Thomson W.

Box

AN

ADDITIONAL TEST

FOR THE DIAGNOSIS OF

AMETROPIA,

WITH A

METHOD TO DETERMINE ITS VARIOUS DEGREES.

BY

WM. THOMSON, M.D.,

FELLOW OF THE PHILADELPHIA COLLEGE OF PHYSICIANS. SURGEON TO WILLS HOSPITAL FOR DISEASES OF THE EYE, ETC.

NEW YORK:
WILLIAM WOOD & COMPANY,
27 GREAT JONES STREET.
1872.

AN

ADDITIONAL TEST

FOR THE DIAGNOSIS OF

AMETROPIA,

WITH A

METHOD TO DETERMINE ITS VARIOUS DEGREES.

BY

WM. THOMSON, M.D.,

FELLOW OF THE PHILADELPHIA COLLEGE OF PHYSICIANS. SURGEON TO WILLS HOSPITAL FOR DISEASES OF THE EYE, ETC.

NEW YORK:
WILLIAM WOOD & COMPANY,
27 GREAT JONES STREET.
1872.

PREFACE.

In accordance with a request from the Surgeon-General, the Optometer described in the *American Journal of Medical Sciences* has been rendered more simple in construction, as will be observed from an examination of Fig. 1; and it is believed that it will prove of practical value to the medical officers of the army, in the examination of recruits and malingerers, as well as in the diagnosis and treatment of diseases of the eye, when it becomes necessary to ascertain its condition as an optical instrument.

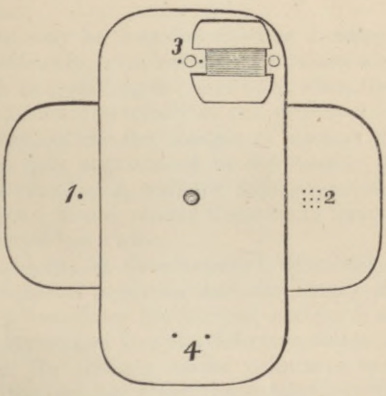


Fig. 1.

To the former description is now added a cut of an eye, which will demonstrate by its dotted line that the red image must appear to the left in hypermetropia when the hole to the right is covered with red glass, since, in accordance with the law of projection, any impression made upon the right side of the retina would be referred to the left side of the observer, and in hypermetropia the red image would fall upon the right side, when the cut is so placed before the observer as to put the dotted line towards his right. The reverse of course obtains in myopia, when the red flame then appears to be on the side covered with red glass, since its image then falls upon the left of the retina, and appears to be on the observer's right.

When this instrument is not at hand, a comprehension of its principles enables one to construct an efficient substitute by making two pin-holes in a card $\frac{1}{8}$ inch apart; and instead of the red glass covering and uncovering quickly one of the holes, at the same time, ascertaining from the patient whether the light which then appears and disappears, is on the same side with the hole covered, or on the opposite side.

A disc of tin placed upon a spring candlestick is also depicted in a cut, and this appliance has been found of great clinical service in ascertaining the distance between the two points of light, and hence the degree of ametropia corresponding thereto in the table.

1607 Locust Street, Philadelphia,
June, 1872.

AN ADDITIONAL TEST FOR THE DIAGNOSIS AND CORRECTION OF THE OPTICAL DEFECTS OF THE EYE.

By WILLIAM THOMSON, M.D.,

Surg. to Wills Hospital for Diseases of the Eye, and late Assist. Surg. U. S. A.

Before any object can be seen distinctly, the rays of light which are emitted or reflected from it must be so refracted by the cornea, lens, and humors of the eye, as to cast upon the layer of the rods and cones of the retina its inverted and perfectly defined image.

If the eye be regarded as an optical instrument composed of a refracting apparatus, the cornea and lens, and a receptive screen, the retina, it needs no argument to prove that there must exist a harmony between the refractive power and the antero-posterior axis, to secure perfect definition.

The human eye may be thus described as a camera of one inch in length antero-posteriorly, with refracting surfaces which are equal to a lens of one inch in focal length: and only when the rods and cones of the retina are situated precisely at the principal focal point of the refracting combination do the images of distant objects fall upon them, so as to be fully appreciated by the brain. Any variation in the length of the visual axis, without a corresponding change in the refractive apparatus, would render the retinal images indistinct, and would result in imperfect vision.

It may be considered as demonstrated by actual measurement as well as by mathematical analysis, that the length of the visual axis does frequently depart from the normal standard, and that to this mechanical and anatomical fact the defective vision in such instances may be ascribed. To the eye whose refractive system and visual axis harmonize, Donders has given the name Emmetropic, and to the eye which departs from this happy construction, Ametropic.

The ametropic eye may have a visual axis either too long, when it becomes Myopic, or too short, when it is called Hypermetropic. In myopia, the retina is too remote from the cornea and lens, and the images of distant objects are formed before it, and are indistinctly seen: its point of perfect vision is at a finite distance, which may, in extreme cases, be placed at one or two inches only anterior to its cornea. In hypermetropia the axis is too short, and the images would fall behind the retina; objects are clearly seen only when the refracting power of the crystalline lens is increased by a contraction of the ciliary muscle, and the focus of the refracting combination thereby shortened, to correspond with the diminished antero-posterior axis.

The following table, for example, will express numerically these diversities, as ascertained by the best authorities:—

Emmetropic.	Average length of axis	. . . 22.23	millimetres.
Myopic.	Possible " "	. . . 25	"
Hypermetropic.	" " "	. . . 20	"

Astigmatism is but a further subdivision of ametropia, in which one or both of the simpler forms may be found in the same eye, which may then be emmetropic in one meridian, and myopic, or hypermetropic, in the other; or myopia and hypermetropia may coexist in the same eye, in meridians at various angles to each other.

To diagnosticate and correct the impaired vision caused by these forms of ametropia, the method usually employed, clinically, is to place before the suspected eye various convex, or concave, spherical, or cylindrical glasses of known focal length, and to direct the patient to examine with them certain test-types, those of Snellen being usually preferred, which are composed of letters of such sizes as to present angles of 5′ at the distances at which they are intended to be seen.

As the power of refraction and length of axis are in the proper proportion in an emmetropic eye, any convex or concave glass must diminish its visual power: as the refraction is too great in myopia, its reduction by concave glasses improves vision: as the refraction is too low in hypermetropia for its short axis, convex glasses, by increasing it, add to the visual power; and in describing these defects the power of the glass, whether convex or concave, which gives the best definition, is used to designate the degree of ametropia.

The ophthalmoscope is also usefully employed to ascertain the state of the refraction of the eye, by examinations which are fully described in the text-books on ophthalmic surgery.

Usually, a full assortment of test-glasses is required, and with them and the test-types a series of careful observations must be made to ascertain the presence and degree of ametropia; and as an addition to these methods, or when the apparatus above mentioned is not at hand, it is hoped that the simple test below described may be of service to those interested in this branch of surgery.

Let the reader take any strong convex lens, say one of six inches in focus, and, standing at ten feet distance from a gas-light or lighted candle, project upon a piece of ground glass, held between the eye and the light, an image of the flame, which will be seen, inverted and distinct, when the screen is a little beyond six inches from the lens; a circle of light replaces the image, increasing or diminishing in size, as the lens is moved to or from the screen. Now cover the lens with a piece of cardboard having two circular apertures in it, each ¼ inch in diameter, and ¾ inch apart, and two spots of light will appear on the screen when the lens is moved within or beyond its focus, becoming more distinct as this point is approached, and uniting into one distinct image of the flame at the proper focal point. The least movement from this point will cause the image to become double; and by this it is known that the screen is not placed at the point to coincide with the refractive power of the lens, or, in other words, that the axis or distance from screen to lens is not harmonious with the refracting power.

This is precisely the condition of the ametropic eye, and by the simple test described below, its retina is enabled to perceive the double images it produces.

For this purpose a disk of sheet brass $1\frac{1}{2}$ inch in diameter may be placed directly before the eye, having in it, at a distance apart of $\frac{1}{8}$ inch, two perforations, each $\frac{1}{32}$ inch in diameter. When the eye regards a gas-light distant twenty feet through these perforations, two circles of diffused light are perceived at the disk, which overlap at their inner margins, and produce a bright elliptical space. Should the eye be emmetropic, the gas-light will be seen in the overlapping space, clearly defined and *single;* but if either myopia, hypermetropia, or astigmatism be present, *two* lights appear, but only where the circles overlap.

A card with two pin-holes one-eighth of an inch apart will enable any one to see the double images, after making himself myopic or hypermetropic artificially, by a concave or convex glass (preferably, however, a convex), through which he may look at a candle or gas-light, at a distance of ten or twenty feet, observing that the greater the distance from the object, the more marked will be the separation of the images.

So striking is the double vision thus produced, that a glance through the double diaphragm is sufficient to indicate any ametropia; and so exact is the test that with my own eye, corrected and with relaxed accommodation, a concave or convex $\frac{1}{72}$ doubles the light; and my friend Dr. Wm. F. Norris, who is familiar with the subject of refraction, can detect a myopic astigmatism in one eye of a $\frac{1}{60}$ by the same means.

Having now ascertained that ametropia is present in any case, it will be requisite to know whether it arises from myopia or hypermetropia, and, the following test will suffice. Draw through the two perforations a line, and, holding the disk before one eye so that this line shall be horizontal, cover the right hole only with a piece of thin red glass, and if myopia be present a red flame will stand on the right side, an uncolored one on the left: but if hypermetropia exist the red image stands on the left, the uncolored one on the right side. In myopia the double vision is direct or homonymous, in hypermetropia it is crossed.

The following diagram, Fig. 2, of an emmetropic eye, indicates the path of the light admitted through each opening, and the position of each image which is thus formed.

By the rotation of the disk so that the line through the holes is carried from the horizontal to the vertical meridian, any existing astigmatism becomes apparent. In a case recently examined of myopic astigmatism of one-sixth in the horizontal meridian, the vertical being emmetropic, there was but a single image seen when the holes stood one above the other, but widely separated double ones when the holes were placed side by side.

It is evident that a correction of the visual defect can be made with the gas-light, since it only requires that the ordinary test glasses should be placed before the eye, armed with a double diaphragm, observing that in hypermetropia concave glasses separate the images and that convex make them approach, until, when the eye is perfectly corrected, they unite into a single sharp image. The reverse obtains in myopia, the convex separating, and the proper concave fusing them into one.

Should it be found difficult to fix the attention of children or unintelligent persons upon the overlapping space where alone the double images must be sought for, a number of openings may be used through

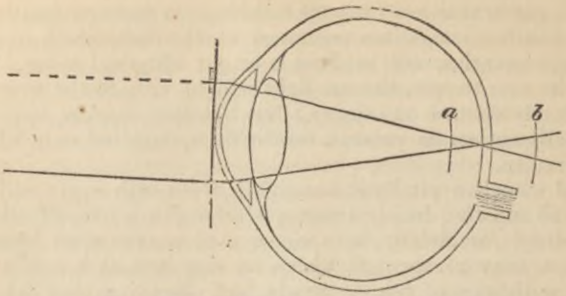


Diagram showing Hypermetropia at *a*, Myopia at *b*.

which the objects will be multiplied in proportion to the number of perforations which occupy the space of the pupil, and a disk of perforated Bristol-board has been found to answer very well in such instances.

There is one positive advantage over the test-types which this method possesses, since the acuteness of vision does not enter so largely into the problem, and an eye of low visual power may be diagnosticated and corrected, so long as it can perceive a bright spot of light; and even an amblyopic eye can thus be examined if necessary. A patient was recently examined by the writer, who for several years past had been using concave glasses of $\frac{1}{1.5}$; there was entire loss of vision in one eye, and a decided nuclear opacity in the lens of the other, which prevented an examination by the ophthalmoscope to ascertain either the condition of the retina, or the state of the refraction. The acuteness of vision was $\frac{1}{12}$ only, and it was important to know, in view of a possible operation, whether the degree of myopia was really so great. She could easily perceive the test-light, and it was found by the double holes that no glass would fuse the double images but one that was equal to that which she had been using for some years.

To obtain a better and more steady object than a flame, I have used a disk of card-board nine inches in diameter, which is attached to a gas-burner so that it will rotate upon a pivot placed through its centre, on one side of which a slit four inches in length, and $\frac{3}{8}$ inch in width has been cut, and on the other, a circular perforation $\frac{3}{8}$ inch in diameter, both covered with tissue paper. These appear as a bright band and circular spot of light, having sharp outlines, and each subtending at twenty feet an angle of 5′. For astigmatism the band can be placed at any angle by rotating the disk, and when so used the two small perforations should be placed before the eye at right angles to the direction of this band.

Having now described in detail the use of a double perforation, it remains to show that, from the same causes, an ametropic eye can be recognized by a single perforation in the diaphragm; for when a bright point is regarded by such an eye, and the disk with the single opening held close to the cornea is moved rapidly, the light will appear to dance, to an extent which will depend on its distance from the eye, and on the degree of the ametropia. The single diaphragm is useful as a check upon any other method of correction, for until all ametropia is removed by proper glasses, the point of light will continue to dance or move in some one or other direction.

These observations will all hold good for myopia, but for hypermetropia I wish it to be understood that they presuppose a relaxation of the accommodation.

The power of accommodation seems, however, to be to a certain extent neutralized when the eye looks through these small openings, and in three individuals, specially examined for this purpose, it was found to be reduced from a $\frac{1}{4}$ to $\frac{1}{11}$ in one, and from $\frac{1}{4}$ to $\frac{1}{24}$ in the other two, as tested by the ability to fuse the double images at twenty feet through concave glasses. Further clinical observation will be requisite to ascertain this point so important in the recognition of the degree of hypermetropia.

To enter upon the discussion of the optical laws by which these various effects are produced would extend this paper beyond its allotted space, as would likewise any complete history of the observations of others, although it may be said that Scheiner, in 1619, described the effect of a screen with two slits in causing double images of an object when placed within the point of perfect accommodation; that upon the same law optometers have been constructed by Young, Stampfer and others, and that Helmholtz, in his *Physiological Optics*, explains the use of such diaphragms to ascertain the near point, in his discussions on the range of accommodation.

As a ready means, however, of recognizing and correcting ametropia, for which it is proposed above, it is hoped that it may be found to possess some clinical value.

AN ADDITIONAL METHOD

TO

DETERMINE THE DEGREE OF AMETROPIA.

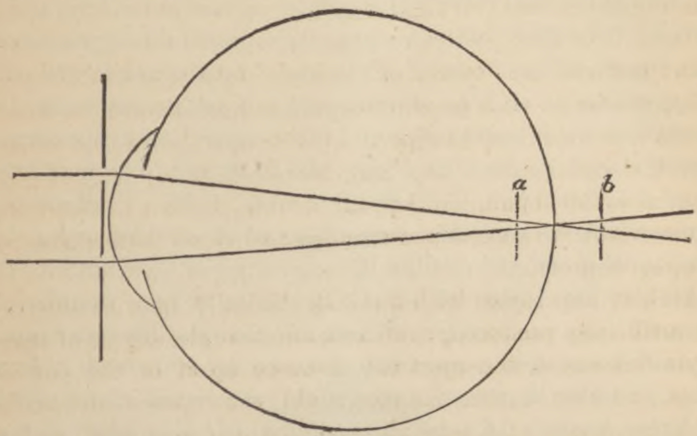
In the *American Journal of the Medical Sciences* for January, 1870, will be found a description of a test for ametropia, based on the experiment of Scheiner. It was there shown that whenever the visual axis is too long or too short, a point of light, used as a test-object, will appear double to the eye of an observer when it is examined through two small perforations in an opaque screen.

A short experience with the disk clinically, or with ametropia artificially produced, convinces one that the degree of ametropia influences the apparent distance apart of the double lights, and that if that distance could be computed with accuracy, the degree of ametropia could be diagnosticated, and a correcting lens selected without a prolonged empirical examination.

After a sufficiently full demonstration of the laws of refraction as applied to the human eye, and an exhaustive analysis of its refracting surfaces of different curvature and its media of varied density, Donders gives his authority, in addition to that of Helmholtz, for the adoption, for purposes of calculation, of the simplified diagrammatic eye of Listing, which consists, as is well known, of a single refracting surface of 5 mm. radius in curvature, and a medium whose index of refraction is 1.333, whose posterior focus is 20 mm., and its anterior focus 15 mm. from its refracting surface.

From a comprehension of these cardinal points, it becomes possible to trace, in this simple eye, the course of any given ray of light; to find the points of conjugate foci; to ascertain the dimensions of retinal images, or of circles of diffusion which fall upon the retina in ametropia; and these values thus found may be considered equal to those which would exist under the same circumstances in the human eye, with its complicated apparatus, composed of two complete dioptric systems.

Should an opaque screen, having in it two perforations, each .5 mm. diameter, and 4 mm. apart, be placed before a Listing's eye, its single surface would be converted into two minute lenses, prismatic in form, with their bases towards each other, and capable of forming independent images, which, when the length of axis is normal, fall upon the same point at the posterior focus. Rays of light, from a source of illumination sufficiently



Listing's Eye three times enlarged, showing *a*, Hypermetropia of $\frac{1}{6.5}$; *b*, Myopia of $\frac{1}{6.5}$.

distant to afford parallel rays, would pass through these two openings, would be refracted at the anterior surface, and would converge to a point at 20 mm. distant posteriorly, where the two images would be exactly superimposed and would produce the effect of a single picture; and in this transit would be afforded, as a fixed quantity for future use, a triangle of two sides, each 20 mm. in length, united by an arc of 4 mm.

Should the retina of this eye be either advanced towards or removed from its refracting surface, an ametropia would be produced; the images formed by the rays passing through the holes would fall upon it separated from each other in proportion to the departure from the length of the normal axis; and a single point of light, at a distance, for example, of twenty feet, would, in accordance with the law of projection, appear double; and the two flames would be apart to a greater or less degree, in accordance with the amount of ametropia.

These considerations lead to the search for some fixed quantity without the eye which shall bear a proportional value to the known measure within it, and the convenience of the metrical system leads me to propose for calculation an angle of 5 metres radius, with arc or sine of 1 m., as equal to the angle of 20 mm. radius and 4 mm. arc with which we are already acquainted.

As a familiar illustration, let it be supposed that the two rays which are transmitted by the screen from a point of light five metres distant are two rigid wires, in contact anteriorly, and at 20 mm. from their posterior extremities, passed through a screen, bent towards each other, and brought into contact. Should these posterior ends be moved apart, a much greater excursion would be made anteriorly; and if the separation at the former point should amount to 4 mm., the latter would be found distant about 1000 mm., since 20 : 4 :: 5000 : 1000. Furthermore, we are able to ascertain where these wires would converge before or, if prolonged, behind the screen when their anterior extremities are separated either by being drawn asunder, or crossed upon each other. When, for example, the anterior extremities are drawn apart 250 mm., we say 250 : 5000 :: 4 : 80 mm.; and we thus imitate very nearly the course of the rays in a hypermetropia of 1-80 mm. or $\frac{1}{3}$, which diverge when they leave the eye as though they had their origin from a point 80 mm. or 3″ behind the nodal point. In like manner we imitate a myopia of $\frac{1}{3}$ by crossing the anterior ends and causing there a separation of 250 mm., when the wires would be found to converge and intersect each other at 80 mm. nearly in front of the screen.

From the last demonstration it arises, that if we are justified in using Listing's eye for comparison, and if we can clinically measure the distance between the double images as seen through the screen, we are able to ascertain where those rays, if prolonged, would unite, before or behind the nodal point, and thus determine in a very expeditious and happy manner the degree of ametropia.

For this purpose the patient is placed 5 metres distant from a small point of light, having before his eye an opaque screen with two perforations in it, each .5 mm. in diameter, and placed 4 mm. apart, through which, in the overlapping space between the two holes, as described in a previous paper, he searches for the double images. Myopia or hypermetropia may be determined by placing over one of the holes a piece of ruby glass, when one of the images will become red, and be found on the same side with the hole covered in myopia, but crossed and on the opposite side in hypermetropia, a result which is explained by the well-known law of projection.

Having ascertained the presence and kind of ametropia, the red glass is removed, and the distance apart of the two images is measured by means of another small flame or light held in the hand of the surgeon, which is brought into the patient's field of vision whilst he looks at the first mentioned fixed light. The second flame is moved in a line with the double images until the patient is able to say that one of the moving flames coincides with or overlaps one of the fixed ones, and that but three instead of four flames are perceived; and when this is accomplished, this distance of the fixed from the moving flame is ascertained by an ordinary rule or measure. Several other methods have been employed with success, and the ingenuity of each surgeon will enable him to overcome any difficulties he may encounter in these manipulative details.

A blackened tin disk, ten inches in diameter, having white lines one inch apart painted on its face, attached to a spring candlestick by a pivot, having in its centre an opening $\frac{1}{4}$ inch in diameter, through which the light of a candle may be transmitted, affords a very useful instrument. Let the patient regard this small point of light, and when he sees it double, he can at the same time determine the number of white lines between the lights, and hence the distance, since the lines are one inch apart. By rotating the disk and changing the position of the screen, any meridians of the eye can be examined, in cases of astigmatism.

The brief notes of a few cases will illustrate the use of this method.

Mrs. G., placed 5 metres from a point of light (a gas-burner turned low), saw two lights through a disk, whose apertures were apart 4 mm., and the one colored red stood on the side of the hole covered with red glass, thus demonstrating myopia. A candle lighted and held by the surgeon was now brought near to the gaslight, and it also appeared double, but it could be distinguished from the gas by its motion and its larger flame. It was moved back and forth until the left-hand flame of the candle overlapped the right-hand one of the gas-burner; and, when this was accomplished, the distance from gas-burner to candle was measured with a common rule, and found to be five inches, or 121 mm. Then 121 : 5000 :: 4 : 165, which, reduced to English inches by dividing by 25.5, or to French inches by dividing by 27, gives 6.5 in English inches as the distance of convergence of the rays from the nodal point. The myopia was then found to be corrected perfectly by a $-\frac{1}{6}$ placed $\frac{1}{2}$ inch in front of the nodal point.

In a case of aphakia, after a successful operation for cataract, the distance between the double lights was found to be 10 inches, or 250 mm.; and $\frac{5000 \times 4}{250} = 80$ mm., or 3.2 inches. This case required for its correction a $+\frac{1}{3.5}$, $\frac{1}{2}''$ from the nodal point, showing that the hypermetropia$=\frac{1}{3}$.

A case of hypermetropic astigmatism in a person able to give concise replies, and who could fully relax his accommodation, gave the following results. With the holes so placed as to analyze one meridian, the distance apart was $4''=101$ mm.; and in the meridian at right angles to first, 4.5, or 115 mm. Let x be the degree of ametropia, and we have the formula: $x = \frac{5000 \times 4}{101} = 196$, or 7.7 in., which indicates that the rays diverge from this meridian as though they arose from a point 7.7″ behind its nodal point, and that a convex $\frac{1}{8.2}$ would suffice for its correction.

After atropia an $\frac{1}{8}$ was found sufficient, combined with a cylinder of $\frac{1}{50}$, to overcome the greater ametropia of the other meridian.

It will be found convenient to use the English measures for these calculations, and to reduce Listing's eye and the other quantities to the following values:

Radius,	5 mm.	= 0.2	English inch.
Anterior focus,	15 "	= 0.6	" "
Posterior "	20 "	= 0.8	" "

The distance apart of apertures in the screen, 4 mm. = 0.16.

The distance from observer to test-light, 5 metres = 200 inches nearly, or $16\frac{2}{3}$ feet.

The rule, then, would be to multiply the distance from the eye examined to the test-object by the arc of the small angle, and divide the result by the distance apart of the two lights, as ascertained by measurement.

Mr. W. suffers from a high degree of myopia, using $-\frac{1}{4.5}$, which does not fully correct it. The distance apart of the images was 8 inches. Then $\frac{200 \times 0.16}{8} = \frac{32.00}{8} = 4$. With $-\frac{1}{3.5}$ the double lights were perfectly fused together, and his myopia corrected.

Mr. M., with the disk so placed that a line uniting the holes was horizontal, saw the points of light apart $4\frac{3}{4}$ inches, and in the vertical meridian they were 3″ apart. $\frac{200 \times 0.16}{4.75} = 6.7''$. $\frac{200 \times 0.16}{3} = \frac{32.00}{3} = 10\frac{2}{3}$. In these meridians the points of light were brought together respectively by $-\frac{1}{6}$ and $-\frac{1}{10}$, and the myopic astigmatism was fully corrected by a sphero-cylindroid lens, $-\frac{1}{10} \frown - \frac{1}{16}$ cy.

Mr. D., myopic astigmatism; the images apart in one meridian 5 inches, in the other $1\frac{1}{2}$. $\frac{200 \times 0.16}{5} = \frac{32.00}{5} = 6\frac{2}{5}$. $\frac{200 \times 0.16}{1.5} = 20$. A glass $-\frac{1}{5.5}$ corrected the greatest, and $-\frac{1}{20}$ the least myopic meridian, and a spherical and cylindrical of $-\frac{1}{20} \frown - \frac{1}{8}$ cy was ordered.

It will be observed that, by the English measure, the formula is so simple that it can most readily be remembered, viz., 200×0.16, divided by the distance between the lights; and that a separation apart of $1'' = \frac{1}{32}$ of ametropia. I have constructed a table, which will save the slight trouble of making even this short calculation.

Distance of Images apart.	Degree of Ametropia.	Distance of Images apart.	Degree of Ametropia.
$\frac{1}{2}''$	$\frac{1}{64}$	$5''$	$\frac{1}{6 \cdot 5}$
1	$\frac{1}{32}$	6	$\frac{1}{5 \cdot 3}$
$1\frac{1}{2}$	$\frac{1}{20}$	7	$\frac{1}{4 \cdot 5}$
2	$\frac{1}{16}$	8	$\frac{1}{4}$
3	$\frac{1}{10}$	9	$\frac{1}{3 \cdot 5}$
4	$\frac{1}{8}$	10	$\frac{1}{3 \cdot 2}$

In selecting a glass for the higher degrees of ametropia, its distance from the nodal point must be considered, and a lens chosen for myopia $\frac{1}{2}''$ stronger, and for hypermetropia $\frac{1}{2}''$ weaker, than that which would be required after a calculation by the present method.

Having satisfied ourselves that an ametropia does exist in any given case, and that the visual axis is too long or too short, we can measure the axis with precision by using the Listing eye for comparison. We know that when an object is placed so near the eye as to give divergent instead of parallel rays, its image must fall behind the position of the posterior focus. These points of emission and convergence are the conjugate foci, and are found by the formula $f' f'' = F' F''$; f' being the distance of the object from the anterior focus, and f'' the distance of the image from the posterior focus; F' and F'' being the known quantities of the anterior and posterior foci. The proportion is $f' : F' :: F'' : f''$; hence $f'' = \dfrac{F' F''}{f'}$.

In the case of Mrs. G., we found a myopia of $\frac{1}{6 \cdot 5}$, and we know that an object distant $6\frac{1}{2}$ inches from her nodal point has its image on her retina. Should we desire to ascertain how much her visual axis is too long, assuming with the best authorities that it should be normally 22.23 mm., we subtract from $6.5 = 165$ mm. the distance from nodal point to anterior focus $= 20$ mm., and we have $f' = 145$; to find $f'' = \dfrac{F' F''}{f'}$ we say $f'' = \dfrac{20 \times 15}{145} = 2.07$. The retina is 2.07 mm. distant from its proper position, and her axis is therefore $22.23 + 2.07 = 24.30$ mm. in length.

The same formula is used for hypermetropia; but as the distance from the nodal point to the object is negative, f' is found by adding the distance of the point of convergence behind the eye to the distance from the nodal point to F', and with hypermetropia of $\frac{1}{6.5} = 165$ mm. $f' = 165 + 20 = 185$, $f'' = \frac{20 \times 15}{185} = 1.6$. Subtract this quantity from 22.23, and we have the length of axis which gives rise to this degree of hypermetropia $= 20.63$.

An instrument for making these examinations has been constructed for me by Mr. Zentmayer, which consists of four disks of sheet-brass $1\frac{1}{2}$ inches in diameter, attached together by a pivot passing through a small projecting handle upon each disk.

No. 1 has in its centre a single perforation, 1 mm. in diameter.

No. 2 has 12 perforations, $\frac{1}{2}$ mm. apart.

No. 3 has 2 perforations, 3 mm. apart.

No. 4 has 2 perforations, 4 mm. apart, those in the last three disks being all $\frac{1}{2}$ mm. in diameter.

It is known that when an ametropic eye regards a distant point of light, a circle of diffusion must fall upon its retina; and that by the exclusion of peripheral rays, by means of a small perforation in an opaque screen, definition may be so much improved as to enable the point of light to be distinctly seen. A rapid to and fro motion of the screen will bring other portions of the diffused circle on the retina under the influence of the diaphragm, and the test-light will, to the observer, appear to dance in accord with these motions. Screen No. 1 is used for this purpose.

The entire circle of diffusion may be influenced by a series of perforations by the use of disk No. 2, through which the test-light will appear to the observer multiplied.

No. 3 has fixed in a groove a small slip of ruby-colored glass, which may at will be pushed over one of its holes, and thus color one of the double images of the test-light red. Myopia is distinguished from hypermetropia in this manner, and this disk is used when the point of light is employed instead of the ordinary test-types, and a glass is empirically sought for which will fuse the two images and correct the ametropia. The overlapping space is larger than in disk No. 4, the double images are more easily found, and the examination of dispensary patients or children is made with precision and rapidity.

Disk No. 4 is employed for the calculation of ametropia in the manner and by the formula above described.

Note. An ametropia $= \frac{1}{32}$ is indicated when the two points of light appear to be 1 inch apart.

A band of light, passing through a slit in a screen $\frac{1}{10}$ inch in width, presents an angle of nearly two minutes at 16 feet—an angle of 1 minute being chosen by Snellen as the standard for normal acuteness of vision.

It follows that if this band should appear twice as wide, by becoming double, but not separated, it would indicate the tenth part of $\frac{1}{32}$, or an ametropia of $\frac{1}{320}$, and an ametropia of even this low degree might, with care, be recognized.