

## LETTERS TO THE EDITOR.

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## Gravitation and Light.

In a recent letter (*NATURE*, December 25, p. 412) and elsewhere I have expressed doubt as to the security of the inferences regarding the influence of gravitation on the light from distant celestial bodies, which are advanced as tests of the Einstein formulation. A closer and less sceptical general scrutiny is possible. The difficulty was to recognise how a theory which professes to supersede an æther with its definite space and time, by concepts purely relativist, could manage to effect direct comparison, at a distance and without tracing transmission across the intervening space, of the radiations of a molecule at the sun and those of a molecule of the same substance at the earth. This body of doctrine seems, in fact, to consist of two chapters. A blind man could work out the purely relativist theory, which would indeed represent rather closely the process of groping from point to adjacent point in space and time by which he must acquire his own scheme of knowledge. But to compare his results with the world of experience a practical astronomer is needed, with very different equipment; he relies on the rays of light, in conformity with the optical theory that prescribes their function as messengers across space.

It thus appears to be necessary to examine directly what changes in the propagation of rays of light would arise under the modified gravitation, and, if possible, to bring out more explicitly and demonstratively the further postulate that is needed to reconcile them with the proposed test-relations. The postulate which is sufficient to sustain the optical predictions proves to be this: that all the way to the sun and throughout the solar system the formula for the element of fourfold length by which the nature of the space is determined does not contain explicitly that one co-ordinate which is more especially related to time, but involves only its differential. This is, of course, a reasonable assumption; but it is of an absolute type regulating the whole space, assumed to be thus settled in advance on the Newtonian plan, not of the relativist type which would profess only to explore it gradually from place to place as it arises.

But we can analyse further and more definitely. The new theory implies that if this quadratic formula characteristic of the space involved in its product terms the differential of that co-ordinate which stands closest to time, then the velocity of the rays of light in any direction at any place would be different according as they are travelling forward or backward. That could only mean that the co-ordinates define at such a locality a frame of reference which is itself in motion. But in motion with reference to what? The relativity of language is doubtless capable of supplying an answering formula; but it would only be wrapping up in abstractions the simple statement that when at any place the quadratic characteristic of the spacial extension involves the differential of the co-ordinate specially related to time in its product terms, then there is latent in it a specification of its own mode of change at that place with respect to uniform space-time. If no such products are contained, the space is not locally in motion, and we may say that the frame of reference is fixed in the æther. That is, the fourfold space-time frame in which we set the universe is everywhere deformed and awry, but it is then nowhere in move-

ment relative to light; or, in graphic terms, the co-ordinate system would involve a fourfold curvilinear frame instead of a rectangular one when it is set in a uniform fivefold extension, but it is to be nowhere in movement when set in that higher auxiliary space. The physical properties of the rays of light can scarcely be invoked to obtain an astronomical test of results, by providing in their vibrations a universal scale of time, without becoming to the same degree a criterion of the relation to light of the whole construction; if they can settle universal time by optical vibrations, they can equally well be applied to settle absolute space in each locality. It comes to this, that radiation can be utilised to determine the space and time absolutely.

This point of view involves no destructive criticism of the substantial and brilliant mathematical theory, which, of course, ought to evolve correctly the consequences of the postulates that are put into it. But it does demur to the popular presentation which asserts that space and time and the æther have now been transcended. The outstanding problem, stripped to its essentials, was to find whether gravitation could be brought into line with radiation in this very arresting feature: that the time which is most appropriate by far for its analytical formulation is a changing local time mixed up definitely, though very slightly, with spacial relations. The value of the new theory is that it opened out a way by which this problem could be attacked, while previously no approach was in sight; and, still more important, that it has not improbably led to an answer in the affirmative. This, of course, is a very remarkable consummation, comparable to Faraday's detection of an influence of magnetism on light, though more fundamental in that it relates to free space; it must promise substantial advance as regards the formulations on which we construct our ultimate plan of physical activity, either along its present lines or some other that would represent the result with equal approximation. But beyond that the extreme relativist developments, where they are not metaphysical dogmatics, are a very interesting extrapolation towards the possible or probable physical formulation of a universe in which bodies are moving thousands of times as fast as the stars are found to move in our own.

Reference may be made to forthcoming Proceedings of the Cambridge Philosophical Society and Monthly Notices of the Royal Astronomical Society.

Cambridge, January 17.

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## The Outlook of British Technical Optics.

THE symposium and general discussion on "The Microscope: Its Design, Construction, and Applications," held in the rooms of the Royal Society at Burlington House on January 14, under the auspices of the Faraday, Royal Microscopical, Optical, and Photomicrographic Societies, in co-operation with the Optical Committee of the British Science Guild, with Sir Robert Hadfield, president of the Faraday Society, in the chair, was a landmark in the history of British optics. Whether judged by the number, value, and variety of the exhibits and the papers contributed, or by the number of people who attended, the symposium was a success.

At the present time the microscope possesses a unique interest for those concerned with British optical industries. It demands greater technical knowledge and skill in its designer and producer than any other optical instrument, and the demand for it, both actually and potentially, for work of the most far-reaching importance is so great that it may fairly be said to be the keystone in the arch of an industry which has already been recognised as one of such

vital national importance as to constrain the Government to treat it as a "key industry." But there is no royal road to success even in manufacture and commerce. If this country is ever to stand in the forefront as a producer of microscopes for the world's needs the position to-day must be boldly and courageously faced. The lessons of the war must not be forgotten. We shiver yet when we remember the single thread upon which the production of optical munitions depended in this country. Our glass-makers, beaten by their foreign rivals, receiving neither help, encouragement, nor even recognition from the Government, had been content to continue their patriotic efforts to maintain the industry, on the urgent representations of a few far-seeing scientific men, until long after those efforts held out any promise of pecuniary reward. That danger, happily, has passed, and the complete solution of the optical glass problem is now only a question of time. Many of the glasses now produced in this country compare favourably with the best of those of our foreign rivals. The varieties available are limited, but the leeway is being rapidly made up.

It is often stated that the late supremacy of the Germans in optical production was the direct and necessary result of the glass-making labours of Abbe and Schott completed in the year 1886. This is not a correct statement of the case. The fact is that, when Abbe and Schott broke down the barriers to optical progress imposed by the limited varieties of glass available, Germany had in reserve a small army of scientific workers, equipped with the necessary technical knowledge and skill, ready to fill the breach and carry on the work of utilising the new glasses in the invention of new optical systems and in the improvement of old. But the world moves quickly, and inventions and discoveries, however valuable intrinsically, are likely to remain barren unless a country has a sufficient number of men equipped with the necessary knowledge to exploit them instantly and to the full. Indeed, it is only such men that can appreciate the value of inventions and discoveries. The necessity for a broad and generous scheme of national education in optical matters thus becomes apparent. When the users of optical instruments are sufficiently educated to be able to distinguish and appraise good designs and work, makers will be encouraged to meet their demands. In the absence of such education the faddist has his day, and the maker concerns himself too often in meeting the demands of fashion.

It is satisfactory to know, then, that, so far as this country is concerned, a great deal has already been done to foster optical education. The establishment of the Technical Optics Committee, which includes representatives of the British Optical Instrument Makers' Association, the War Office, the Admiralty, the National Physical Laboratory, the London County Council, the Royal Society, and the Imperial College of Science, is in itself sufficient evidence that the question has been taken up with great thoroughness. The establishment of a department of optical engineering and applied optics at the Imperial College will ensure a supply of capable and well-educated young men for the needs of the industry generally. Prof. Conrady is doing yeoman service in the establishment of an English school of optical designers and computers, the need for which was so acutely felt during the war. The outlook, then, so far as education is concerned, is decidedly promising. Indeed, in some important respects the scheme of education here is already in advance of that of any other country.

When we turn, however, to the purely engineering side—the production of the microscope as a mechanical

instrument—the outlook is not so satisfactory. At the present time the Government is pledged to afford protection to the optical industries. This will probably be done by a continuation of the licensing system, which has for the moment been suspended because of Mr. Justice Sankey's decision, but there is little doubt that the system will be reimposed, either by the reversal of that decision or by legislative enactment. Now the public at the present time, with just cause, are very suspicious of anything in the nature of Protection. During the past few years Protection has so often resulted in unscrupulous profiteering at the expense of the community that the public may well be excused for looking with suspicion upon any proposal to continue the system. In the case of the microscope, for example, there is little doubt that at the back of the minds of many people there is a fear that Protection will be taken advantage of by manufacturers to foist upon the market inferior goods at greater prices than could be obtained in a free market. But the symposium has proved conclusively that this danger, in the case of microscopes at any rate, is a very small one. One or two important makers exhibited new models, designed for mass production, which showed clearly how thoroughly and seriously the problem had been taken up. Microscope production in this country is now a young, vigorous, and promising organism, which, in the course of a year or two, will probably be able to stand up and fight its way in the world without artificial support.

The real difficulty at the present moment lies in the fact that efficient production means mass production, and mass production means large enterprises carried on with large capital. Everyone is agreed that production by the old methods, requiring the employment of a large proportion of highly skilled craftsmen—the artistic method—must be replaced by machine methods. Efficient and successful production in the case of the microscope involves, as it does in so many other cases, specialisation, standardisation, and the use of repetition machinery attended by unskilled labour to produce interchangeable parts, the whole of the activities being supervised and directed by the highest technical knowledge and skill. But this involves the speculative investment of capital. The maker, on the other hand, who can ensure a moderate success with little risk by carrying on producing operations on a small scale to meet the immediate needs of the country is under a great temptation to do so rather than risk everything in an attempt to secure large profits by mass production. The present position, therefore, is a serious one for the trade generally. If the mass production of optical instruments is necessary to the success of the industry and to the realisation of the end and aims of the Government, then it is very unlikely that that success will be achieved by Protection alone. Some much more substantial assistance must be given, and this assistance is not likely to be given by private enterprise.

An interesting fact brought out by the papers and discussions at the symposium was the urgent demand for greater resolving power in the microscope. This matter was particularly dealt with by Mr. J. E. Barnard, who showed a very interesting series of slides taken with the ultra-violet microscope to demonstrate the greater resolution obtainable with the shorter wave-length light. The metallographers, on the other hand, in some cases appeared to be insisting upon large magnifications without always clearly recognising that these do not involve greater resolution. The half wave-length limit to resolution, first advanced in effect by Fraunhofer, cannot substantially, at any rate, be evaded, and this fact must be clearly recognised.

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