ON THE NEWTONIAN CONSTANT OF GRAVITATION.[1]

II.

I HAVE already stated that two measurements, viz. the horizontal distances between the axes of the wires which support the lead balls, and of the fibres which support the gold balls,

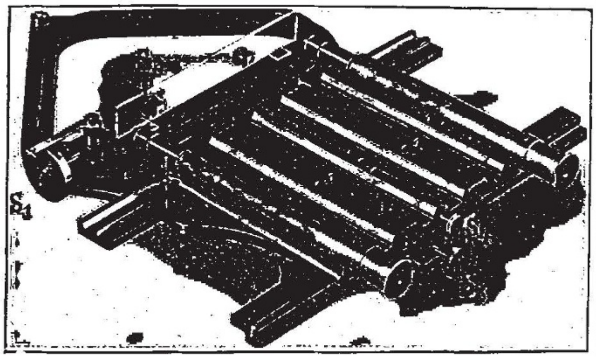


FIG. 4.

must be made with the highest degree of accuracy attainable, for on these the result directly depends. In order to accomplish this, I had to design a special instrument, an optical compass, which is illustrated in Fig. 4. This is an arrangement which rests upon the lid of the apparatus on the circular V-groove seen in Fig. 1, so that it can rotate without shake. Upon the lower framing rests the focussing slide, and on this a pair of traversing slides, each carrying a microscope in one or other of three grooves. The two traversing slides are drawn together by a spring, and can be separated by a screw cone, forming a very delicate fine adjustment. This is operated by the screw-head S_4; S_3 is a focussing screw giving a fine adjustment to the focussing slide. S_2 S_2 are two parallelising screws, the purpose of which is to bring the microscopically-divided glass scale into focus at each end simultaneously. S_1 is a micrometer screw-head, which is employed to push the scale bodily to the right by measured amounts. The two microscopes are focussed upon, say, the right sides of the wires, the focussing slide is then withdrawn, leaving them relatively unchanged, and the microscopic scale is then put in its place. The distance from wire to wire is thus transferred directly to the scale, and the fractional part of any one division of 1/100 inch is all that has to be referred to and measured by the screw. Every slide in this apparatus is geometrically arranged, so that the movements are all perfectly free, unconstrained, and without shake. In measuring the distance between the fibres, which must be done while they are freely suspended, so that a force of a millionth of the weight of a grain will give them a considerable motion, means have to be provided to exclude draught, which yet must not interfere with the apparent distances of the fibres. No microscope cover-glass is any use for this purpose. It is sure to be prismatic, and when inserted between the microscope and an object, it will certainly cause it to shift its apparent position. A piece of clear mica is perfect in this respect, no movement, even with a high power, being visible. I mention this, as it well illustrates the sort of trap that is ever set for the experimentalist. If I had not been aware of this, and had used, as would be natural, a window of microscope cover-glass, then each fibre would have appeared as definitely in its place as before, but the place would have been wrong, perhaps by 1/1000 inch, and thus a consistent error affecting all the experiments alike would have been introduced,

FIG. 5.

[1] Continued from p. 334.

and no multiplication of observations or taking of means would have eliminated it. It is on this account that it is so important in experimental work to vary the conditions in every way, so as to discover unsuspected consistent errors.

The microscope scale was made by Zeiss, and is a most perfect example of scale construction. In order to test the accuracy and find the errors of the scale, I took advantage of my visit to Cardiff, for the meeting of the British Association, to compare it with a series of Whitworth standard bars on Prof. Viriamu Jones's very perfect Whitworth measuring machine. For this class of work sunshine or dust give great trouble, but I was fortunate in having splendid weather for my purpose, as visitors will probably remember. It rained without ceasing during the two days that I was making these measurements.

Having now very imperfectly described the apparatus and the place in which I have carried out my experiments, I will next show a series of photographs, which I took by magnesium

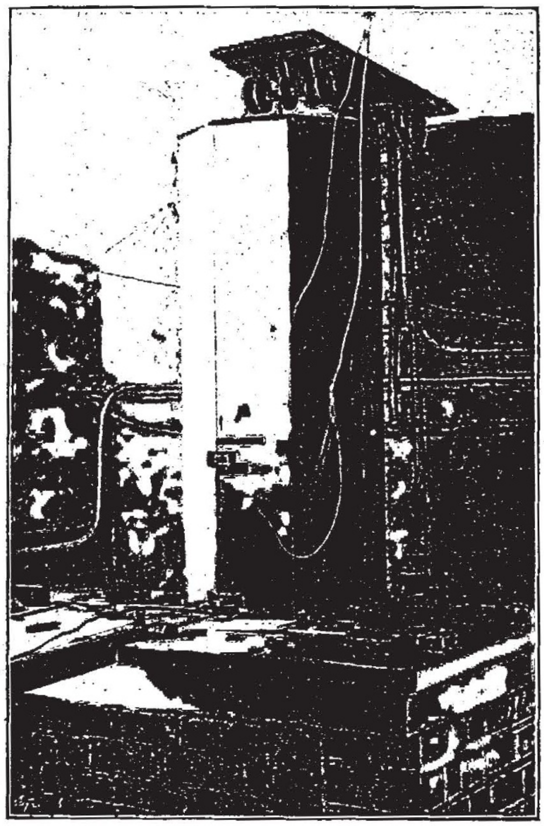


FIG. 6.

light, to give a better idea of the appearance of the apparatus and its surroundings. Fig. 5 is a view of the vault showing the clock, the eye end of the big telescope, and the little telescope. In the distant corner is seen the felt screen with a long slit, through which the scale and telescope can be seen from the mirror of the instrument. This, of course, is on the table behind the screen. Fig. 6 is a view of the corner itself, with the screen drawn back. The octagon protecting house, which surrounds the apparatus, is seen in position. Here again a slit is cut large enough to allow the scale and telescope to be seen from the mirror. Fig. 7 is a view of the instrument with the two halves of the octagon house separated. Here a further system of screens consisting of concentric brass tubes may be seen, but the lower one, which surrounds the window, has been removed and placed upon the table. The driving gear is also seen in this photograph, and a tube coming from the screw under the instrument which holds the central tube, which tube is also seen in Fig. 1. This tube enables me to control the motion of the mirror from the telescope without approaching the corner in which the apparatus is set up. This is done as follows: the back window at the level of the mirror is made of metal, with a hole in it in which is screwed a metal tube lightly filled with cotton wool. This is not central, but opposite one end of the mirror. The tube on the table does not fit the screw, but is merely bent up and enters it loosely. By gently drawing air from the end of the tube at the telescope a very feeble draught is produced in the apparatus, for nearly all the required air is supplied by leakage round the pipe near the screw, very little entering through the window pipe, in consequence of the resistance offered by the cotton wool. In this way, if the mirror is

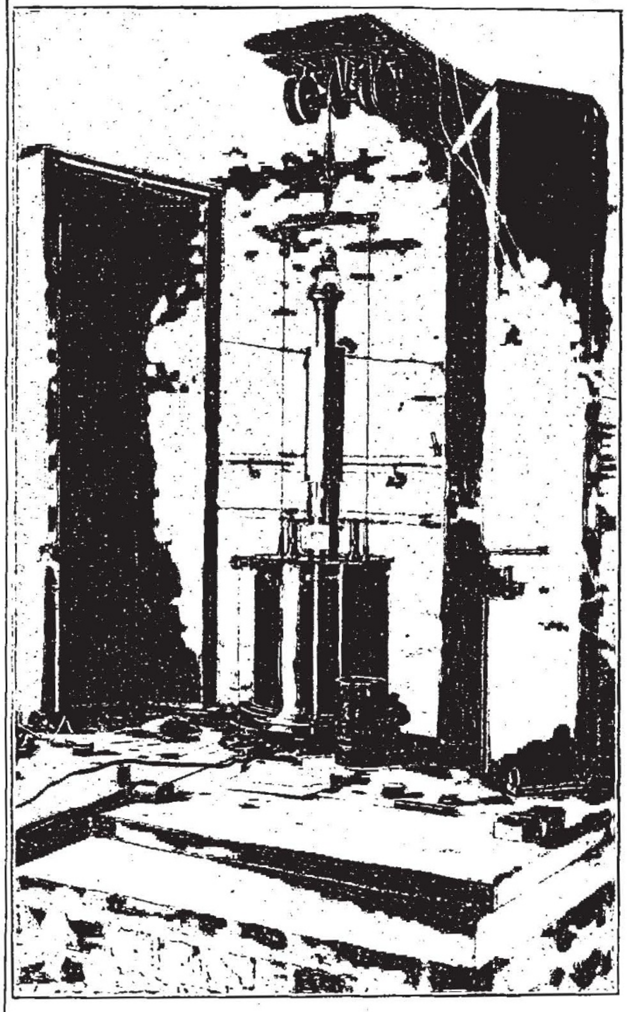


FIG. 7.

moving it may be gently brought to rest without impact, or it may be given a swing of any desired amplitude. So perfectly does this work, that the mirror may be steadied very quickly so as to move through less than a scale division, an amount which corresponds to six or seven seconds of arc, or to a force of less than one thousand millionth of the weight of a grain.

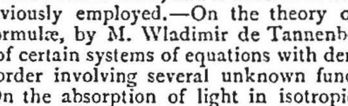
The operations for any complete experiment are fourteen in number. I do not intend to go through these seriatim, as time will not allow me to do so. It is sufficient now to say that the first eight are necessary to get the instrument and scale relatively fixed and adjusted, the vertical measures made, and generally all ready for operation 9, in which the optical compass is employed. This is a most important one, for not only are the horizontal measures made, on which so much depends, but in addition the plane of the wires and fibres are made identical, the corresponding scale reading is found, and any eccentricities are measured and may be corrected.

(*To be continued.*)

SOCIETIES AND ACADEMIES.

PARIS.

Academy of Sciences, July 30.—M. Lœwy in the chair.—Conditions necessary for the production and the perception of murmurings in tubes through which air-currents pass, by M. A. Chauveau.—On certain of the later geological and climatic phases in Barbary, by M. A. Pomel. The quaternary period was marked in Barbary by (1) a rainy phase with formation of alluvial deposits, followed by (2) a dry period characterised by the formation of travertinous crusts, and (3) the partial submergence and reappearance of the coast districts with the production of a narrow band of marine beds and a moderately humid climate, which has since deteriorated to the present condition of excessive dryness.—Report on M. Bigourdan's memoir "On the micrometric measurement of small angular celestial distances, and on a method of perfecting this kind of measurement," by MM. Lœwy, Tisserand, and Wolf. The method used by the author for the measurement of micrometric angular distances consists in the use of glass points in place of the micrometer threads, so that the image is never blotted out by superposition. It allows of much easier work, and is at least as accurate as any method previously employed.—On the theory of differential quadratic formulæ, by M. Wladimir de Tannenberg.—On the integration of certain systems of equations with derived partials of the first order involving several unknown functions, by M. Riquier.—On the absorption of light in isotropic and crystallised media, by M. G. Moreau.—A contribution to the study of the structure of steel, by M. F. Osmond. With moderately hard steel, containing 0·45 per cent. of carbon and 0·35 per cent. of manganese, the structure was found to vary gradually in samples all originally heated to 825° C. and quenched in water at 15° C. after cooling to 720°, 690°, 670°, 650°, and 640° respectively. Hardening from 640° left the structure almost the same as slow cooling. With hard steel, containing 1·24 per cent. carbon, the variation is more rapid; the temperature of maximum hardening lies very near to that of no hardening. The structure, as studied by polished surfaces, in steel of moderate hardness gives information concerning (1) the maximum temperature of heating, (2) the temperature from which it has been hardened, and (3) the rate of cooling.—A refractometer with a chamber capable of being heated, and its application to measurements with fatty substances, by M. Féry.—On the constitution of rhodinol from essence of Pelargonium, by MM. Ph. Barbier and L. Bouveault. Rhodinol is demonstrated to be a primary alcohol, $C_{10}H_{18}O$, containing one ethylenic grouping; it is a cyclic compound, and its rotatory power and that of its derivatives prove the presence of an asymmetric carbon atom. The consideration of the foregoing, together with the ease with which on oxidation it yields acetone and α-methyladipic acid, leads to the provisional formula:—



—Action of thionyl chloride on some inorganic acids and organic compounds, by M. Ch. Moureu. With mineral acids $SOCl_2$ gives the corresponding chlorhydrins; with aldoximes it yields nitriles by dehydration; with oxalic and formic acids it behaves just like sulphuric acid. In each case equal volumes of hydrogen chloride and sulphur dioxide are liberated.—On the stability of aqueous solutions of mercuric chloride, by M. E. Burcker.—The oxidation of beer worts, by M. P. Petit.—The mechanism of the influence of toxic substances acting by means of secondary causes in the production of infection, by MM. Charrin and Duclert. The conclusion is drawn that poisons aid infection by an antiphagocytary action allowing the more rapid multiplication of the disease microbe without increasing the virulence of its virus.—On some new laws of pupillary contraction, by M. Ch. Henry.—Is the use of the Auer burner capable of causing partial poisoning? By M. N. Gréhant. The author quotes experimental results from which he draws the conclusion that the Auer burner in use does not cause poisoning by the trace of carbon monoxide produced.—On the transformation of "Paguriens" into anomourous crabs of the sub-family of the Lithodinæ, by M. E. L. Bouvier.—On the venomous gland of the "Myriapodes Chilopodes," by M. O. Duboscq.—Branchiæ in *Physa lamellata*, by M. Paul Pelsener.—On the Hongkong plague, by M. Yersin. A specific bacillus is found in great numbers in the bubon, but not in the blood.

BOOKS, PAMPHLETS, and SERIALS RECEIVED.

BOOKS.—The Country Month by Month, August: Owen and Boulger (Bliss).—Les Machines Thérmiques: Dr. A. Witz (Paris, Gauthier-Villars).—Object-Lessons in Elementary Science: V. T. Murché, 3 Vols. (Macmillan).—Fur and Feather Series—The Grouse: Macpherson, Stuart-Wortley, and Saintsbury (Longmans).—41st Report of the Department of Science and Art (Eyre and Spottiswoode).—Directory, with Regulations for Establishing and Conducting Science and Art Schools and Classes (Eyre and Spottiswoode).—The Wild Garden: W. Robinson, 4th edition (Murray).—A Treatise on the Measurement of Electrical Resistance: W. A. Price (Oxford, Clarendon Press).—The Animal as a Machine and a Prime Motor: R. H. Thurston (K. Paul).—The Collected Mathematical Papers of Henry John Stephen Smith: edited by Dr. J. W. L. Glaisher, 2 Vols. (Oxford, Clarendon Press).—Progress in Flying Machines: O. Chanute (S. Low).

PAMPHLETS.—Report on the Gohna Landslip, Garhwal: T. H. Holland.—Romanes Lecture, 1894—The Effect of External Influences upon Development: Dr. A. Weismann (Frowde).—Sketch and Check-List of the Flora of Kaffraria: T. R. Sim (Cape Town, "Argus").

SERIALS.—Bulletin of the New York Mathematical Society, Vol. 3, No. 10 (New York, Macmillan).—Geological Magazine, August (K. Paul).—Journal of the Chemical Society, July and August (Gurney and Jackson).—Geologische und Geographische Experimente: E. Reyer, 3 and 4 Heft (Leipzig, Engelmann).—Science Progress, August (Scientific Press, Ltd.).—Scribner's Magazine, August (S Low).—Fortnightly Review, August (Chapman).—Medical Magazine, August (Southwood).—Natural History of Plants: Kerner and Oliver, part 4 (Blackie).—Himmel und Erde, August (Berlin).—Seismological Journal of Japan, Vol. 3, 1894 (Yokohama).—Journal of the Anthropological Institute, August (K. Paul).—Societa Reale di Napoli, Atti della Reale Accademia delle Scienze Fisiche e Matematiche Serie Seconda, Vol. 6 (Napoli).—Rendiconto dell'Accademia delle Scienze Fisiche e Matematiche, Serie 2ª, Vol. 8 (Napoli).

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