

W 80
T 50

ELECTRICITY:
ITS THEORY, SOURCES, AND APPLICATIONS.

BY
JOHN T. SPRAGUE,
MEMBER OF THE SOCIETY OF TELEGRAPH ENGINEERS AND ELECTRICIANS.

SECOND EDITION
(GREATLY ENLARGED).



LONDON:
E. & F. N. SPON, 16, CHARING CROSS.
NEW YORK: 35, MURRAY STREET.
1884.

24 000

PREFACE.

THE fact that the first edition of 2000 copies of this work has been readily purchased, together with letters received from electricians and students all over the world, may be taken to justify the author in believing that, in departing from the nearly universal system of electrical text-books, he has met a widely felt want.

There are two electricities known to the scientific world: the electricity which exists in nature; and the electricity which, created by mathematicians, exists chiefly upon the blackboards of the professor's class-room. It is the first of these electricities which this work endeavours to elucidate. The artificial electricity serves a very useful purpose in calculating the effects which we may look for when using electricity. But that it does not satisfy earnest thinkers is manifest from the fact that recent text-books are gradually adopting and teaching doctrines which were accounted utter heresies when this book first appeared.

As stated in the preface to the first edition, the work was based upon papers which had appeared in the 'English Mechanic' and the 'Telegraphic Journal,' and much of the new matter in this edition has in like manner appeared in the pages of the 'Electrician.'

A few words as to the object of the Author may prevent some misconception. The work is not intended to enable the reader to "cram" for an examination, but to lead him to *think for himself*; not so much to give specific instructions as to any special case, as to assist in forming a clear conception of those general principles which include all cases; and it is hoped that the great number of questions which have been addressed to

the Author will have enabled him to understand, and in considerable degree to meet the desires of the class of readers for whom the work is intended.

As stated in the first preface, "the object has been to review the leading and essential facts, and to so systematize them as to form of them a *catalogue raisonné*, in which all information obtained elsewhere may be readily inserted, and be as readily available when required. Many mere facts found in all other books on electricity may here be omitted, or only slightly glanced at; but on the other hand, *principles* are dwelt upon, and the instruments necessary for their study fully explained, so that those who may have some mechanical aptitude may construct them for themselves, the very best possible way of understanding them."

It has been the aim of the Author to keep up with the great and rapid progress of electrical applications, so that the work is very greatly enlarged and several additional branches of the subject taken up. The rapid advances made, and the fact that the work has been eighteen months in passing through the press, may account for some peculiarities in the arrangement and treatment of some parts of the subject.

In these days of claims and counterclaims as to priority of ideas, it may be as well to remark that the history of electric discovery and progress does not enter within the scope of this work, but that, where occasion calls for reference to such subjects, it has been the desire of the Author to give honour where honour is due upon purely scientific considerations.

117, GREEN LANE, BIRMINGHAM,
April, 1884.

CONTENTS.

CHAPTER I.

INTRODUCTORY.

Matter. Atoms. Ether. Valency and atomicity. Molecular types. Chemical notations, equivalent and atomic. Force and Energy as related to matter. Electricity not convertible into work. The two constituents of electricity, a molecular function and energy Pages 1-13

CHAPTER II.

STATIC OR FRICTIONAL ELECTRICITY.

Primary condition of development. Electrics and conductors. The Electrophorus. Electroscopes. Primary experiments. Clerk Maxwell and Dr. Lodge on Charge, Potential, and Repulsion. Repulsion non-existent. The Fluid theories. Molecular polarization. How it produces electricity. Meaning of connection to earth. Earth not a reservoir. Surrounding surfaces and induction.—35. Frictional machines. Induction machines. The Voss and Holz machines. Electrometers. Dry piles.—51. The Leyden jar. Condensers. Charge and induction. Quantity. Density. Attraction and repulsion. Tension. Potential, definitions of.—62. Distribution. Actions of points. Surface density. Induced charges. Condensation. Bound electricity, meaning of. Inclosed spheres. Inductive and conductive circuits. Capacity.—76. Relations of Static and Dynamic electricity. Dielectrics, properties of. Retardation. Specific inductive capacity, table of. Paraffin, uses of.—83. Discharge. Properties of the electric spark. Velocity of electricity; its dual nature. Polar actions and formation of the electric field of force 14-91

CHAPTER III.

MAGNETISM.

Magnet and filings. Curve of force. Magnetic curves. Molecular constitution of magnets. Relation to electricity. Ampère's theory. Molecular theory. The magnetic field. Reason of attraction and repulsion. Bjerknes and Stroh: their mechanical illustrations. Magnetic force, laws of.—104. Magnetizing. Steel for magnets; forms of. Influence of heat.—107. Terrestrial magnetism. The earth a magnet. Position of its poles. Variation. Horizontal intensity. Magnetic field, strength, moment. Magnetic intensity and capacity.—112. Auroras. Magnetic storms. Diamagnetism. Relation of magnetism to absorbed energy. Magnets have no proper work power, or force 92-114

CHAPTER IV.

GALVANIC BATTERIES.

Zinc in acid. Zinc and copper. Heat or energy developed. Molecular polarization set up. Definition of poles and plates. General principles. Relations of energy to matter and to molecular constitution. Sources of quantity and electromotive force. Amalgamation. Zinc. Sulphuric acid. Size of cells. E M F and size. Resistance. Current, constancy. Density of current.—131. Copper and zinc cells. Platinized silver. Various forms of construction. Porous jars. Electric endosmose.—137. Daniell's cell; various forms of: E M F of. Nitric acid, table of strengths. Aqua regia. Bichromate of potash. Voisin's red salt. Iron in batteries. Platinum.—152. Carbon: artificial: connection to. Circulation of liquids. Various constructions. Bichromate battery. Manganese. Leclanché. Alkaline cells. Fitting up batteries. Commutators.—168. Work and constancy of cells. Cost of working. Proper use of different batteries.—172. Secondary batteries, charge and discharge of. Planté. Faure. Formation. Construction. Loss of gases. Faure's battery. Other makes. Management, and work capacity of .. Pages 115-189

CHAPTER V.

MEASUREMENT.

Galvanometers: needles for. Astatic needles. Laws of angles. Horizontal magnetic intensity. Tangent galvanometer. Sine. Curves of action and of graduation. Sprague's Universal. Differential. Thomson's Reflector. Voltmeters. Ratio of gases to current. Calorimeters. Heating of wires. Coulomb-meters. Electric meters.—223. Principles of measurement. Natural units. The B. A. system. Absolute units. Force and Energy. Gravitation. The C. G. S. system. Electric units, dimensions of. The practical units. Volt. Ohm, &c., general table of.—237. Resistance measures, construction of. Wheatstone Bridge. Potential, distribution of. Resistances and bridge combined 190-255

CHAPTER VI.

CURRENT.

Quantity and intensity. Ohm's laws. Analogy of electric and water current. What resistance really is. Electromotive force. Mechanico-motive force. Potential energy. Laws of falling bodies. Relations of Force, Energy, and Potential. Potential considered as representing square root of energy. Laws of Current. Why resistance so called is equal for all currents. Hydraulic analogy of current. Chemical value of the ampère 256-271

CHAPTER VII.

CONDUCTIVITY AND RESISTANCE.

Specific conductivity. Alloys. Heat and conductivity. Resistance, definition of. Resistance as a velocity. Work as resistance. Counter or —E M F. Inductive resistance. Energy absorbed in magnetizing. Derived circuits. Shunts. Internal resistance of cells, measurement of.—283. Conductivity of Metals, &c.: Table of. Temperature correction. Dimensions of wires. Wire gauges, various. Formulæ and constants of wires. Purity of copper.—294. Table of wires. Resistance of liquids. Earth circuit. Heating of wires. Dissipation of heat by conduction, convection, and radiation. Safe current in wires. Cost of conduction. Pages 272-307

CHAPTER VIII.

ELECTROMOTIVE FORCE.

Measurement of E M F: apparatus for. Experimental processes. Relations of energy and matter. Mechanical equivalent of heat. Intrinsic energy. Combustion. Salts.—319. Table of properties of the elements. Energy of chemical processes. How energy becomes E M F. The equivolt.—325. Table of correlation of units, &c. Contact and chemical theories. General law of energy. Electric circuit, phenomena of. Positive metal sets up E M F. Action at negative plate.—336. Table of E M F of batteries. Details of energy in electric actions. E M F and chemical affinity. Work and the square of current. Energy expended in circuit. Potential considered as energy 308-355

CHAPTER IX.

ELECTROLYSIS.

Terms used. Generating and decomposing cells. Diagram of full circuit. Laws. Valency. Theories of Berzelius and Faraday, opposed and united. Gas volume. Electric equivalent. Counter E M F of electrolysis. Formula of work. Decomposition cell a condenser. Transmission in liquids. Secondary actions. Action at electrodes. General law of minimum energy. Mixed electrolytes. Water not an electrolyte. Typical reactions. No transfer of ions. The work of electrolysis .. 356-385

CHAPTER X.

ELECTRO-METALLURGY.

Electrotyping and Electro-plating. Preparation of objects. Cleanliness. Cleaning processes for different metals. Old work. Moulds. Plaster of paris. Elastic moulds. Insects and flowers. Conducting surfaces. Stopping off. Smee's laws. Strength of solutions. E M F and resistance required. Density of current. Tension. Rate of deposit. Effects of position. Circulation. Size and distance. Apparatus. Principles of solutions.—414. Depositing copper. Bronzing. Rate of work. Cyanide of potassium. Silver depositing. Spoilt solutions. Gilding. Coloured gold. Nickeling. Iron and platinum. Alloys. Brass and bronze deposits 386-440

CHAPTER XI.

TERRESTRIAL ELECTRICITY.

Earth currents; causes and laws. Magnetic storms. Supposed static charge of the earth. Theories of earth magnetism. Cosmical electricity. Maxwell's theory of light. Atmospheric electricity. Supposed causes. Potential energy of vapour. Earthquakes, volcanoes, and cyclones. —449. Thunder-storms. Ball lightning. Duration and brightness of lightning. Lightning conductors: laws of.—455. Earth connections. Faraday's comparison of Static and Dynamic electricity explained. Quantity and Potential both included in the usual expressions

Pages 441-460

CHAPTER XII.

ELECTRO-MAGNETISM.

Electric actions in conductors. Reactions of currents on magnets. Static and magnetic charges are potential energy stored. Right and left handed helices. Theory of magnetic field. Induced currents in conductor crossing the field.—473. Dynamo-electric machines. History of the earlier forms. Evolution and development. Principles of all dynamo machines. All matter exists under a balance of varying forces. How magnets develop currents.—490. Action of the field magnets. The Gramme machine, the Siemens machine, the Bürgin, and others. Laws of proportion. Shunt, series, and compound machines. Laws of E M F developed. Characteristic curves. Efficiency of machines.—514. Electric motors: various types. Relative efficiency of motors. Cost of working.—519. Energy of fuel. Gas as fuel. Cost of mechanical energy. Cost of electric energy. Transmission of energy.—523. Electro-magnets, laws of. Magnetic capacity of iron and steel.—530. Induction coils, laws and construction of. Mercury breaks. Dimensions of noted coils. Medical coils. Management of wires 461-547

CHAPTER XIII.

ELECTRIC LIGHTING.

Light a motion and a perception. Sound; absorbed notes. The spectrum; dark lines. Draper's experiment. Degrees of Temperature, Table of. Ratios of light to energy. Photometry: standard of light: chemical measures. Absorption. Distribution of light.—559. Light not produced from electricity; energy its source in all lights alike. The voltaic arc: its temperature. Colours by arc light. Penetrating power: resistance and E M F. Products of the arc. Uses of the arc light. Heat rays.—556. Arc lamps: differential principle. Werdermann lamp. Jablochkoff and other "candles." Preparation of carbons.—570. Incandescent lighting. Atomic heat and volume: radiation capacity. Swan's first lamps.—575. Form and size of carbon wires. Efficiency of lamps. Advantages of incandescent system. Law of light ratio to current and work. Cost of the light. 548-582

CHAPTER XIV.

MISCELLANEOUS.

Telegraphy: duplex and quadruplex. Automatic transmission. Electric organ. The Motograph. Electric Bells: construction and system. Switches. Telephony. The Phonautograph. String Telephone. Phonograph. The Telephone: order of invention. Current required. Construction. Action of the Telephone. Edison's transmitter and receiver. Use of induction coils. Varley's and Dolbear's condenser, and other forms. Induction and its remedy. The Microphone. Various theories of. Air film a conductor. Relation of resistance to current and pressure. Principles of construction. Distance of transmission. Telephone system and circuit. Radiophony. Selenium and its properties. Hughes' induction balance. Microtasimeter. New source of electricity. Wimshurst machine. Thermo-electricity. Clamonds and Noe's piles. Conservation of electricity Pages 583-623

CHAPTER XV.

DICTIONARY OF TERMS.

Short definitions and explanations 624-638

INDEX 639