with gearing as practically constructed. The upper pulleys have to be carefully counterpoised as indicated. It has not been found that any appreciable disturbance is caused by the inertia of the moving parts, even when the speed of working is high. The pre- dicter of the India Office takes about four hours to run off a year’s tides, but greater speed seems attainable by modification in the gearing. The Indian instrument, in the store department at Lam­beth, has pulleys for the following tides (see chap. iv.) :—M2, M4, M6, K1, S1, S2, O, N, P, K2, Q, v, J, L, λ, 2MS, 2SM, MS, Ssa, Sa.

§ 39. Numerical Harmonic Analysis and Prediction.

In chapter iv. we have discussed the application of the numerical harmonic method to a long series of hourly observations. An actual numerical example of this analysis, with modifications to render it applicable to a short series, such as a fortnight, is given in the Admiralty Scientific Manual, 1886, where also an example of the numerical and graphical prediction of the tides may be found. The formulæ used are those given in chapter v.

VII. Progress of the Tide-Wave over the Sea, and the Tides of the British Seas.

§ 40. Meaning of Cotidal Lines.

Sufficient tidal data would of course give the state of the tide at every part of the world at the same instant of time, and if we were where μ is in degrees. Therefore, if we draw over the ocean a succession of lines defined by equidistant integral values of the Greenwich time of high water, and if we neglect the separation of the moon from the sun in longitude in twelve hours, the successive lines will give the motion of the semi-diurnal tide-wave in one hour.

§ 41. Cotidal Lines of the World.

No recent revisal of cotidal lines has been made with the aid of the great mass of tidal data which is now being accumulated, and we therefore reproduce (fig. 6) the chart of the world prepared by Sir George Airy for his article on “Tides and Waves.” The parts of the world for which data are wanting are omitted. The Roman numerals upon the cotidal lines denote the hour in Greenwich time of high water on the day of new or full moon. Airy remarks (§§ 575-584) that the cotidal lines of the North Atlantic are ac­curately drawn, that those of the South Atlantic are doubtful, and in the Pacific east of New Zealand are almost conjectural. The embodiment of recent observations in a cotidal chart would neces­sitate some modification of these statements.

When a free wave runs into shallow water it travels with less velocity and its height is increased. This is observable in the flexure and crowding of the cotidal lines near continents and oceanic islands, as, for example, about the Azores, the Bermudas, and the coast of South America. The velocity of the tide-wave gives good information as to the depth of the sea. In the North Sea it appears to travel at about 45 miles an hour, which corresponds to a depth to follow the successive changes we should be able to picture mentally the motion of the wave over the ocean and the successive changes in its height. The data are, however, as yet very incom­plete and only a rough scheme is possible. A map purporting to give the progress of the tide-wave is called a map of cotidal lines. For a perfect representation three series of maps would be required, one for the semi-diurnal tides, a second for the diurnal tides, and a third for the tides of long period. Each class of map would then show the progress of the wave for each configuration of the tide­generators. But as yet the only cotidal maps made are those for the mean semi-diurnal tide, and only for the configuration of new and full moon. The knowledge of the tides is not very accurate throughout the world, and therefore in the maps which we give it is assumed that the same interval elapses at all places between new and full moon and spring tide.

At spring tide, as we have seen in (87) and (88), h2=(M + M,) cos 2 (ψ∕-μ),

since A - μ, becomes then equal to -μ. As a rough approximation spring tide occurs when the moon’s transit is at one o’clock at night or in the day. We only assume, however, that it occurs simultan­eously everywhere. Now let τ be the Greenwich mean time of high water, and l the E. long. in hours of the place of observation, then, the local time of high water being the time of the moon’s transit plus the interval, and local time being Greenwich time plus E. long., we have τ=μ∕(γ-σ)-l=2/29μ-l + 1h, of 140 feet, and we know that the depth along the deeper channel is greater and along the sides less than this. In the Atlantic the wave passes over 90o of latitude, from the southern to the northern one o’clock line, in twelve hours, that is at the rate of 520 miles an hour. If the Atlantic tide could be considered as a free wave generated by the Pacific tide, this velocity would correspond to a depth of 18,000 feet. Airy considers, however, that the Atlantic forms too large a basin to permit the neglect of the direct tidal action, and thinks that the tides of this ocean derive extremely little of their character from the Pacific.

“There is another consideration,” he says, “which must not be left out of sight. It is that, supposing the cotidal lines to be accu­rately λvhat they profess to be—namely, the lines connecting all the points at which high water is simultaneous—they may, nevertheless, with a compound series of tide-waves, not at all represent the ridge of the tide-wave which actually runs over the ocean. Thus an eye at a great distance, capable of observing the swells of the tide-waves, might see one huge longitudinal ridge extending from the mouth of the Amazon to the sea beyond Iceland, making high water at one time from Cape de Verde to the North Cape, and at another time from Florida to Greenland, and another ridge transversal to the former, travelling from the coast of Guiana to the northern sea ; and the cotidal lines which we have traced may depend simply on the combination of these waves. It does not appear likely that we can ever ascertain whether it is so or not ; but it is certainly possible that the original waves may have these or similar forms ;