

Trial Lenses in Vision Correction

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ABSTRACT

When prescribing corrective lenses (eyeglass lenses), the prescriber may determine the optimum parameters for the lenses with a technique involving calibrated trial lenses, placed in an eyeglass-like "trial frame". In this article, this process and its apparatus are described. An introductory section gives background in some areas of lens theory and the nature and correction of certain vision defects.

INTRODUCTION

Caveat

I am not an eye care professional, nor do I have any formal training in the practice in that field nor in its own unique branch of optical science. The information in this article is my own interpretation of the results of extensive (mostly quite recent) research into the available literature, through the prism of my own scientific and engineering background and outlook.

Refraction

In general optical theory, *refraction* refers to the "bending" of light rays by a lens or prism. But in the field of vision correction, *refraction* also refers to measuring the optical parameters of "refractive" flaws in a person's vision with the objective of properly specifying eyeglass lenses that will best correct those flaws.

Two techniques of refraction are commonplace, using the *refractor* and the *trial lens system*.

The refractor

A refractor¹ is the scary mask-like instrument that is placed in front of your face while the examiner turns various dials while asking. "Which is better, one [click] or two?". It is essentially an eyeglass simulator. It places lenses of different optical parameters in the path of the patient's vision. Simplistically, those parameters are varied until the

¹ Often called a "phoropter", although Phoropter is a trademark of one manufacturer for their instruments.

patient experiences the best vision (in different contexts). The resulting “prescription” is a specification for the optical parameters of eyeglass lenses that should have the same effect on the patient’s vision.

Figure 1 shows a typical refractor.

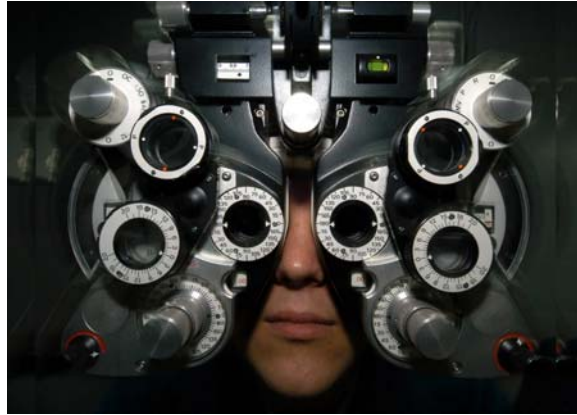


Figure 1. Refractor

U. S. Navy photograph, P.D.

The trial lens system

The trial lens system also simulates the effect of eyeglasses in a more direct way. It uses a special eyeglass frame (the *trial frame*) into which interchangeable, calibrated lenses can be readily placed (solo or in combination) until the best vision is obtained. The prescription then specifies the parameters of eyeglass lenses that should parallel the optical behavior of the final setup in the trial frame.

The entire “kit” of trial frame and a large arsenal of different trial lenses (perhaps as many as 266 of them) is often housed in a tidy case, leading to the entire system often being called a *trial case*.

Figure 2 shows a typical modern trial frame with lenses in place.



Figure 2. Trial frame

Pros and cons

The refractor is, generally speaking, a more convenient tool for conducting refraction. It is always a little tricky to slip the various lenses into and out of their “slots” in the trial frame while the frame is in place on the patient’s head. On the other hand, often young children and some adults are intimidated by the refractor (can you imagine, after seeing figure 1?) and children in particular may enjoy the game as the examiner works like a close-up magician in manipulating the trial lens system. (“Is that a lens in your ear?”)

From an objective standpoint, many experts feel that the indications given by skilled use of the trial lens system are more insightful than those gained with the refractor. Some clinics insist that, after the patient has been examined with a refractor, and a prescription drafted, the examiner emulate that prescription with trial lenses and have the patient actually walk around, look at familiar documents, crochet, maybe swing a putter, and so forth, before confirming and issuing the prescription.

There are then logistic and economic considerations. A nice trial case is about the size of a large briefcase, and can easily be taken to “storefront clinics”, clinics in remote areas, and the like. That is hardly practical for a refractor. A nice trial case can be purchased today for perhaps \$750.00, while a first rate refractor is over ten times as costly.

BACKGROUND

Lenses

This whole activity is about lenses—the lenses that will be used to correct a patient’s vision, and the lenses used in the trial frame. Let us first review some pertinent things about lenses.

In figure 3, we will see some important properties of a biconvex, convergent lens.

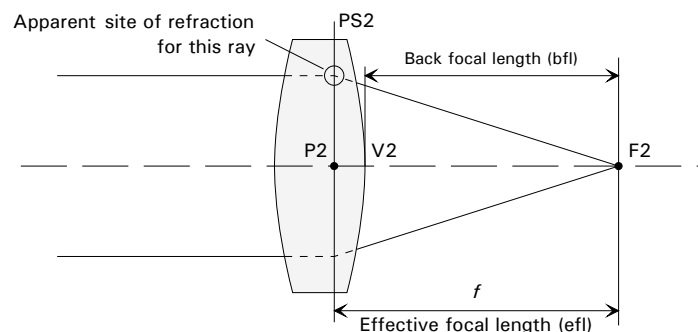


Figure 3. Focal lengths of a lens

We see the lens in an important situation. We consider rays of light, perhaps coming from the same point on an object at an infinite distance, that arrive parallel to each other and to the lens axis. In that situation, ideally, the lens will converge all such rays at a point on the axis called the *second* (or rear) *focal point* (F_2).

We realize that in reality, the refraction of these rays (that is, the deflection in their direction of travel) occurs once as they cross the front surface of the lens and again when they cross the rear surface.

But if we consider the action from the standpoint of the lens as a “black box”, then (in this case, with the arriving rays parallel), it appears that the rays are deflected just once, at a plane we call the *second principal surface*, labeled PS_2 .²

It turns out that perhaps the most important property of the lens is its *focal length* (called, formally, its *effective focal length*, but don't let the “effective” throw you off—it is the “real” focal length).

For a reason we will develop shortly, a distance that is critical to the use in vision correction, in the scheme that has been adopted for that art, is the distance to the second focal point from the rear surface of the lens (to be precise, from the rear surface at the axis, a point called the *second* (or rear) *vertex* of the lens, V_2 . This is called the *back focal length*, bfl , (or back focal distance)

In the correction of vision, we will be concerned with the properties of two classes of lens.

The *refractive power* of a lens (often, just *power*) is the reciprocal of the focal length (that is, the effective focal length). The modern unit is the inverse meter (m^{-1}), but the traditional unit (and always used today in vision correction work) is the *diopter*, which has the same definition. A lens with a focal length of 1.0 m has a power of 1.0 diopter.

The focal length may be positive (for a converging lens) or negative (for a diverging lens); the power carries the corresponding sign.

Consistent with the emphasis in vision correction work on the *back focal length* of a lens, in that field we are most often concerned with a different definition of power, the *back vertex power*. It is the reciprocal of the *back focal length*.

² Why “surface”, not “plane”? Because in reality, this is usually a curved surface, not a plane. However, our theoretical examination of the behavior of rays is always conducted in an infinitesimal region near the axis (even though we don't draw it that way), and in that context it doesn't matter whether the surface is a plane or not. So we label it a surface (for rigor), and draw it as a plane (for convenience).

Two classes of lens

In the correction of vision, we will be concerned with the properties of two classes of lens.

Spherical lenses

The lens that is familiar in such areas as photography or astronomy is rotationally-symmetrical. That means that its cross section is the same shape in any plane containing the axis. A lens whose surfaces are portions of a sphere is the traditional and most familiar type of rotationally-symmetrical lens, and in the field of corrective lenses, rotationally-symmetrical lenses (whether their surfaces are actually portions of spheres or not) are referred to as *spherical lenses*.

The important performance consideration is that the refractive effect of such lenses is the same along any “meridian”—a transverse line passing through the axis—whether the “6 o’clock to 12 o’clock” meridian or the “2 o’clock to 8 o’clock” meridian.

Cylindrical lenses

The surfaces of a *cylindrical lens* are portions of a cylinder (not necessarily circular cylinders).

The important performance consideration is that their refractive effect is different in different directions (along different meridians). It is the greatest along a meridian that is a right angles to the cylinder axis (sometimes called the *power meridian*), zero along a meridian parallel to the cylinder axis (the *axis meridian*), and has intermediate values at meridians in between.

Refractive error of vision

The term *accommodation* is used in the field of vision science to refer to the eye’s ability to focus on objects at different distances. Ophthalmic lenses, as found in eyeglasses and contact lenses, are in part intended to overcome deficiencies in the eye that prevent the person from fully utilizing that capability.

The basic “defects” in accommodation (often described as “refractive errors”) are:

Hyperopia³ (“far-sightedness”) is the deficiency in which the total range of accommodation is “offset outward”, such that distant objects (even at “infinity”) can be focused, but the near limit is not nearly as close as is normal. From a theoretical standpoint, the far limit is

³ Usually called in formal ophthalmological writing “hypermetropia”.

“beyond infinity”, although since there are no objects there that is not of any value to the person.

Simply, we correct hyperopia with a converging (positive power) lens.

Myopia (“near-sightedness”) is the deficiency in which the total range of accommodation is “offset inward”, such that close objects can be focused on but the far limit is short of infinity.

Note that in both these it is assumed that the person still has the normal “span” of accommodation; it has just been shifted from the desirable place (so one “end” is forfeit).

The basic cause of these defects is that the focal length of the eye’s lens system (which comprises two lens elements, the cornea and the “crystalline lens”) is not appropriate for the distance from the lens to the retina.

Simply, we correct myopia with a diverging (negative power) lens.

Presbyopia (“old person’s vision”) is the deficiency in which the eye is able to make less change in the distance at which it focused than is “normal” (an ability called *accommodation*). It may be combined with *hyperopia*, which case the far limit of the range of vision is “beyond infinity”, and the near limit may still be a large distance.

Or it may be combined with *myopia*, in which case the far limit may be at a modest distance, and the near limit not much closer.

In “full blown” presbyopia, the eye cannot change its vision distance at all, so the near and far limits become the same (and what distance that is can be affected by myopia or hyperopia).

The basic cause of presbyopia is decline in the effectivity of the eye’s mechanism for changing the focal length of the crystalline lens.

We correct for presbyopia with bifocal lenses, which have one power to be used for vision at a distance and another (more positive) power to be used for near vision.

Astigmatism

Astigmatism is a refractive defect that is not a flaw in accommodation.

In astigmatism, the eye cannot, in the same “state of accommodation”, focus on a line at a certain distance running in one direction and a line at the same distance running in a different direction.

We correct astigmatism with a cylindrical lens (or, more likely, by having the effect of a cylindrical lens combined with the effect of a spherical lens). The axis of the spherical lens must be appropriate to the orientation of the astigmatism being corrected.

The use of vertex power

The effect of a lens on vision correction depends on the *power* of the lens (and here I mean in the conventional optical theory sense—the inverse of the *effective focal length*) the distance from the first principal point of the eye's lens system and the second principal point of the corrective lens.

Our dealings with this would be greatly simplified if we adopt a standard distance between the eye and the lens, as then only the power of the lens needs to be taken into account.

But doing so is made difficult for two reasons. Firstly, the second principal point of the lens is not discernible in any simple way, and thus measuring to establish the standard distance, when mounting the lens, is not easy.

Further, the location of the second principal point on the lens varies dramatically with the shape of the lens. A certain distance in the case of one shape of lens may place the lens so far from the face as to seem silly, while on another shape of lens that distance would result in the lens being pressed against the face (or worse).

We can ameliorate these difficulties by instead adopting a standard distance from the eye to the back of the lens (in particular, to its rear vertex—the point on its axis at its rear surface).

Fortunately, when we adopt such a norm, we find that the effect of the lens on vision correction (for distant vision) is consistently determined by the back vertex power of the lens.

Thus, in vision correction work, we (whenever possible) place the back vertex of the lens at a fixed distance from the eye (and if that is not practical in a specific case, we describe the alternate distance in those terms). Then, we specify lenses in terms of their back vertex power. And it all works out.

The prescription

Basically, in the case of bifocal lenses, the prescription that defines the needed optical parameters is typically written for each eye in a form such as this (there are several variants):

OD +3.50/ +0.75 X 30 add 1.75

The meanings of the elements are:

OD (*oculus dexter*): This is for the right eye. (For the left eye, it is OS, *oculus sinister*).

+3.50: The lens overall has a spherical power component of +3.50 D.

+0.75: The lens overall has a cylindrical power component of +0.75 D with its axis at 30^{o4}.

add +1.75: In the near-vision segment, the spherical component of the power is 1.75 D more positive than specified for the lens overall (thus +4.25 D in this example). The cylindrical component of the power in the segment is taken to be the same as specified for the lens overall.

Near vision effective vertex power

Imagine that we had a spherical lens with a vertex power of +3.50 D. If we consider its use in the correction of hyperopic vision, assuming that the lens is placed so its rear vertex is at a standard distance from the eye, the value +3.50 D tells us exactly its effect on the correction of distant vision—exactly what degree of hyperopia it would correct in distant vision.

But if we consider the use of that same lens in the correction of near vision at some assumed near distance, assuming again that the lens is placed so its rear vertex is at a standard distance from the eye, the value +3.50 D does not in general tell us exactly its effect on the correction of near vision. Here, we have lost the great convenience of the vertex power telling us the effect on vision correction.

A slightly different value, called the *near vision effective vertex power*, does tell us exactly the effect of the lens on near vision (at some assumed distance).

The difference between the *near vision effective vertex power* of a lens and its vertex power is called the *near vision effectivity error* (NVEE). It is ordinarily negative, meaning that the near vision effective vertex power is less positive than the vertex power. The amount of the NVEE depends on the curvature of the front surface of the lens, the thickness of the lens (at the center), and the distance for which we are interested in correcting the near vision.

The power in the near vision segment of a bifocal lens implied by the prescription (as the sum of the basic spherical power and the “add”)

⁴ The axis runs, in normal scientific terms, from 0° to just shy of 180°, but 0° is actually written as 180°, so the range as written is from just above 0° to 180°.

sis intended to be the near vision effective vertex power in the near vision segment of the finished lens.

THE TRIAL CASE

The trial frame

Figure 4 shows a typical modern trial frame, from our personal collection. This one is made in Hong Kong, and closely follows the design of the American Optical Company models 11070 (U.S. made) and 11072 (made in Japan). The design, in specific detail, actually goes back to about 1939 (amazingly modern in terms of “industrial design”).



Figure 4. Trial frame (after AO design)

The positions of the two side assemblies can be adjusted laterally by two small micrometer knobs in order to place the center of the respective lens laterally in line with the patient's pupils. The positions can be read on scales. The sum of the two readings will be the *interpupillary distance* (PD).

The nosepiece assembly, which actually provides for the location of the frame on the patient, can be adjusted in two ways. It can be moved fore-and-aft, so as to adjust the distance of the trial lenses from the eye to meet the standard distance or the special distance chosen for the patient.⁵ It can be adjusted up-and-down, so as to place the centers of the lenses vertically in line with the patient's pupils.

The temple pieces have adjusting knobs which adjust their angle with respect to the frame proper, in turn adjusting the angular “tilt” of the lenses with respect to the line from the eye to the center of the aperture (the *pantoscopic angle*). The lengths of the temple pieces can

⁵ Some trial frames have a little gunsight-like feature on each side allowing the distance from the reference plane of the frame to the front of the cornea to be precisely measured. Ours (illustrated) is not quite that fancy.

also be adjusted to suit the location of the patient's ears after the eye distance has been set.

On each side, there is a ring with two bars each having three notches to receive trial lenses, plus a set of three spring clips for holding them in place. The front notches are spaced 3.5 mm center-to-center.

Each ring can be separately rotated with a small knurled knob. Although all the trial lenses rotate together, this is only of importance to a cylindrical lens, if present. A scale allows the orientation of the axis of a cylinder lens (indicated by a "tick mark" on the lens) to be ascertained.

There is also on the rear of each side a similar provision for holding a fourth lens, when needed. There is no mechanical provision for rotating that lens.

For historical comparison, Figure 5 shows another trial frame from our personal collection. This is from American Optical Company, and is believed to date from about 1890.



Figure 5. Trial frame (ca. 1890)

In this design, the two units are moved symmetrically by a single screw (with a knob on each side, however). Two scales are provided for this movement, both in inches (as for all movement scales on the unit). The one on our right shows the interpupillary distance. The one on the left shows the separation between the temple pieces. In this specimen, all the scales are of engraved ivory. The cylinder axis scale on the left side (to our right in the photo) has lost a piece (there is evidence of other repairs nearby).

It will hold one trial lens on the front (rotatable with a small knob to the side) and one to the rear (not mechanically-rotatable).

The lenses sit in round-bottomed grooves in two circular posts, held with a spring clip.

On the front side, the posts have a second groove, presumably to facilitate the temporary placing of a second lens, but no spring clip is provided to complete its residency. This is presumably used in connection with the placing of an incremental lens to confirm the power of the trial lens in place.

The trial lenses

The trial case typically includes as many as 266 lenses. They include:

- Spherical lenses, with a wide range of powers, both positive and negative, generally 0.12 D, 0.25 D, and then in steps of 0.25 D up to a certain point, then in steps of 0.50 D, and then finally in steps of 1.00 D. At least two of each power are included.
- Cylindrical lenses, again in a variety of powers, often both positive and negative, mostly in steps of 0.25 D.
- Special lenses used for various special tests, “opaque” disks used to block one eye, and so forth.

Figure 6 shows three trial lenses of the “traditional” type from our personal collection. They have thin metal rims (typically 1.5-1.7 mm thick), with a rounded edge, and an overall nominal diameter of 38 mm (1.5”). Generally, spherical lenses of this type are symmetrical (same curvature on each surface). Cylindrical lenses usually have one flat (“plano”) surface.



Figure 6. Trial lenses—traditional

The leftmost lens is a spherical lens. The next two are cylindrical lenses.

The cylindrical lenses have a pair of tick marks on the glass near the rim. These indicate the orientation of the cylinder axis (see second and third lenses—the tick marks have been darkened here for better visibility).

In some cases, the cylindrical lenses also have “frosted” portions outside a central roughly-rectangular clear portion (see the third lens). The cylinder axis of the lens runs along the center of the clear portion. The purpose of the frosting is to allow the examiner to quickly grasp the general orientation of the cylinder lens without having to refer to

the tick marks, as well as to readily distinguish the cylindrical lenses from the spherical lenses.

The metal tabs serve to hold the lenses for manipulation, and also carry a designation of the lens power.

In some cases, the difference between plus and minus power was conveyed by the color of the tab, in some case by the shape of the tab, in some cases with a sign pierced through the tab, and in some cases with two or more of those. (Those shown are from a set in which the sign was conveyed both by a pierced mark and by the shape of the tab.)

In some cases, the class of lens (spherical or cylindrical) is indicated by the shape or color of the tab, but in most cases, the user is left to ascertain that by the presence or absence of the tick marks showing the axis of cylindrical lenses (and the frosting, for sets having such).

Lenses of this style are still offered by almost all trial case suppliers.

Figure 7 shows four trial lenses of the “modern” type (from Marco Ophthalmic, Inc.) from our personal collection. In these, the lens proper is in an anodized aluminum mount (for some manufactures, it is plastic), with a nominal diameter of 38 mm and a typical edge thickness of 1.7 mm.



Figure 7. Modern trial lenses

The left lens is spherical, the right one cylindrical (see discussion below on identification).

Naturally, the actual lens has smaller diameter than the mount. Such a smaller diameter that was found in the “traditional” lenses is intentional, having been found to be advantageous in the avoidance of various undesired effects. Common actual working diameters are 25 mm for the moderate powers (as seen above) and 18 mm for the larger ones (perhaps above 8.00 D).

Typically, in such sets, the spherical lenses are of the meniscus form (curved overall, with a positive curvature on the front surface and a negative curvature on the back surface). Often they follow the

“corrected curve” design, in which the overall curvature, for a given power, is optimized in order to minimize certain aberrations. They may also follow (or closely follow) the “additive vertex power” system (described later).

In some cases, the cylindrical lenses have a flat (“plano”) back surface, and a cylindrical front surface. In other cases, they have a spherical rear surface (concave) and a toroidal front surface with a convex spherical component (to give the cylindrical power desired, while taking the spherical power to zero despite the back surface curvature).

Normally the sign of the power is included in the marking, and as well, the frames are black for plus power and red for minus (as prescribed by the international standard).

The distinction between spherical and cylindrical lenses is often only shown by virtue of the fairly prominent tick marks on the mount showing the axis of cylindrical lenses. In the Marco spherical lenses, the power is marked twice (suggesting that it applies to “both meridians”, although of course that could be any two meridians). For the cylindrical lenses, the power only appears once (at the specific meridian to which it applies, the “power” meridian, at right angles to the cylinder axis).

TRIAL LENS EXAMINATION

Basics

There are various procedures recommended for the conduct of a refraction using a trial lens system. They all have various subtle advantages.

Here, I will discuss the setup for one procedure, one that perhaps best illustrates the technical principles involved.

In this procedure, the lens that represents the basic power of the final lens overall is placed in the rearmost position (or “cell”), “position 1”—closest to the eye. If a cylindrical component is involved, the trial cylinder lens is placed in “position 2”—farther from the eye.

In figure 8 we see this setup in our “modern” trial frame, with two “modern” trial lenses—spherical and cylindrical—on each side.



Figure 8. Modern trial frame with modern trial lenses

To give history its due, in figure 9 we see the corresponding setup in our antique AO trial frame, with “traditional” trial lenses.



Figure 9. Antique trial frame with traditional trial lenses

Note here that the rear lenses (spherical) are in “position 0”, behind the frame, as this frame only has one fully-equipped position on the front side. The cylindrical lenses shown here are the type having frosted areas to help recognize the general orientation of the cylinder axis (they also have tick marks, not readily visible in this photo, that are read against the calibrated scales).

Without describing the actual step-by-step procedure, the objective is to end up with a combination of the power of the spherical lens and the power and axis orientation of the cylindrical lens that produce the best distant vision with the patient observing a “distant” target.

Then, to determine the optimum lens properties for near vision (as will be implemented in the near vision segment of the final bifocal lens), we place an additional positive spherical lens in the outermost position in the frame (“position 3”). One advantage of this, rather than replacing the main spherical lens with ones of successively more-positive power, is that the result comes out directly in “add” notation. (There is also a subtle technical advantage, which we will cover later.)

Imagine that we end up with this “stack” in the frame for one eye when best distant vision has been attained:

Cell 1 (nearest face): Sphere, +3.50 D

Cell 2: Cylinder, +0.75 D, axis 30°

After we have added the third lens, and best near vision has been attained, we have this stack:

Cell 1 (nearest face): Sphere, +3.50 D

Cell 2: Cylinder, +0.75 D, axis 30°

Cell 3 (outermost): Sphere, 1.75 D

Then we write this as the prescription for the actual lens to be made:

OD +3.50/ +0.75 X 30 add 1.75

Straightforward.

But of course, there are a number of wrinkles, some of which we will now explore.

The additive vertex power scheme

We noted at the outset that the effect of a lens on vision correction depends on both the power of the lens and its distance from the eye.

This is a manifestation of the broader optical principle that the power of a compound lens comprising two lens “elements” is dependent on the powers of the two elements, their respective thicknesses, and the distance between them (measured in a certain way). Here, in effect, the eye’s lens system is one element and the corrective lens the other.

But the concept has a further application in the case of trial lens refraction of a patient, when two or more lenses may make up the “lens” that is being tried. In the situation just described (the distant vision phase), we take the power of the spherical lens to be the spherical component of the power of the “stack”.

Yet would not be exactly so, owing to the fact that the thicknesses of the elements and the distances between them is not negligible. The spherical power component of the “stack” (observed at its rear vertex, that is, at the rear vertex of the rearmost component, the cylindrical lens). This is the cause of an error in the prescription that will guide the making of the actual corrective lens.

We can care of this in a clever way, called the “additive vertex power system”.

Firstly, for all the lenses (of various powers) in the set from which lenses are intended to be placed in “position 1” (closest to the eye—

the “ocular” lenses) [in our example above, those would be the spherical lenses]:

- Have a constant thickness (measured along the axis; that is, between the two vertexes), and
- Have a constant front surface curvature

We mark all those lenses with their actual (back) vertex power.

Then, we design the trial frames so as to give a constant distance between the “front” and “rear” lenses (measured along the axis; that is, between the two adjacent vertexes).

Then, we mark each lens in the set intended to be placed in “position 2” (the “anterior” lenses) with a value calculated by a formula involving:

- The actual (back) vertex power of the lens.
- The standard curvature of the lenses in the ocular lens set.
- The standard axial thickness of the lenses in the ocular lens set.
- The standard spacing between the front and rear lenses when in the trial frame.

Note that we are free to have each of the anterior lenses have any shape we wish, as might be chosen to meet further objectives. There is no requirement for uniformity in the curvature of either surface or in the axial thickness.⁶

Having done all that, the (back) vertex power of the stack of any two lenses, each from the proper set for its position in the trial frame, will be the sum of the markings on the two lenses.

Note that since the “anterior” lenses in the common setup are the cylindrical ones, this result has meaning with regard to the power in the power meridian of the cylinder lens. The cylinder lenses have zero power in their axis meridian, and contribute zero to the power of the combination in that meridian.

If we want “zero” power in the rear position (perhaps the patient needs no correction for hyperopia/myopia, but only for astigmatism)), we must put in the rear position a lens that fulfills our norms regarding front surface curvature and thickness but has zero back vertex power.

⁶ There is a very small implication of the thickness of the anterior lens with regard to the distance assumed for near vision measurement, but this is typically negligible.

Otherwise, the effect of the cylindrical lens on the vertex power of the stack (along the cylindrical power meridian, of course) would not be that implied by its marked power.

In many “additive” trial lens sets (such as the Marco lenses shown above), the design restrictions on the lenses for use in the ocular position to support “additivity” are not strictly observed, the design yielding to other criteria that may be more compelling. Substantial departures, however, can be made without destroying additivity by a consequential amount.

Sadly, despite wishful thinking on the part of some eminent ophthalmic scientists, it is not possible to extend this scheme to embrace three or more ranks of lenses. That is, for example, we cannot establish a third set of lenses, each marked with a number that would always represent the increment to the vertex power of the stack that lens would confer if placed in position 3 regardless of the lenses in positions 1 and 2.

Near vision correction

With regard to near vision correction, we recall the effect of the near vision segment portion of the lens on vision, at a certain assumed near vision distance, is not (in general) the same as the vertex power of the segment (the difference being quantified as the *near vision effectivity error*, or NVEE).

In a bifocal lens prescription (the situation in which we most often encounter the near vision issue), we would like the “add” value to reflect the difference between (a) the near vision effective vertex power of the near vision segment (for the near vision distance in which we are interested) and (b) the power of the basic lens (that is, in its “distant vision part”, outside the near vision segment).

Suppose that, after determining the distant vision correction, we have the patient regard a near test target and then replace the spherical lens in position 2 with lenses of successively more positive power, until best near vision is attained. The marked power of the spherical lens then in place will not be the near vision effective vertex power then in effect; that effective power is lower than the marked vertex power, owing to the effect of NVEE.

Thus, the marked power of the spherical lens then in place does not accurately indicate the needed power in the near vision segment of the actual lens, and does not lead us to the appropriate “add” value in the prescription.

But in fact the approach I described a little earlier, in which we place a positive lens in position 3 to determine the amount of near vision “add”, outsmarts the NVEE. Here’s the underlying concept.

If we visualize the near vision segment of an actual bifocal lens as being made by sticking onto the front of the “base” lens a little “addition” lens with a front vertex power of, say, +1.75 D, then the near vision effective vertex power of the segment will be the power of the base lens plus 1.75 D (just as called for by our model prescription) **for a near vision distance of 1/1.75 m.**⁷ This result is absolute, not diminished by the mechanism that causes NVEE.⁸

We can practice that same game with our “lens construction set”—the trial lens system. With the main spherical lens in position 1, and the cylinder lens in position 2, we have the patient regard a near target. Then we put positive spherical lenses of various powers in position 3, **reversed front-to-back from their normal orientation**, until best vision is obtained.

Recall that in this particular implementation of the additive vertex power system, the spherical lenses are labeled with their actual (back) vertex powers.

Then the marked power of this trial “addition” lens (which is its front vertex power in this situation) is in fact the appropriate “add” for the prescription (based on near vision at the distance that is the reciprocal of that back vertex power).

The Jackson cross cylinder

When determining the optimum parameters for the cylinder component of the lens (for correction of astigmatism), the examiner puts in place cylindrical lenses of various powers, and adjust the lens axis to various angles, until the best near vision is attained. This optimum is a bit “vague”. There is a clever technique that can confirm that the power, and axis, of the trial cylindrical lens is indeed optimum.

The Jackson cross cylinder⁹ (JCC) can be thought of as a composite lens comprising two cylinder lenses, with the same magnitude of power (typically in the range 0.25 to 0.50 D) but one plus and one minus, with their axes at right angles. A pair of dots or tick marks of one color (usually white or black) shows the direction of the axis of the plus cylinder component and a pair of dots or tick marks of

⁷ *Often, the desired “add” is the reciprocal of the desired near vision distance (especially for patients with severe presbyopia), so this condition is fulfilled. What if that is not so? Then the result is not precisely as stated, but is generally quite close.

⁸ Neither is it disrupted by the considerations that led to the “additive vertex power” system for trial lenses.

⁹ Less frequently, “crossed cylinder”, better grammar actually.

another color (usually red) shows the direction of the axis of the minus cylinder component ¹⁰.



Figure 10. Jackson cross cylinder

Figure 10 shows a typical Jackson cross cylinder (± 0.25 D) for use in trial lens refraction.

If we were to place a JCC in front of our “stack” and orient it in four different ways, compared to the axis of the cylinder trial lens in place, in increments of 45° , it would successively have the following effects:

- a. Make the cylinder power more positive (less negative).
- b. Move the cylinder axis slightly clockwise.
- c. Make the cylinder power less positive (more negative).
- d. Move the cylinder axis slightly counterclockwise.

The lens is mounted on a long handle by which it is held to place it. If we place it in front of the lens stack in orientation **a**, and twist the handle so as to flip the lens over, it will be in orientation **c**. If we place it in front of the lens stack in orientation **b**, and twist the handle so as to flip the lens over, it will be in orientation **d**.

To confirm the appropriateness of the power in our current cylinder trial lens, we place the JCC in front of the lens stack in orientation **a**, and ask the patient, “Which is better, one or [flip the JCC] two?”

If the patient prefers “one” (orientation **a**), we know that we need to use a cylinder trial lens with a more positive power; if he prefers “two” (orientation **c**), we know that we need to use a cylinder trial

¹⁰ The convention is reversed between the U.S. and the U.K., probably due to a misunderstanding as to whether a pair of dots showed the axis of a cylindrical component or the direction of the meridian along which that component exhibits its power. The international standard, like U.S. practice, calls for the red dots to indicate the axis of the minus cylinder component.

lens with a less positive power. We then try the test again. If he says they are the same, we know that the current choice of cylinder power is good.

Then we place the JCC in front of the lens stack in orientation **b**, and ask the patient, "Which is better, one or [flip the JCC] two?"

If the patient prefers "one" (orientation **b**), we know that we need to move the cylinder trial lens axis a bit in the clockwise direction; if he prefers "two" (orientation **d**), we know that we need to move the cylinder trial lens axis a bit in the counterclockwise direction. We then try the test again. If he says they are the same, we know that the current choice of cylinder axis is good.

Incidentally, the same scheme, by the same name, is used in a refractor, refined by fancy mechanism engineering. There, the JCC is put in place by a revolving turret, and is flipped with a nice little knurled wheel, aided by a detent.

We can see them in figure 1, in their "parked" positions, with their little white and red dots (U.S. convention here).

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