fainter than would ever have been possible by ordinary visual methods.

The photographic and visual or photo-visual magnitudes of a star having been observed, the "colour-index" is at once obtained. There is a marked dependence of the colour-index upon the spectral type of the star. The basis of the classification of the spectra of stars adopted at Harvard, and now universally accepted, was entirely independent of magnitude or colour considerations, and depended solely upon the type of spectrum. The spectra of the types B, A, F, G, K, M were found to show in this order a progressive change from bright-line to absorption spectra, and the order is intimately bound up with the problem of stellar evolution, and also with the temperature of the stars. The colour-indices found in three separate investigations for stars with spectra of different types are given in the table, together with the temperature of the stars, derived by Russell on the hypothesis that the stars radiate as black bodies. In accordance with the convention on which photographic magnitudes are based, the colour-index for type Ao is zero in each investigation.

Colour-Index.

Spectrum	King	Parkhurst	Schwarzschild	Temperature
				°
Bo	−0·32	—	—	20,000
B5	−0·17	−0·21	−0·20	14,000
Ao	0·00	0·00	0·00	11,000
A5	+0·19	+0·23	+0·20	9,000
Fo	0·30	0·43	0·40	7,500
F5	0·52	0·65	0·60	6,000
Go	0·71	0·86	0·84	5,000
G5	0·90	1·07	1·10	4,500
Ko	1·16	1·30	1·35	4,200
K5	1·62	1·51	1·80	3,200
M	1·62	1·68	—	3,100
N	—	2·50	—	2,300

It will be seen that the colour-index increases almost uniformly from class to class, and that when either the photographic or visual magnitude, and either the colour-index or the spectral type, are given, it is possible to determine the remaining data with very little uncertainty.

(*To be continued.*)

Ocean Tides.

By PROF. J. PROUDMAN, University of Liverpool.

THE tides of the oceans form the most magnificent dynamical phenomenon of our planet, and yet we are extremely ignorant of even their main characteristics. It is only in the immediate neighbourhood of land that they become directly observable, and it is practically only here that they have hitherto been observed.

Much has been done in the way of recording coastal tides and in analysing the records obtained, yet very much more remains to be done even for the purpose of preparing accurate commercial predictions. In this connection the most urgent need is the study of the meteorological effects. Owing to these effects, the tide in a harbour on any day may be several feet different from that due to astronomical causes, which alone appears in the tables of predictions. Now this is of the very gravest concern to harbour authorities, for, in docking a large vessel, to get less water than was expected may be very serious, while to refrain needlessly from docking through fear of this possibility is a fruitful source of delay and expense. And this is merely an instance.

The up-and-down motion of the water-surface is accompanied by oscillating currents. Much rough information is in existence concerning the nature of these currents near land, having been gathered chiefly by naval authorities, as it is of the utmost importance in navigation. But the number of places at which accurate observations of currents have been made with modern instruments is extremely small. No such observations are on record, for example, for the Irish Sea. When the problem of predicting the meteorological effects comes to be tackled in a way likely to lead to success, these shallow-water currents, which are mainly instrumental in producing the local wind effects, will require thorough observation.

But when the tides are viewed scientifically as the oscillations of a great dynamical system, these coastal tides, that almost alone have been observed, appear as the mere fringe, so to speak, of the essential phenomenon. It is in the vast bodies of water constituting the great oceans that the tides have their real being, and the coastal tides themselves will never be completely understood until we know the great oceanic tidal movements. The meteorological disturbances may arise wherever the tides arise, and we want to know, for instance, what effect certain meteorological conditions over the Atlantic will have on the tides in our harbours.

On the side of pure science many problems of wide geodynamical and cosmical interest require as data a knowledge of the ocean tides.

Now it is believed that not a single accurate observation of either tidal elevation or tidal current has ever been made in the deep water of any of the oceans. The best knowledge we possess of mid-ocean tides consists in observations on the shores of oceanic islands, and even this knowledge is not nearly so complete as we could wish.

Mathematically, the tides are "determined" by the size and shape of the ocean basins and certain astronomical data, but the complete solution of the problem is not within the sight of the present generation of mathematicians. If all the possible free oscillations of the oceans could be discovered, then the actual tides could be calculated with ease by a principle which is a generalisation of that of resonance.

Various guesses have been made as to the

nature of the ocean tides, and these have produced several different charts of cotidal lines. By a cotidal line is meant the locus of all points of the ocean surface at which high water occurs at the same instant. The best known of these charts are those of Whewell and Harris, but quite recently a new set of cotidal lines for the world has been published by Sterneck (*Sitz. Akad. Wien,* Bd. 129, 1920).

Whewell's chart was based on the hypothesis that in the Southern Ocean, where the parallels of latitude meet with no great land barriers, powerful tidal waves follow the sun and moon and send off-shoots up the Atlantic, Pacific, and Indian Oceans. Many serious objections have been urged against this.

Harris's charts are based on the principle of resonance, but the details of the application have been rejected by some high authorities. Harris sought in every ocean for regions which, if completely surrounded by land and not subject to the earth's rotation, would have twelve hours for their longest free period of oscillation; and he always found them! He then applied the principle of resonance, ignoring the absence of complete land boundaries and the presence of the earth's rotation.

Sterneck's chart is constructed from the existing observations with the condition that cotidal lines for times differing by six hours shall be as nearly parallel as possible.

These charts differ very widely from one another. In the Pacific Ocean, for example, Harris places three no-tidal points, whilst Sterneck places six.

At the present time there is no method by which we can find out what the ocean tides are except that of directly observing them, and it is high time that serious attempts were made to this end.

If the proposal made by the president of the British Association at Cardiff ever materialises, and a fully equipped oceanographical expedition results, it is very much to be hoped that means will be found of measuring tidal elevations and currents. If trustworthy observations could be made at only a few mid-ocean stations, the light they would throw on the great tidal movements would be enormous. And, even if this very desirable object proves impracticable—for it will probably require new methods and instruments—it is understood that the expedition would often be in water sufficiently shallow for the methods and instruments already developed. Also, the parties of observers which it is hoped might be landed at the most remote islands could obtain tidal records of very great value.

Hitherto, off-shore tidal observations have been restricted to shallow water, but it has to be confessed that in this country very little attention is being paid to the work. No gauge-records of off-shore elevations appear to have been published by any British authority, though trustworthy records are said to have been taken by the French. In this connection we may mention that there is a discrepancy of about 40 miles between the charts of cotidal lines for the Irish Sea as published by the Admiralty and those of many foreign authorities. Very few British current-meter observations have been published, though in recent years the Scandinavians have worked hard at providing the means of taking them. Bell Dawson has done a notable work in Canadian waters, but where is the band of current measurers in this country that can compare with Nansen, Ekman, Pettersson, Jacobsen, Witting, and Helland-Hansen of the Scandinavian countries?

Now, although with the instruments that men of other nationalities have developed we may hope to learn a great deal from the suggested expedition whenever it comes into shallow water, yet preparations ought to be in progress for work in deeper water. Quite near to our shores we could have a small expedition which, besides teaching us much about our own tides, would ever strive to observe in deeper and deeper water, devising such modifications of methods and instruments as the deeper water required, and improving methods and instruments for such depths as had proved practicable at all. It is greatly to be feared that no such efforts are being made.

Obituary.

JOHN BURROUGHS.

THIS veteran naturalist and poet died suddenly while in a train near Buffalo on March 29, within a few days of his eighty-fourth birthday. He was born, a farmer's son, at Roxbury, New York, on April 3, 1837, and had the advantage of a rural education. After about twenty years as school-teacher, journalist, Treasury clerk at Washington, and auditor of United States national banks, he bought a farm at West Park, on the Hudson, and spent the rest of his life fruit-growing, observing, and writing. Year after year he wrote delightful and distinctive essays on natural history and country life, which were received with well-deserved popularity. Mention may be made of "Wake Robin" (1871), "Winter Sunshine" (1875), "Birds and Poets" (1877), "Locusts and Wild Honey" (1879), "Pepacton" (1881), "Fresh Fields" (1884), "Signs and Seasons" (1886), and the list might be continued to his "Breath of Life," published a few years ago.

Burroughs also wrote poems and more than one study of Walt Whitman, whom he knew intimately, and for whom he had an enthusiastic reverence. "Whitman: a Study" is certainly a very remarkable book of its kind, and to the influence of Whitman and Emerson it seems just to say that John Burroughs owed much.