

vides just what is wanted to meet this requirement with all needful accuracy. He has computed a set of auxiliary tables from which the required results may be extracted with a fair degree of rapidity. It is in the explanation of the use of these tables that I fear the Dutch language may prove a difficulty to some would-be users of the method.¹

I shall not try to explain the process in detail, but will only sketch the ideas on which it is founded. It is assumed that sufficient accuracy will be obtained if the phase of each of the constituent tides is specified to the nearest exact hour of mean solar time. It is easy to compute the fall and rise of any constituent tide for successive hours. For example, suppose that we consider the tide M_2 , that its amplitude is, say, 174 (expressed in cm. or any other unit), and that we designate the hour of its high water as 0 h.; then its march would run thus:—

h.	0	...	174		h	3	...	9
	1	...	152			4	...	-76
	2	...	92			&c.		&c.

Now if at any given place, and on any given day, we find the incidence of the high water of M_2 to the nearest clock hour, it is easy to write down the successive heights from the table in a schedule numbered from 0 h. to 23 h. If, for example, high water of M_2 is found to occur at 13 h. of clock time on the day in question, we should write 174 opposite 13 h., 152 opposite 14 h., and so on. The same process may be carried out for each of the principal component tides, and the sum may be obtained for each hour of the twenty-four, thus furnishing the resultant height of water. Auxiliary tables are furnished by Dr. van der Stok from which it is easy to determine the incidence of each partial high water in clock time, and tables of fall and rise are given for any required amplitude.

I should guess that it would take from twenty minutes to half an hour to compute and draw a fairly accurate tide-curve for any given day. If this estimate is correct, it would take a computer a month to draw a tide-curve for a whole year. Probably the work would be quicker when the tide is to be found for a succession of days, and in any case the task would not seem to be prohibitive to compute a year's tide-table with accuracy sufficient for practical purposes.

The paper also gives an example of the synthesis from harmonic constants of the tidal currents at a place called Sembilangan. This last statement may well prove almost unintelligible even to a man versed in tidal work. For a full explanation I must refer the reader to Dr. van der Stok's "Études des Phénomènes de Marée sur les Côtes Néerlandaises."² Four of this series of papers have been already published by the Nederlandsch Meteorologisch Instituut. I have not seen the first, but the second and third are dated 1905, while the last is of later date than the paper which we are now reviewing. I gather that the first of the series gives a method of obtaining tidal constants from observations taken every six hours, and the subject is resumed in the last paper, which contains an immense mass of information about the constants along the whole length of the Dutch coast. But I must revert to the subject of tidal currents discussed in the second and third of the series, and explain in outline what is meant by the harmonic analysis of tidal currents.

¹ Something of the kind has been done by Harris in his "Manual of Tides," part iii., p. 183. His procedure seems to be more elaborate, and probably more accurate, but also less rapid than that devised by Dr. van der Stok.

² These papers ought to have been noticed in the article "Bewegung der Hydrosphäre" of the German Encyclopædia of Mathematics. My article was really written before the publication of Dr. van der Stok's first three papers, but in the subsequent and final revision for the press I carelessly took these papers merely to relate to local hydrography. References are given in them to other papers by MM. Phaff, Petit, van Heerdt, &c., on the hydrography of the Dutch coast.

The author caused a large number of observations to be made from light-ships off the Dutch coast, and then undertook to make an elaborate study of the tidal currents which had been noted. He found it possible to define the velocities and phases of the components of current by means of a notation analogous to that used in defining the rise and fall of the tide. Thus the velocities for the several kinds of tide were specified in centimetres per second, and the phases by angles analogous to the κ 's in use in the more ordinary harmonic analysis. A similar investigation had been carried out at Sembilangan, in the Dutch Indies, and it is the result for that place which is given in the paper under review.

It is clear that the harmonic constants which define the horizontal motion of the water cannot claim a high degree of accuracy, but it affords a conspicuous advance that the attempt should have been made and crowned with a certain amount of success.

The vortices off the Dutch coast are very complicated, and the author refers to Airy's theory ("Tides and Waves," §§ 358-63) as affording in some measure an explanation of the facts, although he does not find the explanation by any means complete.

In No. ii. of the papers to which I now refer, Dr. van der Stok integrates, for the light-ship station of Schouwenbank, the expressions for the components of velocity, and thus finds the trajectories of a particle of water under the influences of the tides M_2 , S_2 , and M_1 ; he also determines the general drift of the water. The figures illustrative of his conclusions are very interesting, and I commend these papers to the notice of all who are interested in tidal theory.¹

G. H. DARWIN.

THE LEANING TOWER OF PISA.

THE first stone of the campanile of Pisa was laid in August, 1174, by Bonanno of Pisa and William of Innsbruck, but accounts given us by various authors are very conflicting and uncertain in regard to the construction of this splendid work of art, which, after being interrupted several times, was completed nearly two centuries later.

The tower, which is entirely of white marble, is of cylindrical shape, hollow in the centre, with a spiral staircase constructed in the thickness of the outer wall which leads up to the belfry floor. The first tier is surrounded by fifteen large columns, with vaulted arches half-encased in the wall, and the six upper tiers are each decorated by an equal number of peristyles with arches, supported by altogether 192 isolated columns. The eighth and last tier, of smaller diameter, on which are placed the bells, was constructed, according to tradition, by one Tommaso, architect and sculptor, a pupil of Andrea Pisano.

As is commonly known, the tower, the height of which is about 56 metres, has a noticeable leaning on its axis, and the cause of this leaning gave rise to bitter controversy among the Pisan writers in past centuries, some of whom attributed the strange piece of architecture to the high ingenuity of the builders, while others more reasonably maintained that the explanation was to be sought in the instability of the Pisa subsoil.

The recent investigations of a competent Government Commission, composed of Profs. Mario Canavari, Paolo Pizzetti, and Agenore Socini, and Drs. Giovanni Cuppari and Francesco Bernieri, have not only confirmed that the leaning of the tower is certainly due to a subsidence of the ground, but that this

¹ Similar results will be found in Hellard Hansen and Nansen's "Norwegian Sea. Report on Norwegian Fishery," vol. ii., 1909, No. 2, p. 107; and Miss Kirstine Smith's "Gezeitenroccern," Havelundersøgelser, vol. ii., No. 13, 1910.

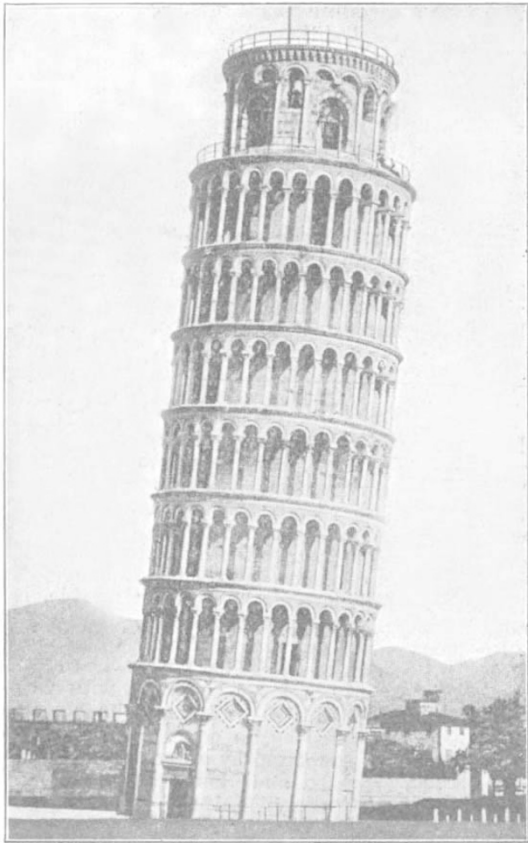
subsidence has gone on increasing in the last eighty years, and this serious conclusion has attracted the attention of competent authorities.

The investigations of the Commission have clearly brought out the following facts:—

(1) The tower does not rest on a mass of masonry extending over the whole area of the circular base, as was hitherto supposed, but is supported only by a more limited annulus of masonry corresponding to the cylindrical form of the superstructure.

(2) The foundations, hitherto supposed to be about 8 metres deep, are, on the contrary, much more superficial, and hardly sink to 3.60 metres below the level of the ground.

(3) A spring of water rises at the junction of the foundations with the surrounding permeable earth, causing serious damage to the foundations them-



The Leaning Tower of Pisa.

selves. A tank excavated near the tower in 1839 for the purpose of maintaining the surrounding basin dry and preserving the base in good condition was made very deep, and much below the level of the actual edge, thus collecting other waters, which were pumped out regardless of the safety of the tower.

(4) The slope of the tower, according to the measurements made in 1829 by Messrs. Cresy and Taylor, which may be regarded as correct, was, from the first to the seventh tier, 86.5 mm. per metre of height. The slope, as now determined by optical appliances by Prof. Pizzetti, and directly by the plumb-line by the engineers, Drs. Cuppari and Bernieri, is—again from the first to the seventh tier—92 mm. per metre. The slope has therefore increased $5\frac{1}{2}$ mm. per metre, and there is thus an external displacement of 2.868 metres, and a total deviation of the axis, from the first to the

seventh tier, of 3.265 metres, exceeding that found by the English observers in 1829 by nearly 20 centimetres.

The Commission has not been able to decide whether the increase in the leaning took place gradually or at intervals as the result of different causes. One such cause might be the excavation of the tank and the ill-advised pumping operations already mentioned; another might be sought in the effects of the earthquake of 1846, which was fairly violent at Pisa, and, as asserted by Leopoldo Pilla in his account of the times, caused the tower to oscillate in an alarming way. "Those people who had the opportunity of observing it during the shock," writes the great geologist, "assure me that its swaying was a terrible sight."

In spite of these serious conclusions, the Commission is nevertheless unanimously of opinion that the famous tower of Pisa still possesses good stability, and that the present condition of the same is not such as to give rise to excessive apprehension for the future.

A. BATELLI.

RECENT BOOKS ON BOTANY.¹

(1) MR. SCOTT ELLIOT has attempted an ambitious task, *i.e.* to give a popular and at the same time comprehensive account of modern botanical research. On the whole, he has been thoroughly successful, and has produced a readable book, which may well impress the layman or amateur botanist with the extent and scope of the botany of to-day. But (though this is perhaps inseparable from a work of this kind) one is almost bewildered by the rapidity with which the scene changes from the polar regions to the tropics, or the subject under discussion from, *e.g.*, the effect of electricity on plants to the origin of the British flora. In the preface the author states that he is particularly interested in "open-air botany, the story of the conquest of the world by green vegetation," and it is when discussing topics of this kind that he appears at his best. Such descriptions as that of the soil, with its manifold complexities of life and structure, or of a "Chroolepus Forest" are distinctly good, even if a trifle exaggerated. The chapters on bacteria, Arctic and Alpine floras, and the re-conquest of the water are amongst the best in the book. In a few cases, however, Mr. Elliot has attempted the impossible. Thus, in a chapter on the fern alliance, he condenses into three octavo pages an account of the alternation of generations, Bower's theory of the origin of the fern sporophyte, the reduction of the gametophyte in flowering plants, and a description of the pteridosperms. The result can scarcely be other than to cause confusion in the mind of the non-botanist. In describing the growth of the living crust of mosses on the top of a sphagnum bog (p. 74), the author suggests that "these moss plants may, for aught we know to the contrary, be the identical individuals which perhaps began to grow there at the close of the Glacial period." This raises the interesting metaphysical problem of how far the conception of individuality is applicable to plants. Unfortunately, Mr. Elliot does not discuss the question, though he briefly refers to it again on p. 152. It is to be expected that some inaccuracies should creep into a book of this nature. A desire for brevity is probably responsible for the statement on p. 109 that the

¹ (1) "Botany of To-day: a Popular Account of Recent Notable Discoveries." By G. F. Scott Elliot. Pp. 352. (London: Seeley and Co., Ltd., 1910.) Price 5s. net.

(2) "The Book of Nature Study." Vol. v. Edited by Prof. J. B. Farmer. Pp. viii+224. (London: Caxton Publishing Co., n.d.)

(3) "A Text-book of Botany for Students, with Directions for Practical Work." By Amy F. M. Johnson. Pp. viii+335. (London: Allman and Sons, Ltd., n.d.) Price 7s. 6d.