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THE MAGNETIC CIRCUIT.

The Magnetic Circuit. By H. du Bois, Ph.D. Translated by E. Atkinson, Ph.D. Pp. xviii + 362. (London: Longmans, Green, and Co., 1896.)

NO one is better fitted than Dr. du Bois to write a treatise on the magnetic circuit. He is well known for his experimental investigations in magnetism, and abstract magnetic theory is clearer and more comprehensive for his restatement of its main propositions. His German treatise, "Die Magnetische Kreise," published some five years ago, attracted considerable attention in this country. It gave in reasonable compass an excellent account of magnetic theory, methods of magnetic measurement, and of recent magnetic research, in which Dr. du Bois' own contributions to knowledge formed an important part, not merely on account of their intrinsic value, but of their clear and first-hand and withal modest statement.

A translation of this book, made by Dr. Atkinson with the assistance and revision of the author, and one or two other experts in the subject, was published in 1896, and was thoroughly welcomed by the already considerable and continually increasing number of experimentalists in electricity and magnetism. Some apology for so late a review of so important a work is necessary, and this is now offered by the reviewer, whose fault it has been that an account of it has not long before now appeared in NATURE. Still "good wine needs no bush," and the work of Dr. du Bois carries its own guarantee of excellence on the face of it.

The book begins with a very valuable summary of magnetic quantities and conceptions, in which the fundamental ideas of magnetic force, magnetic induction, intensity of magnetisation, permeability and susceptibility, &c., are fully explained, and the graphical representation of their values for actual cases is fully illustrated by curves of induction and magnetisation obtained for actual specimens of iron and steel.

The question of the effects of the ends of a bar of magnetised iron or steel, or of a narrow crevasse or joint between two parts of a bar or ring, is taken up towards the end of Chapter i., and is continued in Chapter ii. Ewing's representation of the effect of the cut, by a shearing of the curve of magnetisation for the uncut bar or ring, is given, and illustrated, as before, by the results of actual investigations—mostly those of Ewing himself. The effect of a cut leads to a further discussion of that of an end, and thence to a discussion of Coulomb's law for the distance action of a magnetic pole, and of the field at a point due to a pair of equal and opposite "point-charges" of magnetic matter.

Of course this action at a distance is what is actually observed, and there is an advantage in starting with what are the immediate results of experience. Still, if the book, as no doubt it will, should pass soon to a new edition, we should like to see some account of a more "mediumistic" view of the matter included. It is possible, and in connection with the electromagnetic theory of light it is very desirable, to consider magnetic force and magnetic induction not only as both existing

as directed quantities at every point of a magnetised body, but at every point of the electromagnetic field, in ether or other "interferric" material, as well as in iron itself. With electric induction and electric intensity also introduced as the analogues of the magnetic quantities, with k for the electric inductivity, and μ for the magnetic inductivity of the medium, whatever it may be, all difficulties as to units disappear if k and μ are regarded as depending upon real physical properties of the medium which, if fully known, would determine the dimensions of these quantities, and $1/k\mu$ is seen in a natural way to be the square of the velocity of propagation. The serious difficulties which students feel with respect to this matter, and which are only apparently overcome by an unsatisfactory process, are entirely avoided.

In Chapters iii. and iv. we have an Outline of the Theory of Rigid Magnets, and a discussion of Magnetic Intensity and Magnetic Induction. The account of rigid magnetism and of induction here given is based in the main on that source of all theory on the subject, Lord Kelvin's Mathematical Theory of Magnetism, and on the digest of this part of the subject given in Maxwell's great treatise, and includes most of the more valuable results obtained by Kirchhoff, and by later writers who have commented on or developed the theoretical principles laid down by these masters. Here Dr. du Bois has himself done good service. He has given solutions of important problems of induction, and generally, as stated above, in certain points improved the presentment of theory; work of which English readers now reap the full advantage.

A chapter on the Magnetisation of Closed and of Radially Divided Toroids, which is divided into two parts—(a) Theoretical; (b) Experimental—closes the first part of the treatise. This chapter is exceedingly important. Kirchhoff's theory of the magnetisation of a solid of revolution is given, and its results for rings of rectangular and circular section are deduced. This investigation of Kirchhoff's gave rise to the experimental investigations of Stoletow and Rowland, the results of which have only confirmed its correctness.

Results are next deduced for a radially divided ring, which are fully illustrated in the experimental investigations described later. Thus we have the subject of leakage of magnetic induction introduced and clearly discussed and illustrated. The great practical importance of this part of the subject will be obvious when its application to dynamo machines is considered, and a large part of the experimental investigations which have been carried out have had to do with the question of the distribution of tubes of induction in or near more or less narrow gaps in what may be regarded as closed circuits or rings of iron.

The great importance of having a magnetic circuit nearly closed was recognised by Faraday, and was more or less present to the minds of makers of magnets, both permanent and electro, down to the beginning of the present active manufacture, on a large commercial scale, of dynamo machines.

Then it was that Hopkinson came forward with his explicit statement of the laws of the magnetic circuit, and their application to the construction of the field magnets of dynamos, a piece of work for which practical

science owes him a heavy debt. The magnetic circuit, and the mode of testing the performance of dynamo machines by means of characteristic curves, which themselves give valuable information regarding the magnetisation of the circuit, really did for the dynamo machine very much what practical thermodynamics and the indicator did for the steam-engine.

After an account of the General Properties of Magnetic Circuits, Dr. du Bois proceeds in his Chapter vii. to a discussion of the Analogy of the Magnetic Circuit with other Circuits. Here the author, as we think very properly, condemns the use of the term "Ohm's Law" to express the fact that magneto-motive force in the circuit divided by the magnetic reluctance is equal to the flux of induction in the circuit. This, it has always appeared to us, is using the term "Ohm's Law" to describe what is a mere result of definition. The equality of the magneto-motive force multiplied by the permeance (permeance = $1/\text{reluctance}$) of the circuit to the flux of induction is a result of definitions of induction and field intensity, and to thus use it to introduce into magnetics the confusion which many have fallen into with regard to the law of Ohm in voltaic circuits. In the latter case, the law, properly speaking, expresses the proportionality of the current in a conductor to the difference of potential between two points in the conductor near its ends when the conductor is not the seat of any internal electromotive force. This result has no counterpart in magnetic circuits, and no "Ohm's Law" holds there.

In Chapter viii. the Magnetic Circuits of Dynamos or Electromotors is dealt with, the work of the brothers Hopkinson, the empirical formulæ for the magnetisation curves of such machines given by Frölich and others are all described, and the application of all this thoroughly practical theoretical discussion is focussed on the construction and arrangement of the field-magnets and armature of the machine.

We are immediately carried on in a natural sequence to magnetic cycles and hysteresis, and the immensely important researches on the magnetic properties of iron carried out by Ewing and others. The results in this field are, however, before all our readers specially interested in the subject, and the subject is so large and so full of detail, that we cannot with any advantage continue our sketch of the contents of the book.

The magnetic circuits of electromagnets, containing an account of the devices used by Ewing and the author to obtain very intense fields, and of methods of measuring such fields, is given in Chapters ix. and x. Up to about fifteen years ago determinations of field intensities had been confined to measurements of the earth's field-intensity or intensities of like magnitude, and a paper (*Philosophical Magazine*, 1882) by the present writer, describing methods which were in use in the Glasgow University Physical Laboratory, contained perhaps the first published statement of how the field between the poles of a powerful electromagnet could be quickly and accurately measured.

In this connection also we have one of the author's notable contributions to magnetics, in his account of the researches which he carried out at Berlin on the magneto-optical method of measuring intense fields.

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Here we must conclude our review of a most fascinating book. It cannot be praised too highly as a piece of work sound from every point of view, and tending to the advancement of knowledge. Dr. Atkinson and his colleagues have performed their work of rendering the book into English very carefully indeed, and on the whole the version reads like a book originally written, and well written, in English. Only in one or two places have we found, in a fairly extensive comparison of the German and English, that the sense has not been exactly caught. For example, at p. 340 a method of investigation there referred to is rather hardly treated by being described as "circuitous." The German "umständlich" ought here to be rendered by "circumstantial."

A. GRAY.

AUDUBON.

Audubon and his Journals. By Maria R. Audubon. With zoological and other notes by Elliott Coues. 8vo. Two vols. Vol. I., pp. xiv + 532; Vol. II., pp. viii + 554. Portraits, copies of diplomas, photographs, &c. (New York: Charles Scribner's Sons, 1897.)

NATURALISTS and many who are not naturalists will find this an entertaining book. It gives in great detail the incidents of certain years of Audubon's life, years in which he was carrying on his work in the field, or else meeting every day men who are still noteworthy. The book is founded upon unpublished journals and letters, of which parts are given at length. All has been corrected by recollections handed down in the family, and the zoological information has been revised by Dr. Elliott Coues. A summary of the naturalist's life is prefixed. We have now a full and lively account of what is most memorable in the life of Audubon.

Some readers who are not naturalists will turn with curiosity to the passages in which mention is made of places which are now populous American cities, but which, when Audubon dwelt there, or passed through, were backwoods settlements. Others will be glad to note small particulars concerning the naturalists, merchants, and men of letters whom Audubon saw during his visit to Europe in 1826-29—Cuvier, Bewick, Jameson, Selby, Jardine, Rathbone and Roscoe. Others again will study the character and methods of a man, who partly by real merit, and partly by the good-luck of becoming known to men who could write, has been widely accepted as a typical naturalist. Some of us can hardly remember the time when we had not heard of Audubon as the man who faced all dangers and fatigues, caring nothing for comfort or profit, if only he could learn more and more of the wild creatures which fly from the face of man. There is matter here for readers of very different kinds, and all should thank those who have rescued so many old papers, and arranged them so carefully.

Audubon was a real naturalist, if ever there was one. He had the passion for observing and drawing birds almost as a gift of nature. As a boy and young man he was fit for nothing else, but the responsibility which a family brings made him in middle life a sensible man of business. He was never a man of science. He never received from others, nor gave himself any kind of training in scientific method; he never studied the anatomy of