shall explain; the wheels and rails will serve as the return wire. This system worked well at the *workshop*. In practice a special difficulty was encountered. The dirt sticking to the rails and felloes of the wheels formed a sort of crust so insulating as to prevent adequate communication with the earth. The increase of resistance produced by this interposition of finely conducting bodies was often sufficient to arrest the vehicle. The remedy was happily beside the evil, and a second conductor was established parallel with the first, in communication with the second pole of the generator, on which runs a second traverser, identical with the former. These two cars follow on their respective tubes the movements of the vehicle, and ensure a good and constant communication between the electrical generator and the motor. Fig. 1 represents the carriage and the station at the Place de la Concorde. At the height of the knife-board are seen the two conducting tubes supported at certain distances by posts, and in the intervals by iron wires, like the floor of a suspension bridge. The carriage is exactly the same as the ordinary tramway car. The motor is placed underneath the feet of the inside passengers; it is a Siemens dynamo-electric machine, with horizontal inductors similar to that which produces the current in the Palais de l'Industrie. The distance traversed is about 500 metres, and is accomplished in one minute. The work expended reaches 8 horse-power in the curved

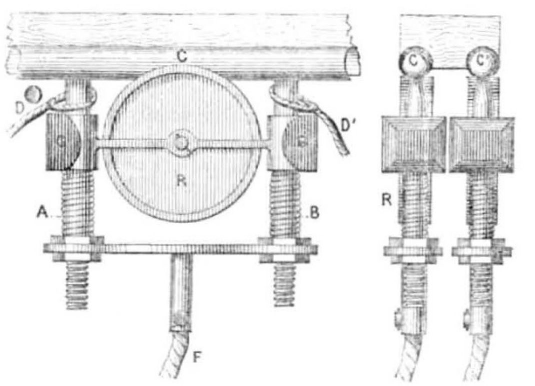


FIG. 2.—Traversers conducting the current to the carriage.

part; on a level straight run it does not exceed $3\frac{1}{2}$ horse-power. The transmission of motion to the wheels is effected by means of a fall-chain. By a happy coincidence, which belongs to the very nature of the electric motor, the *static effort* is maximum when the motor is in repose. This renders the starting very easy, and no difficulty is met with from this point of view. To regulate the speed, resistances are introduced into the general circuit, which reduces the intensity of the current, and consequently the work of the motor; this operation is very simply effected by means of a lever placed at each end of the carriage. For stopping, the current is broken, and at the same time an ordinary brake is applied.

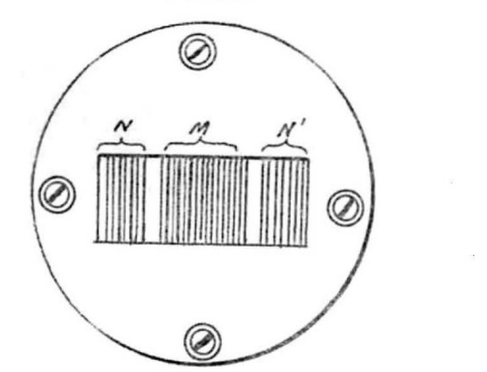
As to the mode of communication of the conductors with the carriage, we have said that it is effected by means of two identical traversers; it will suffice to describe one of them. Fig. 2 represents in detail one of these traversers. It is composed of a rectangular frame, bearing in its centre a wheel, of which the groove R is semi-cylindrical, and is applied against the exterior part of the conductor C, formed of a brass tube 22 millimetres in diameter and slit on its lower part along all its length to a breadth of about 1 millimetre. In this tube slides a cylindrical core of 12 centimetres in length, on which are fixed, at its extremities, two vertical shafts, A, B, which support the wheel or roller. Two springs supported on these vertical shafts press the wheel against the tube, and maintain an elastic contact between the tube and the wheel. The carriage may then be moved; the wheel runs against the tube, the core glides in the interior, without the communication ceasing to be, if not perfect, at least quite sufficient for the purpose. Only at times a few sparks are seen at the moment when the carriage passes the coupling of the tubes; these sparks are due to small instantaneous ruptures of the current which do not affect the regular working of the system. The experiment shows that the wear and tear scarcely affects the tube, and bears almost entirely on the core placed in the tube; but nothing is easier than to replace a core. The current reaches the machine by the copper conductor F. The traction of the carriage is effected by the cords D or D', according to the direction.

The electric railway of the Palais de l'Industrie presents the first practical solution of an electric traction in the case of a tramway. Of course it is easy to see how this application of electricity is capable of the greatest development, and that by modification of details the principle might be applied to railways.

THE BOLOMETER

AN instrument a thousand times more sensitive to radiant heat than the thermopile, and capable of indicating a change of temperature as minute as 1-100,000th of a single Centigrade degree, deserves the attention of the physicist. When to these qualifications it can be added that the new instrument is far more prompt in its action, and more reliable than the thermopile for the *quantitative* measure of radiation, then, indeed, no apology is needed for a detailed description. The instrument is termed by its discoverer, Prof. S. P. Langley, the *bolometer*, or *actinic balance*. The earliest design of the in-

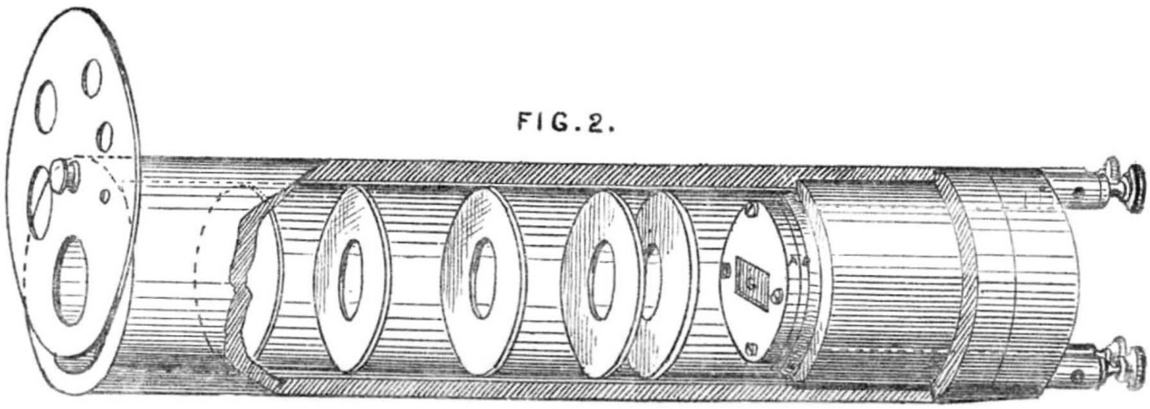
FIG. 1.



ventor was to have two strips of thin metal, virtually forming arms of a Wheatstone's bridge, placed side by side in as nearly as possible identical conditions as to environment, one only of them being exposed to radiation. Such radiation would slightly warm the strip and therefore alter its electric resistance, and the amount of this change would be indicated by the movement of the needle of the galvanometer placed in the middle circuit of the "bridge." For various reasons iron was eventually chosen as the material for the thin strips, as it combines the qualities of tenacity and laminability, with a greater sensitiveness in its electric resistance to temperature changes than either gold, platinum, or silver. Preliminary experiments made with a simple strip of iron in comparison with several delicate thermopiles showed the advantage of the new method of investigation. A large Elliott thermopile of sixty-three pairs, a very sensitive thermopile of sixteen small pairs, and a delicate linear thermopile of seven pairs of elements were selected. The iron strip taken was 7 millims. long, ·177 millims. broad, and 0·004 millims thick. Its resistance was 0·9 ohm. The three former instruments were one after the other connected with a short-coil mirror galvanometer of sufficient delicacy. The same galvanometer was used in the bridge, the three resistances used with the strip being respectively ·9, ·4, and ·4 ohm, and the total current employed being a little over half a weber. The result showed the sensitiveness of the three instruments and of the strip to heating by radiation to be respectively as 1, 4·1, 16·3, and 226·3.

The actual bolometer embodies the principle of the preliminary experiment with various additional refinements. Sheets of *steel* (palladium and platinum can also be used) are rolled out until of a thickness of from ·01 to ·002 of a millimetre is attained. Out of these sheets small gratings are cut or punched, having the individual bars about 1 millimetre wide and 1 centimetre long. Two systems of strips are arranged so that the current from a suitable battery divides itself, half passing through each, the interposed galvanometer showing no deflexion when the two currents are of equal strength. Fig. 1 shows the general arrangements of the gratings of strips. A rectangular opening is cut in a disk of ebonite of 3 centimetres

FIG. 2.

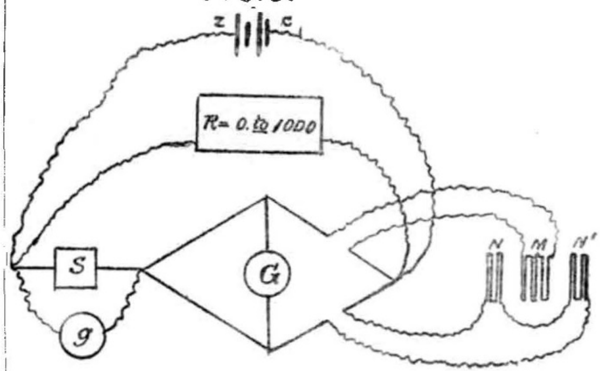


diameter. A second disk of the same size is clamped behind it, and between the two the gratings or systems of strips are fixed. That system which is to be exposed to radiation is placed in the centre of the rectangular opening at M. It consists of fifteen strips, eight of them being in front, and seven at a little distance behind. The second system is divided into two halves, N and N′, on each side of M, each half consisting of seven similar strips, four in front, three behind. Every joint is soldered, and the resistance of the fourteen strips in N N′ is made up equal to that of the fifteen strips in M by the interposition of a short wire in the circuit. M is placed in one arm of the bridge, and N N′ in the other, as indicated in the diagram of Fig. 3.

To protect the bolometer from air-currents, sudden changes of temperature, and from danger in handling, it is inclosed in a cylinder of ebonite lined with sheet copper. This is represented in Fig. 2, where the tube is drawn partly in section to display the interior. At the anterior end of the tube is a revolving diaphragm with suitable apertures. Within, a number of cardboard diaphragms or stops are placed, being retained in position by rings of ebonite tube between them. Behind these is the grating G of the bolometer fixed between the two disks of ebonite A and B. At the back there is a layer of solid non-conducting material, through which the conducting-wires pass to the two terminals. In the posterior end of the case are contained the resistance-wires by which to bring the two systems to equality; this being advisable because, if they are unequal at the beginning of the experiment, though they can be balanced by taking proportionally unequal resistances in the other arms of the bridge, according to the well-known law, any general rise of temperature will produce a *greater increment* of resistance in the system whose resistance is at first greater, producing a continuous "drift" in the galvanometer needle. Fig. 3 shows the connections of the bolometer and the bridge. A battery of one or more Daniell's cells, Z, C, provides a current the strength of which is controlled at will by changing the resistances in a box of coils, R, arranged as a shunt to the bridge-circuit. The working current is measured by a shunted galvanometer, *g*, and the two systems of strips M and N N′ of the bolometer are connected to their respective places in the bridge by four insulated wires twisted together and covered with flannel. A modification of the usual formula enables the change of resistance of M to be calculated from the currents observed in the galvanometer G.

The results of the new instrument are somewhat startling. A sunbeam one square centimetre in section will, according to Prof. Langley, warm one gramme of water 1° C. in one minute. It would therefore raise a sheet of water 1-500th of a millimetre thick, and 1-10th

FIG. 3.



of a square centimetre in area, 83⅓° C. in one second, supposing all the heat to be retained. And as platinum has a specific heat of only ·032, the same sunbeam falling on a strip of platinum of these dimensions should, on a similar supposition, raise it in one second to 2603° C., a temperature sufficient to *melt* it! This result is, however, prevented by the re-radiation which the strip almost instantaneously exerts.

An examination of the heating effect of rays from different portions of the spectrum of solar radiations was made, but under conditions different from those of the measurements made by Müller, Herschel, and Tyrda

These experimenters worked with spectra obtained by prisms of quartz, rock-salt, and other refractive substances. Prof. Langley used the far purer spectrum obtained by reflection from the surface of one of Rutherford's diffraction-gratings ruled on speculum-metal. This showed the result that *the heat-maximum* (of solar rays) *in a normal spectrum is not in the infra-red rays, but is at least as far up the visible spectrum as the orange near the D-line.* This result is so important that we append the figures. In the upper line are the wave-lengths of rays in millimetres; in the lower the corresponding reduced galvanometer deflections.

λ	·00035	·0004	·0005	·0006	·0007	·0008	·0009	·0010	·0011
δ	12	55	207	256	198	129	80	58	41

[The H line in the violet has λ = ·00039; the D line in the orange has λ = ·00059; and the A line at the end of the visible red has λ = ·00076.]

We give the above figures as stated by Prof. Langley; but we cannot help remarking that if these were obtained by letting sunlight fall upon strips of *polished metal* they cannot be accepted offhand as a true representation of the facts of solar radiation, as they merely in that case indicate the position of the maximum of *the rays absorbed by the metal surface employed.* A blackened surface would without doubt tell a very different tale and show a maximum for other rays.

In conclusion it may be pointed out that the fundamental principle of the bolometer is identical with that of Siemens' electrical pyrometer, where also changes of temperature are measured by changes in the electric resistance of a conductor. But though the principle be identical the application is quite novel; and we must congratulate Prof. Langley on the skill and ingenuity with which he has applied an unpromising principle to the construction of this most interesting and most promising instrument of research. S. P. T.

NOTES

THE announcement will be received with regret that Prof. Huxley, in consequence of the pressure of other duties, has been compelled to resign the Secretaryship of the Royal Society. It is believed that Prof. Michael Foster will probably be his successor.

SIR C. WYVILLE THOMSON has not yet resigned the chair of Natural History in Edinburgh University, though we regret to learn that he is likely to do so in a few days.

THE arrangements for the Crystal Palace Electrical Exhibition are progressing very satisfactorily. Major Flood Page has gone over to Paris to put himself in direct communication with the different administrations there and with the largest exhibitors. Applications for space have been very numerous, especially from English manufacturers. The Postmaster-General has signified his intention of sending all the apparatus now in Paris, and in addition there will be a considerable accession of modern apparatus in use in the Post Office Telegraph Department. The display will be essentially a display of the electric light. The whole of the building will be divided off and illuminated by the different inventors and manufacturers of lamps. The new Edison light will be shown in operation in the Concert Hall, and very great interest is evinced in the public display of this light. The effect produced by it in Paris was quite startling, and it is generally believed that Mr. Edison has solved the problem that he set himself, viz. to produce a light to supersede gas in our houses.

THE success of women in the late Honours Examinations of the University of London in Arts, Science, and Medicine was very remarkable. In the conjoint Honours Examination in Mathematics for candidates for the 1st B.A. and 1st B.Sc. Examinations Miss Charlotte A. Scott obtained the first place in the first class, with marks qualifying for an exhibition. In the 1st B.A. Honours Examination in English subjects Miss M. L. G. Petrie obtained a precisely similar position, whilst two other ladies, Misses C. A. J. Cluer and H. E. Clay, were also placed in the first class. In the 1st B.A. Honours Examination in German, Misses A. Page and H. H. Brown were placed in the first class, the former qualifying for a prize. Miss F. H. Prideaux actually carried off the supreme honours in Human Anatomy at the Honours Examination of the 1st M.B., being placed first in the first class, and being awarded the Gold Medal in Anatomy. In the Honours Examination in Materia Medica and Pharmaceutical Chemistry Mrs. M. A. D. Scharlieb attained a place in the first class.

THE first meeting of the one hundred and twenty-eighth session of the Society of Arts will be held on Wednesday, November 16, when the opening address will be delivered by Sir Frederick J. Bramwell, F.R.S., chairman of the Council. The following are among the papers which will be read during the session:—The American system of heating towns by steam, by Capt. Douglas Galton, C.B., F.R.S.; practical hints on the manufacture of gelatine emulsions and plates for photographis purposes, by W. K. Burton; stained glass windows, by Lewis Foreman Day; photometric standards, by Harold Dixon; telephonic communication, by Lieut.-Col. C. E. Webber; the causes and remedies of bad trade, by Walter R. Browne, M.A.; the native tribes of the Hudson's Bay Territories, by Dr. Rae, F.R.S.; the manufacture of ordnance, by Col. Maitland; some practical aspects of recent investigations in nitrification, by R. Warington; the production and use of gas for purposes of heating and motive power, by J. Emerson Dowson; gas for lighthouses, by John Wigham (illustrated by an exhibition of some of the gas flames and apparatus used in lighthouses); the relation of botanical science to ornamental art, by F. Edward Hulme, F.L.S., F.S.A.; the storage of electricity, by Prof. Silvanus Thompson, D.Sc.; the high-pressure steam-engine, by Loftus Perkins; the industrial resources of Ireland, by J. Philips Bevan; a new chemical compound, and its application to the preservation of food, by Prof. Barff, M.A.; the distribution of time by a system of pneumatic clocks, by J. A. Berly; tonnage measurement, by Admiral Sir R. Spencer Robinson, K.C.B., F.R.S.; tools and cutting edges, by D. A. Aird; the teaching of forestry, by Col. G. F. Pearson; the art of turning, by P. W. Hasluck. The usual short course of Juvenile Lectures, given during the Christmas holidays, will be by Mr. W. H. Preece, F.R.S., the subject being "Recent Wonders of Electricity." The following are the subjects of the courses of the Cantor lectures for the session just about to commence:—First course, on some of the industrial uses of the calcium compounds, by Thomas Bolas, F.C.S.; second course, on recent advances in photography, by Capt. Abney, R.E., F.R.S.; third course, on hydraulic machinery, by Prof. John Perry; fourth course, on book illustration, old and new, by J. Comyns Carr. In connection with Capt. Abney's lectures, it is intended to arrange for an exhibition of photographic apparatus, processes, &c. These lectures originated in 1863, with a bequest to the Society of Arts by the late Dr. Cantor. Since that date three or more courses have been given every session, each course dealing with some application of science or art to industry or manufactures.

WE understand that Mr. Donald McAlister, Fellow and Lecturer of St. John's College, Cambridge, has undertaken to prepare for Messrs. Macmillan and Co. an English edition of Prof. Ernst Ziegler's "Text-Book of General and Special Pathological Anatomy," which is on all hands regarded as the standard authority on its subject. The book will range with Dr. M. Foster's "Text-Book of Physiology," Gegenbaur's "Comparative Anatomy," and other works published by the same firm.