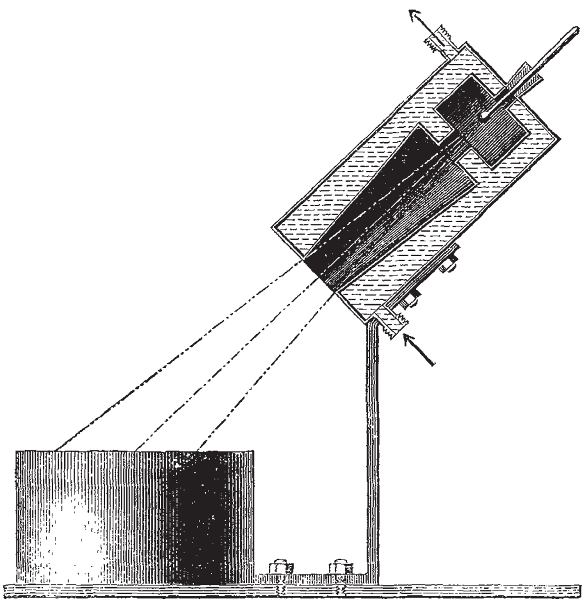
RADIANT HEAT

LORD ROSSE has shown* that the diathermacy of flame cannot be determined by the method described by Mr. W. Mattieu Williams, in his communication to NATURE, vol. vi. p. 506. Referring to the discrepancy which the reader may remember that Mr. Williams pointed out, Lord Rosse says: "The explanation of the discrepancy seems to be that the radiant heat from a flame, like that from any other body, varies as the inverse square of the distance and therefore the total effect is proportional to $\frac{1}{d^2} + \frac{1}{d'^2} + \frac{1}{d''^2}$ + &c., not $\frac{1}{d} + \frac{1}{d'} + \frac{1}{d''}$ + &c., where d, d'', &c., are the distances of the flames from the thermometer; in which latter case the order of lighting the jets would answer the desired object."

Mr. Williams, in order to meet the objection raised, presents calculations based on the assumption that the mean distance between the seventeen small flames and the thermometer is 14 in. The space from centre to centre of the flames being $\frac{1}{4}$ in., the distance between the thermometer and the centre of the nearest flame will be 12 in. Evidently Mr. Williams is not aware that a thermometer placed at a distance of 12 in. from his cluster of diminutive flames, cannot indicate 53° C. (127·4° F.), unless the surrounding atmosphere be heated to a temperature exceeding 123° F. Had he ascertained, experimentally, that the radiation of a cluster of such feeble flames, at the distance of 12 in. from the thermometer, imparts a temperature less than 3° C. above that of the atmosphere, he would no doubt have admitted the correctness of Lord Rosse's explanation of the supposed discrepancy, as freely as he admits the correctness of the theory on which that explanation is based.

The subject having attracted much attention, the writer has deemed it necessary to institute a series of experiments in order to test the accuracy of the table of temperatures which Mr. Williams desires Lord Rosse to accept on the ground that "the maximum error is less than $\frac{1}{10}$ of a degree, and the mean error lies between that and $\frac{1}{784 \cdot 25}$ of a degree."

Before entering on an examination of the result of the experiments adverted to, it will be necessary to call attention to the fact that, the transverse sectional area of a flame produced by 17 jets arranged in a straight line, $\frac{1}{4}$ in. apart, consuming 5 cubic feet of gas an hour, corresponds with the area of a circle of 0·87 in. diameter. The distance between the nearest point of the flame and the thermometer being 12 in., it will be found on calculation that the mean angle subtended by the heat rays projected towards the thermometer will be 4° 9′. Agreeably to the laws of radiation, the temperature produced at a given point by the heat rays projected from a deep radiating body, depends on the mean angle subtended. It may be shown, therefore, that in order to produce the differential temperature of 53° — 19° = 34° C (61·2° F.), observed by Mr. Williams, the intensity of the flame must far exceed that capable of being developed by any chemical means. A brief explanation of this important subject will be proper in this place. The accompanying illustration represents a pyrometer constructed by the writer for measuring with desirable precision intensities of all degrees. The pyrometer consists of a conical vessel communicating with a cylindrical chamber, as shown in the sectional elevation, both being surrounded by an external vessel through which a current of water, of uniform temperature, is circulated. The thermometer for registering the temperature produced by the radiation of any incandescent body, is inserted in the cylindrical chamber at a fixed distance from the opening of the conical vessel; hence the angle subtended by the heat rays projected by the radiating body towards the bulb of the thermometer, will remain constant whatever be the distance of that body from the instrument. Of course the radiation must be large enough to cover the entire field contained within the radial lines drawn from the bulb through the circumference of the opening of the conical vessel. We have already adverted to the fact that the temperature transmitted to the thermometer depends on the subtended angle. Consequently, by ascertaining practically what degree of temperature is imparted to the thermometer of the pyrometer, by a radiator of *known* intensity, we can determine the intensity of any other radiator by merely observing the temperature it imparts to that thermometer. It should be stated that in the pyrometers which have been constructed, the diameter of the opening of the conical vessel is $\frac{1}{6}$th of the distance from the thermometer; hence the angle subtended is very nearly 11° 26′ Experiments made with an incandescent block of cast-iron, arranged as represented in the illustration, have shown that when the temperature of the block is 1930° above that of the surrounding atmosphere, the thermometer of the pyrometer indicates a temperature 20·7° higher than the circulating water in the casing. Applying the pyrometer in a similar manner, for ascertaining the temperature of a mass of overheated fused cast-iron, the indication of the thermometer has been found to reach 31·4° above that of the water in the enclosure. Now, the temperature of radiators is proportional to the radiant heat which they transmit, provided the subtended angles be alike; hence it follows that the temperature of the fused metal must be $\frac{31 \cdot 4 \times 1930}{20 \cdot 7} = 2940°$ above that of the water in the casing surrounding the conical vessel. Adding the latter temperature, viz. 60°, we ascertain that the actual temperature of the fused metal will be very nearly 3000°. The result of several experiments shows that this temperature corresponds with that determined by the practical expedient resorted to during the investigation, of melting wrought-iron in the fused mass. It should be mentioned that in



Pyrometer for various intensities.

constructing the scale of the new pyrometer, the radiant power corresponding with given subtended angles and given temperatures, has been ascertained with critical nicety by experiments conducted within a vacuum. For the purpose of demonstrating that the distances assumed by Mr. Williams in his reply to Lord Rosse are greatly exaggerated, a reference to the amount of radiant heat transmitted to the thermometer by the fused metal will no doubt be most convincing. We have before stated that the heat rays projected towards the thermometer from a flame produced by seventeen gas-jets subtend a mean angle of only 4° 9′, while the heat rays projected from the fused metal towards the thermometer of the pyrometer, subtend an angle of 11° 26′. The areas corresponding with these angles being $4 \cdot 15^2 : 11 \cdot 43^2 = 1 : 7 \cdot 6$, it follows that, unless the intensity of the gas flame is 3000° × 7·6 = 22800° F., it cannot transmit to the thermometer the same temperature as the fused metal, viz. 31·4° F. But Mr. Williams records an increment of temperature of 53° – 19° = 34° C. (61·2° F.); hence $\frac{61 \cdot 2 \times 22800}{31 \cdot 4} = 44723°$ F., must be the temperature of his flame, if twelve inches be a true distance.

Having thus proved by demonstration that the distances assumed by Mr. Williams are exaggerated, let us now briefly examine the result of the experiments which have been made with an apparatus constructed agreeably to the description contained in his original communication. In carrying out these experiments, it was deemed necessary, before inserting the recording thermometer in a box as directed, to expose the same to the radiant heat of the flame, freely suspended in the atmosphere

* NATURE, vol. vii. p. 28.

but carefully protected from currents of air by screens appropriately arranged. The horizontal gas-pipe with its perforations, ¼ inch between each, having been so adjusted that the distance between the central perforation and the thermometer was 14 in., the 17 jets were ignited, and the supply of gas regulated at precisely 5 cubic feet per hour. The temperatures imparted to the thermometer during the experiment are recorded in Table A. It

TABLE A.

Time.	Indication of Thermometer.	Temperature of surrounding Atmosphere.	Differential Temperature.
m. s.	Deg. Fah.	Deg. Fah.	Deg. Fah.
0 0	62·8	62·8	0·0
6 2	64·4	62·8	1·6
12 5	65·6	63·0	2·6
18 6	66·5	63·2	3·3
24 8	67·0	63·4	3·6
30 11	67·3	63·6	3·7
36 9	67·4	63·7	3·7

will be seen on examining this table that the temperature imparted to the thermometer at the expiration of 36 minutes, was only 3·7° F., in place of 61·2° observed by Mr. Williams; the rate of discrepancy being thus 3·7 : 61·2 = 1 : 16·56.

This extraordinary discrepancy between the temperatures published by Mr. Williams in his original communication, and the distances assumed in his reply to Lord Rosse, having been fully established by the experiment, the arrangement was changed, the thermometer being brought within 3 in. of the flames. But even at this short distance, the thermometer exposed to the radiant heat during an interval of 29 minutes, indicated a differential temperature of only 22·6° F., in place of 61·2° F. as stated by Mr. Williams—a fact clearly showing that the high temperature observed by him was owing to the intervention of the box in which he inserted the thermometer. Such a box composed of polished tin plate, open at the end presented towards the flame, was accordingly applied; its position being such that the space between the thermometer and the flame measured 3 in., as before. The 17 jets being ignited and the supply of gas regulated at 5 cubic feet per hour, the column of the thermometer rose rapidly, attaining a height of 136° in 20 minutes. Deducting the temperature of the surrounding air, 63·5°, the increment of heat proved to be 72·5°, thus showing that by the intervention of the box, the differential temperature was increased threefold. It scarcely requires explanation that owing to the close proximity of the flame the air in the box becomes heated, imparting its heat to the thermometer, by convection; while the reflection of the heat rays against the sides and bottom of the polished box, imparts radiant heat to those parts of the bulb which are not exposed to the direct radiation of the flame.

In view of the foregoing explanation it will be evident that, in a properly conducted experiment, the temperatures recorded in Mr. Williams' table cannot be produced unless the thermometer be placed even nearer than 3 in. from the flame. But admitting that the recorded temperatures could be developed at a distance of 3 in., it will be found that the mistake to which Lord Rosse has called attention is fatal to Mr. Williams' deductions. Referring to Table B, constructed in accordance with

TABLE B.

No. of jet from Thermometer.	Energy Transmitted.	No. of jet from Thermometer.	Energy Transmitted.
1	2·77	10	0·90
2	2·37	11	0·82
3	2·04	12	0·75
4	1·77	13	0·69
5	1·56	14	0·64
6	1·38	15	0·59
7	1·23	16	0·55
8	1·11	17	0·51
9	1·00		

the theory pointed out by Lord Rosse in his letter to NATURE, it will be seen that each pair of jets so far from developing an equal amount of radiant energy, as indicated by Mr. Williams' table, they differ to a very great extent. For instance, while the two jets on each side of the centre develope respectively 1·11 and 0·90 (the energy transmitted by the central jet being represented by unity), the two outside jets develope respectively 2·77 and 0·51. Accordingly, the energy developed by the central pair will be 1·11 + 0·90 = 2·01, while the outside pair develope 2·77 + 0·51 = 3·28. Leaving out of sight the imperfections of the method adopted in making the observations, this great difference of the radiant energy transmitted to the thermometer by each pair of jets, is conclusive against the deduction concerning diathermacy of flame, which Mr. Williams has based on his published table of temperatures. J. ERICSSON

SCIENTIFIC SERIALS

THE *Archives des Sciences Physiques et Naturelles* contains a long and admirable article by Prof. Plantamour, on the meteorology of Geneva and the Great St. Bernard for 1871, a year of very exceptional weather at these places. In a series of carefully compiled tables, the various meteorological phenomena observed are compared in every possible way, and deserve the study of meteorologists. The second paper is an exceedingly interesting one from the work published by M. de Candolle, "Histoire des Sciences et des savants depuis deux Siècles," &c., containing the result of much acute and original research, on Transformations of Movement among Organised Beings. The other two principal papers are one by M. Ernest Favre, on the Geology of the Ralligstöcke on the banks of Lake Thun, and one by MM. de la Rive and Sarasin on the rotation under magnetic influence of the electric discharge in rarefied gases, and on the mechanical action which this discharge may exercise in its movement of rotation.

Transactions of the Wisconsin Academy of Science, Arts, and Letters, 1870-72. This academy was organised in 1870, "by a convention called by the Governor and more than one hundred other prominent citizens of the State," its general objects being "the material, intellectual, and social advancement of the State," as well as, or rather by means of the advancement of, science, literature, and the arts. This first volume of Transactions contains some specimens of the work already done by the Academy in its various departments, to which is prefixed an extremely interesting *résumé* of what has already been done by Wisconsin for science. This is followed by a long list of papers on various subjects read before the Academy since its formation. Of the scientific papers contained in the volume before us, Dr. Lapham contributes one "On the Classification of Plants;" Mr. J. G. Knapp "On the Coniferæ of the Rocky Mountains;" Prof. Irving on "The Age of the Quartzites, Schists, and Conglomerate of Sank Co. Wisconsin;" Prof. Chamberlain a few suggestions, some of them original, as to a Basis for the Gradation of the Vertebrata; and Prof. Davies "On Potentials and their Application to Physical Science;" in which he attempts to give a *physical* interpretation to the potential function, and to illustrate it and its use by some simple examples. We hope the Academy will continue to produce as satisfactory work in the future as it has done since it commenced.

WE have received numbers 8, 9, 10, and 11 of the *Australian Mechanic and Journal of Science and Art* for August, September, October, and November, and highly creditable is the quality of the contents to its able editor, Mr. Ellery, Superintendent of Melbourne Observatory, and a hopeful sign of the intelligence and progress of the Australian people it is, that such a high-class scientific journal should have a paying circulation in so young a colony. Mr. Ellery himself is contributing a series of valuable and well-illustrated articles on "How to make and how to use a Spectroscope," while another contributor, "Delta," concludes in the August number a series of seven papers on "Spectrum Analysis." The subjects treated of are very various, and mostly practical, but whatever the subject of an article may be, science and the application of scientific principles are never lost sight of. There is a series of articles on agriculture, in which the application of science to this department of industry is well illustrated; and in an article on "Science and Government," principally with reference to the supply of coal, the writer concludes thus:—"There is scarcely any subject within the range of material science, however trifling it may at first appear, that has not a direct and important interest for the whole community, and especially for those who hold the responsibility