# Advanced Opticianry and Optical Formulas

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### Learning Objectives

- How to compensate prescription based on vertex distance
- How to compensate prescription based on tilt
- Calculate expected lens thickness
- Calculate minimum blank size
- How to find power in oblique meridians
- Applying the formulas to real life situations
- Factors of lens magnification



It can sometimes feel that the optical field can have endless opportunity for learning new topics with the constant advances in technology and new materials available. But despite the constant learning required to keep up to pace in the optical industry it is often the fundamentals that go overlooked. As vital as keeping up with the changes in the industry are we must not forget to advance our knowledge in the fundamentals of optics as well.

Throughout this course we will cover several topics mainly pertaining to the use of optical formulas. Although there are countless formulas relating to the physics of light and lenses the formulas we will focus on are directly applicable in the optical field. Many of these topics are often unused or unknown to many opticians but through implementation of these techniques you will be able to gain an advanced level of knowledge and ensure that your patient is receiving the best possible care.

Most of the formulas in this course require many steps and when applied to a real life scenario will require use of multiple formulas in conjunction. The math is often not too difficult but can seem intimidating at first due to the amount of steps involved. Through practice these formulas will become easier to use. This course assumes you have a basic understanding of optical equations such as prentice's rule and decentration calculation.

**Minimum Blank size calculation**

One of the most useful formulas to have memorized and be able to use when needed would be the minimum blank size formula. This formula can be utilized in several different ways. One of the most common uses would be determining whether or not your lab will be able to process the order given the lens power and decentration using finished lens blanks or if a lens would require surfacing. Another one of the most significant uses would be in its relevance in calculating lens thickness, a formula that we will discuss later in this course. Luckily the minimum blank size formula is very simple and can be used with ease.



The Minimum Blank Size formula is:

(Decentration)*2+ED=Minimum Blank Size in mm

In the formula the decentration is the difference between the monocular pupillary distance and the horizontal geometric center of the frame. The ED is the effective diameter of the frame and is the longest diameter drawn through any two points of the eye piece. Usually this measurement is from the upper nasal side of the eyewire to the lower temporal side of the eyewire. Once you have measured the pupillary distance and the effective diameter of the frame and have calculated the decentration for each eye then you have all the variables needed to work the minimum blank size formula. Keep in

mind that in order to obtain the minimum blank size for each lens you will have to work the formula twice, once for each eye. Let's work through a few examples of this formula in order to get a good grasp of its use.

Example 1:

Decentration: 4 mm OD
5 mm OS
ED: 59 mm

What is the minimum blank size this order can be processed on?

In this example the decentration is already calculated for simplicity but this would normally have to be calculated. From here we would work the problem first for the right eye then again for the left.

(4*2) + 59 = 67 mm minimum blank size OD

(5*2) + 59 = 69 mm minimum blank size OS

We now know the minimum blank size needed for each lens in this situation. With this information you will be able to verify if your lab is able to process the order using finished lens blanks. This is especially useful if you have a finish only lab and need to know if lenses will need to be ordered from an outside lab or not. It is a common practice to add 2mm to the answers above in order to give the lab enough leeway to ensure the manufacture watermarks or etchings are cutout from the final edged lens. Although this is a great rule to follow it is not always necessary so in situations where a minimum blank is very close to what is available to finish it is best to consult with the lab for a second opinion. Let's work through one more example to strengthen our understanding.

Example 2:

Decentration: 9 mm OD
5 mm OS
ED: 65 mm

(9*2) + 65 = 83 mm minimum blank size OD

(5*2) + 65 = 75 mm minimum blank size OS

In the second example we can see a dramatic difference in lens blank size between the right and left lenses. The important correlation to understand here is that with every

millimeter of decentration there is a resulting 2mm increase in minimum blank size. So in this situation as the right eye has 4mm more decentration than the left there is a resulting 8mm added to the minimum blank size. This is yet another reason why proper frame fit is so important.

The other major impact of minimum blank size is it's resulting impact on lens thickness. We all know that as decentration increases the thickness of the lens will increase and that a bigger frame will increase the thickness of the lens as well but do you understand all the factors correlated to an increase in lens thickness? In the following section let's discuss how to calculate lens thickness as well as gain an understanding of how the different variables of the lens thickness formula interact.

**Lens Thickness Calculation**

I'm sure you've had a patient ask this question before, "How thick will my lenses be in this frame?" It's a question that you may be able to give a decent enough answer for such as, "This frame will have significantly thicker lenses than this one," but can you give an exact numerical measure of the expected lens thickness? The ability to do so provides a huge benefit to the patient and can prevent many remake issues due to unexpected lens thickness. The lens thickness formula or the sagittal depth formula is how we would calculate the thickest portion of a lens in a chosen frame. Before we work through the formula and practice a few examples, there are a few significant points to cover first. This formula calculates the thickest portion of a lens and therefore the maximum center thickness of a plus lens and the maximum edge thickness for a minus lens. In a situation where we are calculating prism thickness, this formula will yield the thickest portion of the lens in whichever base direction. A second point to consider is that this formula calculates the maximum thickness, assuming a zero minimum thickness. So, in order to get an accurate measure of expected lens thickness, the minimum center thickness of the chosen lens material must be added to the final answer. As minimum lens thickness can vary greatly across materials and manufacturers, it can be useful to obtain a record from your processing lab or manufacturer recommendations. Always refer to the ANSI minimum thickness recommendations and never grind lenses below this recommendation to reduce thickness. The last consideration would be that due to variance in accuracy of generation, there can be slight discrepancy between calculated lens thickness and actual lens thickness, but this amount will be very slight.

Now that we have covered some of the considerations of calculating lens thickness let's go over the formula and work through a few examples.

**The Lens thickness formula is given as:**

**((Radius^2)*power)/2000(index of refraction-1)**

This formula may look intimidating at first, but once broken down into its component parts, it's really fairly straight forward to use and can be of great use in situations needed. The radius is a variable we haven't discussed yet. The radius is simply half of the diameter of the blank size the lens is edged from. This is how the minimum blank size factors into the lens thickness formula as it gives us a blank size to calculate the radius from. Keep in mind that if the minimum blank size calculated was 69mm, but the manufacturer only makes 67mm and 70mm lens blanks in the chosen lens material, the 70mm lens blank must be used. It is also important not to forget that the radius is half of the diameter of the lens and not the effective diameter of the frame. If these two numbers are confused, you will have drastically different outcomes. In regards to the power of the lens, when there is cylinder power it is recommended to use the highest power of the lens. This will ensure the maximum thickness is calculated. With all that being said, let's work through an example calculation of lens thickness.

Example 1:

Blank size: 75 mm

Lens Power: – 10.00 sph OU

Lens material: CR-39 (1.50)

The blank size in this situation is given but will normally have to be calculated before working this formula. From the information given the only calculation needed before inserting our variables into the equation is to calculate the radius form the blank size. Simply divide the blank size by two to get 37.5mm. Now let's put all our variable into the formula and work it out.

((37.5^2)*10.00)/2000(1.50-1)

14,062.5/1,000=14.1mm maximum thickness

Again remember that this number does not yet factor in the minimum thickness of the chosen material. For CR-39 the ANSI recommended minimum thickness is 2.0mm so we will use this number for our minimum thickness in this example.

14.1+2=16.1mm Maximum lens thickness

We now have a calculated lens thickness given the parameters chosen. Obviously a 16mm thick lens could be very problematic. Given the strength of the prescription we know the lenses will be thick but let's change some of the variables to see how this will impact our resulting lens thickness. Let's say that we are able to change to a frame with

less decentration and change the lens material to polycarbonate with a minimum thickness of 1.5mm.

Blank size: 70 mm

Lens Power: – 10.00 OU

Lens material: Polycarbonate (1.59)

((35^2)*10.00)/2000(1.59-1)

12,250/1,180=10.381mm

10.381+1.5=11.881mm maximum thickness

As you can see by changing two of the variables we have reduced the lens thickness by about 7mm which is a substantial amount. I'm sure you already knew that a higher index of refraction material and better fitting frame would reduce the lens thickness but working through the same situation with different variables should give you a new understanding of this correlation. Remember from the minimum blank size formula that when we reduce the decentration by 1mm we reduce the minimum blank size by 2mm. So in order to reduce the blank size by 5mm like we have in our example a reduction of 2.5mm of decentration would be needed. Although an amount of 2.5mm may not initially seem like that much remember the exponential effect that this change will have on the resulting lens thickness. Let's work through another example of the lens thickness formula with different variables.

Example 2:

Blank size: 65 mm

Power: – 8.00 – 1.00 x 180 OU

Lens material: Hi Index (1.74)

In this situation we will we have to use the highest power of the lens the get an accurate measure of maximum thickness, this gives us a power of -9.00. For this example the minimum center thickness of 1.74 high index will be 1.8mm, the typical minimum thickness for the material.

((32.5^2)*9.00)/2000(1.74-1)

9,506.25/1,480=6.42mm

6.42+1.8=8.22mm maximum thickness

In this example we have used the 1.74 high index lens material which is considered the standard thinnest lens available. It is a common assumption that using this material will yield the thinnest lenses possible but let's change the material to 1.67 high index with an minimum center thickness of 1.5mm and compare how much thickness is actually reduced by the change in material.

((32.5^2)*9.00)/2000(1.67-1)

9,506.25/1,340=7.09mm

7.09+1.5=8.59

As you can see the results of changing the lens from a 1.74 to a 1.67 only increases the expected lens thickness by about a third of a millimeter or 4.5%. So when choosing a lens material for a patient who has a higher prescription be sure compare the expected thicknesses of these two options and consider whether the reduction in thickness is worth it. Remember that 1.74 will be denser than 1.67 high index resulting in greater weight and will also have slight reduction in optical clarity. This is not to say that 1.74 is not a powerful material in reducing lens thickness as there are many situations where the thickness reduction will be significant over that of 1.67 hi-index but it is important to understand that every situation will be different. When debating which lens material is best for your patient take the time to work these comparisons out and guarantee they are getting the best lens for their needs.

So now we have practiced two examples where we change the variables to get a resultant change in lens thickness. Understand how changing the amount of decentration or changing the ED of the chosen frame will change the minimum blank size and therefore the radius variable of the equation. The other controllable variable being the index of refraction and minimum thickness, a decrease in minimum thickness or an increase in index of refraction will reduce thickness. And lastly the third non controllable variable of lens power, an increase in power in either plus or minus will result in an increase in thickness. Having a full understanding of the interaction of these variables should arm you with all information you need to control lens thickness.

Before moving on to the next section which will be on controlling the visible thickness of the lens let's touch very quickly on thickness with prism. As I mentioned earlier if a prescription is Plano power with only a prism correction then the power variable becomes the prism power. In a compound prism prescription the number that must be used would be the prism power written in 360 degree notation. But what would you do if the prescription had correction in addition to prism power? To calculate this you must first run the thickness formula the same as we did above with just the sphere and cylinder correction. The second step would be to run the formula again with just the power of the prism. The amount you calculate for the prism must be divided by two then

added to the maximum thickness from the first formula. Make sure to only add the minimum lens thickness once and not twice. One last thing to keep in mind that this formula cannot account for unusual frame shapes or highly angled frames so ultimate thickness can vary due to this. If your patient has a high power prescription and has interest in a highly angular frame make sure to consider this when you calculate lens thickness.

**Visible Lens Thickness**

Now that you have a detailed understanding of lens thickness calculation we can move on to our next section covering visible lens thickness. The visible thickness of a lens is the amount of thickness that visually protrudes from either the anterior or posterior portion of a frame. In other words it is how thick the edged portion of the lens in a chosen frame is. This section does not contain any formulas but is an important consideration in regards to thickness because it is often the perceived thickness of a lens that is bothersome to a patient.

One of the main ways to control visible thickness is with the frame styling. It may go without saying that a plastic frame will usually cover the most lens thickness making it the best cosmetic option for hiding lens thickness due to the deep bevel. A metal frame will still hide a decent amount of frame thickness but far less than most plastic frames will. And a rimless or semi-rimless will hide none of the thickness so if a patient has a stronger rx these frame styles are usually not the best for minimizing visible lens thickness. Additionally a semi-rimless lens paired with a a plus power prescription will require increasing the minimum thickness to allow for the semi-rimless wire groove. As we learned above adjusting the minimum thickness will have a significant increase in the lenses overall thickness.

Besides hiding some of the visible thickness with the frame styling there are multiple other methods to decrease the visible thickness of the lens. We all know that the thickest portion of a plus lens is located at the ocular center. Because of this the closer the edge of a frame intersects to the ocular center the thicker the lens edge will be. It is because of this that in order to minimize the visible thickness of a plus lens the B measurement not be so shallow as to intersect close to this ocular center leaving the thickest portion of the lens visible. The common rule of thumb is to keep the B measurement 70% or greater of the A measurement, this will allow enough distance from the thickest portion of the lens to minimize edge depth. Do keep in mind though that although the edge will be thinner and more cosmetically appealing having a deeper B measurement will still add to the overall weight of the frame. Be sure to discuss this correlation with your patient and decide what will be the best option for them.

How would this rule work with a minus lens? I’m sure you can already visualize that a deeper B measurement is going to result in more visible thickness throughout the lens so this rule is less beneficial for minus lenses. A great way to reduce visible thickness of a minus lens is to avoid frames that have steep angles as these angles will protrude

slightly further into the thickest portion of the lens blank leaving more thickness visible. Avoiding angles will also lead to better cosmetics as these angles tend to stand out and are more easily noticed.

**Power in Oblique Meridians**

For this section I am going to assume that you already have a solid understanding of lens meridians and knowing how much power is in effect at the cylinder meridian. But what if you need to calculate the power in a meridian when the axis does not fall on either the 90 or 180 degree axis and the 30/45/60 rule cannot be followed? This is when we would need to use the powers in oblique meridians formula. This formula can be most useful when used in conjunction with prentice's rule formula to determine the amount of prism present in the lens in a given direction. This formula is also important in determining the amount of vertical balance present in a pair of multifocals and determining whether slab off is needed. Essentially the power in oblique meridians formula can tell us the power in effect at any angle in the lens. We will discuss the application of this formula later in the course but for now let's break down the formula itself and work through a few examples.

The power in oblique meridians formula involves using some basic trigonometry. For those of you may be uneasy or uncomfortable with trigonometry fear not because the formula is easy to grasp even if you have never taken a trigonometry class before. A scientific calculator will be needed to work this formula but most any modern phone's calculator app will contain all that we need.

**The Power in oblique meridians formula is given as:**

**((sina)^2)*PowerC+PowerS=Power in the meridian we are checking**

In this notation PowerC stands for the cylinder power of the lens and PowerS is the sphere power of the lens. The variable (a) is the difference in degrees between the axis that is present and the axis that we need. So there is a lot going on in this formula let's take some time to break it down before running an example problem. The first step will be to determine the variable (a). If the axis of the prescription is 115 degrees and we are looking for the power in the 180 degrees meridian the difference between these two is 65 degrees, this is the variable (a). If we were looking for the power at 90 degrees that would make (a) 25 degrees. The second step is to take the sin of this number, depending on the calculator you are using you will usually have to enter sin first then enter the variable. Next you will square this number and multiply it by the cylinder power. Understand that what we are doing here is calculating how much of the cylinder power is in effect at the meridian we are checking. To get a final measure of power at the desired meridian the last step is to add the sphere power giving us our final answer. From here we could take this power and insert it into prentice's rule formula to calculate prism with accuracy. Hopefully you're starting to understand how this formula works.

Before working an example I'd like to touch on the basics of sine, cosine and tangent. Although you can definitely work these formulas without knowing what exactly sine is, the more understanding you have the better. To avoid making this a course on trigonometry and keep the focus on optics I will keep this section brief. Essentially sin, cos and tan are ratios of different sides of a right angled triangle. The three side of a triangle are hypotenuse; the longest side, the opposite; across from the given angle, and adjacent is next to the angle. Refer to the table below.

| | | |
|---|---|---|
| Sin (x) | = | Opposite/hypotenuse |
| Cos(c) | = | Adjacent/hypotenuse |
| Tan(x) | = | Opposite/adjacent |

So what does this mean to us? What we are doing to calculate the power in an oblique meridian is more or less drawing an imaginary hypotenuse triangle on a lens with corners on the prescribed axis and the axis we need to calculate power in. This results in an equation with the opposite angle (difference between axis) and the hypotenuse which is why we use sine.

Again you do not need to fully understand this correlation to be able to calculate power in oblique meridians but it can be helpful. So with all that being said let's move back to the formula itself and do our first example.

**Let's work a few examples.**

Example 1:

Rx OD – 4.00 – 2.50 x155
OS – 2.00 – 3.00 x125

**Find the power in effect at 180 degrees for each lens.**

Like we have done before, work the formula for the right lens first then the left. We will round our answer to the nearest quarter diopter in this example.

((sin25)^2)*(-2.50)+(-4.00)

(0.423^2)*(-2.50)+(-4.00)

0.179*(-2.50)+(-4.00)

-0.45+(-4.00)=-4.50

((sin55)^2)*(-3.00)+(-2.00)

(0.819^2)*(-3.00)+(-2.00)

(0.67)*(-3.00)+(-2.00)

(-2.01)+(-2.00)=-4.00

We now know the power in the 180 degree meridian for both the right and left lenses. Let's say for example the we are inspecting a pair of eyewear and notice that the OD pupillary distance is 1mm wide on the finished pair. From here we could use prentice's run to determine if these glasses would be within acceptable standards or if they would need to be reordered. We would use the power in effect at 180 degrees which before finding the power in effect at 180 degrees we would not have been able to accurately calculate the amount of prism induced. Hopefully it's starting to become clear how useful this formula can be.

**Let's work through one more example.**

Example 2:

Rx OD + 3.00 – 2.00 x119
OS + 1.50 – 1.00 x133

**Find the power at 90 degrees for each lens.**

((sin29)^2)*(-2.00)+3.00

0.24*(-2.00)+3.00=+2.50 OD

((sin43)^2)*(-1.00)+1.50

0.47*(-1.00)+1.50=+1.00 OS

Notice in this example that you have to be aware of the plus or minus power of the lens. Since the cylinder is in minus form we are reducing the sphere power by that amount. Additionally this time we calculated for the power in the 90th meridian. This can be used of course to calculate vertical prism imbalance as well as determining image jump induced by multifocals. In certain prescriptions there will be an axis where the power is actually plano. If you have ever looked at a lens through a lensometer and noticed that in a certain direction there is virtually no movement of the mires this is due to this crossing of plano power. If we were to calculate it out and plug our power into

prentice's rule we would have very little resulting prismatic imbalance at this axis due to low or no power.

**Prescription Compensation**

Occasionally you will encounter prescriptions that require minor adjustments to be made to the lens power in order to give the patient the proper correction. This adjustment is know as compensating the lens. One of the most common forms of this is to compensate the lens for vertex distance and one of the less common forms of this would be to compensate the lens for tilt. Any change in the angle a patient looks through a lens creates a change in the perceived power of the lens. In lower power prescriptions this is often such a small change that it is impossible to be perceived but as the power of the lens increases the sensitivity to changes in lens fitting are increased.

The form of prescription compensation you will likely run into most is the need to compensate the lens for the vertex distance. The vertex distance is defined as the distance from the back of a corrective lens to the front surface of the cornea. During refraction the distance a patient's cornea sits behind the lens of the phoropter is a specified distance. This distance is specified in order to achieve consistency across a wide range of equipment. The vertex distance during refraction is known as the refracted vertex distance. When a patient is wearing a frame containing prescription lenses the distance form the back of the lens to the front the cornea is known as the fitted vertex. The refracted vertex can be obtained by contacting the doctor. In order to obtain the fitted vertex distance the measurement must be taken using a distometer. A distometer is a device designed to fit between the back of the frame and the patients eye. The measurement is taken with the patients eyes closed and is calibrated for the thickness of the eyelid. The use of a distometer is not something we will cover in this course and is something that can be better learned by in person training.

There is often a difference between the two measured vertex distances. Normally this difference is insignificant due to the power of the lens but when the prescription is +/- 7 diopters then this difference in vertex distance should be considered. It is beyond this power where a change in vertex distance can result in significant enough of a power change the it may require compensating. The lens itself doesn't actually change power but due to the focusing system of the eye the brain interprets the power differently. If the difference in vertex is small such as 1mm it can be possible to adjust the fitted vertex either by adjusting the nosepads or adjusting the frame in an acceptable manner to match the refracted vertex distance. If this is possible and does not effect proper fit then compensation for vertex may be foregone in lieu of adjustment. But in situations where this difference is significant or the frame cannot easily be adjusted then we will need to compensate the lens power.

Let's go over the formula and work through a couple examples.

The vertex distance formula is given as:

(Power)^2/1000=Change in power per millimeter

Note that the answer this formula gives is a per millimeter measurement. This means that you will have to multiply your final answer by the total difference between the two vertex distances to obtain your final answer. Once you have the total amount of power difference caused by vertex distance change you will have to determine whether you need to reduce the current prescription or increase it. Before we do our first sample let's pause and make sure we have a good understanding between the directional change of the vertex and the effect on the power of the lens.

Refer to the table below:

| | | |
|---|---|---|
| Minus lens moves further from the eye | → | Minus power is reduced |
| Minus lens moves closer to the eye | → | Minus power is increased |
| Plus lens moves further from the eye | → | Plus power is increased |
| Plus lens moves closer to the eye | → | Plus power is reduced |

It can be difficult to memorize this correlation but just remember that plus and minus power and inversely related. If you can memorize that as a minus lens moves further from the eye minus power is reduced then the opposite must be true for a plus lens you can fill in the blanks from there. Keep in mind that this refers to the effect on the lens power and not what we must do to compensate it. We must compensate for the increase or decrease in power by doing the opposite. For example, a -10.00 diopter prescribed lens sits 5mm further away from the eye than during the refraction. We calculate the total power change to be 0.50 diopters. Since moving a minus lens further away from the eye results in a reduction of power the prescription lens the patient is looking through is perceived as -9.50 diopters. In order to bring the lens power back to what was prescribed by the doctor we must use a -10.50 power lens. Hopefully this is starting to make sense. We aren't actually changing the prescription but rather ensuring that the patient is looking through the power that is actually prescribed and not a lower or higher power lens. It is totally within the realm of possibilities as an optician to make this adjustment but it can be worthwhile to discuss the change with the prescribing physician if possible.

Now that we have this basic understanding let's work through a couple of examples of the calculation.

Example 1:

Rx: – 11.00 Sph OU

Refracted Vertex: 15 mm

Fitted Vertex: 12 mm

What is the correct lens power to order for this prescription?

(-11.00^2)/1000=0.12D per mm

15-12= 3mm (closer to the eye)

0.121*3=0.37 total power change

The lens is 3mm closer to the eye and is a minus power which means the power is increased. Meaning that the lens they are looking through is -11.37 diopters. To compensate this difference we must reduce the power by the 0.37 diopter amount of change.

-11.00-0.37=-10.63 diopters

The power of the lens should be ordered at -10.63 diopters

Example 2:

Rx: + 8.00 Sph OU

Refracted Vertex: 15 mm

Fitted Vertex: 11 mm

What is the correct lens power to order for this prescription?

(8.00^2)/1000=0.06 diopters per mm

15-11=4mm (closer to the eye)

0.064*4=0.25 total power change

The lens is 4mm closer to the eye and is plus power which means the power is decreased. Meaning the lens they are looking through is +7.75. To compensate for this difference we must increase the lens power by 0.25 diopters.

+8.00+0.25=+8.25 diopters

The lens should be ordered at +8.25 diopters

So far we have only calculated the effect of vertex distance change on sphere power lenses. Changing the vertex distance does also change the cylinder power of a lens as well. In order to find what must be compensated for the cylinder power the process is relatively the same. You will use the same formula used above but you will use the power at the cylinder axis; the sphere power plus the cylinder power. You will have to work this formula twice, once for the sphere power and once for the cylinder power. Let's do one last example this time with a lens containing cylinder power.

Example 3:

Rx: – 7.00 – 4.00 x 90 OU

Refracted Vertex: 15 mm

Fitted Vertex: 10 mm

What is the lens power that should be ordered for this prescription?

(-7.00^2)/1000=0.05 diopters change per mm

15-10=5mm (closer to the eye)

0.05*5=0.25 diopters total change

The lens is 5mm closer and is a minus power which means the minus power is increased. Meaning the patient is looking through a lens with a sphere power of -7.25. To compensate for this we must reduce the lens power by 0.25 diopters.

-7.00+0.25=-6.75

We now know our sphere power, let's work the equation once again and calculate the cylinder power.

(-7.00+(-4.00))^2/1000

(-11.00)^2/1000=0.12 diopters per millimeter

0.121*5=0.61 diopters total change

-11.00-0.61=-11.61

Again this is the cylinder power that the patient perceives the original lens power to be. In order to compensate we must balance this amount by reducing the prescribed amount of cylinder power by the amount that the perceived power is changed.

-11.00+0.61=-10.39

This will mean that the lens power we should order to ensure the patient perceives the same prescription as prescribed during refraction would be:

-6.75 -3.64 x90

**Compensating a Lens for Tilt**

Similar to how a a lens can require compensation due to change in vertex distance, a change in the pantoscopic or retroscopic tilt of a lens can also result in a change of perceived power. The amount of power change induced by the change in tilt is less significant as the change in vertex distance. Because of this it is usually only very high power lenses that will be effected enough by change in tilt to create a noticeable difference in perceived power. Although the need to compensate for tilt is rare it is important to understand the significance of how this will effect lens power and be able to implement it when needed.

The formula used to show the relationship between optical center placement and the proper amount of tilt that should be used is Martin's Tilt Formula.

**New Sphere Power=D(1+(sin^2a)/3)**

**Induced Cylinder Power= D(tan^2a)**

In these examples the D stands for dioptric power in the meridian of tile and a will be the angle of excessive tilt. When dealing with pantoscopic or retroscopic tilt we are working with the 180 degree meridian and when adjusting face form we are dealing with the 90 degree meridian. It is important to note that this formula is not going to be used the same way you would use the vertex distance formula to actually adjust the power of the lens. In most cases it will be much easier to simply adjust the tilt of the frame. Essentially the benefit of knowing how lens power changes due to tilt is to be able to pinpoint optical center placement and determine the proper amount for tilt given the prescription. Let's work through just one example of Martin's Tilt Formula.

Example 1:

What is the resulting prescription of a -12.00D lens that is mounted in a frame that has 10 degrees of pantoscopic tilt and the ocular center has been placed directly in front of the patient's pupil?

The optical center would be placed in front of the patient's pupil when there is no tilt so in this scenario there is 10 degrees of excessive tilt. We now have all our variables and can place them into our equations.

| | | |
|---|---|---|
| New Sphere Power | = 12.00 | (1+(sin^2a)/3)) |
| | = 12.14 D | |
| Induced Cylinder Power | = – 12.00 | ((tan^2)*10) |
| | = 0.45 D | |

The cylinder power induced is the same power as the sphere power. This gives us a resulting lens power of:

-12.14 -0.45 x180

The axis is assumed to be 180 degrees because this is the direction of excessive tilt. Again remember that the lens power itself is not changing but it is the patient's perception of power that is effected. As you have probably noticed the amount of induced astigmatism is of far greater concern than the change in sphere power. Like I mentioned above you will not likely need to adjust the power of the lens to compensate for tilt but would rather adjust the tilt of the frame accordingly or adjust the optical center accordingly. The optical center should be placed below the pupil one millimeter for every two degrees of tilt. As you may already know having tilt beyond the point of orthoscopic tilt resulting in excessive retroscopic tilt would be cosmetically unacceptable. It is for this reason that we do not need to consider calculations of tilt in this direction.

You now have a calculable measure of how lens power is effected by changing the tilt of a lens in a mounted frame. Even if you do take the time to calculate how much the power has changed it is a good point of reference to understand how the power changes when adjusting eyewear. The next time you are fitting a patient with a high prescription for glasses do not forget about how the tilt will effect their vision!

If you have ever ordered digitally processed lenses you have seen how some of these calculations can change a prescription. When a lens is digitally made the vertex distance as well as tilt and face form are a factor in how the lens power is compensated. All of these calculations are done by the computer's software and combined with a multitude of other information to compensate the lens power accordingly. A digital lens is accurate down to the hundredth of a diopter which is far greater than the eye's ability of detection. But as you have learned above when the prescription is of significant strength then the amount of power change induced by frame fit is far greater. It is because of this that digitally processed lenses become more beneficial as power increases. Understanding the calculations above should also help you understand why the accuracy of measurement by the optician is crucial when ordering digital lenses. Any error made will be exponential when processed digitally leaving the patient with a worse visual experience than had they ordered non digital

lenses. Ensure that your measurements are accurate and understand how the lens will be changed by the digital software when ordering a digital lens for your patient.

**Magnification**

You may be familiar with the concept of magnification and may very well know how to prevent abnormal magnification by base curve selection and so forth. But let's take it a step further and understand fully how to control magnification to the best of our capabilities. A type of lens you may have heard of before is an iesokonic Lens. This lens type is not as complex as you may think, a iesokonic lens is any lens designed to correct or balance magnification issues, an issue referred to as aniesoknia. An iesokonic lens uses different methods to attempt to balance this difference in magnification to allow for a better fusion of left and right images. Some of the primary ways magnification is controlled is by adjusting the base curve, lens thickness and bevel placement(adjusting the bevel placement to place the lens closer or further from a patients eye). Magnification is often often overlooked as a visual concern but is a significant consideration depending on the rx and patient's visual condition. Let's discuss lens magnification and its implementation.

As a general reference a lens' magnification can be controlled by:

-Increasing the curvature to increase magnification

-Increasing the vertex distance of a minus power lens to decrease magnification

-Increasing the vertex distance of a plus power lens to increase magnification

-Increasing the center thickness to increase magnification (decreasing center thickness would in theory reduce magnification but lenses should be ground close to minimum thickness standards so it is not usually a possibility)

Changes in magnification also occur from changes in material but I would not recommend processing an order with two different lens materials as there are many means to adjust magnification and this will likely not be needed. It is beyond the time available in this course to include a full section on calculating lens magnification so this section is more of a brief overview. When ordering lenses for a patient be sure to keep magnification considerations in mind. When there is significant power differences between right and left lenses know that this may result in poor vision due to changes in magnification. Discuss with the lab the best way to process the order in order to control changes in magnification.

**Putting Everything Together In A Real Life Example**

In the last section of this course I thought it would be good to do an example using several of the formulas we've discussed in conjunction with each other in order to get a

good idea of their real life applications. I will assume you have more a basic understanding of the formulas and their use at this point so I will not break them down quite as much in depth as I have above. If something seems unclear refer to the sections above as needed.

Example 1:

You are helping your patient, Patricia, choose between two frames. She knows that she has a stronger prescription and is aware of the fact that a larger frame will yield thicker lenses.

She really prefers the look of **Frame A** but it is larger than her second choice and smaller frame **Frame B**.

If the lenses are only slightly thicker in Frame A she would be happier with the additional thickness and the better looking frame. She knows that she wants Hi-Index lenses with an anti reflective coating regardless of which frame she chooses.

Patricia's prescription is:

**-7.00 Sph OD -7.00 Sph OS**

Her pupillary distance is:

OD 31.5 OS 31.5

**Frame A has the following dimensions:**

A: 52 B: 31 DBL: 15 ED: 58

**Frame B has the following dimensions:**

A: 50 B: 30 DBL: 16 ED: 56

From the information you have here calculate the difference in lens thickness and present it in a way the customer would be able to understand. You can do this simply by stating the added thickness in millimeters or converting the difference into a percentage; such as Frame A will have ____ millimeters thicker lenses than Frame B. Using a PD rule to show the expected lens thickness can be a great visual tool. Let's calculate the difference in thickness so we can help Patricia choose the best pair of glasses for her.

Let's calculate the difference in thickness so we can help Patricia choose the best pair of glasses for her.

**Frame A:**

((52+15)/2) -31.5=2mm decentration

(2*2) +58=62mm minimum blank size

(31^2) *7.00/2000(1.67-1)

6,727/1,340=5.00mm thickness (0mm center)

5+1.5=6.5mm maximum thickness

Since the prescription and the pupillary distances are the same in each eye we do not need to calculate again for the left eye. Let's repeat for Frame B and compare.

**Frame B:**

((50+16)/2) -31.5=1.5mm decentration

(1.5*2) +56=59mm minimum blank size

(29.5^2) *7.00/2000(1.67-1)

6,092/1,340=4.55

5.55+1.5=6.05mm maximum thickness

So now that we have calculated the maximum thickness for both frames we can present this information to Patricia so she can make the best decision for her. Seeing as the reduction in thickness is not drastic it may be likely that Patricia will choose to go with frame A. It may be time consuming to work this formula out multiple times but is a good way to ensure accuracy rather than just stating that the lenses will be thinner. The end result is that both you and the patient can feel confident in their choice and will have a better understanding of what the end product will look like.

**Conclusion**

So in conclusion we have covered a lot of material in a short amount of time. I would expect that there are concepts covered in this course that you may still not be confident in. Learning the optical math is often the most difficult part for any optician and we have just gone over many of the most complicated formulas an optician would need to use. Much of what we have covered is not known or used by most opticians due to how infrequently this information is made available. The main goal of this course was to present many of the advanced optical topics and formulas that are not frequently taught or readily available. I feel that these topics go unlearned not because they are too

difficult to implement but more so because the information is just not as readily accessible as it could be. As I mentioned in the opening section of this course it is always important to keep up to date with the newest trends in eye health but it is vital to continue to advance your knowledge in optics as well.

Through the practice and implantation of the material and formulas we've covered in this course you should have a new grasp on advanced optics and their usefulness in dispensing. Although much of the concepts covered in this course are difficult their use can be greatly beneficially once mastered. Although there are new technologies available today that can do many of these calculations for us without the optician even needing to know what is being calculated it is a great benefit to have a groundwork of knowledge in advanced optical topics in order to fully understand the lens system. This knowledge will make you stronger as an optician and ready to provide the patient with the highest level of care possible.

**Test Questions**

1) What is the fitted vertex distance?

    a) The distance between the retina and the prescription lens
    b) The distance between the back of a prescription lens in fitted eyewear and the front surface of the cornea.
    c) The distance between the front surface of the cornea and the lens of the phoropter.
    d) The distance between the retina and the front surface off the cornea

2) What instrument is used to measure the vertex distance?

    a) A distometer
    b) A metal PD rule
    c) A pupillometer
    d) A phoropter

3) Which of the following is a variable of the minimum blank size formula?

    a) Pupillary Distance
    b) Vertex Distance
    c) Effective Diameter

d) B measurement

4) Which of the following is a determining factor in lens thickness?

a) Lens material
b) ABBE value
c) Frame material
d) Case hardening

5) When do you need to use a vertex distance?

a) +/-10D
b) +/-9D
c) +/-5D
d) +/-7D

6) As a plus power lens is moved further away from the eye the perceived power _____.

a) Increases
b) Decreases
c) is unchanged
d) Cannot be determined with the amount of information given

7) What is true about lens thickness?

a) The perceived thickness of a lens can be bothersome to a patient
b) Lens thickness depends on the frame material
c) All lenses are the same thickness
d) Lens thickness is difficult to measure

8) Assume an order has been determined to have 5mm of decentration in the right eye and the ED of the frame is 54, what is the smallest lens blank this could be ran on?

a) 63mm

b) 70mm

c) 74mm

d) 64mm

9) As a minus power lens is moved further from the eye the perceived power _____.

a) Increases

b) Decreases

c) Stays the same

d) Is impossible to determine

10) What is one way you could increase the magnification of a lens?

a) Flattening the base curve
b) Polishing the edges
c) Increasing the face form
d) Using a steeper base curve

11) The variable (a) in Martin's Tilt formula stands for _____.

a) Excessive tilt

b) Axis of astigmatism

c) Total power

d) Excessive rotation

12) What must you add to your answer after using the lens thickness formula to calculate lens thickness?

a) Maximum thickness

b) Minimum center thickness

c) Index of refraction

d) The ED measurement of the frame

13) What formula would be used to determine whether your lab can process an order on finished lens blanks?

a) Lens thickness formula

b) Vertex distance compensation
c) Minimum blank size
d) Maximum blank size

14) What is usually the best and easiest way to correct an abnormal amount of tilt?

a) Use Martin's tilt formula to compensate the lens
b) Compensate the lens for vertex distance
c) Adjusting the pantoscopic or retroscopic tilt of the frame
d) Increasing the face form

15) You have determined that an order can be processed on a blank size of 68mm, what would this mean the radius of the lens would be?

a) 68mm
b) 32mm
c) 34mm
d) 136mm

16) When should you use two different lens materials in order to balance magnification between right and left lenses?

a) When the base curves must be the same
b) When one lens is minus power and the other is plus power
c) When there is excessive tilt
d) Different lens materials should not be used

17) What are sine, cosine and tangent ratios of?

a) A spherical lens
b) A right angled triangle
c) A left angled triangle
d) A hypotenuse angle

18) Why might a deeper B measurement result in better cosmetic appearance for an individual who has a +5.00D prescription?

a) The beveled edge will be further from the thickest portion of the lens resulting in a thinner edge.
b) The beveled edge will be closer to the center resulting in a thinner edge.
c) A deeper B measurement will not improve cosmetics
d) A wider A will increase cosmetics in this situation

19) Why might you add 2mm to your calculated minimum blank size?

a) To allow room for the manufacture markings to cut out
b) It is part of the final calculation
c) It will help decrease lens thickness
d) To allow for edge polishing

20) If the decentration is increased by 2mm this will increase the blank size by_____.

a) 2mm
b) 1mm
c) 4mm
d) 5mm

21) You are fitting a patient for a pair of glasses, their prescription is -10.00 OU. What would be the amount of power change per millimeter by changing the vertex distance?

a) 0.10D
b) 0.121D
c) 0.20D
d) 0.05D

22) If you determine that the fitted eyewear from the patient above fits 5mm closer to the patients eye than during refraction what is the power of lens that they would perceive if nothing else is changed?

a) -9.50
b) - 8.50
c) -10.10
d) -10.50

23) What power lens should be ordered for the patient above to ensure they perceive the correct prescription?

a) -9.50
b) -10.10
c) -9.90
d) -10.50

24) When adjusting tilt in the 90 degree meridian we are adjusting _____.

a) The retroscopic tilt
b) The pantoscopic tilt
c) Face form
d) The axis of the lens

25) What are the controllable factors in the lens thickness formula?

a) Power, material, radius
b) Material and radius
c) Power and radius
d) D. Material and vertex

26) Calculate the expected lens thickness given the following parameters:

RX: - 9.00
Minimum blank size: 63mm
Material CR-39(1.50)

a) 8.93mm
b) 10.93mm
c) 6.93mm
d) 8.24mm

27) The lab was unable to process the order above on a 63mm lens blank due to manufacture availability and a 65mm blank must be used. What is the new expected lens thickness?

a) 11.51mm
b) 9.51mm
c) 7.51mm

d) D 38.25mm

28) You are inspecting a pair of eyewear and need to determine how much prism is in effect at the 180 degree meridian. The prescription is -3.00 -1.00 x113, how would you determine how much power is in effect at this meridian?

a) The 30/45/60 rule
b) The sphere plus the cylinder power
c) The power in oblique meridians formula
d) The power in hypotenuse meridians formula

29) From the prescription above, how much power is in effect at the 180 degree meridian?

a) -2.82D
b) -3.82D
c) -3.18D
d) +3.82D

30) How much power is in effect at 90 degrees for the following prescription?

+3.50 -3.00 x40

a) +1.74D
b) -1.74D
c) -1.33D
d) +1.33D

31) What is one way to reduce minimum blank size?

a) Choosing a larger frame
b) Choosing a higher index material
c) Increasing decentration
d) Decreasing decentration

32) When a lens has excessive tilt the patient will experience a change in _____.

a) Cylinder power
b) Sphere power
c) Sphere and cylinder power
d) Only a change in perceived prism

33) When either the vertex distance or amount of tilt is changed the power of the lens _____.

a) Is actually changed
b) Is perceived to be changed by the brain
c) Is actually changed and is perceived differently by the brain
d) Is not perceived differently or changed

34) What is an iesokonic lens?

a) An iesokonic lens is a lens used to control differences in magnification
b) An iesokonic lens is used to reduce prismatic imbalance
c) A lens with two different materials
d) A lens with large differences in base curve

35) Aniesokonia is a condition where_____.

a) The eyes cannot create fusion
b) One lens is minus and the other is plus
c) There is a significant difference between retinal image sizes
d) Excessive tilt must be used

36) In digitally manufactured lenses some of the measurements used for compensation are _____.

a) Tilt, vertex distance and face form
b) Tilt, prism and lens material
c) Vertex distance and decentration
d) Decentration, face from and material

37) Why might a higher index lens material not necessarily yield thinner lenses?

a) Lens diameter
b) Decentration
c) Different minimum center thicknesses
d) Higher index lenses will always yield thinner lenses

38) The base curve of a lens is increased from +4.00 to +8.00. What effect will this have on the magnification?

a) Magnification will increase
b) Magnification will decrease
c) Magniffication will not change
d) There is not enough information to know

39) How would increasing the pantoscopic tilt of a lens change the magnification?

a) Magnificaiton would increase
b) Magnification would decrease
c) Pantoscopic tilt would not have a significant effect on magnification
d) There is no way to know

40) Who might benefit from the optician taking the time to calculate out expected lens thickness?

a) The patient
b) The patient and the optician
c) No one
d) This is not a benefit and uses too much time