Table III. Values of Statistic *F* and Critical Values for the Tachometer Problem

Factors	Sum of Squares	Degrees of Freedom	Mean Square	*F*	Critical (One Per Cent)
Location	7.814	2	3.907	11.13	8.02
Conductivity	6.061	2	3.031	8.64	8.02
Coefficient	1.646	2	0.823	2.34	8.02
Thickness	7.226	2	3.613	10.29	8.02
All other variables	3.159	9	0.351		

Table IV. Asphalt-Treating Cycles

Baking time (hours)	1	2	4	6
Vacuum (minutes)	2.5	5.0	7.5	10.0
Pressure (minutes)	2.5	5.0	10.0	15.0
Number of pressure cycles	1	2	3	4
Release between cycles (minutes)	1.0	2.5	5.0	10.0

the vacuum time beyond the point where the desired absolute pressure was achieved; short-pressure cycles did as much as long ones but there was a steady gain with the number of cycles; finally, no time of rest was required between pressure cycles. As a result of these tests, a very high quality insulation was obtained while the best arrangement of the time cycle permitted 25 per cent more production on the existing facilities.

In these few simple cases advanced here to illustrate the type of problem confronting engineers, the fundamental purpose is to demonstrate the logic rather than the mathematics of significance tests. Our first intention is to measure the uncertainty of inductive conclusions rather than rely on intuitive estimates of the odds. It is important that statistical methods be studied not as a new course in algebra but as a logical approach to physical realities that are essentially unstable within limits. Such realism is sure middle ground between rash assurance and blind idealism. The risks which are involved are unavoidable, and the quantitative expression of them is truly a scientific procedure.

Electrical Essays

Network

An electrical engineer finds the two boxes built to Dr. Slepian's specifications as outlined in his December 1948 essay (*p 1141*). The engineer removes the contents of the boxes and installs in each box an air core transformer and one of the resistances he removed from the boxes. The transformers were especially designed for this problem. Subtractive polarity, unity turn ratio, and negligible winding resistance are some of the features of the design. The most important items, however, are the self-inductance of the windings, which is the same for all of them, and the mutual inductance, which is equal to three-fifths the value of the self-inductance. The resistance is added for the purpose of permitting safe testing with direct current, and further masking of the negligible resistance of the windings. The internal connections are shown in Figure 1.

Is it possible to determine by purely electrical measurements at the box terminals which box contains the transformer with series connected windings? What difference, if any, would it make if iron core transformers were used by the engineer?

A. A. KRONEBERG (F '48)
(Southern California Edison Company, Los Angeles, Calif.)

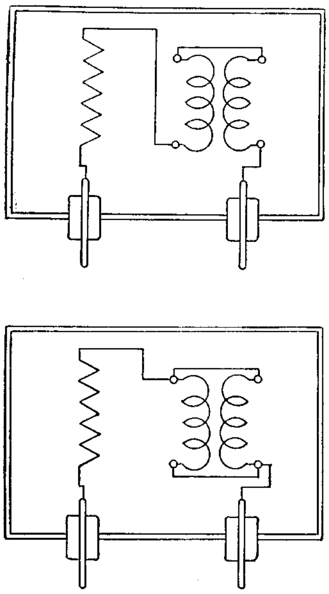


Figure 1

$$M = \frac{3}{5}L$$

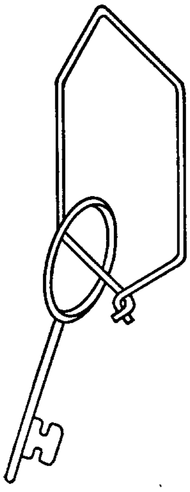
Flux Linkage of an Open Circuit

The engineers employed at the company where I work certainly have me confused. The other day I overheard two of them talking about the voltage or electromotive force induced in a turn on a machine by the varying flux linkage of that turn.

Now I think I know what the flux linkage of a *closed* curve or circuit is, but you know, a turn on a machine is not a closed curve or circuit. It may be nearly closed, or it may be part of a larger circuit which is closed, but most always it itself is not closed. Now how can you tell whether a closed tube of magnetic flux links a circuit or not, if that circuit is not closed?

I walked over to the machine where the engineers were talking, and what do you know! It had a wave winding on it. Now, a turn on a wave winding doesn't come anywhere near closing.

I am not a member of Eta Kappa Nu, not yet anyway, but I like to wear something that reflects my interest in electricity, so I have made myself a key ring shaped like a turn on a machine. But I was smart enough to choose a lap winding, and by twisting together the turn ends, which are already close together, my keys link the ring without any question, and the ring stays linked by the keys, Figure 1. But suppose I had used a wave winding, like in Figure 2. I wouldn't know whether my keys were linked to the key ring or not.



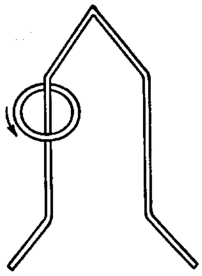


Figure 1 (left). Alter Ego's key ring

Figure 2 (right). Flux linking wave turn

In Figure 2 I have shown a magnetized ring of iron encircling one side of the wave turn. The engineers would say that the flux of this ring links the turn, because this flux is in exactly the same position as that flux, in the machine, which they said was linking the turn. Now as I slip the magnetized iron ring off the coil side, there must be some place where the magnetic flux will no longer be linking the turn.

Question 1. Where does the magnetized ring stop linking the turn?

Question 2. As the ring stops linking the turn, so that the flux linkages are reducing to zero, an electromotive force will be induced in the open turn, since the rate of change of the flux linkages will not be zero, isn't that right? True or false?

J. Slepian, Alter Ego

J. SLEPIAN (F '27)
(Associate Director, Westinghouse Research Laboratories, East Pittsburgh, Pa.)

Answers to Previous Essays

Electrostatic or Electromagnetically Induced Electric Field? The following is the author's answer to a previously published essay of the foregoing title (*EE, Oct '49, p 877*).

"There is but one god, Allah, and Mohammed is his prophet!" There is but one electric field, $\boldsymbol{E}$, (for a particular frame of reference) and Maxwell, our prophet, has proclaimed its properties (in free space) in his eternal equations.

$$\text{div } \boldsymbol{E} = 4\pi\rho \tag{1}$$

$$\text{curl } \boldsymbol{E} = -\frac{1}{c}\frac{\partial \boldsymbol{B}}{\partial t} \tag{2}$$

These equations do not talk of two electric fields, one, $\boldsymbol{E}_s$, an electrostatic field for equation 1 which is concerned with electric charge density ρ, and the other, $\boldsymbol{E}_T$, an inductively produced field, in equation 2 which is concerned with varying magnetic flux-density, $\partial \boldsymbol{B}/\partial t$. No, they speak only of a single electric field, $\boldsymbol{E}$, defined uniquely by purely local measurements of force on a probe, and to which *both* equation 1 and 2 apply. There is but one electric field, $\boldsymbol{E}$, and Maxwell is its prophet!

Of course we may arbitrarily, or for our real or imaginary convenience choose to regard the one field, $\boldsymbol{E}_s$ as made up of an electrostatic part $\boldsymbol{E}_s$, and an inductive part, $\boldsymbol{E}_T$, so that

$$\boldsymbol{E} = \boldsymbol{E}_s + \boldsymbol{E}_T \tag{3}$$

and following our intuition (which may be wrong) that there is some real significance to this resolution of $\boldsymbol{E}$ we may try to find sufficient definitions of $\boldsymbol{E}_s$ and $\boldsymbol{E}_T$ from their supposedly inherently different properties!

Thus we may believe that $\boldsymbol{E}_s$ arises from charges only, and that $\boldsymbol{E}_T$ arises from changing magnetic fluxes only, so that following Cohn* we define $\boldsymbol{E}_s$ and $\boldsymbol{E}_T$ by the following two pairs of equations.

$$\text{div } \boldsymbol{E}_s = 4\pi\rho \tag{4}$$

$$\text{curl } \boldsymbol{E}_s = 0 \tag{5}$$

$$\text{div } \boldsymbol{E}_T = 0 \tag{6}$$

$$\text{curl } \boldsymbol{E}_T = -\frac{1}{c}\frac{\partial \boldsymbol{B}}{\partial t} \tag{7}$$

However, if we confine ourselves and our knowledge of ρ and $\frac{\partial \boldsymbol{B}}{\partial t}$ to a limited region in space, such as outside the black box, and in its neighborhood, these equations 4 to 7 are not sufficient to determine $\boldsymbol{E}_s$ and $\boldsymbol{E}_T$. In that region we may make the field all "electrostatic," $\boldsymbol{E}_s$ or all "electromagnetically induced," $\boldsymbol{E}_T$, or quite arbitrary combinations of $\boldsymbol{E}_s$ and $\boldsymbol{E}_T$, and still satisfy equations 4 to 7.

Hence, this definition of $\boldsymbol{E}_s$ and $\boldsymbol{E}_T$ does not permit us to solve the problem of the essay and determine whether the field outside the black box is electrostatic, or electromagnetically induced.

If ρ or $\frac{\partial \boldsymbol{B}}{\partial t}$ respectively are known everywhere, so that equations 4 and 5 or 6 and 7 can be applied in our computation throughout all space, and if ρ or $\frac{\partial \boldsymbol{B}}{\partial t}$, respectively, are zero beyond some great distance, then $\boldsymbol{E}_s$ or $\boldsymbol{E}_T$ can be determined uniquely, from the defining equations. For example if ρ is known everywhere, then equations 4 and 5 give uniquely

$$\boldsymbol{E}_s = -\text{grad } \psi \tag{8}$$

where

---

* In my essays, generally I have given no literature references, as compiling such would be burdensome, and since I make no claim to scientific novelties in these essays. However, in this essay I do refer to Cohn (*EE, May '49, pp 441–7*), firstly, because of the very high excellence of the paper, secondly, because its pertinence to the subject of this essay, and thirdly, because it has appeared as recently in *Electrical Engineering*.

of the air; for the electromagnetic wave, $c=\sqrt{\frac{1}{eu}}$, where e is the dielectric constant and u, the magnetic permeability of the medium; and for the transverse waves on a stretched string, $c=\sqrt{\frac{\tau}{\rho}}$ where τ is the mean tension, and ρ the density per unit length of the string.

It is generally believed that the combination of equations 1 and 2 requires that $v=c$, and therefore c is frequently called the velocity of sound, the velocity of electromagnetic waves or light, or the velocity of transverse displacement waves, as the case may be. However, actually, c in equation 2 is a material constant calculated from purely static measurements on the system. That $v=c$ is only a deduction made by humans and subject to the usual uncertainty of the correctness of deductions of human origin.

For larger numbers of dimensions, as for example three, we still have

$$u=f(x-vt, y, z) \tag{3}$$

representing a wave travelling in the positive x direction with velocity v. Clearly, equation 3 represents a spacial configuration, $f(x, y, z)$ moving with unchanging amplitude along the x axis with velocity v.

Likewise, for three dimensions, we have a so-called wave equation,

$$\frac{1}{c^2}\frac{\delta^2 u}{\delta t^2}=\frac{\delta^2 u}{\delta x^2}+\frac{\delta^2 u}{\delta y^2}+\frac{\delta^2 u}{\delta z^2} \tag{4}$$

where c is a constant calculated from purely static measurements on the medium carrying the waves, and u represented by equation 3 must satisfy equation 4.

Again, it is generally believed that for all free waves travelling in some particular direction, as for example in the positive direction of x as in equation 3, we must have $v=c$.

This belief is particularly prevalent for electromagnetic waves in free space. Also, since the advent of relativity, the belief is particularly strong that to have v greater than c is most absolutely impossible.

Nevertheless, it is quite possible to write down functions of the form equation 3 which satisfy equation 4 and for which v is not equal to c. Such a function is, for example,

$$u=A \sin \frac{2\pi}{\lambda}(x-vt) \cos\left(\frac{2\pi}{\lambda}\sqrt{\frac{v^2}{c^2}-1}\,y\right) \tag{5}$$

For v we may take any number greater than c, and equation 5 will still satisfy equation 4.

To illustrate equation 5 for electromagnetic waves, take an infinitely long row of long antennas each parallel to the z axis. Let the row be arranged along the y axis, and let successive antennas be $\dfrac{\lambda}{2\sqrt{\dfrac{v^2}{c^2}-1}}$ apart. Excite each antenna with currents of frequency $f=\frac{v}{\lambda}$, but make the phases of the currents in adjacent antennas be opposite. Then the radiation field from this system of antennas will have electric and magnetic field components which are closely given by equation 5 and, therefore, constitute a wave in free space, having a direction of free propagation, x, and a velocity v greater than c.

If the reader prefers that v be less than c, then he may take the function

$$u=A \sin \frac{2\pi}{\lambda}(x-vt) \cosh\left(\frac{2\pi}{\lambda}\sqrt{1-\frac{v^2}{c^2}}\,y\right) \tag{6}$$

Infinitely many other functions of the form equation 3 may be found which also satisfy equation 4 and for which v is not equal to c.

We conclude than that electromagnetic waves in free space exist which travel respectively with any and all velocities, v.

How about this?

J. SLEPIAN (F '27)

(Associate Director, Westinghouse Research Laboratories, East Pittsburgh, Pa.)

Lissajous Figure

Cathode-ray oscillographs are sometimes used to compare waves of two alternating voltage sources differing in phase angle and wave form. One voltage is impressed on the vertical deflection plates and the other on the horizontal deflection plates. A figure is traced on the screen of the oscillograph. It is well known that when the same voltage is impressed on the deflection plates in both the vertical and horizontal axes the figure is a straight line with a 45-degree slope. When two equal sinusoidal voltages in quadrature are impressed on the deflection plates, the figure is a circle. What well-known figure will appear on the oscillograph screen when the two impressed voltages are of the wave forms given in the following?

$$e_1=75 \sin wt-25 \sin 3\,wt \tag{1}$$

$$e_2=75 \cos wt+25 \cos 3\,wt \tag{2}$$

A. A. KRONEBERG (F '48)

(Southern California Edison Company, Los Angeles, Calif.)

Answers to Previous Essays

Flux Linkage of an Open Circuit. The following is the author's answer to a previously published essay of the foregoing title (*EE, Nov '49, pp 984–5*).

I sympathize greatly with my Alter Ego for being confused by his friends, the electrical engineers. They do talk about the flux linkage of an open circuit, as if it had a general, and perfectly definite quantitative meaning, whereas a consistent, contradiction-free definition of flux linkage, suitable for electromagnetic theory, can be given generally only for a *closed* curve or circuit.

That contradiction-free definition is that the flux linkage of a *closed* curve is the integral of the normal component of the magnetic flux over a simply-connected 2-sided surface bounded by the *closed* curve. If the curve is not closed then it does not bound any 2-sided surface, and there is no flux linkage. (Careful, Alter Ego! I do not mean here that the flux linkage is zero. What I do mean is that the flux linkage is undefined and meaningless.)

Maxwell's equation, expressing Faraday's law of electromagnetic induction, given in modern vector analysis form is

$$\text{Curl } \mathbf{E} = -\frac{1}{c}\frac{\partial \mathbf{B}}{\partial t} \qquad (1)$$

where $\mathbf{E}$ and $\mathbf{B}$ are defined relative to some definite frame of reference.

"Curl" is a differential operation which can be defined independently of arbitrary co-ordinate axes, in terms of mathematical calculations from purely local observations or measurements of the vector $\mathbf{E}$ upon which "curl" operates. To determine the component in a given direction of curl $\mathbf{E}$ at a given point, consider a small "element of surface" at the point, perpendicular to the given direction; integrate $\mathbf{E}_s$ around the small *closed* curve bounding the "element of surface"; divide the value of this integral by the area of the bounded "element of surface"; take the limit of this quotient, as the "element of surface," retaining its orientation, approaches zero, the bounding curve converging on the given point. This limit is the value of the component in the given direction of curl $\mathbf{E}$ at the given point.

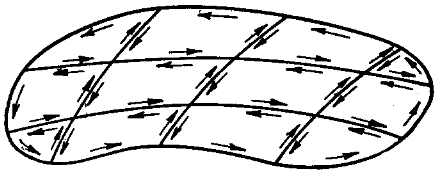


Figure 1. Surface built of surface elements

This definition of curl $\mathbf{E}$ makes equation 1 essentially equivalent to the following statement. For a small enough "element of surface," the integral of $\mathbf{E}$ around the small bounding curve is equal to $-1/c$ times the rate of change of the normal component of $\mathbf{B}$ multiplied by the area of the "element of surface."

We may build up large surfaces by the juxtaposition of these infinitesimal "elements of surface" as shown in Figure 1 of this answer. Adding up each $\mathbf{B}_n$ multiplied by its little area, we get of course, $\int\int \mathbf{B}_n dS$, taken over the whole surface, and the preceding paragraph leads us to assert that $-1/c$ times the rate of change of this surface integral is equal to the sum of the integrals of $\mathbf{E}$ around the boundaries of the various "elements of surface." But these boundaries form a network, and we see that in forming the sum of the integrals of $\mathbf{E}$, we integrate over each internal network portion twice, first in one direction and then in the other, making the net contribution to the integral sum of each internal network portion exactly zero. We are then left with only the external network portions, which form precisely the bounding curve of the surface. Thus the sum of the integrals of $\mathbf{E}$ around the curves bounding the "elements of surface" is equal to the integral of $\mathbf{E}$ around the *closed* curve bounding the total surface.

Thus, we see how Maxwell's equation 1 leads uniquely and irrevocably to statements connecting the values of $\mathbf{E}$ on a *closed* curve, with the values of $\partial \mathbf{B}/\partial t$ on the enclosed 2-sided surface. The meaning of the differential operator "curl" as explained in the foregoing, shows that Maxwell's equation 1 cannot possibly yield any general relation concerning the values of $\mathbf{E}$ on an open curve.

If we accept Maxwell's equation 1 as representing correctly and completely Faraday's law of induction, then Faraday's law must make assertions concerning voltage induced, only in *closed* curved paths or circuits, and flux linkage has meaning relevant to Faraday's law only for *closed* paths or circuits.

For Alter Ego's open key ring, we may close the open turn by drawing an arbitrary curve from the one end of the turn to the other, forming a closed loop. Flux linkage will have meaning for this closed loop, and the induced electromotive force, that is $\mathbf{E}$ integrated around this loop will be different from zero only when the flux linkage is changing, which will be when Alter Ego pulls his magnetized ring across the arbitrary curve.

In the case of the engineers and their machine, let us assume that the coil turn in question is in the stator, so that we do not need to discuss the electromagnetic properties of moving bodies, which we hope to consider in later essays. To give their flux linkage meaning, the circuit or path can be closed by joining the two coil ends by a curve lying wholly in the simply connected space outside the machine. We then see that the flux linkage of this resultant closed path is independent of how we draw this closing curve, so long only as it lies wholly outside of the machine. Thus, with the understanding that the closing curve is to be drawn wholly outside the machine, the engineer may speak of the flux linkage and induced voltage of the machine turn.

Similarly, for the voltage induced in a transformer winding, not short-circuited upon itself, and therefore open, we must to be consistent mean the voltage induced, or $\int \mathbf{E}_s ds$ taken, around a *closed* path including the winding and some arbitrarily chosen closing curve lying wholly outside the transformer case.

J. SLEPIAN (F '27)
Associate Director, Westinghouse Research Laboratories, East Pittsburgh, Pa.)

Network. The following is the author's solution to a previously published essay of the foregoing title (*EE, Nov '49, p 984*).

The impedance of the network in each box reduces to the same value and its performance is expressed by Heaviside equation:

$(R+.8Lp)i=e$ 1

It is, therefore, impossible to detect by external measurements the nature of the internal connections in the box. Were iron core transformers used in the networks the one with series-connected windings would give the same performance as an air core transformer. All the phenomena associated with saturation, hysteresis, and residual flux will be present in the network with parallel connected windings of an iron core transformer and the detection of this connection is therefore possible by external measurements.

A. A. KRONEBERG (F '48)
Southern California Edison Company, Los Angeles, Calif.

If $v(t)$ is obtained from an acceleration voltage $a(t)$ by integration, it is physically necessary that $a(t)$ be brought to zero when the position is limited. This can be done with another high-gain feedback path driven by the voltage across resistor R.

HOWARD HAMER

(Electronics Engineer, Bell Aircraft Corporation, Buffalo, N. Y.)

Electrostatic or Electromagnetically Induced Field?

To the Editor:

Dr. Slepian (*EE, Feb '50, p 188*) puzzles me. Taking the case of the resultant electric field within the conductor of a transformer winding on open circuit, he insists that the resolution of this (nearly) zero field into an induced field and an (almost) equal and opposite electrostatic field reflects no demonstrable reality.

He then defines potential difference as $\int \mathbf{E}\cdot ds$, provided the (one and only) electric field $\mathbf{E}$ has a potential, so that the result is independent of the integration path, and he defines electromotive force only for closed paths.

Now since $\int \mathbf{E}\cdot ds$ between the terminals of the open-circuited winding does depend on the integration path chosen (for if we follow the path of the winding between terminals we get (nearly) zero), there therefore can be no open-circuit potential difference. Yet I once measured what I was given to understand was the open-circuit potential difference of a transformer manufactured by a competitor of Dr. Slepian's company. I got a definite reading of volts with an electrostatic voltmeter. This "demonstrable reality" could not have been an electromotive force since the circuit was not closed, and it now seems that it was not a potential difference either. What errors the competitors of Dr. Slepian's company do fall into, to be sure!

E. G. CULLWICK (M'33)

(Professor of Electrical Engineering, St. Andrews University, Dundee, Scotland)

To the Editor:

I am sorry that I still puzzle Professor Cullwick. The case of induction in an open-circuited coil of an electric machine was specifically treated in my electrical essay, "Flux Linkage of an Open Circuit" (*EE, Nov '49, pp 984-5*), and in my answer (*EE, Dec '49, pp 1081-2*). There, I pointed out that in the space adjacent to and outside the usual electric machine the varying magnetic field is usually of negligible magnitude, and that therefore the electric field has a potential there. By that I mean, of course, that the integral of the electric force from one point of that region to another point is independent of the path of integration so long as the path remains in this region. It has meaning therefore to speak of the potential difference between two points in this region, and those two points might be the terminals of the machine, if we keep to this understanding that paths of integration are always to remain in this outside region. If we use voltmeters to measure this potential difference we must be careful to keep their leads entirely in this external simply connected region which is free from varying magnetic fields.

This property of having a potential in a limited region was true respectively for each of the two fields external to the boxes of Figure 2 and Figure 3 in my essay, "Electrostatic or Electromagnetically Induced Field" (*EE, Oct '49, p 887*). However, this property of having a potential in a limited region is not enough to characterize the field as necessarily electrostatic, even according to Professor Cullwick's arbitrary definition, for as I read his book, "Fundamentals of Electromagnetism," MacMillan, 1939, he would call the external field of Figure 2 all electrostatic, and that for Figure 3 all electromagnetically induced.

I hope this discussion up to this point takes care of the potential difference between the terminals of an open-circuited transformer. I agree that there is a potential difference there, so long as we limit our means for observing it, to lying outside and near the transformer case. However, this to me is not equivalent to saying that the field is all electrostatic. I would say that that question has no uniquely valid meaning, while Professor Cullwick, as I understand him, would say that before he could make a statement as to the electrostatic character of the field even though it has a potential outside the case, he would have to make sure the transformer case was not insulating, and if it was insulating, then he'd have to pry around inside the case before he would make a commitment.

Now, for the electromotive force of an open-circuited complete transformer winding, I certainly will not integrate the electric field along the winding from one end to the other, and call it the electromotive force. As Professor Cullwick says, I'll only get zero. I define electromotive force only for closed paths of integration. However, if I close my path of integration through the coil by a path outside the case, where the field has a potential, then the integral obtained is independent of where I take my closing path in the external region. Thus I give meaning to the engineer's electromotive force of an open winding when that winding can be closed by a path external to the machine, by defining it as the integral of the electric force around the path so closed. It will of course be the same as the potential difference between the coil terminals, this potential difference being defined over paths lying external (see *EE, Dec '49, p 1082, col 2*).

For a part of a coil which cannot be closed by such an external path (for example a half-turn), I give no interpretation of what an engineer might mean by the induced electromotive force. Actually such an electromotive force never appears in any final design or calculation of the engineer. Professor Cullwick believes that he can define such an electromotive force. This I do not deny, but merely point out his definition is arbitrary, and requires knowledge of all the varying magnetic fields in the universe before he can apply it in any case.

I hope this letter may relieve somewhat the puzzlement which I seem to induce in Professor Cullwick.

J. SLEPIAN (F '27)

(Westinghouse Research Laboratories, East Pittsburgh, Pa.)

NEW BOOKS • • • • •

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

BEAMA CATALOGUE 1949–50, published for the British Electrical and Allied Manufacturers' Association, 36 and 38 Kingsway, London, W. C. 2, England, by Iliffe and Sons Limited, Dorset House, Stamford Street, London, S. E. 1, England. 852 pages, illustrations, diagrams, tables, $11^{3}/_{4}$ by 9 inches, cloth, for private distribution. The comprehensive range of products which members of BEAMA can supply is illustrated and described in this collective catalogue which brings together in a compact and convenient manner information for the overseas buyer on products and services of a great industry. Data are grouped alphabetically by firms in three broad divisions: power plant; industrial equipment; domestic and commercial apparatus and appliances. A short account of the history and work of the BEAMA is also included.

ASTM STANDARDS ON COAL AND COKE. Prepared by ASTM Committee D-5 on Coal and Coke, October 1949. American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa. 729 pages, illustrations, diagrams, charts, tables, 9 by 6 inches, paper, $2. This booklet brings together all of the ASTM standards on coke and coal. It gives 28 test methods, specifications, definitions of terms, and numerous proposed methods. Coal sampling, analysis for volatile matter in connection with smoke ordinances, grindability, drop shatter test, tumbler test, screen analysis, size, sieve analysis, cubic foot weight, index of dustiness, and free-swelling are covered for coal and coke.

CHARACTERISTICS OF ELECTRICAL DISCHARGES IN MAGNETIC FIELDS. (National Nuclear Energy Series Division 1—Volume 5.) Edited by A. Guthrie and R. K. Wakerling. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1949. 376 pages, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, linen, $3.50. Covering most of the investigations carried out at the University of California Radiation Laboratory, this book considers the subject with main emphasis on discharges in the vapors of uranium compounds. The majority of the papers presented are based on reports written for use within the Manhattan Project. It is hoped that the data included will make an important contribution to the understanding of the theory of gaseous discharges and indicate areas for fruitful investigations.

COMMUNICATION CIRCUIT FUNDAMENTALS FOR RADIO AND COMMUNICATION ENGINEERS. By C. E. Smith. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1949. 401 pages, illustrations, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, cloth, $5. Second of a projected 4-volume series of which the author's "Applied Mathematics" was the first, this book covers the physics of circuit elements, including vacuum tubes, and discusses the fundamentals of a-c and d-c circuits. In general, each chapter presents the theory, develops design equations, applies them to practical problems, which are completely worked out, and presents exercises for chapter review.

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