through which the less luminous surface layer of the interior gases becomes visible. The varying frequency of spots is accounted for by supposing that at minimum the heat of the central nucleus is prevented from escaping by a photosphere of relatively great thickness, and that afterwards, owing to contraction, the temperature of the nucleus increases to such an extent that the photosphere becomes attenuated and subject to perforations in the form of spots and pores. Radiation from the nucleus is then facilitated, so that the photosphere again increases in depth, and eventually produces another minimum. The chromosphere, prominences, and corona are regarded by Dr. Brester as effects of a permanent aurora, which is maintained by electrons projected from the photosphere.

THE NEW PHYSICS.

COPIES have reached us of five of Prof. Levi-Civita's recent mathematical papers,[1] three of which deal directly with Einstein's theory of gravitation, and suggest some remarks on the aspect of theoretical dynamics, as it appears at present to a comparative layman unable to criticise rival theories in detail. Speaking broadly, we may say that the theory of mathematical physics is based upon a comparatively small number of fundamental differential equations. Until recently time was explicitly or implicitly treated as the independent variable, in terms of which the other variables had to be found; and all phenomena were supposed to take place in a three-dimensional Euclidian space, where we can use the formula $ds^2 = dx^2 + dy^2 + dz^2$ for the distance between two very near points. In the theory expounded by Minkowski and others we have a different formula, $ds^2 = c^2dt^2 - (dx^2 + dy^2 + dz^2)$, where we may regard dt as an element of time, and speak of a "world-point" (x, y, z, t) determined not only by its position, but also by its age. Einstein has developed his gravitation-theory from the general expression, $\Sigma g_{ij} dx_i dx_j$ $(i, j = 0, 1, 2, 3)$, assumed for ds^2, where ds is an element of distance in a four-dimensional space. (It may be remarked that in the previous theory, as Minkowski pointed out, we might take dt as a variation of a co-ordinate distance; then phenomenal processes in our space might be regarded as "sections," so to speak, of a four-dimensional system.)

With Einstein's form of ds^2 we can at once use all the known geometrical theory of infinitesimal geometry in four dimensions, and, in fact, the well-known symbols of Riemann and Christoffel directly enter into Einstein's gravitation formulæ. This is a matter of mathematics merely; the most striking fact, from the physical point of view, is that Einstein has used his formulæ successfully to account for the secular motion of the perihelion of Mercury. This does not show that Einstein has said the last word on the theory of gravitation, but it does show that these post-Newtonian theories provide a calculus which gives a better image of actual facts than the purely Newtonian theory seems able to do. The more predictions the new theory can give us, which are verified by experiment, the more we shall be inclined to trust it; and this is quite independent of what we call the "real meaning" of the symbols involved. For instance, Prof. Levi-Civita's paper No. 2 seems to show that if we could produce a sufficiently strong magnetic field, we should find it inducing upon the three-dimensional space to which, so far, our intuition appears to be confined, a corresponding "curvature" measured by $1/R^2$, where R is a length. Assuming that the field is one of 25,000 gauss, the author deduces that $R = \frac{3}{2} \cdot 10^{20}$ cm., or about ten million times the mean distance of the earth from the sun. As he points out, there is little hope of testing this by experiment, but he obtains a formula for the velocity of light, $V = c_1 \exp(x/R) + c_2 \exp(-x/R)$, with a damping coefficient in the second term, which he suggests might come within the range of observation.

Philosophically, the trouble still seems to be about *time*, in the philosophical sense. If we could look at the universe *sub specie aeternitatis*, we might perhaps find our greatest delight in its unchangeable perfection; but so long as we are constrained by processes (even processes of thought), time, *in some sense or other*, is apparently indispensable, and if we evict it from one habitation, we may expect it forthwith to be in occupation of another.

G. B. M.

[1] (1) "Statica Einsteiniana"; (2) "Realtà fisica di alcuni spazî . . ."; (3) "Sulla espressione analitica spettante al tensore gravitazionale . . ."; (4) "Nozione di parallelismo in una varietà qualunque . . ."; (5) "Sulle linee d'azione degli ingranaggi." (1), (2), and (3) are reprints from *Rendic. della R. Accademia dei Lincei* (Rome, 1917); (4) from *Rendic. del Circ. Mat. di Palermo* (Palermo, 1917); (5) from *Attie Memorie della R. Accad. di Padova* (Padua, 1917).

METEOR ORBITS.

A PAMPHLET on "The Determination of Meteor Orbits in the Solar System," by G. von Niessl, has just been published in Smithsonian Miscellaneous Collections (vol. lxvi., No. 16, Washington, 1917). The pamphlet is a translation by the late Cleveland Abbe of a paper published in the "Encyclopädie der mathematischen Wissenschaften," dated Vienna, 1907. The author, who has had considerable experience in computing meteor paths and orbits, gives his views as to the mathematical treatment of the subject. He indicates the best method to be followed in determining the radiant and geocentric velocity of meteors and fireballs of which multiple observations have been obtained. Not the least interesting part of his discussion is that in which he deduces the mean errors in the results:—

Mean error of azimuth = 5·8°, 351 observations.

Mean error of apparent altitude = 4·1°, 235 observations.

Mean error of radiants = 3·3°, 43 cases, 537 observations.

Mean error of inclination = 6·5°, 250 observations.

The radiant positions of the chief periodical showers he gives to within 1° of probable error.

Tables are furnished of the average terminal velocity and altitude of meteors, from which he concludes that they "can penetrate deeper into the atmosphere in proportion as they move with a low velocity"—a fact previously well ascertained. With regard to atmospheric resistance, von Niessl's opinion is that direct observations make it probable that the velocity of meteors in the upper atmospheric regions is slighter, while in the lower strata of the air it is greater, than theoretical views.

The masses of fireballs and shooting-stars are discussed from various data. Prof. A. S. Herschel dealt with this part of the subject many years ago, and held the view that a first magnitude meteor is usually a few grams in weight, while the very small meteors are only the fraction of a gram. V. F. Sands found from the Leonids of 1867 that the average mass, or weight, of a meteor equal to Jupiter in brightness was 0·67 gram, while a fourth magnitude object was only 0·006 gram.

Von Niessl finds it necessary to assume decidedly hyperbolic orbits for the majority of meteors, for their "observed geocentric velocity far exceeds the limits for parabolic orbits. Therefore the large meteors in general are undoubtedly of interstellar origin." Schiaparelli arrived at similar conclusions half a century ago.

The paper is an instructive contribution to the literature of a branch of astronomy which has been somewhat neglected in recent years. But some of the data on which von Niessl's conclusions are based are old and inaccurate. There is no doubt whatever that for the trustworthy investigation of various difficult questions affecting the subject more exact, modern, and abundant observations are necessary.

GEOLOGY OF THE WITWATERSRAND GOLD FIELD.

THE Rand mining field is geologically one of the most interesting areas in South Africa, as well as the most important economically. Its general structure has been gradually unravelled by the work of the geologists and miners of the Transvaal, and it has now been investigated in detail by the Geological Survey of South Africa. The results of this survey are shown on an excellent map (Geological Map of the Witwatersrand Gold Field, 3 sheets, 1917) on the scale of 1 to 5000, or almost an inch to the mile. It has not been contoured owing to the inadequacy of the topographic surveys, but as the mining fields are on an area of high plains this deficiency is of little practical inconvenience. The map is mainly the work of Mr. E. T. Mellor, who has prepared also a short explanation of 46 pages summarising the geology of the mining field and including a bibliography of the chief literature. The report classifies the rocks and gold reefs of the Rand. The age of the rocks is so uncertain that no precise correlation with those of Europe is attempted. They are divided into three systems with South African names. The youngest, the Karroo, which includes the famous Dwyka glacial deposits and the coal seams, has yielded many fossils, so that its correlation is at least approximately known. The Transvaal system includes the quartzites to the north of the goldfield, a thick series of dolomites and cherts, and the Black Reef series. The oldest of the three, the Witwatersrand system, includes the quartzites, shales and conglomerates of the goldfield. These two older systems are unfossiliferous, and whether they are Lower Palæozoic or pre-Palæozoic is uncertain. The author accepts the view that the gold of the Rand is of alluvial origin, and abandons the long popular theory that it was introduced by infiltration as in ordinary lodes. The alluvial or placer theory has been advocated by several geologists, while the majority of the mining engineers have supported the infiltration theory. Probably the most striking feature displayed by the map is that strike-faulting is far more important than had been suspected. The author concludes that the unworked parts of the goldfield are so extensive that the gold-mining industry has elements of "comparative permanency not found in many other goldfields and more akin to those of a base metal district or a manufacturing centre."

ORGANISED KNOWLEDGE AND NATIONAL WELFARE.[1]

THE future of any nation is secure if it lives up to its possibilities. The nation which does this is bound to be a leader among nations and to command world-wide respect. Its national problems will be solved, and solved intelligently and thoroughly. The greatness of a man is in part born in him and in part the product of his environment. According to eminent biologists, he is about two-fifths born and three-fifths made. Similarly, a nation is great according to its resources and according to its development of these resources. And the development of those resources may be accomplished only through organised knowledge.

(1) *The Function of Organised Knowledge.*—Consider for a moment two manufacturing concerns on an equal footing as regards output, but of which one is continually making progress through improvements in manufacturing processes, developing new and valuable products and investigating the fundamental principles underlying all these processes. This firm will in time outstrip the other in every way; the balance, in fact, is a very delicate one, since the results are cumulative. In quite a similar manner, that nation will advance to leadership in which the increase in organised knowledge and the application of that knowledge are greatest. For this reason, interest in research should be as wide as the nation and should cover the whole gamut of problems from administration to agriculture, from medicine to manufacture. For it is only through the solution of individual problems that general principles can be arrived at and the sum total of useful organised knowledge increased.

It is essential that the wide field to be covered be kept in mind, extending over not only physics, chemistry, engineering, and all their branches, but all the biological and mental sciences as well. In the last analysis an increase in knowledge in the field of the *biological sciences* means more and better food, improved racial stock, and improved public health, as well as increased material welfare in all having to do with plants and animals. Increased knowledge of the fundamental principles of the *mental sciences* means increased efficiency in administration, legislation, education, operation, and research. I do not mean mere book learning in psychology, but such a command of the fundamental principles as will assist in the solution of all practical problems. Increased knowledge of *chemistry* means increased ability to utilise raw materials and an improvement in general health and living conditions. One may almost say that the generalised problem of chemistry is to convert the less expensive raw materials, such as cellulose, petroleum, glucose, various minerals and oils, starch, nitrogen of the air and the like, into food, clothing, tools for our use, and means for national defence. An application of the fundamental principles of *physics* in the way of various engineering problems leads to a fuller utilisation of resources and of new products useful to man, makes inventions possible and effective, and adds to the general increase in operating efficiency in every way.

The utilisation of organised knowledge in national welfare comes about both through knowledge itself and the incentive to apply that knowledge. Both ability and incentive are essential to utilisation. So far as knowledge went, we might have made dyes and optical glass many years ago in the United States, but since they could be bought so cheaply there was no incentive to develop the manufacture of such articles. These are cases of ability without incentive. On the other hand, there has long been an incentive for the fixation of nitrogen and for various mechanical devices, but these have not been forthcoming for lack of sufficient knowledge.

In general, in normal times it is perhaps no exaggeration to say that neither the average individual nor the average nation approaches within 50 per cent. of their possibilities. Nothing short of a war threatening the national existence can shake a nation out of its lethargy. Similarly, the average individual cannot be induced to put forth his best efforts without the strongest of incentives. It is unfortunate that this is the case. However, with sufficient attention given to the problem by trained experts in mental science, it is

[1] Abstract of an address given on April 9 to the Associated Engineering Societies of Worcester, Mass., by Dr. P. G. Nutting. Reprinted from *Science* of September 14.