National Academy of Opticianry

HOW TO USE PRENTICE'S RULE AND FINDING THE POWER OF A LENS IN ANY MERIDIAN

Approved by the American Board of Opticianry

How to Use Prentice's Rule and Finding the Power of a Lens in Any Meridian

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Course Description:

This course will include unwanted prism, prism by decentration, Prentice's Rule, prism imbalance and finding the power of a lens in any meridian.

Instructional Objectives:

At the completion of this course, the participant will be able to:

- Identify unwanted prism
- Be able to induce prism by decentration
- Utilize Prentice's Rule
- Find the power of a lens in any meridian
- Explain vertical imbalance
- Describe ways of correcting vertical imbalance

How to use Prentice's Rule and Finding the Power of a Lens in Any Meridian

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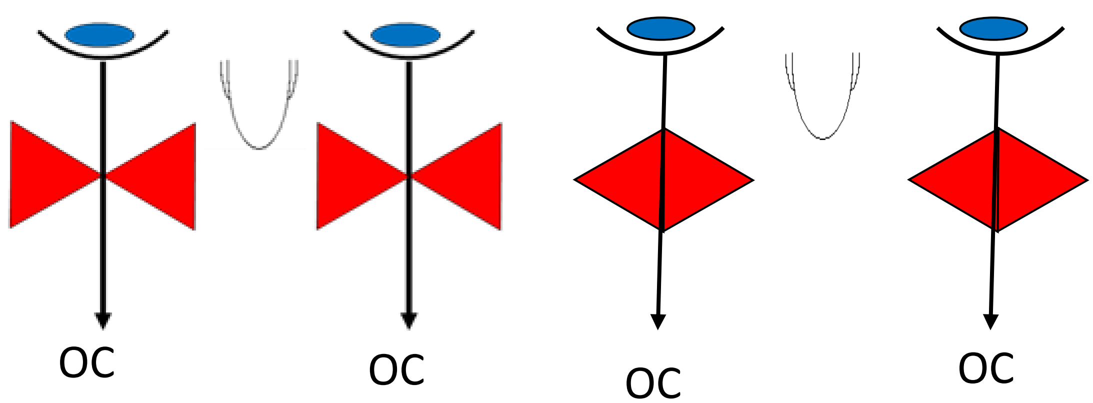
Prismatic Effect

If the optical centers of lenses (except for plano powers) are placed any place other than directly in front of the patient's visual axis, prismatic effect will result. Anytime a patient looks away from the optical center of a lens, prismatic effect occurs. Unwanted prism occurs when unordered prism has been created in spectacles because the optical center(s) of the lens or lenses are not positioned exactly over the visual axis of the eyes. This is unwanted prism, and will cause an imbalance in a patient's vision.

In understanding prismatic effect, let's go back to the characteristics of prisms, remembering that lenses are nothing more than prisms. Light is bent toward the base of a prism and the image is displaced to the apex. Plus lens have the base in the middle and the apex on the edge while minus lenses have the apex in the middle and the bases on the edge.

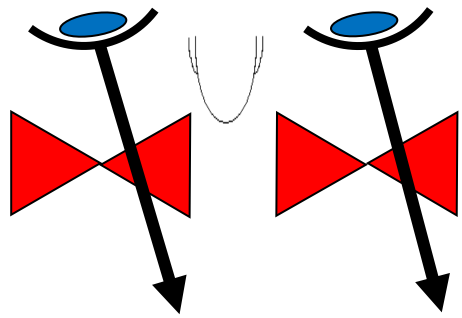
Aligning OC at Patient's Visual Axis

Depending on the refraction, prism may or may not be ordered. When no prism has been ordered in a prescription, placing the optical center of the lens directly in alignment with the patient's visual axis allows the patient to see correctly, when viewing straight ahead. When the patient looks through a pair of spectacles, we oftentimes depict the patient looking directly through the optical centers of the lenses.

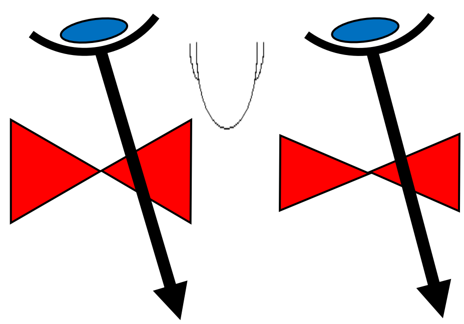


Equal Prism

However, when a person moves their eyes, in ANY direction, prismatic effect is induced by each lens. If both right and left lens powers are the same or almost the same in each eye, the prismatic effect induced is also the same. In the below illustration, let's assume that the powers of the right and left lenses are equal at -1.00 DS OU. The patient would be viewing through base in prism in the right lens and base out prism in the left lens, but the resulting prism would be equal, and although the image would be somewhat displaced, there would be no visual imbalance. The eyes/brain are more capable of tolerating horizontal prism such as this.

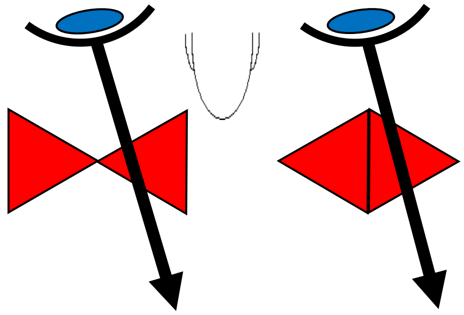


If, however, the powers are different in each lens, whether it is plus in one lens and minus in the other, or just a difference in each lens with both being plus or both being minus, the patient will be viewing through unequal prismatic effect in each eye. In the illustration below, let's say that the power of the right lens is -3.00 and the power in the left lens is -1.00. The patient would be viewing through base in prism in the right lens and base out prism in the left eye, but the resulting prism would be unequal, and the image would be displaced more in the right lens than in the left lens. There **would** be imbalance. In this case, the patient's eye would have to employ accommodation to achieve a single focus, which would result in eye strain or there could be double vision or diplopia, or the vision may even be suppressed in one eye. The eyes/brain are generally more capable of tolerating horizontal prism such as this as well.



In the illustration below, let's say that the power of the right lens is -3.00 and the power in the left lens is +1.00. The patient would be viewing through base in prism in the right lens and base in prism in the left eye, but unequal amounts and the resulting prism would be unequal, and the image would be displaced to the right in the right lens and to the right in the left lens but in unequal amounts. There **would** be imbalance. Again, in this case, the patient's eye would have to employ accommodation to achieve a single focus, which would result in eye strain or there could be double vision or diplopia, or the vision may even be suppressed in one eye.

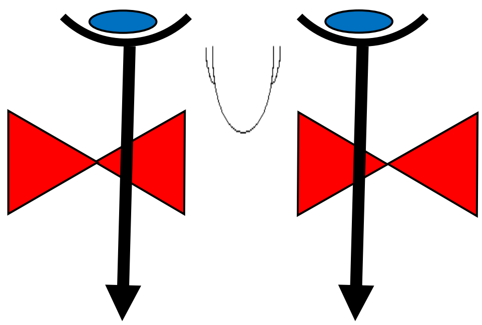
In addition, when there is a difference in the powers of the right and left lenses, there is image size difference as well.



Prism

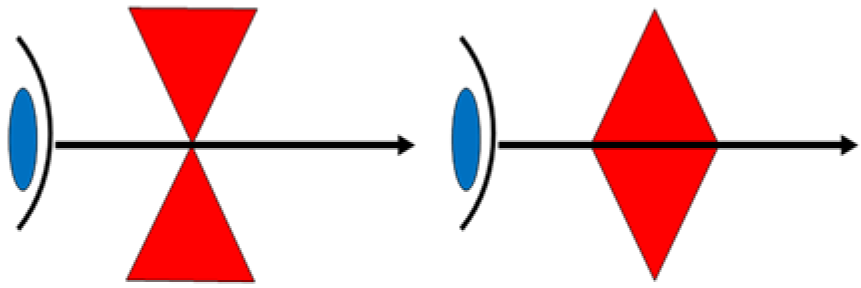
If no prism is ordered and the glasses have been fabricated incorrectly with incorrect decentration, unwanted prism is created. In the illustration below, the patient's eyes are viewing away from the optical center toward the temporal edge of each lens. The optical center (point of no prism) is in (toward the nose). In this case the patient is viewing through base out prism.

If prism has been ordered in a lens, and the power is sufficient, simply moving the optical center can produce the required amount of prism. If the power is not sufficient, then the prism must be ground, (generated) in the lens (Example would be Plano OU.).



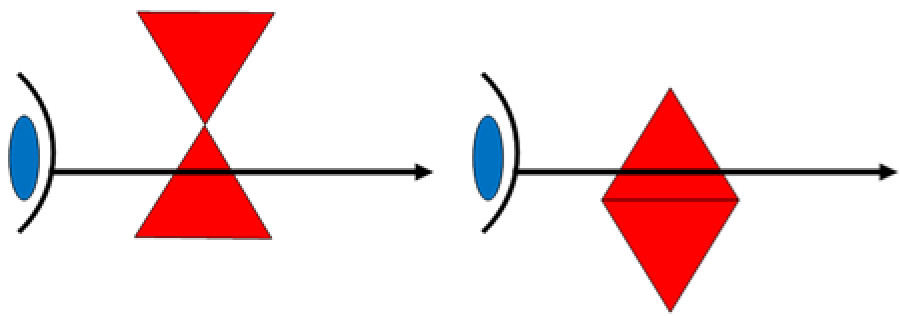
No Prism

These illustrations depict no prism in a minus lens and a plus lens. In each case the patient is viewing through the center of the lens at the optical center, and as long as the eyes are thusly positioned, there is no prism.



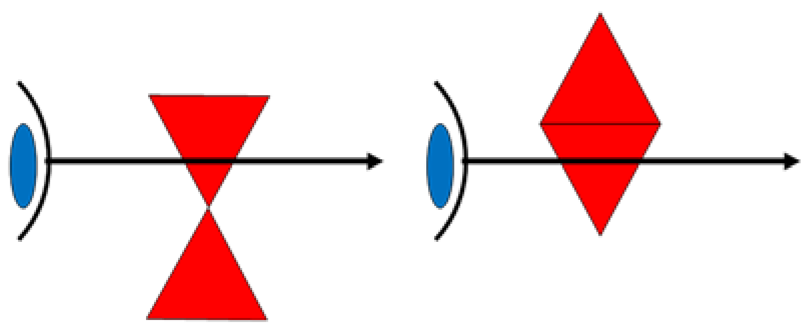
Base Down Prism

These illustrations depict base down prism in a minus lens and a plus lens. Notice that the patient is viewing below the optical center in the minus lens, and viewing above the optical center in the plus lens.



Base Up Prism

These illustrations depict base up prism in a minus lens and a plus lens. Notice that the patient is viewing above the optical center in the minus lens, and viewing below the optical center in the plus lens.



Prentice's Rule

Prism is induced when one looks through any part of a lens other than the optical center of the lens. Thus the optical center of a lens is that point where no prism is located. Light is not deviated (bent) through the optical center.

Prentice's Rule is a formula that determines the amount of prism that is induced when looking somewhere other than the optical center in a lens. The prismatic effect is expressed in prism diopters. The formula is:

$P\Delta = hD$

Where $P\Delta$ = prismatic effect
h = distance from optical center in centimeters
D = power in meridian of prism base

Direction

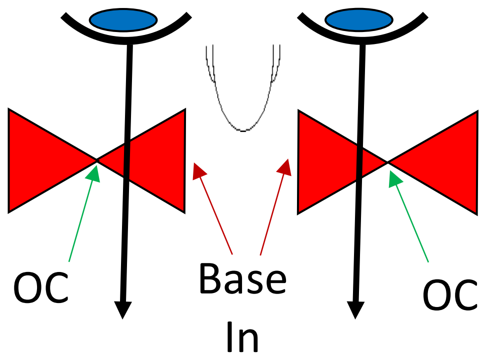
It is necessary to identify the direction of the base as well. Note that since the formula is calculated in centimeters, you must convert to millimeters. That means that you must divide by 10. Move the decimal point one space to the left.

Prentice's Rule

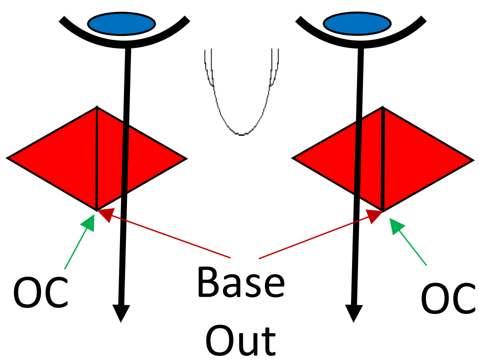
Let's plug in the numbers: For example, given an Rx of -4.00 sphere OU. The patient's PD is 62mm (31mm OU). The glasses are fabricated and when checking them out, it is found that the PD is 66 (33mm OU). That means that the PD is off 2mm in each eye. Using the formula, let's find out how much prism is induced in each eye. Don't forget what the question is and if it is for one eye, or both eyes. Also remember to convert to millimeters, since the formula is in centimeters.

$P\Delta = hD$
H = 2 mm each eye (convert to cm)
H = .2 cm each eye
D = -4.00 OU
$P\Delta = .2 \text{ X } 4.00$
$P\Delta = .8$

We must also identify the direction. The direction of the prism is in relationship to the optical center position of the lens and the viewing position of the patient. Since the PD in this example is wider than it should be and the power of the lens is minus, the prism is base in BI.



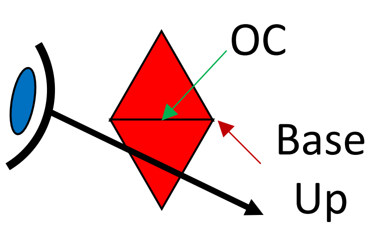
If it were a plus lens, it would be base out BO prism.



Exercise:

Find the prismatic effect 4 mm below the optical center of a +2.50 DS lens:

$P\Delta = hD$
$P\Delta = 4mm \text{ X } +2.50$
$P\Delta = .4 \text{ X } +2.50$
$P\Delta = 1\ \Delta$ BU (prism would be base up because the power of the lens is plus)



Simple Version

This is the simple version. Simply stated it is Prism Δ is equal to h x D divided by 10.

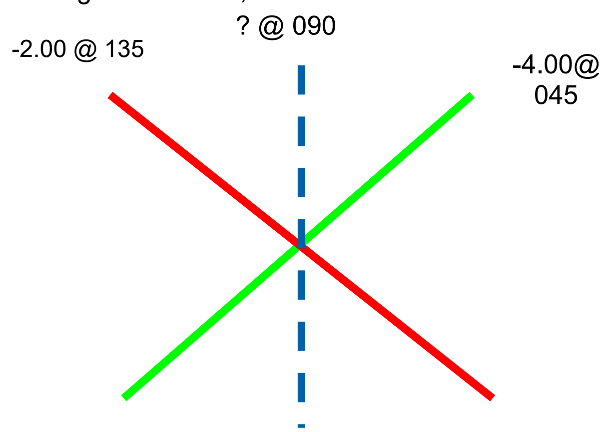
$$P\Delta = \frac{hD}{10}$$

Where P = prismatic effect
h = distance from optical center in centimeters
D = power in meridian of prism base

Finding the Power of a Lens in Any Meridian

The formula is simple when we are considering sphere lenses. However, most prescriptions contain cylinder power, and sometimes we need to find how much cylinder is in a particular meridian. For basic purposes, we will discuss horizontal prism due to decentration in or out or vertical prism due to unequal powers at the reading level.

In a lens, the sphere power relates to the axis. That means that there is NO cylinder power in the axis meridian, only the sphere power. Relating to a lens with cylinder power, the full cylinder power is added to the sphere power and is located 90 degrees away from the axis. Let's say that we need to determine the power in the vertical meridian on a lens that is -2.00 – 2.00 X 135. The vertical meridian is 90. That means that we are looking at an oblique astigmatism, and only part of the cylinder power is present in the vertical meridian (90 degree meridian). By placing the prescription on a lens cross, we can see that the power at 135 is -2.00 and the power at 045 is -4.00. However, we also know that the power doesn't mysteriously jump from -2.00 to -4.00. It gradually changes, so there are varying powers between the two principal meridians. As a matter of fact, each degree constitutes 1/90th of the cylinder power. The axis from the prescription is 45 degrees away from the 90 degree meridian, which is where we wish to find the total power.



RX -2.00 -2.00 X 135

Simple Formula

The change is based on 90 degrees and is 1/90th of the cylinder power for every degree away. The formula can be used to calculate the power of the cylinder in any meridian away from the axis. The formula is the power of the cylinder in any meridian is equal to the original cylinder power multiplied by the sine squared of the angle between the axis and the meridian. I would like to thank Mr. Jim Bellamy for providing this simple method for remembering the formula and to Dr.

Norman Ross (who was the program director for Hillsboro Community College for many years) from many years ago, who reminded me while sitting in a continuing education course. This is a simplified version, and is pretty accurate. Memorize: 0124567889988765421.

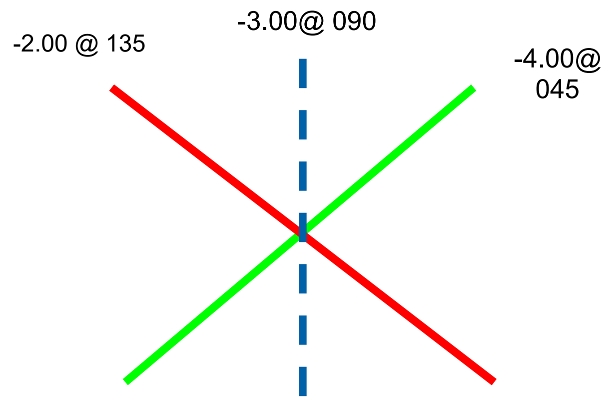
Rather than having to work the more difficult formula, simply create the percentage column by adding the numbers in the second column as you go.

0 + 1 = 1 % at 5 degrees away. For 10 degrees away, simply add 2 + 1 and the result is 3 % at 10 degrees away. And so forth. Quick memorization is that 45 is ½ of 90 so 50% of the cylinder power is 45 degrees away. And so forth. For example if the axis given was 30, and you wanted to find the power in the 90th meridian, you would have to find the power 60 degrees away. If you didn't have the chart and needed to make one, you would begin writing all of the numbers beginning with 0. 0+1+2+4+5+6+7+8+8+9+9+8+8 = 75 % of the cylinder is located 60 degrees away. There is a chart located on the next page that summarizes this.

Because this chart is in 5 degree increments rather than 1-degree increments, it is important not to round off until the final calculation.

Degrees from Axis	Memorize	Percentage of cylinder Power in this meridian
0	0	0
5	1	1
10	2	3
15	4	7
20	5	12
25	6	18
30	7	25
35	8	33
40	8	41
45	9	50
50	9	59
55	8	67
60	8	75
65	7	82
70	6	88
75	5	93
80	4	97
85	2	99
90	1	100

So using this chart and doing the math on this prescription. -2.00 -2.00 x 135, you want to find the total power in the 090-degree meridian. 135 is 45 degrees away from 090, which based on the chart means that you will have 50% of the cylinder added to the sphere in the 090 degree meridian. Therefore, 50% of -2.00 D is -1.00 D. Add that to the sphere power of -2.00 and the total power in the 090-degree meridian is -3.00 D.



RX -2.00 -2.00 X 135

Oblique Lens Formula

Sometimes the chart is not sufficient to be able to determine the exact power because the chart only gives percentages for each 5 degrees. So, for that reason, we will introduce the Oblique Lens Formula. You will need a scientific calculator to use this formula.

The formula is:

$D_T = D_S + D_C \sin^2 \alpha$

Where:

D_T = Total power in the desired meridian
D_S = Power of the sphere in the Rx
D_C = Power of the cylinder in the Rx
α = Axis between the axis in the Rx and the meridian we want

So, let's take an example:

Rx is -3.00 – 2.00 x 030. What is the power in the horizontal meridian?

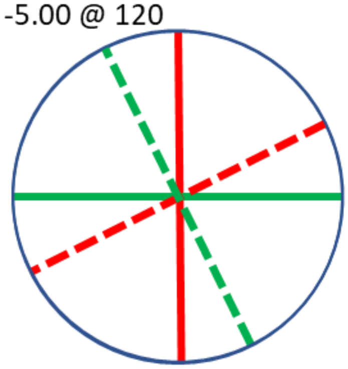
The horizontal meridian is 0-180. Since 30 is closer to 0, we will use that meridian. Therefore, here are our numbers in the formula.

D_T = Total power in the desired meridian
D_S = -3.00D
D_C = -2.00D
α = 30

Mathematical direction for this formula. Do the multiplication first.

$(-2.00) \times \sin (30)^2 + -3.00 = -3.50D$

Using our chart, we would find for this example that the amount of the cylinder used would be 25% and the total power in the 180-degree meridian would be the same as using the sine formula.



Unequal Refractive Errors

So why do you need to know the powers in any meridian. For one example, if your patient has unequal refractive powers that could cause images to be displaced to different degrees. Remember that in plus lenses, the light rays are bent to the base, which is the middle and the image is displaced to the apex, which is the edge. In minus lenses, light rays are displaced to the edge, etc. Also, you have to remember that the stronger the prism (lens) the more bending that occurs and the more the image is displaced. This can cause double vision (diplopia). If the powers are the same or almost the same, the condition is called isometropia, and there is no problem with image displacement. However if there is a difference, double vision (diplopia) could occur. Let's discuss unequal refractive errors for a moment.

Anisometropia

Anisometropia is referred to as "unequal measure". It is the condition when the two eyes require a different degree of correction (1.00 or more) but the same kind of correcting lens (+ or -). The condition may cause vertical prism imbalance at near (double vision/diplopia) or cause a difference in the retinal image sizes between the two eyes.

Example Rx:

OD -7.00 D. sphere
OS -3.00 D. sphere

Example Rx:

OD +7.25 sphere
OS +5.25 sphere

Antimetropia

Antimetropia is referred to as "opposite measure". It is the condition when the two eyes require opposite kinds of corrective lenses (+ or -). The condition may cause vertical prism imbalance at near (double vision/diplopia) or cause a difference in the retinal image sizes between the two eyes.

Example Rx:

OD +1.75 sphere
OS -1.00 sphere

Example Rx:

OD -2.25 sphere
OS +1.50 sphere

Aniseikonia

Anisometropia and antimetropia can cause Aniseikonia, which is "unequal images". Anisometropia or antimetropia may result in the condition whereby two unequal images are sent by the eyes to the brain. It is more prevalent due to refractive surgeries. Meridional Aniseikonia is normal or less aniseikonia in one meridian and more in another due to high astigmatism in that meridian.

Iseikonic Lenses

Iseikonic lenses are used to correct Aniseikonia. You don't call the laboratory and just say I want iseikonic lenses. You have to design them yourself. At the least, you should understand.

The following variables are used:

Base curve
Thickness
Vertex distance
Index of refraction

The use of contact lenses for aniseikonia uses vertex distance by bringing the lenses directly to the eye. We'll discuss vertex distance and compensation in the next chapter.

Vertical Imbalance at the Reading Level

Let's go back and discuss the vertical imbalance at the reading level. For normal reading, the normal eye moves down approximately 8 to 10 mm. As the eye moves down through lens, the plus lens creates base up prism, while the minus lens creates down prism. This explains when there would be a plus power in one lens and minus in the other. However, there could be vertical imbalance as well, if the prescription in both eyes were plus or both were minus, if there was at least 1 diopter difference in the powers. This can cause vertical diplopia or double vision also referred to as vertical imbalance. The amount of vertical imbalance is dependent on two factors. First of all, the total power of the lenses in the vertical meridian (the 090 degree meridian). The second factor is the distance from the optical center to the point of reading (the reading level). There are a number of ways to correct this vertical imbalance at the reading level.

Vertical Imbalance at the Reading Level

Using Prestice's Rule, let's determine if there is imbalance at the reading level in the following Rx. Reading level is 10mm.

-0.25 +3.00 x 180
-1.00 +1.00 x 090

ADD OU +1.50

First you need to determine the total power in the vertical meridian of both lenses.

OD -0.25 +3.00 x 180
ADD +1.50

For the right lens, we want to find the power in the 90th degree meridian. Based on Prentice's Rule, the axis is 90 degrees away from that meridian, so we will use 100% of the cylinder power and add it to the sphere power. That makes our distant power +2.75. Then we must add the ADD power which gives us a total power at the reading level of +4.25.

OS -1.00 +1.00 x 090
ADD +1.50

For the left lens, we want to find the power in the 90th degree meridian as well. Based on Prentice's Rule, the axis is 0 degrees away from that meridian, so we will use 0% of the cylinder power. That makes our distant power -1.00. Then we must add the ADD power which gives us a total power at the reading level of +0.50.

OD -0.25 +3.00 x 180
OS -1.00 +1.00 x 090
ADD OU +1.50

So for the right lens the total power at the reading level is +4.25, while the total power if the left lens at the reading level is + 0.50. The reading level is 10 mm therefore, so…

OD = +4.25
P Δ = 10 x +4.25 must convert to CM
P Δ = 1.0 x +4.25
P Δ= 4.25 Δ BU

OS = +0.50
P Δ = 10 x +0.50 must convert to CM
P Δ = 1.0 x +0.50
P Δ = 0.5 Δ BU

Since both lens powers produce base up prism, the powers are subtracted. Therefore, there is 3.75 diopters of prism imbalance at the reading level of 10 mm.

Correcting Vertical Imbalance at the Reading Level

Correcting vertical imbalance at the reading level needs to be done when the patient would be corrected relatively well in both eyes with their correction. For example, if the patient can be best corrected to 20/25 in the right eye and only 20/200 in the left eye, due to pathology, opacities, etc., there is no reason to attempt to correct the imbalance, since it would not benefit the patient.

Method of correcting vertical imbalance at the reading level may include a number of options. Using different single vision glasses would be one suggestion, but is inconvenient. However, it may correct reading imbalances of over 5 diopters. It would be prudent to remember that even for single vision eyewear, the optical centers (OCs) must be positioned where the patient would be viewing through the lens. Otherwise, the patient must be instructed to move his/her head so that they are viewing directly out of the optical centers of the lenses rather than the periphery or bottom. It requires training. The easiest way is to correctly position the OCs for correct viewing.

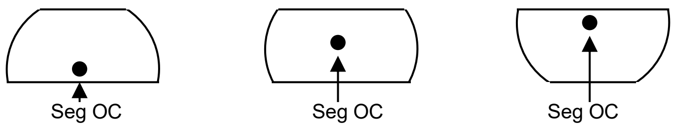
Fresnel press on prisms would be another method, but is considered temporary. It is a useful way to determine if the patient could be corrected with slab-off

Prism Segments

Prism segments are probably the most infrequently used method for correcting vertical imbalance. This is primarily due to the lengthy time that it usually takes for a lab to process this type of lens. A prism seg has the prism ground into the reading segment of a bifocal. This is usually done on a fused bifocal such as a flat top.

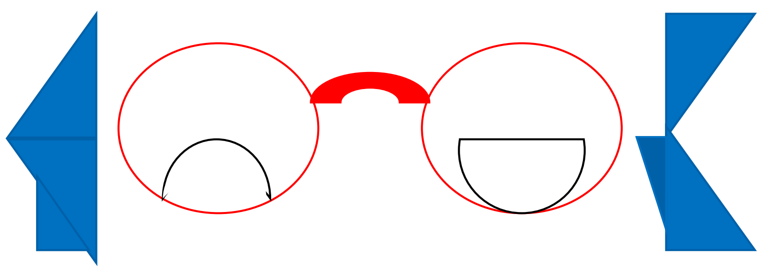
Compensated Segments

The next type of method for correcting vertical imbalance is compensated segments. These are sometimes referred to as ribbon segment bifocals or Compensated “R” segments. The optical centers can be placed from 4mm to 10 mm from the top of the segments. They are useful if the amount of vertical imbalance is at or near 1.5 prism diopters or less.



Dissimilar Segments

Another way to correct a small amount of vertical imbalance at the reading level is the use of dissimilar segments. One could be round segment and the other could be flat top segment. Depending on the width of the flat top, the optical centers for the segments would be positioned at different positions. You may use a round segment on the most plus lens, while using the flat top segment on the most minus of the two lenses. The round segment would produce base down prism, while the distant portion of the lens itself produces base up prism. The flat top segment would product base up prism, while the distant portion of the lens would produce base down prism. They would somewhat cancel the imbalance out. In addition, you may use different widths of flat top segments, as they would have the centers positioned differently as well. Dissimilar segments will only correct about 1 ½ diopters of vertical prism, in addition to the fact that they look unattractive. An alternative would be to use two different sizes of round segs or two



different sizes of flat tops. They would be less noticeable and still produce the desired effect.

It would also be possible to use two different size round segs as the optical centers would be different distances from the seg line. They would not look as strange as a round seg and a flat top, but would not correct as much imbalance either.

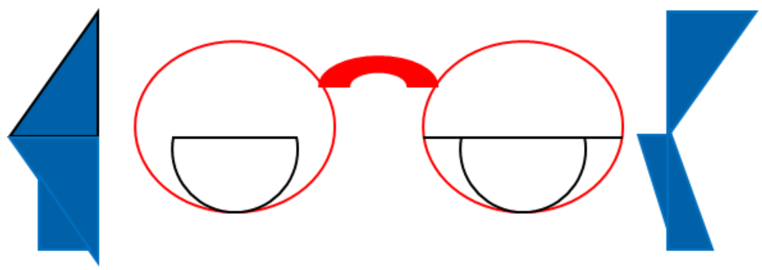
A split bifocal would be similar to a Franklin seg and would have the optical centers ground such as to eliminate imbalance by placing the segment OC where it would be needed to eliminate imbalance.

Prism segments are another option as are the use of Fresnel Prisms in the segs.

There are also a number of lens companies who produce specialty proprietary designs, which we would hesitate to introduce here.

Bicentric Grinding (Slab-off)

Probably the most common way of correcting vertical imbalance at the reading level is with the use of slab-off, which is also referred to as Bicentric grinding. It will correct up to 5 diopters of vertical imbalance. It is most often used on multifocals, but can be done on single vision as well. Routinely, a patient wearing single vision lenses will simply move their head so that the optical centers remain in their visual axis for viewing, however, sometimes that is not possible due to neck problems, or when they may be performing a task that they would be unable to move their head.



Prism by Decentration

How far would you need to decenter a 4.00 sphere lens to produce 1.6Δ? Reverse the formula to read.

h = (P/D) x 10

Solution

h = 1.60 divided by 4.00 x 10
h = .4 x 10
h = 4 mm

If 1.60 diopters of prism is created by 4 mm of decentration, what is the dioptric power of the lens being decentered?

Again you would reverse the formula to read (this time).

D = (P/h) x 10

Solution

D = 1.60 divided by 4 x 10
D = .4 x 10
D= 4.00 diopters

Remember what it is that you are attempting to find out. Write the formula to represent what it is. It makes if very simple.

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