contributed by the editor. Between the general principles and practice of management come sections dealing with what are described as the major divisions of management: distribution, production, personnel and control. Each of these has been contributed by a specialist with considerable practical experience in his own field.

Under distribution, the author includes all direct and incidental sales activities, advertising, public relations, warehousing, stock control and transport. The author of the section on production describes such activities as design, production methods, work measurement, production planning, production control, supervision, buying, store-keeping, works maintenance and inspection. The personnel function of management is described as the nervous system of the organization and includes such topics as industrial relations, training and promotion and withdrawals, physical working conditions, employee services and the mechanics of arbitration. Control is mainly concerned with the financial aspects of management and deals with such processes as the preparation and use of budgets, the application of budgetary control, cost control and clerical management.

In a book with such a wide range of authorship, it is not surprising to find over-lapping and variation in principle and details between author and author; the editor has, in fact, made no attempt to circumscribe the authors so that they would write to an agreed body of principles. What is surprising is that so much of the over-lap consists of tedious repetition and that much of the text is loose, contradictory and, too often, inaccurate.

More serious is the claim that this book should be regarded as the reference book for those wishing to practise 'scientific management'. The whole book is unquestionably founded upon good practical experience; this does not preclude the possibility that other students of management with equally good practical experience might present their ideas on management in a different way. It is questionable, too, whether this essay in empiricism might not have served a better purpose if it had appeared, not as a declared reference book, but as a series of much shorter volumes dealing with particular aspects of the management function; each of the volumes could then be superseded as new knowledge and experience are gained in a branch of study which its most ardent exponents still believe to be in the very early stages of growth. T. H. HAWKINS

# INFORMATION THEORY MADE EASY

## Probability and Information Theory, with Applications to Radar

By P. M. Woodward. (Pergamon Science Series: Electronics and Waves—a Series of Monographs.) Pp. x+128. (London: Pergamon Press, Ltd.; New York: McGraw-Hill Book Co., Inc., 1953.) 21*s*.

EVEN an author with Mr. Woodward's ability of explaining complicated matters in simple and attractive language is rather too severely handicapped if he has to explain information theory on 125 small pages, leading up to three specialized chapters on radar, and if on the way he has to explain all the mathematics required, from probability to Fourier integrals. In this process of condensation and popularization a few things must go by the board. Mathematical rigour is the first victim, and the least regretted. A more serious loss is, in the present case, that this little book may not be a very suitable introduction to the more recondite works on communication theory. Mr. Woodward has followed an 'easy way' of his own invention, which is smooth enough as far as it goes, but is likely to become an impasse later on.

Statistical communication theory centres on Claude Shannon's fundamental theorem: there exists a maximum amount of *certain* information which can be transmitted per symbol *on the average* from an ergodic source through a noisy channel. This maximum can be approached to any limit by suitable coding methods, which deal with the messages in large lumps of symbols. The theorem says nothing about individual messages; evidently a single, short message can convey no certainties whatever.

If $p(x)$ is the probability of a symbol $x$ being sent, if $p(x,y)$ is the joint probability of $x$ being sent and $y$ received, and if $p_y(x)=p(x,y)/p(y)$ is the conditional probability of $x$ having been sent when $y$ is received, the upper limit is

$$H(x)-H_y(x)=-\sum_x p(x)\log_2 p(x)+\sum_x\sum_y p(x,y)\log_2 p_y(x)$$

measured in 'bits' per symbol, that is to say in terms of binary decisions. It is worth while stating this theorem in some detail, because it comprises implicitly perhaps 90 per cent of present-day statistical communication theory—among others the results of Woodward and Davies on radar information. There is, of course, the danger that one may be inclined to forget one or the other of the unfamiliar qualifications in such a long statement.

Mr. Woodward's 'easy way' panders to this human weakness by giving a *detailed* interpretation to the terms which occur in the theorem, and suppressing, at least temporarily, the all-important stipulation 'on the average'. In his view, if a symbol $x$ is received whose *a priori* probability was $p(x)$, there is a transfer of information of the amount $\log_2 p(x)$ bits. If the transmission is marred by noise, one must deduct from this the logarithm of the *a posteriori* probability of $x$ being meant, which is less than certainty. This is a detailed interpretation, quite similar in nature to Ampère's law of the interaction of two 'current elements', or to Poynting's picture of the energy flow, which is a detailed interpretation of the energy integral in Maxwell's theory. The danger of these detailed pictures is that one forgets that they operate with undefined and undefinable quantities. 'Current elements' do not exist, the energy flow density cannot be measured, and information transfer is an empty word until one averages it over long messages. Yet, the didactical and stimulating value of this sort of approach cannot be denied. After all, even Maxwell's field theory is an over-detailed picture, whose purpose is to account for the energy and momentum exchanges between charged particles, which alone are measurable. One must forgive Mr. Woodward all his verbal operations for a stimulating sentence such as "the ideal receiver must directly display the *a posteriori* probabilities".

By and large, this little book admirably fulfils its purpose of making a tasty dish for the moderately mathematically minded engineer out of the driest and most indigestible fare, and giving him a little intuitive understanding in preference to a full-blown inferiority complex. D. GABOR