THE PERFECTED PRISMOMETER: ITS PRACTICAL ADVANTAGES, CONSTRUCTION, AND VARIOUS APPLICATIONS.

By CHAS. F. PRENTICE, New York.

(*With ten woodcuts.*)

IN the first numbers of these ARCHIVES of the year 1890, I described "A Metric System of Numbering and Measuring Prisms," which represented the result of a careful and extensive study of the subject, due to the suggestion of Dr. S. M. Burnett, who had entrusted me with the problem of searching for a system which should prove satisfactory to ophthalmologists as well as avoid conflict with the practical methods of manufacturing opticians. At the close of my investigations I felt that this had not only been accomplished, but that also an instrument in support of that system had been offered as a valuable assistant to opticians.

My familiarity with the routine of manufacture would not allow me to lose sight of the practical side, so that this, being a matter of primary importance to opticians, was kept well in view from the outset. In advocating the metric system and the use of the prismometer, I shall therefore here only do so in so far as they relate to the interests of manufacturing and dispensing opticians; the advantages of the system to ophthalmic practice having been previously set forth.

My argument in favor of the metric system **was** and **is** based upon the **unavoidable variability in the angles of our prisms,** and which must result from the present process of manufacture. Although this has been indicated in the

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previous papers,[1] I shall here take the liberty of quoting from a paper read in connection with my exhibit of the prismometer before the New York Academy of Medicine, October 20, 1890:

"It would, however, be exceedingly difficult and correspondingly expensive to manufacture prisms producing only fixed intervals of deflection. To render prisms sufficiently inexpensive as spectacle glasses it is necessary that they should be produced in large quantities at one grinding."

"The process at present consists in fastening a number of slabs of glass, by means of pitch, or other resinous material, upon a metallic surface-tool. The friction in polishing generates more or less heat, which at times is sufficient to soften the pitch and cause it to yield beneath the slabs. Some slabs will shift more than others, so that the prism-angles will vary more or less throughout. Besides, the underlying layer of pitch can never be of a uniform thickness." Were it not for these facts, I believe competition alone would long ere this have resulted in greater uniformity.

By means of the prismometer I found prisms, more especially of low degree, to vary between ten per cent. and thirty per cent. of their indicated numbering.

It is obvious that if manufacturers were obliged to discard all those prisms which varied from desired fixed intervals of prism-angle, minimum deviation, or any other designated deflection, the price would have to be increased on the perfect prisms sufficiently to compensate for the cost of those rejected, and which would have consumed equally as much material, time, and labor to produce.

Without confining myself to the deflections which should, by calculation, correspond to the prism-angles and index, I found, by means of the prismometer, among a series of prisms, of best Parisian manufacture, only the following number to produce deflections which were *even* alike:

Three doz. prisms	1°	2°	3°	4°	5°	
Number alike	6 = 1.1	7 = 2	6 = 3.1	6 = 3.7	8 = 4.6	prism-dioptries
Balance varying between	0.8 & 1.6	1.8 & 2.5	2.6 & 3.2	3.4 & 3.9	4.4 & 4.8	" "

[1] ARCHIVES OF OPHTH., xix., Nos. 1 and 2, 1890.

These prisms were taken from original papers, and may be credited with having been made of the same material, at the same time, and upon the same tools. Greater precaution on the part of the manufacturer could not be expected.

To the *careful* reader of my papers it must have been apparent that **stress** had **nowhere** been laid upon the possibility of a variability in the index, but, on the contrary, that all my deductions were referred to the commonly accepted index of 1.53.

The privileges, however, were mentioned[1] which manufacturers might avail themselves of, both in respect to prism-angle and index, in seeking to provide prisms of the desired properties.

To any one familiar with the use of optical theodolites[2] and spectrometers[3] it must further be apparent that an endeavor to measure the *minimum* deviation, with prisms of small angles especially, is very tedious and difficult. The apparatus is expensive, requires a degree of accuracy in manipulation, and a knowledge in the reading of verniers, with which opticians can not readily be made familiar. To mount such prisms accurately upon the table of the spectrometer, and rectify the various adjustments of the instrument, are tiresome and slow operations which alone are sufficient to condemn its daily use by opticians whose work must necessarily be expeditious. In the physical laboratory, however, the instrument is undoubtedly invaluable. If the use of an instrument is to be abandoned for measurement of the minimum deviation, we shall find that manufacturers will simply divide the prism-angles by two (2), for the new nomenclature, and so give us the old culprit disguised under a new name. There would be great commercial convenience to be sure, in being able to dispose of the same prism under two names, but no *reform* in the interest of scientific exactness could be effected *without* measurement. Will it be policy under such circumstances to adhere to the *minimum*

[1] Archives of Ophth., xix., No. 1, p. 67, 1890.
[2] *Lehrbuch der Physik.*, Prof. Joh. Müller, Braunschweig, 1878.
[3] "Practical Physics," Glazebrook & Shaw, London, 1889.
"Elements of Physical Manipulation," Prof. Ed. C. Pickering, Boston, 1873.

deviation merely for principle's sake? As the prismometer is intended to measure the refraction of prisms, in terms of the prism-dioptry, it may be well, for the benefit of those who may have found its **simplicity** obscured by the mathematical portion of my papers, again to explain its principles in more simple and somewhat different terms.

We know that a lens-dioptry is the unit of refraction, and corresponds to a lens of one meter focus, Fig. 1.

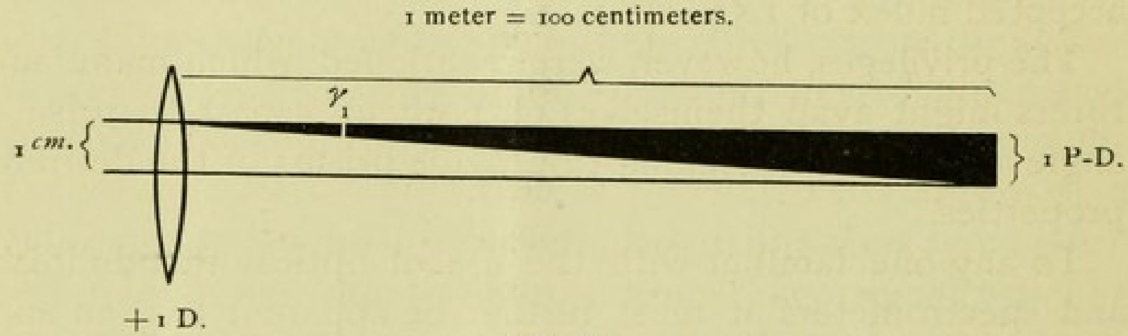

FIG. 1.

The prism-dioptry, *since lenses are but a fusion of prisms of varying angle*, may then be said to be the **linear deflection** which the refracted ray sustains **at the focus of a meter-lens,** when the incident ray impinges upon a peripheral portion of the lens **one centimeter** from the optical centre (Fig. 1).

The prism-dioptry therefore also represents the measure of the angle of deviation γ_1, for an eccentricity or decentration of one centimeter (Fig. 1).

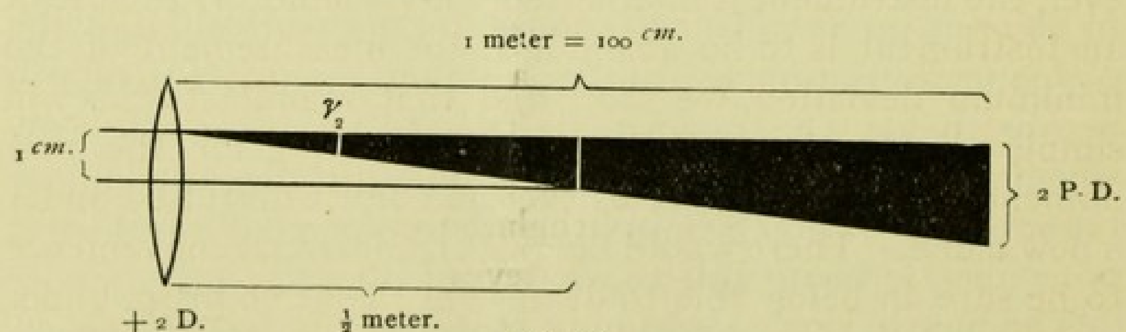

FIG. 2.

A ray impinging upon the same point of a 2-dioptry lens (Fig. 2) will sustain the *same unit* deflection at its focus ½ meter, and will therefore find the measure of its angle of deviation γ_2, expressed by twice the deflection at the meter-plane, or 2 prism-dioptries. A lens being decentred twice or half as much will produce twice or half as many prism-dioptries as the lens possesses lenticular dioptries of refraction.[1] The prism-dioptry is therefore but a sequence to the lens-dioptry. Nothing can be more simple. Thus the prism-dioptry represents the proportion 1:100, which is expressive of a grade of angular inclination in daily use by engineers and scientists the world over. To reduce prism-dioptries to degrees of angular deviation, it is only necessary to divide the prism-dioptries by 100, when they will represent the tangents to correlative angles in degrees, which are to be readily found in any table of sines and tangents. Since different lenses, through varying decentration, will produce different values of the angles of deviation $\gamma_1 \gamma_2 \ldots$, how will it be possible to determine the value of such angles in degrees, minutes, and seconds? The instrument is yet to be invented. The prism-dioptry and the prismometer solve the problem, and in a manner simple and rapid enough to any one of ordinary intelligence.

Since the therapeutic value of prisms is conceded, and their combination with lenses in practice frequent, the prismometer has been constructed with due regard to such combinations, making it possible by its aid to utilize to advantage the prismatic action due to decentration of the lens, for the purpose of offsetting the error which *invariably* exists in the constant prism, after the combination has been ground. Would it not then seem unwise and even arbitrary to hamper the dispensing optician in the practical fulfilment of his work by forcing him to a system of degrees, merely because it harmonizes with the designation of a strabismus which is incorrigible by prisms, or with the graduations found upon perimeters, ophthalmometers, etc., which have no connection with prisms whatever?

The metric system certainly possesses the commendation of reducing all the glasses of the trial case to a uniform nomenclature in dioptries. This alone should be considered a *practical* advantage, fully offsetting the merits of an *unverified theoretical minimum* deviation.

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[1] "A Metric System of Numbering and Measuring Prisms," ARCHIVES OF OPHTH., xix., Nos. 2 and 3, 1890

If I may be permitted to offer a suggestion, let us learn to comprehend the power of our prisms by the limits of refraction, shown by the solid triangles in the preceding figures, when it will become wonderfully easy to fit these into meter-angles, or for that matter to any other angles in space, without necessarily confounding prism-dioptries with meter-angles, or meter-angles with "deviations of the eyes in height," as stated by Dr. Landolt.[1] The latter mistake could only be the result of a misconception of the definitions of the prism-dioptry and its relations to the meter-angle.

In recommending the metric system to the profession and practical opticians, I in conclusion beg to call attention to its superior advantages, as follows:

1. From a mechanical point of view, by taking the unavoidable difficulties of manufacture into consideration.

2. From a commercial and pecuniary point of view, by avoiding unnecessary expense in the production of prisms.

3. By the prismometer, which enables opticians to accurately fill the demands of the system.

Any system which neglects these important considerations *cannot* be considered progressive, nor can it effect a *reform* in the present necessarily haphazard endeavors of the dispensing optician, with whom so much of the blame and responsibility must rest. Opticians have always been on the alert to meet the requirements of the profession, and will no doubt gladly avail themselves of a system and an instrument which will enable them to sustain their reputations as mechanicians.

Taking all the facts into consideration, it suffices to say, that we have prisms of almost every imaginable deflection on hand in the market to-day, so that it merely requires an instrument of simple construction, which may be used in making the proper selection with **accuracy** and **despatch**, and this is precisely what is claimed for the prismometer, which it is my purpose here to describe.

In the accompanying illustration, Fig. 3, the essential operative parts of the instrument are shown as being mounted upon a tri-

[1] "On the Numbering of Prismatic Glasses," ARCHIVES OF OPHTH., xix., No. 4, 1890.

angular truss which is pivoted by a suitable joint to a pedestal, so as to permit of convenient inclination of the whole.

The graduated bar is rigidly supported near its extremities, upon the truss, by two short studs or pillars, the latter being slightly higher than the radius of the circular stage, which is supported at its back by a rod, fitted, sliding, and acted upon by a spring within the bar, so as to automatically effect contact of the face of the stage with the knife-edge, which is also mounted upon the truss, between the stage and the pinhole eye-piece.

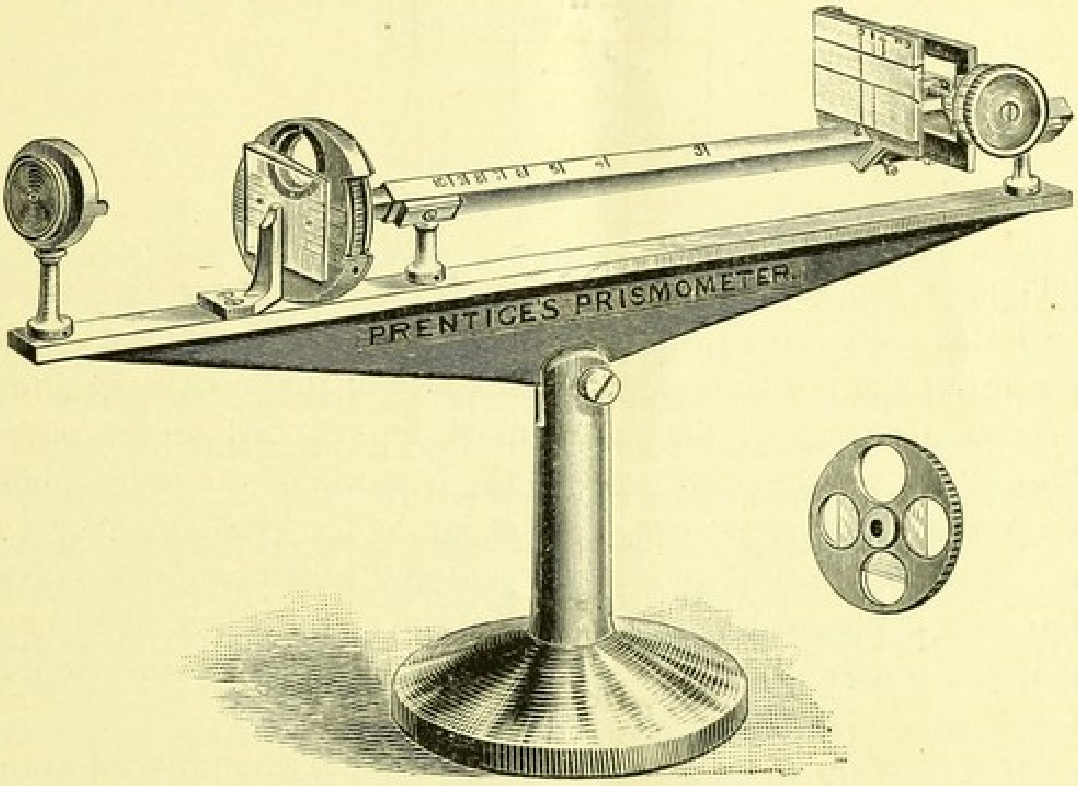

FIG. 3.

The divisions of the graduated bar, numbered 2, 3, 4 up to 10, are placed at $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, up to $\frac{1}{10}$ of the meter[1] length, counted from the knife-edge, which represents the zero-end of the scale. A plane, perpendicular and arranged to slide upon the graduated bar, termed the index-plate, is provided with the index-line, marked zero (0), and two graduations at the right-hand upper edge, marked 1 and 2, which, being equal to correlative centimeter deflections at the meter-plane, correspond to their equivalents in prism-dioptries.

To facilitate subdivision of these graduations the index-plate is provided with a transverse slide, bearing its allotted part of the index-line, which is rendered adjustable by a milled head and

[1] It has been found convenient to construct the instrument to half scale throughout.

micrometer screw, the first complete rotation of which will cause this section of the index-line to travel from 0 to 1, the second complete rotation taking it from 1 to 2. The milled head, being divided into 100 parts, enables us, by its graduations, to determine the position of the index-line of the transverse slide, relatively to the graduations upon the face of the index-plate, in 10ths and 100ths.

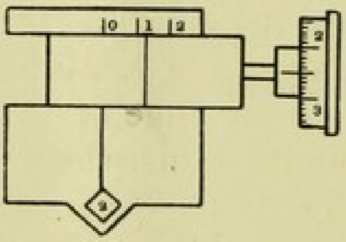

FIG. 4.

Thus, in the accompanying figure (4) we read from the face of the index-plate "1" and from the milled head $\frac{2}{10}$ths and $\frac{5}{100}$ths or 1.25 for the position of the index-line of the transverse slide.

As all readings of deflection must be reduced to the *meter-plane*, it will be necessary to note the position of the index-plate, *which must at all times correspond to one of the graduations of the bar*. Consequently, if the above reading is taken from the index-plate, when placed at the figure "2" of the bar, we shall have twice the number of prism-dioptries at the meter-plane, or $1.25 \times 2 = 2.5$ P-D.

For a reading of "2," from the index-plate, when placed at the graduation upon the bar marked "10," we have 20 P-D, which is the maximum measuring capacity of the instrument. In other words, it is merely necessary to *multiply* the readings of the index-plate by that figure upon the bar which defines the position of the index-plate upon it.

Before placing a prism in position for measurement, it is necessary to carefully determine its *passive* or non-refracting plane. This is accomplished by such slight rotary adjustment of it before the eye, until a line, situated at a convenient distance, is sighted as an unbroken one, being precisely the same method which we employ in determining the axes of cylinders. For convenience of registration, ink dots, in collimation with said line, should be applied to the prism. The stage is provided with a series of horizontal lines, engraved upon it, to facilitate perfect adjustment of the base-apex line of the prism, which is to be introduced between the stage and the knife-edge, with its apex to the right, and gradually forced downward while the ink dots pass successively from one horizontal line of the stage to the other, until the upper edge of the prism exactly bisects the circular opening in the stage. In this position the prism will exactly cover the lower half of the opening, while its lateral upper edge will be in collimation with the lower edge of the transverse slide On completion of this adjustment it is of the utmost importance that the ink dots should coincide with one of the parallel lines of the stage. The observer's eye being placed before the eye-piece, will now perceive the upper edge of the index-plate, and the index-line at zero of the transverse slide, in their true positions, whereas the lower portion of the index-plate, with its index-line, being seen through the prism below, will appear displaced to the right. The position of the observer's eye is now to be carefully maintained, while the graduated milled head is operated with the right hand, until the index-line of the transverse slide has been shifted sufficiently to the right to make contact with the lower index-line seen through the prism. Perfect coincidence of these lines is necessary for an accurate determination of the deflecting power of the prism at any distance. It will consequently be well to previously remove any roughness of the upper base-apex edge of the prism by grinding it to a flat dull edge, and, to be very precise, to take the mean of several readings while the prism is in an undisturbed position. As an example, we shall suppose the prism to have been carefully adjusted in the manner described, and that our readings for three positions upon the bar from the index-plate are as follows :

2d Graduation of the bar, index-reading					$=1.57 \times 2 = 3.14$	P-D.
3d	"	"	"	"	$=1.05 \times 3 = 3.15$	"
4th	"	"	"	"	$=0.78 \times 4 = 3.12$	"

$$\text{Mean}: \frac{9.41}{3} = 3.13 +$$

This precaution, in the interest of exactness, may appear to be unnecessary to some, yet it is here introduced as an exhibit in favor of the capabilities of the instrument.

The prismometer is particularly valuable when it is desired to measure the inherent prismatic action of decentred lenses, and their combinations with prisms.

In such cases it will be necessary to remove a peripheral portion of the lens by grinding it to a dull flat edge, as shown in the accompanying Figure 5.

The lens is then to be placed upon the stage with the flattened edge up, so as to cover half the stage opening; the index-line of the transverse slide having been previously adjusted to zero (o). If, in sighting through the eye-piece, the index-line appears disjoined, it will only be necessary to shift the lens slightly to the right or left to re-establish coincidence of the lines, when the lens is said to be *centred.* While in this position ink dots should

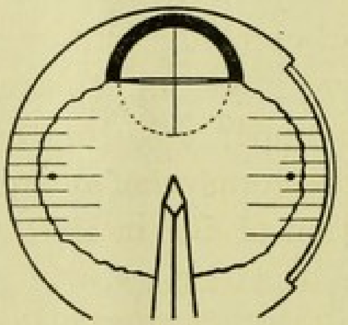

FIG. 5.

be placed upon the outer edges of the lens over a centrally situated horizontal line of the stage, as shown. For this centred position of the lens, in sighting through the eye-piece, we shall find the index-line at zero (o) unbroken, while the lower half of the index-plate will be enlarged or diminished according to the character of the lens employed. Supposing the lens be 3 D convex, we shall find the index-plate to present this view (Fig. 6) when it is placed at the graduation marked "3" upon the bar.

NORMAL PLATE.

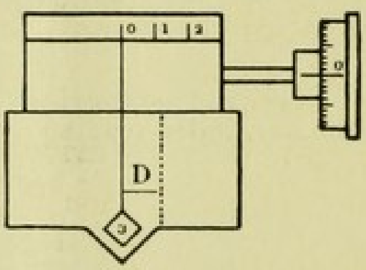

FIG. 6.—MAGNIFIED PLATE.

The lower half of the index-plate is provided with a red line, indicated by a *dotted* line in the figure, corresponding to a deflection of 1 P-D, and which appears proportionately *magnified.* As it will be inadmissible, in our readings, to place a magnified scale on a par with the normal scale of the prismometer, it will be necessary to *register* the magnified unit upon the upper portion of the index-plate, for reference and comparison during decentration of the lens. To accomplish this we displace the index-line of the transverse slide until it coincides with the red line (dotted line, Fig. 7), which, as far as the lens is concerned, now *represents* and *takes the place of* 1 P-D on the index-plate.

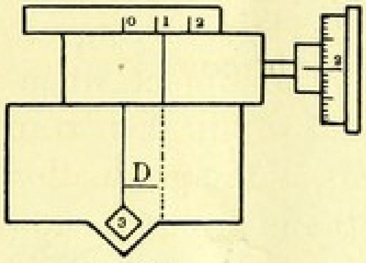

FIG. 7.

Now, by slowly shifting the lens to the left, we shall observe the lines of the lower index-plate to shift to right (Fig. 8).

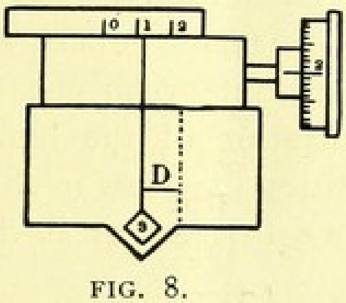

FIG. 8.

When the 3-D lens has been decentred one centimeter, experiment shows that the lower black index-line cuts the index-line of the transverse slide above. Bearing well in mind that the position of the *upper* index-line now *represents* "1," and that our reading has been taken for a position of the index-plate upon the bar at "3," we have 3 P-D as the result of decentring a 3-D lens one centimeter.[1]

In case, however, that the refraction of the lens as well as its decentration have not been previously determined it will be necessary to note the following (see Fig. 6):

It is evident that the $\frac{\text{normal plate}}{\text{magnified plate}}$ as $\frac{1}{D}$, so that the normal prism-dioptries sought $= \frac{1}{D} \times$ magnified readings, for convex lenses, which will be when $D > 1$, and

" " " $= \frac{1}{D} \times$ diminished readings, for concave lenses, which will be when $D < 1$.

[1] "A Metric System of Numbering and Measuring Prisms," ARCHIVES OF OPHTH., xix., Nos. 2 and 3, 1890.

It is therefore only necessary to divide the magnified or diminished readings by D.

The value of D, as we have seen, is determined by first *centring* the lens. It will have a different value for different lenses, and will depend upon the distance of the lens from the index-plate. In fact, D represents the magnifying or diminishing power of lenses for any position of an object, when viewed through them and which may be placed within their respective focal distances. For the 3-D convex lens, at the graduation upon the bar marked "3," measurement by the instrument shows D to be equal to 1.2, Fig. 7. Suppose we decentre a + 3-D lens until we obtain a reading say of 0.6 P-D, which is of course a *magnified* reading we then have $\frac{0.6}{D} = \frac{0.6 \text{ P-D}}{1.2}$ (magnified reading) = 0.5 normal P-D at the distance "3," or 1.5 normal P-D at the meter-plane.

In measuring sphero-prismatic lenses we shall therefore find that the value of the constant prism can either be increased or diminished by a decentration of the lenticular element of the combination, a decentration of 5 *mm* in the above instance being sufficient to contribute 1.5 P-D. ad- or ab-ductive as occasion may demand.

By such means it will be possible to *counteract* the inaccuracies which *invariably* exist in the constant prism after the combination has been ground. When the lens is combined with a prism the flattened dull edge should be cut parallel with the true base-apex ine, the latter being registered with ink dots and adjusted upon the stage as usual.

The most ready means of measuring such a combination—for example, + 3 D spherical combined with 2 P-D (constant prism) — will be to place the index-plate at the distance upon the bar marked "3," when, as before, the lens magnification D = 1.2, and which may be more conveniently determined by *previously centring* a spherical lens of the same refraction. Now, by deductive reasoning, we know that 2 *normal* prism-dioptries will be equal to $\frac{2}{3}$ P-D at $\frac{1}{3}$ the distance, and this would require to be 1.2 *greater* at the *same* distance to appear as the properly proportioned magnified deflection seen through the lens, consequently $\frac{2}{3}$ 1.2 = 0.8 magnified prism-dioptries. We therefore set the line of the transverse slide so as to read 0.8 P-D at the distance marked three ("3") upon the bar, and proceed to decentre the lens until the lower index-line cuts it, when we shall have the desired 2 *normal* prism-dioptries. We may utilize the rule to prove the result: 0.8 mag. P-D $\times 3 = \frac{2.4}{D} = \frac{2.4}{1.2} = 2$ *normal* P-D. Since lenses are capable of providing as many prism-dioptries as they possess lens-dioptries of refraction, it also follows that we shall occasionally be enabled to secure a considerable proportion of prismatic action by decentration alone, provided the spherical lens is of proportionately greater strength. For instance, the 3-D lens will produce 3 P-D for a decentration of 1 cm. so that an available decentration of $3\frac{1}{3}$ $^{m}/_{m}$ could in itself be relied upon to furnish 1 P-D of the 2 P-D in the lens forming the subject of our example.

To facilitate measurement of concave sphero-prismatic lenses the stage is provided with a rotating disk, within, containing three prisms of varying power, with their bases down, and which may be successively carried before the lower half of the opening in the stage as occasion may demand.

The object of these prisms is to counteract the prismatic action in the vertical plane, which would otherwise manifest itself by a confusion of the transverse slide in its contact with the lower portion of the index-plate (Fig. 9), as a result of sighting through the

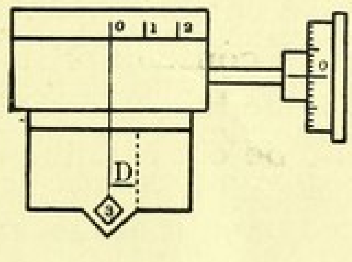

FIG. 9.

upper peripheral edge of a concave lens (acting as a prism with its base up) when placed in proper position on the stage. The extent of the confusion of the parts, as shown in the figure, will naturally depend upon the strength of the lens, so that rotation of the disk will reveal the prism best calculated to re-establish contact, as shown in Fig. 10.

Our choice of the prism being made, the lens is to be removed from the stage so as to *rectify* the position of the disk-prism before the index-line at zero (0), which should naturally present a *perfect* vertical line to view.

As an example, let us suppose the combination — 3 sph. ⊂ 2 P-D (constant prism) to be presented for measurement. We should first select a concave 3-D lens, centring it upon the stage as described, and discover a confusion of the index-plate, at "3" upon the bar, as shown in Fig. 9.

It will be found that the first prism of the disk proves sufficient to re-establish contact, as in Fig. 10.

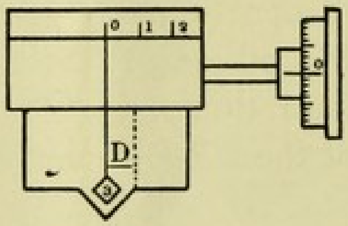

FIG. 10.

Removing the lens, *rectifying* the disk-prism, and *replacing* the lens, we find the diminishing power of the lens D = 0.83. Our object being to secure 2 P-D at the meter-plane, it follows that $\frac{1}{3}$ of this will have to be the reading from the index-plate at "3" upon the bar, or $\frac{2 \text{ P-D}}{3} = 0.67$ in the absence of diminishing power, and consequently $0.67 \times 0.83 = 0.55$ as a result of diminution by the lens.

The index-line of the transverse slide is therefore to be set to 0.55. The spherical lens is now to be replaced by the sphero-prismatic lens, with its base-apex line marked and adjusted upon one of the horizontals of the stage, and shifted upon this to the right or left, until the lower index line cuts the index line of the transverse slide. While the sphero-prismatic lens is in this position, an ink dot is to be placed upon it at the knife-edge, as the dot is intended to ultimately occupy the centre of the frame in which the lens is to be mounted.

Such can be the accuracy of the optician's work, with the aid of the prismometer for the metric system, and of which oculists in America may readily avail themselves by a simple request to have their diagnostic prisms re-numbered by measurement upon the instrument. By these explanations I hope to have succeeded in conveying the fact, that my object has not only been to promulgate a *theory*, but also to render it *useful* and fully *subservient* to *practice*, in the absence of which it should, like many another, only live in minds, and mould in books.

WORKS OF BAUSCH & LOMB OPTICAL CO., ROCHESTER, N. Y.