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"*To the solid ground*
Of Nature trusts the mind which builds for aye."—WORDSWORTH

METEOROLOGISKA
OBSERVATORIUM
UPSALA

London and New York:
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1879

The greatest deviation from the mean in the comparison of two 1 lb. weights in one group of twenty comparisons, when the weather was unfavourable, was 1·20 millionth of 1 lb., while in another group of twenty-seven comparisons (the weather being much finer and more favourable) the greatest error was 1·50 millionth.

To determine the mean density of the earth, a 1 lb. weight was hung from one arm of the balance at a distance of about six feet below it, and was accurately counterpoised in the other pan. A large sphere of lead (about 340 lbs.) was then alternately inserted under the hanging weight, and withdrawn. The difference which its attraction made in the weight of the hanging weight was about 1·45 millionth of 1 lb. This increase of the weight was measured as accurately as possible by means of riders on the beam of the balance. Comparing this with the attraction of the earth on the weight—that is, its weight—we can calculate the mass of the earth in terms of the mass of the lead sphere. The results hitherto obtained are only preliminary, though they seem near enough to former determinations to show that with improved arrangements which the author intends to make, a good value may ultimately be obtained. The mean of 11 determinations is 5·69, with a probable error of 0·15.

Physical Society, November 23.—Prof. W. G. Adams, president, in the chair.—Prof. Ayrton read a paper on the music of colour and of visible motion, which we give elsewhere.—Dr. Schuster then described his new method of adjusting the collimator of the spectroscope for parallel rays of different refrangibility. His plan is very simple, and is based on the fact that if the rays entering the prism are parallel, the focus seen in the telescope will remain constant when the prism is turned round, but if they are not parallel, the focus will shift. The process, therefore, consists in looking through the telescope while turning the prism. If the focus shifts, the collimator has to be adjusted until no shifting takes place. The adjustment must be made with a prism whose sides are perfectly plane, and a good one may be kept for the purpose.

Statistical Society, November 19.—A numerous list of candidates were balloted for and elected Fellows.—The Howard prize medal, with 20*l.*, has been awarded to Surgeon John Martin, L.R.C.S. Edin., of the Army Medical Department, at present serving in India with the Royal Artillery. An *extra* prize medal has also been awarded to Capt. H. Hildyard, of the 71st Highland Light Infantry, his essay being scarcely inferior to that of Mr. Martin.—The President, Mr. G. J. Shaw-Lefevre, M.P., in his opening address, commented on the past work of the Society, especially the papers read by its members during the past session, and the various statistics collected through its operations. Their great object was to study the past so as to understand the present and be able to give a forecast of the future.—Prof. Jevons afterwards exhibited and explained to the meeting the arithmometer of M. Thomas, long in use among actuaries.

EDINBURGH

Royal Society, November 25.—The following office-bearers were elected:—President, Prof. Kelland; Vice-Presidents, David Stevenson, C.E., Bishop Cotterill, Sir Alexander Grant, Bart., David Milne Home, Sir C. Wyville Thomson, Prof. Douglas Maclagan; General Secretary, Prof. Balfour; Secretaries to Ordinary Meetings, Prof. Tait, Prof. Turner; Treasurer, David Smith; Curator of Library and Museum, Alexander Buchanan; Council, Prof. Fleeming Jenkin, Rev. R. Boog Watson, Dr. Hugh Cleghorn, Prof. T. P. Fraser, Prof. Rutherford, Dr. R. M. Ferguson, Rev. W. Lindsay Alexander, Dr. Thomas A. G. Balfour, J. T. Buchanan, Rev. Thomas Brown, Robert Gray, and Dr. William Robertson.

PARIS

Academy of Sciences, November 25.—M. Fizeau in the chair.—The following papers were read:—Critical examination of a posthumous writing of Claude Bernard on alcoholic fermentation, by M. Pasteur. He represents this writing as a sterile attempt to substitute for facts well established the deductions of an ephemeral system.—On the reduction in continuous fractions of $e^{F(x)}$, $F(x)$ designating an entire polynome, by M. Laguerre.—On isosceles figures, by M. Badoureau.—Reply to various communications by M. Levy.—Reclamation of priority, in regard to M. Werdermann's communication on an electric lamp, by M. Regnier.—On a new phenomenon of static electricity, by M. Duter. In certain cases electrification may change the volume of bodies. A large thermometric envelope containing water is made into a condenser by pushing a piece of platinum wire into its exterior, and fixing outside a sheet of tin. Whenever, like a Leyden jar, it receives a charge, the water is observed to descend, remain stationary while the charge persists, and resume its former level on discharge. It is inferred that the glass is dilated. With any kind of armatures the same result is had. Another experiment was to place the above-mentioned arrangement in another thermometric envelope containing water; on electrifying, the water in the measuring-tube of the outer envelope rose, while the other fell. M. Jamin recalled the fact that M. Govi, ten years ago, made an experiment similar to M. Duter's first, and attributed the effect to a contraction of the liquid; M. Duter's second experiment proves that the expansion of the glass is really the cause.—Reply to a note of M. Meunier on the artificial crystallisation of orthose, by MM. Fouqué and Levy. M. Meunier (they hold) had not sufficient data to determine the nature of the minerals produced; his experiments are a mere repetition of those of James Hall in 1798, who fused natural rocks, subjected them to long annealing, and found the metal grains obtained had sometimes a crystalline texture. The authors, far from having got results with orthose like those of M. Meunier, find a marked difference between this felspar and others as to its structure after reproduction by igneous fusion; it does not take the ordinary crystalline structure, and this reveals the necessity of intervention of volatile elements in genesis of acid rocks.—Note on the element called *Mosandrum*, by Prof. Lawrence Smith. He claims priority in having called attention to the absence of the oxide of cerium, and to new characters of certain earths in the mineral samarskite, and having indicated a new one he called *mosandrum*.—Double stars; certain groups of perspective, by M. Flammarion. He gives a list of couples that are merely optical groups, due to the meeting, in the same visual ray, of stars situated one beyond the other in space, and having different proper motions.—On the number of complete arrangements where consecutive elements satisfy given conditions, by M. André.—On various derivatives of spirit of turpentine, by M. De Montgolfier. He has studied the action of sodium chiefly in chlorhydrates of turpentine, solid and liquid.—On a cyanised derivative of camphor, by M. Haller.—Action of salts of chromium on salts of aniline in presence of chlorates, by M. Grawitz. He notes the advantage of using these salts in place of vanadic salts; they are less rare and dear, and have even greater energy. $\frac{1}{10}$ of a milligramme of bichromate of potash, per 125 grammes of aniline salt dissolved in water, still developes black.—On the physiological action of borax, by M. De Cyon. Borax added to meat to the extent of twelve grammes daily (a quantity ten times that required by the Jourdes process), may be taken in food without causing the least disorder in general nutrition. Substituted for marine salt, borax increases the power of assimilating meat, and may cause a large increase of weight in the animal, even when the alimentation is exclusively albuminoid. This all applies to pure borax only.

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THURSDAY, DECEMBER 12, 1878

LORD RAYLEIGH'S "THEORY OF SOUND"

The Theory of Sound. By J. W. Strutt, Baron Rayleigh, F.R.S. Vol. II. (London: Macmillan and Co., 1878.)[1]

THE second part of Lord Rayleigh's highly instructive work on acoustics contains the mechanics of oscillatory motions in liquids and gases. Atmospheric air is that medium by which by far the greater number of sound-waves are conveyed to our ear, since it is only exceptional that this happens through solid bodies which are in contact with our teeth or with the bones of the skull. But it is just for this reason that all circumstances are of considerable importance, which influence the transmission of sound-waves in the air, *i.e.*, change either their velocity, their direction, or their intensity. This part of the theory has been worked out very minutely and completely by the author. We find here the compilation and demonstration of a large number of facts which, in other works on acoustics, are hardly mentioned. The author, after having first developed (in Chap. XI.) the general laws of the motion of liquids as expressed in hydrodynamical equations, and then explained the difference between rotational and irrotational motion of fluids, passes on to the simplification of the equations, which is determined by the circumstance that with sound, as a rule, we have to do with oscillations of extremely small amplitude. First, the motion of plane waves is investigated, and it is shown that with waves which move only in one direction half their equivalent of work consists in the *vis viva* of motion, and the other half in the potential energy of the compression and dilatation of the medium. Then follows the explanation of the influence which the change of temperature, taking place with compression or dilatation of gases, exercises upon the velocity of transmission of sound. It is shown, in the manner first employed by Prof. Stokes, that if a perceptible quantity of heat could be exchanged between the compressed and dilated layers of the waves during the lapse of one oscillation, the intensity of the sound-waves would very quickly decrease in their transmision and they would die away.

The subjects treated of up to this point are generally known among physicists; less known are a series of other results of the theory. The author next gives a comparatively very elegant and easily intelligible demonstration of the results at which Poisson and Riemann arrived, when investigating the propagation of sound-waves for which the velocities of oscillation are no longer infinitesimal when compared to the velocity of transmission. It appears that the different layers of the wave transmit their phases with different velocities, viz., with that velocity which represents the sum of the ordinary velocity of transmission of the smallest waves and of the oscillation velocity of the particles of air oscillating in the same direction. The compressed layers of the wave, therefore, are propagated quicker than the dilated ones, thus they must gradually change the shape of the wave, and finally overtake the preceding dilated layers. What would happen in that case, whether perhaps a breaking of the waves of air would take place, is not yet clear, since the hydro-dynamical equations apply only to velocities changing continuously.

These circumstances have not always been considered in experimental researches concerning the velocity of sound. A precise answer to the question regarding the magnitude of this velocity can only be given, if we confine ourselves to oscillations of extreme smallness.

The author has also investigated under what conditions a sound-wave of finite amplitude can move forward without changing its form. It appears that this could happen only under the supposition of a special law for the compressibility of the medium, which does not correspond with the law applying to gases.

The propagation of sound in the atmosphere is subjected to yet other perturbations, which partly arise from the different temperatures and moistures of the superposed strata, and partly from the different force of winds. At the surface of water or extensive masses of solid substance, the sound-waves of the air are totally reflected even under very small angles of incidence; under perpendicular incidence their reflection, although not total in the strict sense of the word, is nearly as complete. For that part of the sound which enters the new medium, the same law of refraction holds good which applies to waves of light. But also from a surface of hydrogen one-third of the sound coming through air at a vertical incidence is reflected, and the angle of incidence for total reflection is not larger than 15¼ degrees.

The problem to determine theoretically how the propagation of sound in the atmosphere is changed by the different temperatures of its strata cannot yet be solved completely. However, it can be ascertained in what direction the most powerful effect must travel. On account of the great dimensions of the strata of the atmosphere, compared to which the wave-length of the large majority of audible tones disappears entirely, the conditions of the propagation of sound are similar to those of light. We may imagine the sound-waves dissolved, as it were, into rays of sound, and then look upon each separate ray as being almost completely independent of the motion of its neighbouring rays. This is no longer admissible if obstacles are in the way of the travelling sound, the dimensions of which exceed the sound wave-lengths only in moderate proportions, as is the case in our houses and rooms, with the transmission of sound through windows and doors. Then, as in the case of light under similar circumstances, diffraction takes place. The great difference in the propagation of sound and light, as it becomes evident in ordinary experience, has its cause in the very different magnitude of wave-lengths. The greater the wave-length the greater the diffraction on the passage through the same aperture. These circumstances, which are forgotten so frequently, the author considers in Chapter XIV. When sound is propagated in the unbounded space of the atmosphere the conditions of the problem are such, that they allow of its decomposition into rays of sound. If a source of sound is near the ground then its sound rays are all bent into an upward direction, as Prof. Osborne Reynolds first pointed out, and those which travel in a direction parallel to the ground are mostly annihilated through friction or other obstacles. The sound proceeding from

[1] For Vol. I. see NATURE, vol. xvii. p. 237.

G

a source near the ground is, therefore, not heard far off by an observer standing on the ground. It is heard at a much greater distance if the observer or the source of sound be in an elevated position. The state of the atmosphere will have great influence upon these conditions. In dry air and sunshine the deflection of sound upwards will be greater than in moist air which forms clouds above, or during rain.

The decrease of temperature in the upper strata of the atmosphere causes sound to travel at a lesser speed than in the lower ones. Now if a wind is blowing, the velocity of which increases with the height, then, as Prof. Stokes remarks, this causes an increase in the velocity of the sound-waves in the direction of the wind, and a decrease in velocity in the opposite direction; thus, for sound which travels in the former direction, the retarding effect of decrease of temperature is neutralised, and for that travelling in the latter it is augmented. We therefore hear better if the wind blows towards us from the source of sound than if the contrary takes place. Indeed, by an upper windy layer, sound produced in the lower tranquil air may be totally reflected. This influence of wind is remarkable also because it forms an exception to the law demonstrated by myself, viz., the law of reciprocity in the propagation of sound, if the sound-source and the observer change places.

The problems of the reflection of sound by fixed walls, for instance, the phenomena of whispering-galleries, speaking-trumpets, and the echo, are treated in the same manner. Although here the admissibility of the decomposition of sound into sound-rays does not, as a rule, appear quite so unquestionably justified, yet the phenomena observed agree with this hypothesis on the whole.

An essential progress in the application of the theory upon experiments has been made by the author in the calculation of the influence of the open apertures of organ pipes and resonators upon their pitch. In my own demonstration of this part of the theory I had started from those forms of motion which did not render the calculation too difficult, and had then derived the corresponding forms of pipes; finally, I had so determined the optional constants of my hypotheses, that the form of pipe approached the form wished for, the cylindrical one, for instance; yet I remained confined to a few forms if I did not wish to complicate the calculation too much. Lord Rayleigh, on the contrary, supposes a given form of pipe, and has employed the maxims, developed in the first volume of his work, regarding the variation of conditions under which sound-motion takes place, to determine the limits within which the true value of the desired magnitude must lie, and has indeed been able to draw these limits so narrowly for the most important problems, like that of the cylindrical open pipes, that practically the solution is perfectly sufficient. In this way he has been able to treat simultaneously a number of problems, which hitherto had not even received an approximate solution, for instance, the determination of the proper tones of resonators of the shape of bottles with wide body and narrow neck.

Besides the problems mentioned, which are of direct importance to experimental physics, a series of others are worked out, where the mathematical solution can be completely given, such as the propagation of sound in balls, spherical layers and rectangular boxes filled with gas, the reflection of sound from the outer surface of a ball, and the communication of sound to air by oscillating balls and strings. These problems are valuable not only as theoretical exercises, but also with regard to our understanding of physical phenomena. They are examples affording to the mental eye of the physicist a particularly perfect insight into the essence of sound-motion and the changes it undergoes, when the conditions under which it occurs are changed. Thus he obtains quite as good a conception of the typical behaviour of sound as if he had actually seen the phenomena, and this conception will also guide him safely in cases of observation, where the exterior conditions are not as simple as they are in the theoretical example.

At the end of the volume Lord Rayleigh has placed the words: "The End." We hope that this may be only the provisional, not the definite end. There is still an important chapter wanting, viz., that on the theory of reed-pipes, including the human voice. For the former, at least, the principles of their mechanics can already be given, and the methods the author employs seem to me to be particularly well adapted for further progress in these domains.

After reed-pipes we would mention the theory of singing flames, and the blowing of organ-pipes. In the latter case the leaf-shaped current of air, which comes from the wind-case, forms a sort of reed, which oscillates under the influence of the oscillating column of air in the interior of the pipe, and which throws its air now into the interior of the pipe, and now outside.

Altogether, the whole of this important class of motions, where oscillatory movements are kept up through a cause which acts constantly, deserves detailed theoretical consideration. The action of the violin bow, and the sounding of the Æolian harp, also belong to this class.

Lord Rayleigh certainly deserves the thanks of all physicists and students of physics; he has rendered them a great service by what he has done hitherto. But I believe I am speaking in the name of all of them, if I express the hope, that the difficulties of that which yet remains will incite him to crown his work by completing it.

H. HELMHOLTZ

OUR BOOK SHELF

Zoologischer Anzeiger. Herausgegeben von Prof. J. Victor Carus. (Leipzig: Wilh. Engelmann.)

THE idea of a zoological "advertiser" seems to us a most excellent one, and we both welcome and heartily recommend to our readers who are interested in the animal kingdom this little fortnightly journal of Prof. Carus. The editor purposes to publish a number every two weeks, each number to contain from sixteen to eighteen pages, and the yearly subscription to be six shillings. The first number bears the date of July 1, 1878, and already a dozen numbers have appeared. The plan of each number is to commence with a retrospect of the current literature of zoology, a retrospect that we need hardly say will be well done by one so learned and able in the matter of bibliography as the editor of that most necessary work, the "Bibliotheca Zoologica." Then each number contains some short notices on zoological subjects in connection with museums, chiefly such as have a practical bearing. Thus in No. 2 we find an article by G. von Koch, of Darmstadt, on a method by which sections can be made of substances of different

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