

## 2. GENERAL THEORY

### AN EXPERIMENTAL METHOD OF STUDYING THE DYNAMO MACHINE

C. F. Brackett

Vol. i—1884, pp. 1-3, paper No. 7

Description of a method of exploring the magnetic field of an experimental generator, designed to show the effect of iron in the armature core and that of current in the armature winding.

*Discussion*, pp. 3-4, by Messrs. N. S. Keith, C. F. Brackett, and E. A. Sperry.

### CHEMISTRY OF THE CARBON FILAMENT

Edw. P. Thompson

Vol. i—1884, pp. 1-11, paper No. 10

Brief description of the chemistry of carbon filament manufacture and short description of the Swan, Stanley, Thompson and Weston processes of carbon filament manufacture.

*Discussion*, pp. 11-13, by Messrs. W. D. Sargent, Wm. H. Preece, N. S. Keith, John Kelly, and Chas. Stagl.

### ON THE DIFFERING TEMPERATURE COEFFICIENTS OF THE DIFFERENT COILS OF A FINE RHEOSTAT

W. A. Anthony

Vol. iv—1887, pp. 137-140

Account of resistance variations in precision rheostat due to temperature, and suggestions for design of rheostat so as to reduce such errors to a minimum.

*Discussion*, pp. 140-148, by Messrs. ——— Wallace, W. A. Anthony, Frank L. Pope, Geo. B. Prescott, Jr., S. S. Wheeler, C. O. Mailloux, T. C. Martin, J. A. Powers, O. E. Michaelis, Geo. A. Hamilton, and Elihu Thomson.

Brief reference to Weston's experiments on German silver. Effect of winding strains on resistance of wire.

### NOVEL PHENOMENA OF ALTERNATING CURRENTS

Elihu Thomson

Vol. iv—1887, pp. 160-173

Experimental investigation of repulsive action between changing magnetic field and electric conductor, developing principles which are applied to the operation of alternating current motors (repulsion motors).

*Discussion*, pp. 174-183, by Messrs. S. S. Wheeler, C. O. Mailloux, Geo. B. Prescott, Jr., Elihu Thomson, J. M. Pendelton, Carl Herring and J. A. Powers.

General remarks on electric repulsion; its use in electric measuring instruments.

### ON THE CHANGE FROM NEGATIVE TO POSITIVE OF THE TEMPERATURE COEFFICIENT OF SOME CARBON FILAMENTS

W. A. Anthony

Vol. iv—1887, pp. 198-199

Brief reference to some experiments which indicate a change of sign of the coefficient of resistivity of carbon filaments.

*Discussion*, pp. 199-200, by Elihu Thomson.

Observations which tend to substantiate Professor Anthony's conclusion.

**PHENOMENA OF RETARDATION IN THE INDUCTION COIL**

William Stanley, Jr.

Vol. v—1888, pp. 97-108

Discussion of alternating current phenomena, comparison of efficiency and losses in alternating current and direct current generators; explaining the mode of operation of transformers, action of induction coil in series with arc lamps.

Discussion, pp. 108-134, by Messrs. Townsend Wolcott, William Stanley, Jr., Herbert Howson, S. S. Wheeler, P. H. Vander Weyde, George B. Prescott, Jr., C. O. Mailloux, E. W. Rice, Jr., T. C. Martin, Jos. Wetzler and J. W. Howell.

General remarks on the operation of alternating current apparatus. Reference to hysteresis. Description of auto-transformer. Difficulties experienced in parallel operation of alternating current generators. Mode of operation of synchronous motors.

**ELECTRIC ENERGY FROM CARBON WITHOUT HEAT**

Willard E. Case

Vol. v—1888, pp. 195-200

Account of experiment with primary cell with graphite positive electrode.

*Discussion*, pp. 201-210, by Messrs. C. O. Mailloux, Townsend Wolcott, Jos. Wetzler, F. B. Crocker, C. S. Bradley, ——— Grimshaw, and Willard E. Case.

Method of calculating theoretical e. m. f. of any primary cell.

**IMPOSSIBILITIES AND LIMITATIONS OF CHEMICAL GENERATORS OF ELECTRICITY**

Francis B. Crocker

Vol. v—1888, pp. 277-288

Description of method of calculating e. m. f. with large number of actual calculations compared with the observed values. Results of tests of e. m. f. of different metals, with free chlorine, bromine, and iodine in different electrolytes. Technical data on cells with zinc as electro-positive material and various depolarizers and electro-negative materials. Discussion of the efficiency and opportunities for improvement of chemical generators.

*Discussion*, pp. 288-294, by Messrs. Otto A. Moses, F. B. Crocker, P. H. Vander Weyde, Edw. L. Nichols, C. O. Mailloux and Elihu Thomson.

General remarks on the chemical generation of electric energy.

**LIGHTNING ARRESTERS AND THE PHOTOGRAPHIC STUDY OF SELF-INDUCTION**

E. G. Acheson

Vol. vi—1889, pp. 74-98

Experimental study of the effect of discharge of spark gap lightning arresters upon insulation stresses. Investigation of the effects of various arrangements of ground connection. Photographic records of spark dischargers under various circuit conditions exposed through revolving perforated disk.

*Discussion*, pp. 98-106, by Messrs. Otto A. Moses, E. G. Acheson, E. T.

Birdsall, Leonard le C. Hamilton, Lemuel W. Serrell, Joseph Wetzler, William E. Geyer, Charles Cuttriss, Allan V. Garratt and Holbrook Cushman.

**LIGHTNING ARRESTERS AND THE PHOTOGRAPHIC STUDY OF SELF-INDUCTION**

Joseph Stanford Brown and Charles T. Child

Vol. vi—1889, pp. 135-143

Detailed analysis and criticism of Mr. Acheson's paper. Circuit diagram redrawn to bring out more clearly the electrical relations. Consideration of the condenser action of the cable upon the spark gap arrester performance.

*Discussion*, pp. 143-155, by Messrs. J. S. Brown, C. O. Mailloux, Ralph W. Pope and ——— Abdank.

- Replies to criticisms of Mr. Acheson's paper.

**MAGNETISM IN ITS RELATION TO INDUCED ELECTROMOTIVE FORCE AND CURRENT**

Elihu Thomson

Vol. vi—1889, pp. 269-286

Theoretical analysis of electro-magnetic induction phenomena in conductors, induction coils, transformers and dynamo machinery, showing the effect of form and nature of electric and magnetic circuit as well as density and speed of cutting magnetism.

*Discussion*, pp. 286-292, by Messrs. M. M. Garver, Elihu Thomson, Otto A. Moses, Joseph Wetzler, C. O. Mailloux, J. P. Wintringham, Louis Ducan, George H. Stockbridge and Edward Weston.

**ON MODERN VIEWS WITH RESPECT TO ELECTRIC CURRENTS**

Henry A. Rowland

Vol. vi—1889, pp. 342-357

Brief review of experiments that establish the existence of electromagnetic waves. Description of Hertz's wave detector. Skin effect upon the wave front of electricity traversing a conductor.

No discussion.

**A REVIEW OF MODERN ELECTRICAL THEORIES**

William A. Anthony

Vol. vii—1890, pp. 33-42

Outline of working hypothesis of space filled with wheels which are set in motion by flow of electricity. Reference to Hertz's work in proving existence of electromagnetic waves. Possibility of selective radiation in producing cold light.

*Discussion*, pp. 42-54, by Messrs. Otto A. Moses, W. K. Anthony, M. M. Garver, A. E. Kennelly, Townsend Wolcott, Michael Pupin, Nikola Tesla, and F. B. Crocker.

General remarks on Maxwell's and Faraday's theories of electricity. Distinction between difference of potential and e. m. f.

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PHENOMENA OF ALTERNATING CURRENT INDUCTION

Elihu Thomson

Vol. vii—1890, pp. 132-150

Experimental lecture on electromagnetic induction phenomena, demonstrating repulsive forces due to secondary currents and time-lag of magnetism. Numerous experiments since become classic are illustrated.

No discussion.

PRACTICAL ASPECTS OF THE ALTERNATING CURRENT THEORY

M. I. Pupin

Vol. vii—1890, pp. 204-217

Brief résumé of the development of fundamental laws of electricity, giving the discoveries of the laws and the date of discovery. Mathematical consideration of the ideal transformer.

*Discussion*, p. 287, by Messrs. O. T. Crosby, M. I. Pupin and Elihu Thomson.

A NEW METHOD OF ANALYZING ARMATURE REACTIONS OF ALTERNATORS

Charles P. Steinmetz

Vol. vii—1890, pp. 434-438

Development of equation for calculation of effect of armature reaction upon the e. m. f. of constant potential and upon the current of constant-current alternators.

*Discussion*, pp. 439-445, by Messrs. Thorburn Reid and Charles P. Steinmetz.

REPORT OF THE COMMITTEE ON THE VALUE OF THE "HENRY"

Vol. viii—1891, pp. 31-56

*Discussion* of report and of Kennelly's paper on "Inductance and Its Proposed Unit 'Henry,'" by Messrs. Frank B. Crocker, Cary T. Hutchinson, Geo. A. Hamilton, Thorburn Reid, A. E. Kennelly, C. O. Mailloux, Chas. P. Steinmetz, W. A. Anthony, Ralph Pope and S. S. Wheeler.

Definitions of inductance. Physical significance of inductance.

A PHOTOGRAPHIC STUDY OF THE ELECTRIC ARC

Edward L. Nichols

Vol. viii—1891, pp. 214-221

Account of experiments that show the intermittent character of alternating current arc and explaining the cause of surging. Measuring wave form and photographs of arc observed, with revolving mirror under various conditions.

*Discussion*, pp. 222-226, by Messrs. Elihu Thomson, Edward L. Nichols, Carl Hering, C. O. Mailloux and Thos. D. Lockwood.

Explanation of cause of wave distortion by arc. Beginning of custom of presenting the Institute with portraits of past Presidents.

EXPERIMENTS WITH ALTERNATE CURRENTS OF VERY HIGH FREQUENCY AND THEIR APPLICATION TO METHODS OF ARTIFICIAL ILLUMINATION

Nikola Tesla

Vol. viii—1891, pp. 267-319

General discourse on the nature of electricity. Notes on the design and construction of very high frequency generators. Account of experiments

with very high frequency and high potential currents, demonstrating the character of discharges through air as affected by electrodes, frequency, potential and various other conditions. Proposal to produce electrostatically incandescent illumination that has the same efficiency and the same economical characteristics of the usual incandescent lamp. The different types of discharge, the lamps and generator are fully illustrated.

No discussion.

#### MAGNETIC RELUCTANCE

A. E. Kennelly

Vol. viii—1891, pp. 485-51

Account of the development of the theory of magnetism, the polar, the vein and the circuit theories. Review of experiments made by Rowland, Ewing, Low and others. Typical magnetization curves for different grades of iron and steel and of nickel and cobalt at different temperatures. Reference to original articles and full data tabulated for all curves.

*Discussion*, pp. 518-532, by Messrs. A. E. Kennelly, Carl Herring, J. Stanford Brown, Louis Bell, Chas. E. Emery, M. I. Pupin, Charles P. Steinmetz and Thos. D. Lockwood.

Analogy between magnetic circuit and electric circuit and between magnetism and elasticity. Hysteresis in gases. General remarks on engineering formulas.

#### ON THE LAW OF HYSTERESIS

Charles P. Steinmetz

Vol. ix—1892, pp. 3-51

Account of experimental investigation of magnetic hysteresis. Description of apparatus used and results of tests on different types of magnetic circuits and different qualities of material. Hysteretic constants for various classes of iron and steel.

*Discussion*, pp. 51-60, by Messrs. Thomas D. Lockwood, C. P. Steinmetz, Charles S. Bradley, Joseph Wetzler, A. E. Kennelly and M. I. Pupin.

General remarks on law of hysteresis.

#### NOTE ON THE MOLECULAR MOVEMENTS IN A CONDUCTOR

A. E. Dolbear

Vol. ix—1892, pp. 95-97

Experimental demonstration of rotation of molecules in conductor.

*Discussion*, pp. 97-100, by Messrs. C. O. Mailloux, Townsend Wolcott, A. E. Kennelly, M. I. Pupin, Harold Binney, F. B. Crocker, Carl Hering, Samuel Sheldon and Charles J. Kintner.

#### NOTE ON SOME EXPERIMENTS WITH ALTERNATING CURRENTS

Louis Duncan

Vol. ix—1892, pp. 179-190

Description of apparatus for simultaneous observation of several different wave forms by the contact method.

*Discussion*, pp. 190-191, by Messrs. Henry S. Carhart and Edward L. Nichols.

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**RATIONAL AND EMPIRICAL FORMULAE SHOWING THE RELATION BETWEEN THE MAGNETOMOTIVE FORCE (H) AND THE RESULTING MAGNETIZATION (B)****Charles E. Emery**

Vol. ix—1892, pp. 192-222

Development of a rational method of calculating the magnetization of iron, based on analogy to the laws of mechanics.

No discussion.

**DERIVATION AND DISCUSSION OF THE GENERAL SOLUTION FOR THE CURRENT FLOWING IN A CIRCUIT CONTAINING RESISTANCE, SELF-INDUCTION AND CAPACITY, WITH ANY IMPRESSED ELECTROMOTIVE FORCE****Frederick Bedell and Albert C. Crehore**

Vol. ix—1892, pp. 303-374

Development of equations covering all possible cases of an electric circuit containing resistance, inductance and capacity.

No discussion.

**THE REVERSAL OF POLARITY IN PLATING DYNAMOS****Harris J. Ryan**

Vol. ix—1892, pp. 525-526

Experimental determination of the voltaic action between unplated carbon and copper.

No discussion.

**ON THE LAW OF HYSTERESIS. (PART II).****Charles P. Steinmetz**

Vol. ix—1892, pp. 621-724

Investigation of hysteresis between any two limits of flux density, either of opposite or of equal sign. Description of apparatus, method of measurement and development of equations relative to the quantities involved. Hysteresis with pulsating magnetism. Magnetic constants for different types of irons and steels. Magnetic characteristics of wire and laminations magnetized transversely. Meaning of the area of the hysteresis loop. Theory of molecular magnets.

Appendix I, pp. 725-729.

Relative Merits of Different Methods of Measuring Flux Density.

Appendix II, pp. 745-747.

Efficiency of Electro-magnetic Conversion of Energy. Limits of the Law of 1.6th Power.

Appendix III, pp. 756-758.

Limits of Linear Law of Metallic Reluctivity.

*Discussion*, pp. 730-744 and 748-755, by Messrs. W. J. Hammer, A. E. Kennelly and Wm. Stanley, Jr.

**IMPEDANCE****A. E. Kennelly**

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Development of crank diagram and explanation of the use of vector impedance diagrams. Tables giving impedance factors for iron wires with different currents. Impedance factors of copper wires with different spacing and frequencies from 40 to 140 cycles per second. Appendices: Development of formula for inductance of parallel wires. Meas-

urement of impedance factors for three parallel wires. Analysis of periodic wave into harmonic components.

*Discussion*, pp. 217-232, by Messrs. W. J. Hammer, Douglass Burnett, T. D. Lockwood, M. I. Pupin, A. E. Kennelly, William E. Geyer, C. S. Bradley, Frank J. Sprague and C. P. Steinmetz.

Explanation of the method of using complex quantities.

#### THE ACTION OF CONTINUOUS AND ALTERNATING CURRENTS ON FUSE METALS

C. P. Matthews

Vol. x—1893, pp. 251-265

Development of Preece's law of fusing currents and résumé of some of his experiments giving constants for various materials. Experimental study of cooling effect of terminals, time element in fusing action and effects of alternating currents on fusing point of commercial fuses.

*Discussion*, pp. 266-269, by Messrs. E. J. Houston, C. P. Matthews, Elmer G. Willyoung, E. L. Nichols, and Milton C. Canfield.

General remarks on fuse testing.

#### PRACTICAL ASPECTS OF LOW FREQUENCY ELECTRICAL RESONANCE

M. I. Pupin

Vol. x—1893, pp. 370-394

Mechanical analysis of resonance phenomena. Account of experimental study of electrical resonance determining the relation between e. m. f. rise and the various factors of the circuit, bringing out the practical bearing of low-frequency electrical resonance.

*Discussion*, pp. 395-399, by Messrs. N. Tesla and M. I. Pupin.

Description of thermo-magnetic generator.

#### RESONANCE ANALYSIS OF ALTERNATING AND POLYPHASE CURRENTS

M. I. Pupin

Vol. xi—1894, pp. 523-550

Description of current and e. m. f. wave analysis with resonant electric circuit. Study of harmonics, their amplitude and phase under different circuit conditions.

*Discussion*, pp. 551-558, by Messrs. W. A. Anthony, C. P. Steinmetz, A. E. Kennelly and M. I. Pupin.

Difference in behavior of current and e. m. f. harmonics. Nature of hysteresis.

#### ON THE LAW OF HYSTERESIS (PART III), AND THE THEORY OF FERRIC INDUCTANCES

Charles P. Steinmetz

Vol. xi—1894, pp. 570-608

Theory and laws of hysteresis. Mathematical treatment of the losses in iron by hysteresis and eddy currents. Distortion of exciting current at different flux densities.

*Discussion*, pp. 609-616, by Messrs. Frederick Bedell, C. P. Steinmetz, A. E. Kennelly and M. I. Pupin.

General remarks on hysteresis and exciting current wave distortion.

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REACTANCE

Charles P. Steinmetz and Frederick Bedell

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Fundamental equations and vector diagrams for calculation of electric circuits having resistance, inductance, capacity and mutual inductance. Definition of reactance.

*Discussion*, pp. 648-649, by Prof. H. J. Ryan.

A STUDY OF THE RESIDUAL CHARGES OF CONDENSERS, AND THEIR DEPENDENCE UPON TEMPERATURE

Frederick Bedell and Carl Kinsley

Vol. xi—1894, pp. 656-681

Experimental study of condenser discharges. Influence of temperature upon insulation resistance of various dielectrics.

No discussion.

ON THE PRODUCTION OF ROTARY MAGNETIC FIELDS BY A SINGLE ALTERNATING CURRENT

Ludwig Gutmann

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Explanation of rotation of polyphase winding in a single-phase field.

*Discussion*, pp. 846-856, by Messrs. M. I. Pupin, T. Wolcott, A. E. Kennelly, Samuel Sheldon, Carl K. McFadden, L. L. Summers, Ludwig Gutmann and Elihu Thomson.

General remarks on the behavior of polyphase wound armature in single-phase field.

PROPERTIES OF FUSE METALS WHEN SUBJECTED TO SHORT CIRCUITS

Walter E. Harrington

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Experimental investigation of fusing currents for different metals under various conditions. Tables of fusing currents for copper, aluminium and lead and zinc composition metals. Preece's law and constants for various metals.

*Discussion*, pp. 234-244, by Messrs. Leonard Waldo, Charles P. Steinmetz, F. B. Crocker, C. J. Reed, W. A. Anthony, Elihu Thomson, Geo. W. Blodgett, Allan V. Garratt, Walter E. Harrington, Carl Hering, and Wm. Brophy.

Physical operation of fuses. Function of fuses.

THE CAUSE OF DEATH IN ELECTRIC SHOCK

A. M. Bleile

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Report of test made on dogs to ascertain the effect of large electric currents on living organisms, and also the value of artificial respiration in case of shock.

*Discussion*, pp. 396-404, by Messrs. G. W. Blodgett, A. M. Bleile, John C. Shedd, Jules Neher, Elihu Thomson, Allan V. Garratt, W. A. Anthony, Walter E. Harrington, Harry Alexander and F. B. Crocker.

Experiments and experience with electric shocks. Physiological effects of frequency. Nature of human body as conductor of electricity.

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**ALTERNATING CURRENT CURVES**

Charles E. Emery

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Development of equations for alternating current quantities represented by triangular, sine, parabolic, rectangular and other curves. Relations between curves in quadrature.

*Discussion*, pp. 470-480, by Messrs. M. I. Pupin, Charles P. Steinmetz, and Charles E. Emery.

Application of Fourier's series to wave analysis. Actual wave form of different types of alternators.

**DISCUSSION OF SURGICAL VALUE OF RONTGEN RAY**

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**AN ANALYSIS OF TRANSFORMER CURVES**

Charles K. Huguet

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*Discussion*, pp. 216-221, by Messrs. A. E. Kennelly, E. L. Nichols, C. P. Steinmetz, C. K. Huguet, C. T. Rittenhouse, C. A. Adams, Jr., E. E. Ries and C. F. Scott.

Relation of hysteresis to distortion of exciting current.

**AN EXPERIMENTAL STUDY OF ELECTRO-MOTIVE FORCES INDUCED ON  
BREAKING A CIRCUIT**

F. J. A. McKittrick, with an introduction by Dr. Edward L. Nichols Vol. xiii—1896, pp. 245-268

Construction of high frequency galvanometer provided with mirror and photographic attachment. Description of test made with the apparatus. Reproductions of current and e. m. f. curves.

*Discussion*, pp. 268-269, by Messrs. W. A. Anthony, A. J. Wurts, E. L. Nichols and J. W. Howell.

**THE RONTGEN RAY, AND ITS RELATION TO PHYSICS**

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Topical discussion, by Messrs. Henry A. Rowland, Elihu Thomson, M. I. Pupin, A. E. Kennelly, Max Osterberg, Louis Duncan, W. M. Stine, C. O. Mailloux and C. T. Rittenhouse.

General remarks on the theory and properties of Röntgen rays. Brief history of development of knowledge of the Röntgen ray.

**CONDUCTIVITY OF INCANDESCENT CARBON FILAMENTS, AND OF THE SPACE  
SURROUNDING THEM**

John W. Howell

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*Discussion*, pp. 42-53, by Messrs. John W. Howell, Louis Duncan, A. E.

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General remarks on problems in the construction of carbon filament incandescent lamps.

**APPLICATION OF HYPERBOLIC ANALYSIS TO THE DISCHARGE OF A CONDENSER**

Alexander MacFarlane

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Development of equations for the discharge of a condenser using hyperbolic functions.

*Discussion*, pp. 175-181 and 250-252, by Messrs. C. P. Steinmetz, A. E. Kennelly, F. A. C. Perrine and A. MacFarlane.

Meaning of complex imaginary quantities. Field and limits of algebra.

**INSULATION AND CONDUCTION**

Reginald A. Fessenden

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Theory of the conduction of electricity in solids, liquids, and gases. Requirements of an insulating material. Dielectric properties of various types of insulating materials.

*Discussion*, pp. 151-160, by Messrs. F. B. Crocker, W. S. Franklin, M. I. Pupin and R. A. Fessenden.

General remarks on the theory of insulation and conduction.

**THE GRAPHICAL TREATMENT OF ALTERNATING CURRENTS IN BRANCHING CIRCUITS**

Henry T. Eddy

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Study of general electrical circuits, showing the effect of varying the constants of the circuits and the frequency of the e. m. f.

*Discussion*, p. 504, by Dr. A. E. Kennelly.

**PROPAGATION OF LONG ELECTRICAL WAVES**

M. I. Pupin

Vol. xvi—1899, pp. 93-142

Description of experimental investigation of the propagation of long electrical waves for various kinds of circuits. Development of mathematical theory.

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**SYMBOLIC REPRESENTATION OF GENERAL ALTERNATING WAVES AND OF DOUBLE FREQUENCY VECTOR PRODUCTS**

Charles P. Steinmetz

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Development of formulas and examples of their application on different types of circuits.

*Discussion*, pp. 297-304, by Messrs. Louis Bell, Elihu Thomson, A. E. Kennelly, W. E. Goldsborough, C. A. Thomas, Jr., T. J. Johnston, C. P. Steinmetz, H. J. Ryan, Samuel Sheldon and D. C. Jackson.

Representation of alternating quantities in polar co-ordinates.

**AIR-GAP AND CORE DISTRIBUTION**

W. E. Goldsborough

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Experimental investigation of the distribution of flux in an iron core under different conditions of load and position with reference to the field pole.

*Discussion*, pp. 481-483, by Messrs. C. P. Steinmetz, J. B. Blood and W. E. Goldsborough.

Practical value of authors' results.