

numbers are classified under the heading "Other Special Sorts of Complex Numbers," while the older papers are properly classified under the heading "General." Again, Hamilton groups are classified under "Quaternions," and not as one would expect under "Groups." Occasionally the subdivision of headings is carried so far as to be a hindrance instead of a help. For instance, references to papers on matrical equations are scattered over five separate headings, instead of being under one heading with two or three subheadings. Several short notes also have been omitted which might well have found a place. A short note appearing early in the development of a subject is of more importance than a similar one appearing at a later stage. If it was impracticable to classify all such notes minutely, they might have been given under the main headings without any subclassification.

Another difficulty which is likely to occur now and again in the use of the Index is that occasionally short papers are published for the first time in the collected works of an author. Such papers are not classified in the Index, which only includes periodicals in its list. In the case of matrices, too, several interesting accounts of the subject have appeared as appendices to treatises having no direct connection with this subject except in so far as matrices are required for some portions of the analysis. Such articles are of course not indexed, although they are sometimes of some importance.

Such criticisms of detail might no doubt be carried much farther; they affect, however, only points of comparatively small importance, and do not affect materially the great service which the Index will render to the mathematical public. At a moderate estimate it will lessen the labour of forming bibliographies, or of hunting up references, by considerably more than one-half. An exceedingly useful feature of the work is a list of periodicals which gives the names of the principal British libraries in which they are to be found. This should effect a great saving of time for those who are not so fortunate as to be situated close to any of our principal libraries.

The Index is published by the Cambridge University Press, and, as is usual in books published by them, the printing leaves nothing to be desired.

#### MODERN MARINE ENGINEERING.

*Marine Engineering (a Text-Book).* By Engineer-Commander A. E. Tompkins, R.N. Third edition, entirely re-written, revised, and enlarged. Pp. viii + 812. (London: Macmillan and Co., Ltd., 1908.) Price 15s. net.

MARINE engineering has been developed in many directions during recent years, and the influence of these developments upon the design of steamships has been marked. Within a period of fifteen or sixteen years water-tube boilers have practically taken the place of cylindrical (or "tank") boilers in all classes of warships; steam-turbines have been introduced for ship-propulsion, and have already superseded reciprocating engines in the Royal Navy,

while growing in favour in other war-fleets and in mercantile steamships; oil-fuel has been adopted as a supplement to or substitute for coal; and now internal-combustion engines are being introduced and greatly increased in size and power. It is a natural consequence of these changes that numerous additions should be made to the literature of the subject, and that new editions of standard text-books should appear.

Among these text-books, intended primarily for the use of students, the work under review holds a distinguished place. The author is an experienced engineer officer of the Royal Navy, who has served long at sea in charge of machinery, and has also been occupied for some time as instructor and lecturer in marine engineering at the Royal Naval College, Greenwich, and the Royal Naval War College. At both these establishments he had to do chiefly with naval officers, whose technical knowledge of engineering was much the same as that of students beginning work on the subject. He has consequently given explanations of both theory and practice in simple language, which makes the book serviceable, not only to students of marine engineering, but to general readers desirous of obtaining acquaintance with modern methods and the most recent designs of marine engines and boilers. This third edition is virtually a new book—re-written and considerably larger than its predecessors—bringing information up to date. It deals briefly with types of boilers and machinery which have been made obsolescent by the progress of recent years, and aims at the presentation of "a summary of the best practice of the present day." It is but justice to the author to say that this intention has been realised.

The theory of thermodynamics is treated in an elementary manner, and its applications to the formation and expansion of steam are explained. One section is devoted to marine boilers, and the various types of water-tube boilers now in use are fully described. Another section treats of combustion, giving details of the methods adopted for efficiently burning coal and liquid fuel, and particulars of the various kinds of liquid fuel now in use. The conclusions reached by the author are that, for a given weight of coal and oil, oil gives from 25 to 30 per cent. greater energy, reduces the space for stowage by 10 per cent., makes it much easier to replenish fuel-supplies, and decreases the number of firemen by 50 per cent. The determining factor in regard to the extended use of oil-fuel is now, as it has been for the last twelve years, the question of adequate supplies at reasonable rates. Reciprocating engines still hold the field in the mercantile marine, and are described at length in their latest forms. Condensers, evaporators, feed-water systems, superheaters, and other accessories also come under review; and so does auxiliary machinery of various kinds—including steering and capstan engines, refrigerating apparatus, air compressors, hydraulic machinery, electrical apparatus, and other classes of machines, all of which are essential to the efficient working of a modern steamship. The care and management of propelling

and auxiliary machinery and boilers in a modern steamship involve great responsibility, and an interesting section of the book is devoted to the discussion of the preservation and repair of boilers, the adjustment of machinery, and the duties of the watch-keeping engineer. A comparatively brief sketch is given of the modern theory of the resistance experienced by ships when moving through water, and of the conditions influencing the efficiency of propellers. In all cases the author illustrates his conclusions by modern instances and recent experiments, showing himself to have been a diligent student of published data. This is a distinctive feature of the book throughout.

The final section describes "recent developments" in marine engineering, including marine steam turbines and the applications of internal-combustion engines to ship propulsion. The Parsons type of turbine naturally receives most attention, having been applied so much more extensively than any other type, and the descriptions and illustrations are excellent. The arrangements of turbine machinery described include those of battleships, cruisers, the latest Cunarders, and certain small, swift vessels of the destroyer class. A summary of the results obtained on contract trials and actual service is also given. It is interesting to note how rapidly the Parsons system has made its way abroad as well as at home. So far, its only rival—and that at a very great distance—is the Curtis turbine, which has been successfully applied in the United States scout-cruiser *Salem*, of which the contract trials took place subsequently to the completion of the book.

In regard to internal-combustion engines the author gives much information, indicating the features in which they must still be regarded as experimental, as well as those in which they promise a possibility of further advances in speed and fuel-economy.

The volume is well produced, has a good index, and contains about 400 illustrations. It deserves and will secure a good reception from all who are interested in the subjects of which it treats. The author has the courage of his opinions, and, in not a few instances, exception may be taken to his conclusions; but in all cases the materials for judging independently are given, and readers can claim no more.

W. H. WHITE.

#### THE MOON'S MOTION.

*The Inequalities in the Motion of the Moon due to the Direct Action of the Planets.* By Prof. E. W. Brown, F.R.S. Pp. xii+93. An Essay which obtained the Adams Prize in the University of Cambridge for the Year 1907. (Cambridge: University Press, 1908.) Price 6s. net.

PROF. BROWN is much to be congratulated on having at length written the word "Finis" to his lunar theory. His achievement has been a very great one, for he has completely solved the problem that he had proposed to himself, viz. the motion of the moon under the attraction of known bodies; he has pushed his solution sufficiently far beyond the

standards required by observation to cover any probable increase in the accuracy of observation during the near future; his mathematics have been elegant, and his numerical computations performed under systems of check that command, not only his own confidence in their accuracy, but that of his readers. At last, therefore, we are entitled to say that any discrepancy between theory and observation must be attributed to fresh causes and not to imperfect calculation. A similar remark has somewhat readily been made before after the completion of other lunar theories, but a degree of numerical accuracy far beyond Hansen or Delaunay may safely be claimed for Prof. Brown's theory.

The memoir especially under review is the investigation of the direct action of the planets, which was recently awarded the Adams prize in the University of Cambridge. The subject was unknown to Hansen, whose tables are still in use. In 1876 Prof. Newcomb discovered an empirical term in the moon's motion. Shortly afterwards Mr. Nevill attributed this term to the action of Jupiter. Some years then elapsed, and Dr. G. W. Hill gave a computation of the new term, and a little later Radau computed a large number of planetary terms in the moon's longitude. It is remarkable that both Hill and Radau gave  $0''.90$  as the coefficient of Newcomb's term, and both of them were 20 per cent. in error. Radau's results are in other respects free from sensible error, and it is unfortunate that the term which started the whole subject should have been the one most difficult to calculate with accuracy. Quite recently Prof. Newcomb and Prof. Brown have published their researches. It is clear that the latter has reached a higher order of accuracy, but the former's memoir is probably amply good enough for comparison with observation. They agree in an increased coefficient of  $1''.1$  for Newcomb's empirical term. It is not possible to compare either investigation with the other at any intermediate stage before the conclusion.

This is perhaps the time to give an answer to the question, How will the actual motion of the moon agree with Prof. Brown's theory? We have already expressed our belief that any want of agreement will point to the action of unknown causes. Possibly, therefore, Prof. Brown's work will be even of more importance if his tables fail to predict the motion of the moon than if they succeed.

As regards short-period inequalities, we believe that Prof. Brown's tables will be practically perfect. We should like, however, to invite the attention of astronomers in thirty years' time to one point. Let every discordance between observation and tabular position be multiplied by the sine and cosine of the moon's longitude and the mean taken. If this be done for the last fifty years, the result is too large to attribute to accidental error; nor will the alteration of the moon's parallax and the insertion in the new tables of a Venus term with coefficient  $0''.7$  entirely remove the difficulty. Possibly the past observations have been affected by a systematic error, but be the cause what it may, the point is worth remembering and looking into when the proper time comes.