bridge, contains particulars of many interesting, and some scarce, works in anthropology, archæology, folk-lore, mythology, botany, geology, mathematics, astronomy, and physics. We notice in the astronomical section a set of the *Astrophysical Journal*, and the "Nautical Almanac" for 1875–1916.

OUR ASTRONOMICAL COLUMN.

RELATIVITY AND GRAVITATION.—According to the original form of the theory of relativity, an absolute velocity v in space cannot be determined by any physical means, all matter as well as electrical and optical fields being contracted, in the terminology of the older physics, in the same ratio $(1-v^2/c^2)^{\frac{1}{2}}$. Using the same terminology, Einstein's recent gravitational theory requires a gravitational field to suffer contraction in this same ratio, so that an absolute velocity v must remain for ever hidden from our knowledge. Einstein has shown that this theory, suitably generalised to cover independently-moving bodies, leads to changes in the perihelia and eccentricities of the four inner planets which agree well with those observed. In the *Phil. Mag.* for August Sir Oliver Lodge suggests an alternative explanation of the changes in Mercury's orbit. In accordance with pre-relativity theory, the mass of Mercury, when moving with velocity v, is supposed to be $m_0(1-v^2/c^2)^{-\frac{1}{2}}$; of this only the stationary mass m_0 is supposed subject to gravitation, while the sun's gravitational field is not supposed to suffer distortion as it moves through space. The assumed increase in inertia, uncontrolled by gravitation, is found to lead to a revolution of Mercury's orbit in its own plane, which will agree with that observed if the sun has a velocity of about 68 km. a second towards longitude 294°. This velocity would also give an apsidal progression for Mars about equal to that observed, but in the September *Phil. Mag.* Prof. Eddington has shown that it would give orbital distortions for the earth and Venus enormously greater than those observed. In these papers no allowance is made for the distinction between longitudinal and transverse electromagnetic mass, but it seems impossible that this correction could reconcile theory with observation; indeed, the discussion suggests that no theory of the general type suggested by Sir Oliver Lodge can be made to fit all the facts, so that the relativity theory appears to be left in a stronger position than ever.

PHOTOGRAPHS OF NEBULÆ.—A remarkable collection of photographs of nebulæ taken with the 60-in. reflector of the Mt. Wilson Observatory has been published by Mr. F. G. Pease (*Astrophysical Journal*, vol. xlvi., p. 24). The objects selected were in general nebulæ of unknown structure, or nebulæ which were known to exhibit unusual features. Most of the exposures were made with aperture ratio F/5, but several of the bright planetary nebulæ were also photographed with the 80- and 100-ft. focus Cassegrain arrangements of the telescope, in order to give a larger scale. The exposures ranged from ten minutes to seven hours. It is interesting to note that the perfection of the photographs was increased in the case of very long exposures by the use of two guiding stars, which allowed of correction being made for variation in size and for rotation of field produced by refraction and imperfect adjustment of the telescope. In addition to the sixty-five nebulæ which are fully described, attention is directed to others which appeared incidentally on the plates, and to a number of uncatalogued nebulæ and nebulous stars. The photographs show a great amount of intricate detail, and bear witness alike to the excellence of the instrument and the skill of the observer.

THE 100-IN. REFLECTOR AT MOUNT WILSON.—An illustrated description of the great reflector of the Mount Wilson Observatory is given by Mr. Pease in the *Scientific American* for August 11. As supplementing the account already given in the columns of NATURE of July 12 (vol. xcix., p. 385), it may be noted that the moving parts of the telescope, which is mounted on the English pattern, weigh 100 tons. The greater part of the weight is taken up by the mercury flotation system, 40 tons at the north pedestal and 60 tons at the south pedestal. The driving clock is regulated by an isochronous governor of the conical pendulum type, and the weight is wound up automatically at intervals of twelve minutes without interference with the driving. The clock itself stands 6 ft. high and occupies a floor space of $5\frac{1}{2}$ ft. by 4 ft. The actual diameter of the mirror is 101·2 in., and its focal length 507·5 in., giving an aperture ratio of 5·05. Elaborate arrangements have been made to maintain the mirror at constant temperature by water circulation. Manipulation of the dome and telescope involves the use of forty motors of 1/20 to $7\frac{1}{2}$ horse-power, with an aggregate of 50 horse-power and more than thirteen miles of wiring. It is estimated that about 300 million stars will be within range of the new instrument.

INDUSTRIAL FATIGUE.[1]

UNDER the above title Prof. Spooner has collected articles written by him in 1916 for publication in *Co-partnership*. The pamphlet is a useful contribution to the discussion of reconstruction, which already is receiving anxious attention from many who realise its extreme importance and its extreme difficulty.

Evidently in so small a space but few details can be given, but the author has touched upon many points which show how wide is the problem and how great are the difficulties which surround it. Perhaps the main impression left upon the mind after a perusal of these fifty-nine pages is one of the immense amount of scientific investigation which remains to be done before industrial processes—to say nothing of industrial management can be placed on a thoroughly satisfactory footing. It is only quite recently, and largely on account of present conditions, that the general public and directors of industry have begun to realise that science after all is merely crystallised and systematised knowledge, and that to attempt to conduct industrial processes without it is to dispense with one of the greatest aids to success. Now, however, the leaven is spreading. Many firms operating processes which depend on scientific principles have their own scientific staff working in admirably equipped laboratories, and so far as their own processes are concerned little more is needed, though it would undoubtedly contribute to the general advance if the results of the investigations carried out could be made available for all to profit by. But apart from these questions there are larger problems which affect all industries, and which can only be dealt with effectively by some central authority. Such, for instance, is the question of the number of hours' work per week which will enable an operative to produce the largest output without injurious fatigue. Evidently no general answer can be given to such a question. The answer must vary with conditions, and all conditions must be studied in order that their influence in producing fatigue may be determined. But certain fundamental facts may be established, and perhaps the most im-

[1] "Industrial Fatigue in its Relation to Maximum Output." By Henry J. Spooner, C.E. Forewords by Sir Robert Hadfield, F.R.S., and Mr. J. R. Clynes, M.P. (Co-partnership Publishers, Ltd., 6 Bloomsbury Square, W.C.1.) Price 6*d.* net.

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portant that has yet emerged is that *output is not necessarily proportional to the hours worked.* The recognition of this fact alone has led to the emancipation of countless victims of long hours, to their lasting benefit, and to the benefit of the factories for which they work. Prof. Spooner points out that conclusions as to overtime and Sunday work, based on accurate scientific investigations, agree with those that managers of industrial works have long known to be more or less true. It is a lamentable result of our inability to take advantage of knowledge lying close to hand that lines of conduct indicated by such conclusions should have been followed by so few. It is nevertheless a distinct gain that the study of industrial fatigue must always in future be recognised as an essential factor in a right determination of the conditions of labour, and that never again will the fortunes of tens of thousands of workers hang entirely upon the will of uninstructed and often unsympathetic employers. Moreover, by placing industry on a scientific basis it will be demonstrated that the interests of master and man are identical, and many of the differences between capital and labour will cease to exist.

There is only space in a short notice to refer to unnecessary fatigue, dilution and subdivision of labour, restriction of output, scientific management, motion-study and time-studies, welfare work, labour turnover, and after-the-war problems, but on all these points Prof. Spooner has something of interest to say. Scientific management, as its name implies, is an application of scientific principles to factory management. Where properly applied there can be no question of its legitimacy, or of its advantages to capitalist and worker, since these are its conditions of success. Unfortunately, it has been sadly misunderstood in this country. Only recently the workers in a large factory, being convinced that it meant more work and less pay, stated emphatically to the writer: "We *will not have* Taylorism here," whilst in the pamphlet before us we find the writer of a foreword describing it as "tending to make the workman into a machine."

The facts of the case are as follows: Some years ago the late Dr. Taylor, struck by the enormous waste of effort involved in industry, took up the study of the subject, and, as a result, introduced his system of scientific management. He recognised that the ordinary comparison of the human body to a steam-engine, whilst possessing elements of truth, was likely to lead to erroneous conclusions, since the conditions of action in the two cases are profoundly different. He showed that in the case of the human body the percentage of the working day for which the muscles could remain under load without undue fatigue was strictly limited, and that this proportion was greatly influenced both by the severity of the labour and by the distribution of the work and rest periods. In such a simple task as the handling of pig iron he showed that a remarkable gain in efficiency could be reached and maintained for long periods by the introduction of appropriate intervals for rest, so that the day's wages could be increased, or, alternatively, the same wages as before could be earned and time saved.

By his lamented death industry was deprived of a great benefactor, but his work remains, and, by great good fortune, his mantle has fallen upon worthy successors. Frank Gilbreth and his co-workers still continue the work, and by the ingenious application of photography to recording movements involved in industrial processes have introduced in "motion-study" a method of investigation of which the effects are only now beginning to be felt. The method aims at recording the movements performed in a given process by learner and by expert. These movements are found to differ chiefly in the direction of a simplification of the movements of the expert, and of a discarding of a number of unnecessary movements observed in the learner. But even in the expert certain unnecessary movements will probably be found, and by the discarding of these also his expertness will be increased, whilst in the case of the learner it becomes possible to arrange a definite course of instruction in the performance of the necessary movements only, which leads at once to great simplification and to the learning of precise series of motions, in place of the old system whereby the learner tried blindly to imitate his teacher. That economy of effort must follow the adoption of such a system is evident, but its results are surprising. Efficiency is very largely increased, and tasks can be performed in far less time than before. The increased efficiency may be used in different ways. It may be used to increase output, but if this be done, labour should share in the increased profit. The increased output may be produced actually more cheaply than the original output, since standing charges should be less in proportion, and therefore the extra output should be profitable to the owners when paid for at old rates. On the other hand, the worker is enabled to turn out more output with the same expenditure of energy and the same amount of fatigue.

Thus the unusual situation arises of the owner being in a position to pay higher wages, whilst the workers do not necessarily demand that payment, since their fatigue and labour are not increased. And yet it is just upon this very point that the ship has split. In some cases, as a result of increased output, rates for piece-work have been "cut"; the workers have resented this, and have adopted the "ca' canny" attitude. The movement has spread, and in many factories the miserable situation has developed of the owners being unable to increase wages because the men will not work honestly, whilst the men will not work honestly because they fear that rates will be "cut."

The other alternative, which in normal times would probably be adopted, largely provides for the maintenance of output at the old level. Since, however, efficiency has increased, this output is now produced in a shorter working day. There remains the time saved, and much of this may legitimately be devoted to bringing into the life of the worker those things which up to now he has lacked. In many industries want of leisure has led to want of health, waning interest, and the impossibility of living a rational life. With leisure, these unfortunate conditions may be changed. A mere reduction of fatigue, if used to increase output, would lead to discontent. But used to increase leisure it may achieve much. For besides the benefits which leisure itself would bring must be considered its effect upon the relations between capital and labour. Capital has no direct interest in the leisure of the worker, though the fact that it is prepared to adopt measures to increase that leisure is itself an indication of a changing attitude. But increased leisure should lead to better education of the worker, and better education will facilitate an appreciation of industrial conditions. Ultimately, it may be hoped, a real understanding between capital and labour may be possible.

It is a calamity that the system which appears to offer the best chance of such an agreement should be so far misunderstood as to be described as an attempt to drive the worker.

Prof. Spooner may be congratulated upon having done something to clear away this misunderstanding. His pamphlet is a valuable contribution to the question of industrial fatigue. A. F. STANLEY KENT.

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