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SIR WILLIAM THOMSON'S POPULAR LECTURES.

Popular Lectures and Addresses. By Sir William Thomson, LL.D., F.R.S., F.R.S.E., &c. In Three Volumes. Vol. I. Constitution of Matter. With Illustrations. ("Nature Series.") Pp. xi. + 460. (London: Macmillan and Co., 1889)

TO review a book by the leader of British physical science in the ordinary sense of reviewing would be absurd. To attempt an estimate of merit and demerit or to offer a superficial criticism might easily become an impertinence.

The object of a review in such a case as this is mainly to give persons who have not concentrated their attention on physics some idea of the nature of the book, so as to enable them to form a judgment how far it is suitable and accessible to them.

For, inasmuch as the greater part of what is published by the author of this book is stiff reading for trained physicists and mathematicians, and inasmuch also as the subjects of which he treats even in popular lectures are usually extremely abstruse, and such as require, if they are to be accurately stated at all, a very carefully-selected form of words and a rather involved construction of sentences, the idea may easily grow that anything by Sir William Thomson is mainly unintelligible. And unintelligible it probably is to the general public in their after-dinner arm-chairs. Unintelligible it quite possibly was to a large percentage of the audience in their after-dinner seats at the Royal Institution, though the personality of the man and the magnetism of his enthusiasm could hardly fail to enchain the attention of the most cynical or casual hearer.

In the printed book this personal charm is fainter; it is not absent—to those who have ever heard him the manner in which the illustrations are brought forward, the very tone of voice with which the sentences were delivered, are continually suggesting themselves—but it is fainter; and it becomes a question how far these lectures, which are undoubtedly scientific, are really popular, *i.e.* are really adapted to intelligent persons interested generally in the subject but who make no claim to be specialists in it. To answer this question I will run through the contents in such order as may be convenient.

About the middle of the book there is a quite popular and easy essay on the sense-organs of man, including that most important and fundamental sense—the sense of muscular exertion—without which it is doubtful if we should be conscious of an external world at all, insisting on a distinct sense of heat, and lumping together taste and smell; an essay in which certain much-needed clarifying statements are made to counteract some confusions introduced by more than one very popular book, as, for instance, the familiar difficulty about the relationship between light and radiant heat.

Next comes a lecture on the wave theory of light, delivered in America, giving to anyone who has attended

a course of lectures or read some popular treatise on light a very good general notion of what is meant by the elastic-solid theory of the ether, and of the way in which the difficulties introduced by supposing light to consist of ordinary mechanical transverse vibrations of an elastic medium have to be met.

Then follows a perfectly beautiful series of discourses or articles on the age of the sun's heat, which, looked at from the point of view of the general reader, perhaps form the gem of the whole.

The cool collected way in which a possible and more or less probable way of forming our sun is gone into, with every detail clear-cut and closely reasoned out, forms a study than which nothing more instructive, more suggestive, and more wildly interesting is likely to be accessible with equal ease to the imaginative reader.

A sustained power of attention, a period free from interruption, and a power of forming vivid conceptions, are all that is needed for a comparatively uninstructed reader to receive some of the most splendid cosmical speculations of our time. He may not know exactly why when the two earth-like bodies start to rush together it is stated that they will meet in six months, or that the collision will last half an hour, and perhaps he may find some difficulty in picturing the equatorial zone or disk and the axial rod between which forms the mass will subsequently oscillate till it settles down into a globular and white-hot sun; but he may rest assured that none of these statements nor any such numerical statements met with in this book are random ones; they are all the result of exact mechanical knowledge and arithmetic, and whether they be precisely true or not, they are, at all events, righter than anything else he is likely to come across.

Irrespective of that on which stress is laid in the title, *viz.* the age of the sun's heat, we have in these essays a popular and very clear exposition of the solution of that long-standing puzzle—the means by which solar heat is maintained.

With lumps of matter of ordinary size (*i.e.* not incomparably greater or less than the human body) gravitation is a force altogether insignificant in comparison with chemical affinity, and accordingly while the combustion of a lump of coal transforms great quantities of energy, the force of gravitative attraction between two such lumps or between one lump and the oxygen it can combine with is so minute as to require a Cavendish and a Boys to demonstrate its existence to an audience. But with lumps of matter of sizes such as are found in the depths of space the case is quite otherwise. Between them gravitative attraction is furiously greater than any known kind of chemical affinity; and the work such masses can do in falling together, nay even the work one lump can do in slowly contracting upon itself, is sufficient to maintain radiation at the sun's prodigious rate.

Take a large enough mass of gas (*i.e.* of detached atoms), let its parts gravitate together continually, and you have a sun—a sun, moreover, obeying simple mechanical laws, and with a life-period, in its molten and therefore uncrusted and radiative state, of roughly calculable length.

It may be worth while parenthetically to remark that, whereas the chemical (or electrical) attraction between two atoms at any distance exceeds their gravitative

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attraction at the same distance more than a thousand million billion billion times, the atoms being regarded as spheres oppositely electrified each to about the potential of a volt, the gravitative attraction between two worlds the size and density of our earth exceeds their electrical attraction when likewise oppositely charged each to a volt in just about the same ratio. The ratio of the forces depends, in fact, on the fourth power of the linear dimensions of the bodies concerned—other things being fixed. For a couple of small bullets the two forces would be approximately equal.

Again, if every atom be regarded as separately charged, and able to combine with each other, we get the maximum possible energy of combustion, which may be put down as at the most 20,000 therms per gramme. The heat of formation of our moon by combustion is on this estimate very comparable to that developed by the falling together of its materials from infinity under gravitation. But whereas the energy of combustion is simply proportional to the masses concerned, the energy of gravitation is proportional to the product, *i.e.* to the second power of the masses; and so we find that when a body is as big as the sun the gravitative energy of its mere earthquake subsidence as it shrinks is enormously greater than that which could be afforded by the combustion of an equal mass. So also it is shown to be greater than could be caused by any reasonably permissible hail of meteorites from infinity: meaning by “reasonably permissible,” such a hail as would not introduce planetary perturbations of a conspicuously non-existent amount.

Returning now to the beginning of the volume, we find an altogether admirable, but rather stiff discourse on capillarity. How it can help being stiff when it enters into problems usually treated by the higher mathematics, and hitherto reserved for specialists, I do not know. It is a serious mathematical essay done into ordinary language. The diagrams of the precise shape of liquid surfaces are beautiful, and such as are nowhere else to be found. To a reader who will concentrate his thought upon this discourse, it will gradually become luminously clear, but perhaps the conscientious person who always reads books from cover to cover, may run the risk of being choked off by the accident of its coming first.

Appended to it are three notes, one on the “tears of strong wine,” as explained by Prof. James Thomson; one on the author’s remarkable and beautiful discovery of the reasons why mist globules cannot form without a nucleus, why big rain-drops form at the expense of little ones, and why put-away clothes get damp; and lastly, a note on the sufficiency of Newtonian gravitation to explain cohesion. This latter is a highly ingenious piece of special pleading. It is so easy to prove that gravitation will *not* explain cohesion, on any of the commonly current mental ideas of what atoms are like; but here, by assuming a sufficiently violent concentration of substance in certain regions, and sufficient absence of all substance from other regions of an atom, it is shown that cohesion *may* be explained by gravitation. At least, it can be seen that different atoms can cling to each other, but it is not so clear how the various parts of the atoms themselves hang together. No-how, it seems to me, unless they are exaggeratedly fibrous structures, and unless the ends of the fibres of one atom cling on to the next, and thus build

up a body like a cobweb. Nothing but cobweb can cohere by gravitation, so it seems to me (perhaps wrongly, of course); and although one has gradually learnt that no hypothesis concerning reality is *a priori* absurd or unlikely, yet this does not feel, nor indeed is it intended, as anything final or satisfactory.

Then comes a long lecture on electrical units of measurement, wherein the foundations of the conventional “absolute” systems of electrical measurement are explained and illustrated by showing how by means of electrical observations the fundamental standards of length, mass, and time might, if lost, be conceivably recovered. The subject is rather technical, and scarcely of sufficient general interest to repay the unelectrical reader, though there are here, as everywhere, numerous suggestive remarks. One might, perhaps, suggest that the distinction between the conventional and the essential is not always sufficiently borne in mind and enforced.

The lecture on the size of atoms is intensely interesting to everybody. Physicists know by how many different lines of argument a limit of smallness for the space occupied by an atom can be fixed, or an actual estimate of the number of molecules in a given lump of matter can be made. A number of these methods suggested by the author are here stated, and, with many illustrations, explained. But, besides this, there are instructive mechanical models or images illustrating Prof. Stokes’s theory of phosphorescence, Cauchy’s theory of dispersion, and the polarization of light by small particles.

The remaining subjects dealt with in this volume—elasticity regarded as a mode of motion, and a kinetic theory of matter—are closely related to each other, are wholly the author’s own, and are among the most brilliant speculations of the century. But a small inkling of the great field thus opened up is given here—enough, however to afford to the reader some glimpse of the possibilities of development lying in this direction.

Such are the contents of the volume before us, and a more comprehensive collection of scientific addresses has seldom been published. They do not, of course, really represent Sir William Thomson at his best: neither they nor any other intelligible production of his is able to convey to the general reader an adequate notion of the magnitude of his solid work, or of the grounds for the veneration with which his contemporaries regard him.

Such as they are, however, every physicist will be glad to read these papers again in this handy form, and every intelligent and educated man who feels an interest in the strong thought of physical science during this eventful century will do well to make a serious effort to grasp at least the main outlines of the profound studies shadowed forth in this small volume.

OLIVER J. LODGE.

THE MATHEMATICAL THEORY OF POLITICAL ECONOMY.

Éléments d'Économie Politique Pure. Par Léon Walras.
(Lausanne: F. Rouge, 1889.)

THE appearance of a new and enlarged edition affords us a wished-for opportunity of calling attention to this original work. Its author is one of the favoured few