come to be regarded as the platinum scale *par excellence*, and has been adopted as the standard of reference in many recent researches.

Fusing Point of Platinum.

As an illustration of the facility of applying this method, the determination of the fusing point of platinum on the platinum scale may be taken. This is a difficult experiment to perform by any other method. In performing the experiment by the measurement of the electrical resistance, it suffices to take a fine wire of which the electrical constants are accurately known, and to raise it gradually to its melting point by steadily increasing the current. The observation of the resistance of the central portions of the wire at the moment of fusion gives directly the temperature required on the platinum scale. In attempting to perform the same experiment by the expansion method, we are met by the difficulty that the platinum begins to soften and stretch at a temperature considerably below its melting point. Owing to the smallness of the expansion, a very slight viscous extension produces a relatively large error. In the resistance method it is not necessary to subject the wire to tension, and a small strain would in any case produce an inappreciable error on account of the very large increase of resistance with temperature. To obtain an equal degree of accuracy by the calorimetric method (2), or the thermo-electric method (3), it is necessary to use a furnace in which relatively large quantities of platinum can be melted. This has been done by Violle for method (2), and by Barus and Holborn and Wien for method (3). The latter used a linear formula for extrapolation, although their gas-thermometer experiments appeared to indicate a cubic formula for temperatures below 1200° C.

The temperature of the melting point of platinum on the platinum scale by the resistance method (4) is approximately $pt = 1350°$, and varies but slightly for different specimens of platinum. The result when reduced to the scale of the gas-thermometer by assuming that the rate of increase of resistance diminishes uniformly with rise of temperature (according to the usual formula of platinum thermometry, which has been verified with great care at moderate temperatures) gives a temperature of 1820° C. on the scale of the gas-thermometer. It is not improbable that platinum may deviate slightly from this formula at the extreme limit of the scale in the close neighbourhood of its melting point, but the evidence for this result is at least as good as that obtainable by any of the other methods. The observations are very easy and accurate as compared with the calorimetric method, and it is not necessary to make any arbitrary assumptions with regard to the formula of reduction, as in the case of the thermo-electric method.

As the accuracy of this formula has recently been called in question, on what appears to be insufficient grounds, by certain German and French observers, it is the more interesting at the present time to show that it leads to a result which cannot be regarded as improbable at the extreme limit of the scale. A different formula has recently been employed by Holborn and Wien, and supported by Dickson (*Phil. Mag.*, December 1897). The writer has already given reasons (*Phil. Mag.*, February 1899) for regarding this formula as inferior to the original, of which, however, it is a very close imitation. The above observations on the melting point of platinum, if reduced by Dickson's formula, would give a result $t = 1636°$ C., which appears to be undoubtedly too low as compared with the results of other methods, however great the margin of uncertainty we are prepared to admit in these difficult and debatable regions of temperature measurement.

It should be observed that the results of Violle by method (2) are consistently lower than those given by the resistance method in the case of silver, gold and copper. We should, therefore, expect a difference in the same direction at the F.P. of Pt. as found by method (4), and not a difference in the opposite direction as given by the thermo-electric method, on the arbitrary assumption of a different type of formula for extrapolation at high temperatures. It is a matter of some interest that the assumption of linear formulæ for both the specific heat and the rate of change of resistance should lead to results so nearly consistent over so wide a range of temperature in the case of platinum.

Comparison of the Thermo-couple and the Platinum Thermometer, (3) and (4).

The chief difficulty and uncertainty encountered by Paschen in his experiments on radiation, was that of arranging the thermo couple so as to be at the same temperature as the radiating strip of platinum. It is better for this reason to measure the temperature of the strip itself by means of its electrical resistance, the method adopted by Schleiermacher, Bottomley and Petavel. The same difficulty occurs in the direct comparison of the scales of the thermo-couple and the platinum resistance thermometer. The simplest method of avoiding this objection appears to be that recently adopted by the writer, of enclosing the thermo-couple completely in a thin tube of platinum, which itself forms the resistance thermometer. There can then be no question of difference of temperature between the two, and the same tube may serve simultaneously for the expansion method, and as a radiating source for bolometric investigation of the law of radiation. The uniformity of temperature throughout the length of the tube can be tested at any time by means of potential leads, or by shifting the thermocouple to different positions along its length. The method of electric heating is employed, and the central portion only of the tube is utilised in the comparison.

(*To be continued.*)

THE ORBIT OF THE LEONID METEOR SWARM.[1]

THE great Leonid swarm of meteors consists of ortho-Leonids which pursue nearly the same path round the sun, and clino-Leonids which move in orbits sensibly differing from the ortho-orbit. The present investigation is concerned with the ortho-Leonids. They form a dense stream extended along a portion of an immense orbit round which they travel in 33¼ years. This orbit has its perihelion a little inside the Earth's orbit, and its aphelion a little outside the orbit of Uranus. It intersects the orbits of these two planets, but lies in a plane inclined to the ecliptic, so that the meteors which traverse it pass under the intervening planets on their outward journey and over them on the homeward journey.

Accordingly, the orbits of the intervening planets—Mars, Jupiter and Saturn—pass through the orbit of the meteors; and they, as well as Uranus and the Earth, whose orbits intersect it, and Venus, which lies but little beyond, are well situated for exercising a perturbating control over the motions of the Leonids. But the influence of Mars and Venus is inconspicuous, and that of the Earth only sensible on the meteors which pass close to it; so that nearly the whole of the perturbating effect upon the greater part of the swarm is due to Jupiter, Saturn and Uranus.

The procession of ortho-Leonids is so long that it takes between two and three years to pass each point of its orbit; and accordingly when it streams across the earth's path, which it does three times in a century, the earth has time to come round to the point of intersection in at least two successive years, and on each such occasion receives one of the greater Leonid showers—a splendid spectacle, but of such brief duration, lasting only a few hours, that it is visible only from the side of the Earth, which happens at the time to be its advancing side.

The first of these great displays recorded in modern times was that witnessed by Humboldt and Bonpland on the morning of November 12, 1799, when travelling in South America. It was quite unexpected. So was the next great shower which visited Europe on the morning of November 13, 1832, and was followed by a still greater display which was seen from numberless stations in America in 1833. This recurrence of the phenomenon after an interval of 33 years led to its being expected in 1866, and diligent preparations were accordingly then made by astronomers to avail themselves of the opportunity of acquiring more information about the mysterious visitants. These meritorious efforts resulted in a great accession to our knowledge. Prof. Hubert A. Newton collected the records of several ancient observations which showed that the swarm returns to the Earth at intervals of 33¼ years, and that the date on which the meteors are seen had advanced by 3½ weeks since A.D. 902. From their periodic recurrence, he found that they must be moving in one or other of five orbits which he described, and from the advance in the date he inferred that the longitude of the node of the orbit has been advancing, an effect which must be due to perturbations. Prof. Adams ascertained which of Newton's five orbits is

[1] "Perturbation of the Leonids." By G. Johnstone Stoney, M.A., D.Sc., F.R.S., and A. M. W. Downing, M.A., D.Sc., F.R.S. (Abstract of a paper read before the Royal Society on March 2.)

the real one. Schiaparelli detected the dynamical explanation of the fact that the swarm is lengthened out like a stream along a portion of Adams's orbit. And Leverrier adduced evidence that the Leonids have been less than eighteen centuries within the solar system: that in fact they were diverted into their present elliptic orbit at the end of February or beginning of March in the year A.D. 126, in consequence of having then passed, while still a compact cluster, close to the planet Uranus. Adams further pointed out that there is a comet moving nearly in their track.

These were great achievements; of which the most noteworthy is the great discovery made by Prof. Adams when he determined definitely the real orbit in which these bodies move. This he accomplished by computing the perturbations which would be suffered in each of the five possible orbits, and comparing the calculated amount of the shift of the nodes with that which had been obtained by comparing the ancient with recent observations.

The main swarm of Leonids is again returning. A shower of several hundreds of meteors, produced by the extreme front of the ortho-stream, was observed last November in America. Still greater showers may be expected this year and next year, and perhaps a considerable display in the year following; and it is eminently desirable that this opportunity of increasing our knowledge in this entirely new branch of astronomy shall not be lost. It is the second occasion when astronomers have been able to foresee when the opportunity is about to present itself.

In 1866, the great object was to ascertain the orbit. To determine this, what was wanted was the average amount of the perturbations, and it was this average which Adams computed. But to make a further advance—to explore more fully the past history of the Leonids, or their present condition, or to predict the future—a more intimate acquaintance with the perturbations is essential. Now perturbations reach each meteor individually. They differ from one revolution to another, and within each revolution they variously affect the meteors that occupy different stations along the stream.

The present investigation was entered on as a commencement of the more searching inquiry indicated above. The stream is regarded as divided into segments of such moderate length that the perturbations which operate on the meteors occupying any one of them may be regarded as sensibly the same. One of these segments is selected—that through which the Earth passed in 1866—and the actual perturbations to which the elements of its orbit are being subjected throughout an entire revolution, have been computed by the method of mechanical quadratures. The revolution extends from 1866 November 13, when the Earth passed through this segment of the stream, till 1900 January 27, when the same segment will return to the intersection of the meteoric orbit with the Earth's orbit.

The inquiry has already led to remarkable results. During this revolution an entirely abnormal amount of perturbation has acted on the meteors in the selected segment of the stream. This perturbation has been produced chiefly by the attraction exercised by the great planets Jupiter and Saturn, and its unusual amount has been occasioned by a near approach of Saturn when that segment of the stream, for which the calculations were made, was on its outward journey, and a still more close approach of Jupiter, when the meteors were on their homeward journey. These events have resulted in such a perturbation of the orbit, that the shift of its node during this revolution has had more than $3\frac{1}{2}$ times its average amount, and that the periodic time has become augmented by as much as $\frac{1}{6}$ of a year.

This last perturbation will have a remarkable effect on the future history of this segment of the stream, unless it is compensated by what occurs elsewhere or in subsequent revolutions. It indicates, too, that whatever portion of the stream has been most perturbed in this revolution is falling back towards the parts behind and retreating from the portions in front; thus introducing a new inequality of distribution of density along the stream, superadded upon whatever inequalities of a like kind may have existed previously. Thus some parts of the stream are becoming unduly crowded with meteors. Others of the perturbations indicate that in this remarkable revolution a new sinuosity of sensible amount is being set up in the stream. These effects have been made conspicuous by the fortunate circumstance that the revolution for which the calculations have been made has happened to be one in which the perturbing forces have attained an intensity far exceeding the average.

The information supplied by this inquiry in regard to the time when the Leonid shower of next November may be expected is considerable, but far from complete. It may be stated as follows:—At the epoch 1899, November 15, the longitude of the node of the orbit for which the calculations have been made will be $53° 41'.7$, a position which the earth will reach on 1899 November 15d. 18h. It is probable, therefore, that the middle of the shower of the present year (1899) will occur nearly at this time, since the segment of the stream, for which our calculations have been made, is situated in the stream less than three months' journey of the meteors behind the segment which the Earth will encounter next November. This conclusion, however, rests on two assumptions: (1) That the two segments were, in 1866, moving in orbits that did not much differ; (2) That the perturbations which these segments have since suffered have not much differed. Both assumptions are probable, but unfortunately neither is certain; so that the prediction can only be offered with reservation. If the shower occurs at the time anticipated, it will be visible from both Europe and America.

A NEW PHOTOGRAPHIC PRINTING PAPER.

WITHIN the last few months several new brands of photographic printing papers have been placed on the market, all of which are characterised by the possibility of all the manipulations involved in the exposure and development of the prints being performed in an ordinarily lighted room. The basis of most of these papers is a very slow bromide emulsion, with varying proportions of chlorides to modify its qualities for particular purposes. The paper issued under the name of "Dekko" by Messrs. Kodak, Ltd. (late the "Eastman Photo. Materials Co."), is one of this class. As stated in the circulars accompanying the paper, its special feature is that it may be exposed, developed and fixed in an ordinary room illuminated by artificial light or weak daylight, thus doing away with the necessity of a special dark room for its treatment.

The paper may be safely handled for placing in the printing frame and developing at a distance of 8 or 10 feet from an ordinary full gas flame, or nearer if the light be turned down. With the Welsbach light or daylight it is advisable to shade the light with one thickness of orange paper.

For exposure the instructions recommend from three to five minutes at a distance of 6 or 8 inches from an ordinary gas burner for a negative of medium density. For daylight from one to two seconds at 2 feet from the shaded window will be sufficient. In this connection, however, we would urge the convenience and certainty with which these contact prints may be made by exposure to the light of burning magnesium. The light given is extremely actinic, as is at once appreciated if its spectrum be examined; it is more portable than any other illuminant, and may consequently be used where others are quite inaccessible, and as the metal in the form of ribbon is fairly pure, the light evolved from the combustion of a given length is practically constant.

The development of the paper is similar to that of ordinary bromide paper, except that the process is much quicker, full density being obtained in at most thirty seconds. The formula recommended for ordinary black tones is a mixture of hydroquinone and metol. The paper, however, lends itself readily to the production of varied tones from brown to bright red, these being obtained by variations both of exposure and developer. A special developer for warm tones is given in the printed instructions.

Fixing is carried out in the usual manner, and the prints should be washed for at least an hour, after which they are ready for mounting.

This paper will prove a useful addition to the printing papers already on the market; its simplicity of working and long range of colours obtainable recommending it for the amateur, while the professional will find it of great service for producing quantities of permanent prints of uniform appearance at any season of the year.

LOCAL AUTHORITIES FOR SCIENCE AND ART INSTRUCTION.

THE Directory issued by the Department of Science and Art in 1897, contained a section which has since become widely known, and will probably take a prominent place in educational politics for some time. The new paragraph—referred to as Clause