planetary systems, and whilst the field is thus left open to the nebular hypothesis or other rival theories, it is submitted that tidal friction has a bearing on those theories which cannot be neglected.

A numerical comparison of the distribution of moment of momentum amongst the several planetary sub-systems shows that the terrestrial system differs considerably from all the others, but it would hardly be logical to postulate an absolutely independent mechanism in this case, and it is not very easy to reconcile the genesis of the moon close to the earth with the formation of a ring in the midst of a planetary agglomeration of meteorites. Let us now summarise the advantages and disadvantages of M. Faye's scheme.

The conception of the growth of planetary bodies by the aggregation of meteorites is a good one, and perhaps seems more probable than the hypothesis that the whole solar system was gaseous, and that the influence of hydrostatic pressure was felt throughout. The internal annulation of the meteorites is left unexplained, and this compares very unfavourably with Laplace's system, where the annulation is the very thing explained. The difference of orbital motion of the inner and outer meteorites of a ring, the development of that difference as time progresses, and the consequence of direct and retrograde rotation at different distances from the sun is an excellent idea. But it is necessary to this idea that the inner planets should have been formed the first, and we are met directly by the fact that the single surviving ring, that of Saturn, is nearer to the planet than are the satellites. It is, of course, possible that special causes have preserved this ring, but we should be driven to the startling conclusion that Saturn's ring is the oldest feature of his system.

The actual distribution of satellites in the solar system is at variance with M. Faye's theory, for, according to him, the internal planets were generated from rings whose motion was such as would give greater moment of momentum to the planetary agglomeration than would the external ones. The number of satellites manufactured should be greater the greater the amount of rotation in the primitive agglomeration of meteorites, and thus the nearer planets should be richer in satellites than the remote ones.

The celebrated experiment of Plateau, in which a drop of oil rotating in alcohol and water is made to parody Laplace's solar system, is worthy of attention, and it tells against Faye and in favour of Laplace. It is of course to be admitted that surface-tension does not duly represent gravity.

On the whole, then, we must hold the opinion that there are great difficulties in the acceptance of M. Faye's theory, notwithstanding its excellences. The time does not appear yet ripe for definite judgment on this very complex subject, but science is undoubtedly the gainer by such suggestive theories. Whilst a false statement of fact always proves a serious detriment, the enunciation of false or partially true theories is always the incentive to, or initiation of, the discovery of truth.

G. H. DARWIN

SIR WILLIAM THOMSON ON MOLECULAR DYNAMICS[1]

II.

IN the present article Sir William Thomson's spring and shell molecule will be described and its theory sketched, in so far as this has been investigated with the view of getting over some of the difficulties which surround the wave theory of light. In Helmholtz's memoir on anomalous dispersion, a sketch of such a theory was published. But this new molecule differs from that of Helmholtz in several points, chiefly in the fact that absorption is not accounted for by any viscous action in the molecule dissipating the energy of vibration into low grade heat. Most readers who have ever visited the natural philosophy lecture-room in Glasgow University will recognise a very old friend in this new molecule, where they have seen it vibrating, I suppose, any time since the University occupied its present site. In appearance the molecule has been changed, but its theory as taught to the students there is identical. For a description of this molecule let us refer to page 10 of the lectures :—

"Imagine for a moment that we make a rude mechanical model. Let this be an infinitely rigid spherical shell; let there be another absolutely rigid shell inside of that, and so on, as many as you please. Naturally we might think of something more continuous than that, but I only wish to call attention to a crude mechanical explanation possibly of the effects of dispersion. Suppose we had luminiferous ether outside, and that this hollow space is of very small diameter in comparison with the wave-length. Let zig-zag springs connect the outer rigid boundary with boundary number two. I use a zig-zag, not a spiral, spring which has the helical properties which we are not ready for yet, such properties as sugar and quartz have in disturbing the luminiferous vibrations. Suppose we have shells two and three also connected by a sufficient number of spiral springs, and so on; and let there be a solid inclosed in the centre with spring connections between it and the shell outside of it. If there is only one of these interior shells, you will have one definite period of vibration. Suppose you take away everything except that one interior shell; displace that shell and let it vibrate. The period of its vibration is perfectly definite. If you have an immense number of such shells with moveable molecules inside of them, distributed through some portion of the luminiferous ether, you will put it into a condition in which the velocity of propagation of the wave will be different from what it is in the homogeneous luminiferous ether. You have what is called for, viz. a definite period; and the relation between the period of vibration in the light considered and the period of the free vibration of the shell will be fundamental in respect to the attempt of a mechanism of that kind to represent the phenomena of dispersion.

"If you take away everything except the one shell, you will have almost exactly, I think, the view of Helmholtz's paper—a crude model as it were of what Helmholtz makes his paper on anomalous dispersion. Helmholtz, besides that, supposes a certain degree or coefficient of viscous resistance against the vibration of the inner shell, relatively to the outer one. Helmholtz does not reduce it to a gross mechanical form like this, but merely assumes particles connected with the luminiferous ether and assumes a viscous motion to operate against the motion of the particles."

In the lectures the action of such a molecule when subjected to forced vibrations was illustrated by a model of ingenious construction, which among the irreverent passed by the name of the "wiggler." A steel wire was hung vertically, and five or six lathes 2 feet long and 2 inches wide were attached in a horizontal position to the wire, each one having three pins fixed in it for this purpose. These lathes were loaded at their ends, the weight on each lathe being less than that on the one above it. The lowest lathe was attached to a pendulum arrangement which impressed forced vibrations upon the system, the period being adjustable. The theory of such a system is the same as that of the molecule described above.

But in working out the theory a third type of vibrator was used, the identical one which vibrates in the lecture room at Glasgow. This is a series of weights attached to each other by vertical springs which can be stretched. The highest is the heaviest, and the others are arranged in the order of weight.

[1] Continued from p. 463.

Calling P the lathe with forced vibrations (corresponding to the external massless shell acted on by the ether), and ξ its displacement, m_0, m_1, &c., are the successive masses, x_0, x_1, &c., are their displacements

$$u_2 = -\frac{c_2 x_1}{x_2},$$

and measures the relative displacement of m_1 and m_2. c_1, c_2, &c., are the constants of successive spring connections. $c_2(x_1 - x_2)$ is the force of restitution in virtue of the spring connection between x_1 and x_2. τ is the period of forced vibration.

We thus arrive at the equation

$$\frac{du_i}{d\tau} = -\frac{2}{\tau^2} \cdot \frac{1}{x_i^2} m_i x_i^2 + m_{i+1} x^2_{i+1} + \ldots + m_j x_j^2),$$

and since the right hand member is essentially negative, it follows that all the u's diminish with increase of period. The critical cases occur when the period of forced vibration agrees with the natural period of any of the shells or lathes. When the forced vibration is very rapid, all successive masses move in opposite directions. When the forced period is slower, u_1 becomes zero, and x_1 is infinite—*i.e.* the vibration of the lowest mass is infinite in comparison with the forced vibrator, and so with the other vibrators. When the forced period is slower, u^1 becomes negative, *i.e.* the lowest mass begins to vibrate in the same direction, as the forced vibrator. Successive critical cases occur as the forced period reaches the natural periods of successive vibrators. At the critical period for any one vibrator, all those below it are vibrating in one direction, while the critical one and those above it are executing very large vibrations in opposite directions successively.

These critical periods are admirably adapted for explaining absorption and also anomalous dispersion. In highly absorbing media which cut off a band of light from the spectrum, the refractive index for colours neighbouring to the band is remarkable; thus light of greater wave-length than the band is refracted more, and light of less wave-length than the band is refracted less than in normal substances. Lord Rayleigh considered this to be due to the mutual influence of the vibrating molecule and ether. If the point of support of a pendulum is vibrated in a different period, the period of the pendulum is changed. Lommel seems to have been the first to make dispersion depend upon associated matter.

The influence of a large number of the spring and shell molecules distributed through the ether upon the velocity of light in that medium is examined and shown to depend upon the wave-length or period. Finally at p. 108 we obtain the following formula:—

$$\frac{\tau^2}{\lambda^2} = \frac{1}{l}\left[\rho - c_1\tau^2\left\{1 + \frac{c_1\tau^2}{m_1}\left(\frac{\kappa_1^2 R_1}{\kappa_1^2 - \tau^2} + \frac{\kappa_2^2 R_2}{\kappa_2^2 - \tau^2} + \ldots\right)\right\}\right]$$

ρ and l measure the density and rigidity.

$$R_i = \frac{\text{Energy of } i\text{th shell}}{\text{Energy of the whole}}.$$

κ_i = the ith critical period.

"This is the expression for the square of the refractive index, as it is affected by the presence of molecules arranged in that way. It is too late to go into this for interpretation just now, but I will tell you that if you take τ considerably less than κ_1 and very much greater than κ_2 you will get a formula with enough disposable constants to represent the index of refraction by an empirical formula, as it were, which from what we know, and from what Sellmeier and Ketteler have shown, we can accept as ample for representing the refraction index of most transparent substances. We have the means of extruding its powers and introducing the effects of those other terms, so that we have a formula which is more than sufficient to give us a mathematical expression of the refrangibility in the case of any transparent body whose refrangibility is reliable."

In fact the above formula is equivalent to the well-known formula of Cauchy and others, viz.

$$\mu = \mu_0\left(A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4} + \ldots\right)$$

when we are not dealing with critical cases. Examining the formula for $\frac{\tau^2}{\lambda^2}$ or μ^2, we see that as τ approaches κ_1, μ^2 becomes infinite, and for τ a little greater than κ_1, μ^2 is negative, which is impossible, and we can have no assignable velocity for such a period—*i.e.* there is absorption for all values of $\tau > \kappa_1$, which make μ^2 negative. Moreover, owing to the existence of a critical period, κ_1, the refractive index is abnormally increased for values of τ which are just less than κ_1, and it is abnormally diminished just when μ^2 becomes positive. This means that the refrangibility of rays in a highly absorbent medium, in the neighbourhood of the band of absorption, is anomalous in the direction indicated by Kundt in his researches on anomalous dispersion. Here is what we find at p. 150 on critical values of τ and the manner of absorption:—

"We shall try to see something more of the effect of light propagated through a medium of a period exactly equal K_1. I believe each sequence of vibrations will throw in a little energy which will spread out among the different possible motions of the molecule. The combination of the sequences, forming what we call continuous light, is not a continuous phenomenon at all. I believe that the first effect when light begins will be: each sequence of waves of the exact period throws in some energy into the molecule. That goes on until, somewhere or other, the molecule gets uneasy. It takes in an enormous amount of energy before it begins to get particularly uneasy. It then moves about, and begins to collide with its neighbours perhaps, and will therefore give you heat in the gas, if it be a gaseous molecule. It goes on colliding with the other molecules, and in that way imparting its energy to them. The energy will be simply carried away, by convection if you please, or a part of it perhaps. Each molecule set to vibrating in that way becomes a source of light, and so we may explain the radiation of heat from the molecule after it has been got into the molecule by sequences of waves of light. I believe we can so explain the augmented pressure of a gas due to the absorption of heat in it.

"We may consider, however, that the chiefest vibration of the molecule is that in which the nucleus goes in one direction, and the shell in the opposite direction, but with a great amount of energy in the interior vibrations and very little in the shell, so that the shell may go on giving out phosphorescent energy for two or three hours or days, simply vibrating for ever, except in so far as the energy is drawn off and allowed to give motion to other bodies."

A great deal more is said about the influence of critical periods upon anomalous dispersion, but, as the author says, "it is like fiddling when Rome is burning to discuss anomalous dispersion when double refraction is waiting to be explained," so I will pass from this subject.

We have in the lectures some indications of the effect of introducing a gyrostat inside the shell molecule, especially with relation to magnetic rotation of the plane of polarisation. On this subject the author said sadly: "But alas! my results give me another law, not more effect with greater frequency, but less effect with greater frequency, according to the inverse square of the wave-length. I therefore lay it aside for the present, but with perfect faith that the principle of explanation of the thing is there" (p. 244).

But, on returning to this country, a more complete theory of the gyrostatic molecule was worked out, sent to

America, and incorporated in the lectures. In my next and concluding notice I shall touch on the further developments if space permits.[1] GEORGE FORBES

(*To be continued.*)

CITY AND GUILDS OF LONDON INSTITUTE

THE Fifth Annual Report of the Council of this Institute, which was presented last week to the Governors by the Lord Chancellor, gives evidence of marked progress in all departments of the Institute's operations. During the last five years, the advance made in this country in providing technical schools of various grades has been very great, and brings us educationally within a measurable distance of France and Germany. Much praise is certainly due to the City Companies for the very energetic manner in which they have set about giving effect to the important objects they have undertaken. The Technical College at Finsbury and the Central Institution at South Kensington are important additions to the educational establishments of the metropolis. That the Finsbury College has supplied a great want is shown by the rapid increase in the number of students during the two years since it was opened. The number of evening students might have been expected to be large, because in very few places, if in any, do evening students have the same advantages as at Finsbury of obtaining practical instruction in physics and mechanics. But the great success of the College is shown in the increasing number of its day students. In little more than two years the number has increased from 30 to 148; and nearly all these students are in regular attendance throughout the whole day, and go through the complete course of instruction as laid down for them in the programme. Some changes have taken place in the staff of the College in consequence of the opening of the Central Institution. Mr. Philip Magnus has been relieved of the duties of Principal, which he temporarily undertook in addition to his other duties as organising Director of the Institute, and Profs. Ayrton and Armstrong have resigned the Chairs of Physics and Chemistry for similar positions at the Central Institution. The appointment of Dr. Silvanus Thompson as Principal and Professor of Physics at Finsbury promises well for the future of the College, and the Council have been well advised in this selection. The Professorship of Chemistry is still vacant.

The Central Institution, which is to form a kind of technical university, was formally opened in June last, but, as generally happens, the completion of the fittings has occupied more time than was anticipated, and the Institution is consequently not yet in working order. The Prince of Wales, who has shown great interest in the progress of the Institute, issued an appeal to the Lord Mayor and to the Masters of the several Companies for additional funds to defray the cost of the fittings, which brought in over 17,000*l*. It may be expected, therefore, that this Central College will be very completely furnished with all the necessary appliances and apparatus for scientific and technical instruction.

The Council of the Institute refer with satisfaction to several passages in the Report of the Royal Commissioners on Technical Instruction, showing the great need in this country of improved facilities for higher technical teaching. It is a common error, which the building in South Kensington will help to correct, that technical education has reference to artisans only, and that the improvement of the skill of the working man is the great *desideratum* in the commercial interests of the country. But this is not so. The difference between foreign countries and our own in the facilities afforded for the education of artisans is not so marked as in the opportunities for the higher education of masters and managers of works.

But the City Guilds Institute, whilst giving prominence in its scheme to the provision of this higher education at its Central Institution, has done a great work in assisting in the establishment of evening technical schools in all the principal manufacturing centres of the kingdom, by means of its system of technological examinations. The Director's special Report on this part of the Institute's work is full of detailed information as to the increase in the number of candidates and of subjects of examination, and is supplemented by remarks of the examiners on the causes of the failures of the candidates. The percentage of failures is decidedly high; but the Institute very wisely insists upon a high standard of excellence, so that its certificates may be accepted by masters and employers as proof of the efficiency of those who hold them. In many crafts, this would be impossible, if the certificates were awarded on the results of a written examination only; but the practical tests which have this year been added afford a guarantee, which would otherwise be wanting, of the technical skill, as well as of the knowledge of the candidates. In the examination in "weaving," for instance, the candidate is required to design an original pattern, to prepare it for the loom, and to weave it in suitable material, besides answering questions on the analysis of patterns, the structure of the different kinds of looms, &c. In mine surveying, also, a practical examination was last year held at the Pease's West Collieries, in which the candidates were engaged, with the examiner, in surface and underground work during the three days. Whilst the Institute's examinations are thus conducted there can be no doubt of their efficiency, and of their affording a valuable supplement to those of the Science and Art Department. Most of the Institute's examiners complain of the candidates' want of skill in drawing; and it is satisfactory to note that the attention of the Education Department has been called to this general defect in the education given in our primary schools, and that it is likely to be remedied by the provisions for teaching linear drawing throughout the Standards contained in the New Code for 1885.

The Report of the Institute concludes with an appeal for additional funds. If the Council are to develop the work they have begun they require a much larger income than they now dispense. A good beginning has been made, but it is little more than a beginning, in the establishment of technical schools in this country. Leicester, Nottingham, Sheffield, and Manchester have received some assistance from the Institute; but there are many manufacturing towns still requiring help, and the wants of the metropolis are by no means satisfied. It is to be hoped, therefore, that the appeal of the Council, backed by the powerful support of the Lord Chancellor, will meet with a ready and adequate response.

THE PEABODY MUSEUM AT NEW HAVEN, U.S.

THE accompanying illustration of this fine museum is reproduced from *Science*. The Peabody Museum, Mr. Ingersoll informs us, stands on the corner of Elm and High Streets, just without the *campus* of Yale College. The building is due to the liberality of George Peabody, who gave a sum of money, in 1866, to erect a house for the collections. Thanks to the financial prosperity of Massachusetts, the bonds for a hundred and fifty thousand dollars had greatly increased, and those set aside for the first wing of the building had become worth a hundred and seventy-five thousand dollars when the trustees began to build. With that sum they have erected one of the finest buildings, for its purpose, in the United States—a lofty and ornamental structure of red brick and cream-coloured stone, whose broad and numerous windows

[1] Corrections to first notice in issue of March 19:—For *asphasia* read *aphasia*. P. 462, line 41 of second column, for *a few seconds*, read *for a few thousandths of a second*. P. 463, line 35 of first column, for *without* read *with*.