apparent time by being fast or slow by the equation of time ; this time-scale represents the time-of-clock of the moon’s transit, either upper or lower. The scale is perhaps most conveniently arranged in the order V, VI, . . ., XII, I . . . IIII. Then each interval of time from transit to high water is set off as an ordinate above the corresponding time-of-clock of the moon’s transit. A sweeping curve is drawn nearly through the tops of the ordinates, so as to cut off minor irregularities. Next along the same ordinates are set off lengths corresponding to the height of water at each high water. A second similar figure may be made for the interval and height at low water.@@1 In the curve of high-water intervals the ordinate corresponding to XII is the establishment, since it gives the time of high water at full moon and change of moon. That ordinate of high-water intervals which is coincident with the greatest ordinate of high-water heights gives the mean establishment. Since the moon’s transit falls about fifty minutes later on each day, in setting off a fortnight’s observations there will be about five days for each four times-of-clock of the upper transit. Hence in these figures we may regard each division of the time-scale I to II, II to III, &c., as representing twenty-five hours instead of one hour. Then the distance from the greatest ordinate of high-water heights to XII is called the age of the tide. From these two figures the times and heights of high and low water may in general be predicted with

Trans., 1831 sq.) improved the method of Laplace by taking into account all the observed tides, and not merely those appertaining to certain configurations. He divided the observations into a number of classes. First, the tides are separated into parcels, one for each month ; then each parcel is sorted according to the hour of the moon’s transit. Another classification is made according to declination ; another according to parallax ; and a last for the diurnal inequalities. This plan was followed in treating the tides of London, Brest, St Helena, Plymouth, Portsmouth, and Sheerness. Whewell (Phil. Trans., 1834 sq.) did much to reduce Lubbock’s results to a mathematical form, and made a highly important advance by the introduction of graphical methods by means of curves. The method explained above is due to him. Airy remarks of Whewell's papers that they appear to be “ the best specimens of reduction of new observations that we have ever seen.”

VI. Tidal Instruments and Tidal Prediction.

§ 35. General Remarks.

Practical tidal work is divisible into the three stages of observa- vation, reduction of observations, and prediction.

The simplest observation is that of the height of water on a

fair approximation. We find the time-of-clock of the moon’s upper or lower transit on the day, correct by the equation of time, read off the corresponding heights of high and low water from the figures, and the intervals being also read off are added to the time of the moon’s transit and give the times of high and low water. At all ports there is, however, an irregularity of heights and intervals between successive tides, and in consequence of this the curves pre­sent more or less of a zigzag appearance. Where the zigzag is perceptible to the eye, the curves must be smoothed by drawing them so as to bisect the zigzags, because these diurnal inequalities will not present themselves similarly in the future. When, as in some equatorial ports, the diurnal tides are large, this method of tidal prediction fails.

This method of working out observations of high and low water was not the earliest. In the Mécanique Céleste, bks. i and v., Laplace treats a large mass of tidal observations by dividing them into classes depending on the configurations of the tide-generating bodies. Thus he separates the two syzygial tides at full moon and change of moon and divides them into equinoctial and solstitial tides. He takes into consideration the tides of several days embracing these configurations. He goes through the tides at quadratures on the same general plan. The effects of declination and parallax and the diurnal inequalities are similarly treated. Lubbock (Phil.

graduated staff fixed in the sea, with suck allowance as is possible made for wave-motion. It is far better, however, to sink a tube into the sea, into which the water penetrates through small holes. The wave-motion is thus annulled. In this calm water there lies a float, to which is attached a cord passing over a pulley and counterpoised at the end. The motion of the counterpoise against a scale is observed. In either case the observations may be made every hour, which is preferable, or the times and heights of high and low water may be noted. We have explained in § 34 the methods of reducing the latter kind of observation. Although more appropriate for rough observations, this method is susceptible of great accuracy when carefully used. It has been largely super­seded by the harmonic method, but is still adhered to by the British Admiralty. In more careful observations than those of which we are speaking the tidal record is automatic and continuous ; the reduction may be, and probably at some future time will be, mechanical ; and the prediction is so already. We shall therefore devote some space to general descriptions of the three classes of instrument. The harmonic reductions are at present (1887) actu­ally done numerically, and in chapter iv. we have indicated the nature of the arithmetical processes.

§ 36. The Tide-Gauge.

The site for the erection of a tide-gauge depenαs on local circum­stances. It should be placed so as to present a fair representation of the tidal oscillations of the surrounding area. A tank is gener­ally provided, communicating by a channel with the sea at about 10 feet (more or less according to the prevalent surf) below the lowest low-water mark. In many cases on open coasts and fre-

@@@1 An example of this kind of curve for the high-water heights for Bombay, drawn automatically by a tide-gauge, would be shown by joining all the high waters together (as in fig. 3) by a continuous curve ; and a similar curve may be constructed for the low waters. In this case, however, the hours of the clock are repeated twice over, so that the morning and evening tides occur in different halves of the figure, and the hours are not hours of the moon’s transit, but the actual times of high water. It is obvious that the separation of the morning and evening tides prevents the occurrence of the zigzags referred to.