

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