



Refraction Training Manual

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1. Introduction

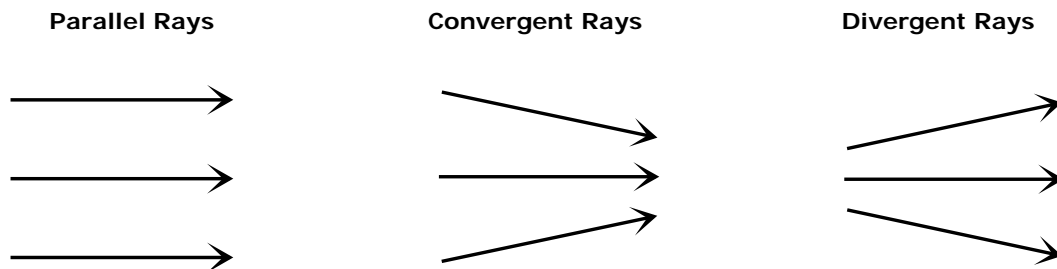
For many of our patients, the major diagnosis will be the need for glasses. Many more patients need to be assessed for glasses before an accurate diagnosis can be made. The ability to refract a patient quickly and accurately must, therefore, be a great asset in your clinic.

This manual is designed to help you understand about refractive errors, to guide you in refracting a patient accurately, and determine what treatment the patient needs.

2. Basic Optics

Everything we see is seen because light is reflected from it. The object itself does not produce light (unless it is a light source!). This explains why we cannot see in the dark - there is no light to reflect from objects.

A BEAM of light consists of light RAYS, which are shown as straight lines in optical diagrams. A beam of light can be PARALLEL, DIVERGENT or CONVERGENT. The rays from a spot or point source of light are divergent, but if looked at from a distance may be considered to be parallel.

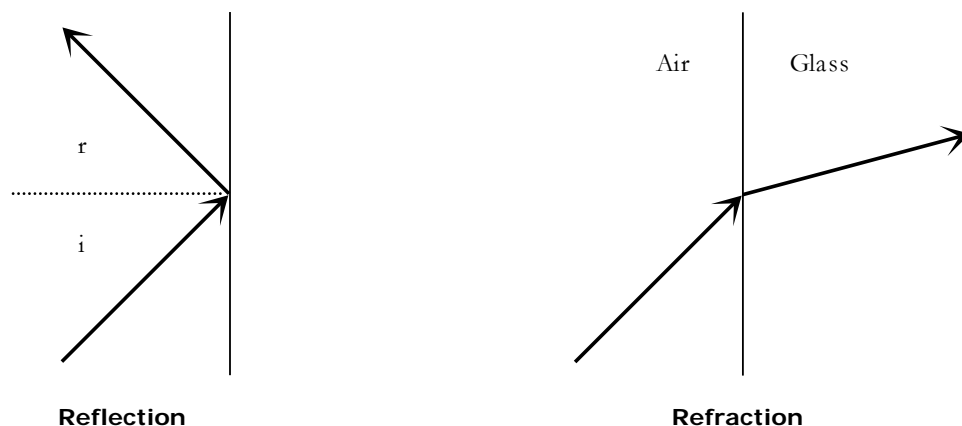


Light can be REFLECTED or REFRACTED.

REFLECTION of light occurs from surfaces, most notably mirrors. The Law of Reflection states that - 'the angle of reflection is equal to the angle of incidence'. This means that, if a ray of light hits a mirror at a certain angle, it will bounce away at an equal angle.

REFRACTION of light is the change of direction a ray takes when the ray passes from one medium (e.g. air) to another medium with a different refractive index (e.g. glass). The refractive index is a measure of how well the medium is able to bend light.

Light can be refracted by **lenses** or **prisms** which are made from transparent materials such as glass and optical plastic.

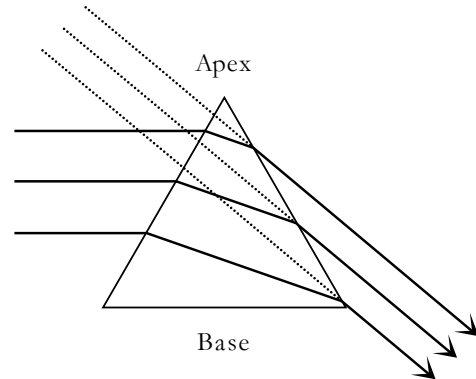


Prisms

A prism is a wedge shaped piece of glass with 3 flat surfaces at angles to each other. One surface forms the base and the other 2 surfaces meet at the apex. The angle at the apex is called the apical angle, and the bigger this angle is, the greater the refracting power of the prism. Prism power is measured in Prism Dioptres.

Definition: A one Prism Dioptre lens will refract light by 1 cm over a distance of 1 metre (100 cm).

A prism will deviate light passing through it towards the base of the prism, and an object viewed through the lens will appear to be displaced towards the apex of the prism.



Optical Lenses

A lens has at least one curved surface. Optical lenses normally have both surfaces curved. Whilst a prism deviates light, a lens will focus light. Light will be refracted at BOTH surfaces of a lens, and the amount of refraction will be related to the refractive index and curvature of the surfaces. A higher refractive index produces more refraction, as does steeper curvature. The power of a lens is measured in Dioptres.

Definition: A one dioptre lens will focus light at one metre (100 cm). This is written as 1.00 DS.

The **FORMULA** relating **POWER** and **FOCAL LENGTH** is

$$P = 1 / f$$

where P is the power and f is the focal length of the lens in metres. It can also be written

$$f = 1 / P$$

Thus a 1.00 DS lens has a focal length of 1 metre (100 cm) and a 10.00 DS lens has a focal length of 0.1 metre (10 cm).

As far as we are concerned it is easier and better for us to think in centimetres rather than metres. This makes the formula

$$P = 100 / f$$

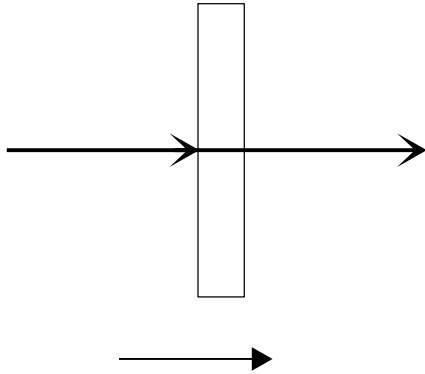
or $f = 100 / P$

where f is now measured in centimetres.

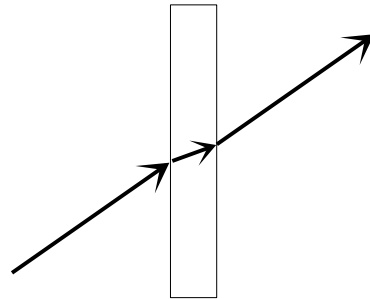
This formula is vital for much of the work we do. You must be able to use it freely, being able to convert focal length to dioptic power, and from dioptic power to focal length.

Plano Lenses

These lenses have no refractive power (i.e. 0.00 DS).



Light entering the lens at right angles are not bent, but pass straight through the lens.



Oblique light rays will be (refracted) at both surfaces and end up leaving the lens at the same angle.



Plano lenses can be flat or curved. Plano spectacle lenses are always curved, and both surfaces have the same curvature.

They are not normally used, but sunglasses are generally plano. Also, safety glasses may be plano.

Positive/Plus/Convex Lenses

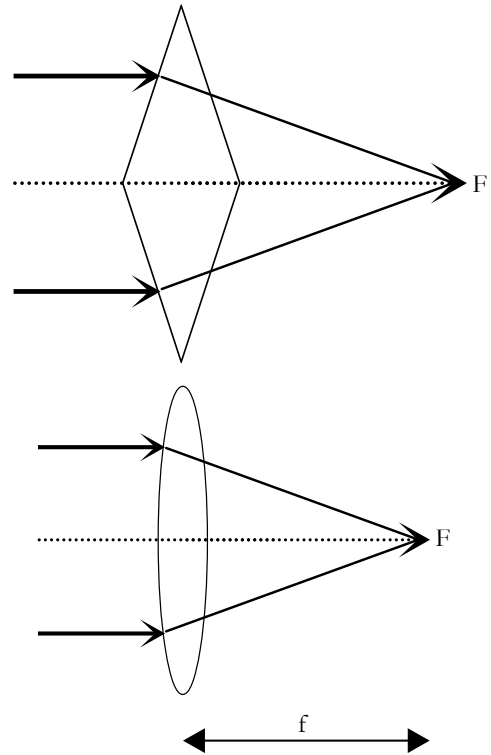
(Abbreviation DS or Sph)

These **CONVERGE** light. They are used in hypermetropia, presbyopia and aphakia. Low vision devices also use this type of lens.

A convex lens can be thought of as two prisms with their **bases together (or apices apart)**. Light is refracted towards the base. This helps us when we consider some of the effects of lenses.

A convex lens will converge light towards a point which is called the focal point (focus) of the lens. The stronger the lens, the shorter is the focal length.

(F = focal point of the lens)



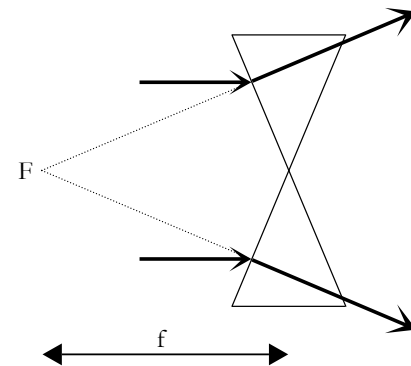
Negative/Minus/Concave Lenses

(Abbreviation DS or Sph)

These will **DIVERGE** light. They are used in myopia.

A concave lens can be thought of as two prisms with their **bases apart** or **apices together**. Light is refracted towards the base of the prism.

A concave lens diverges light as if the rays are coming from the focal point, which lies between the object and the lens.

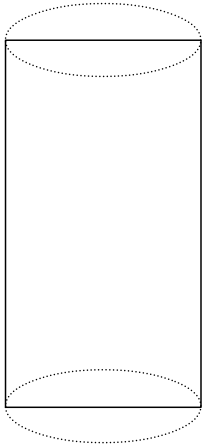


Cylinders

(Abbreviation DC or Cyl)

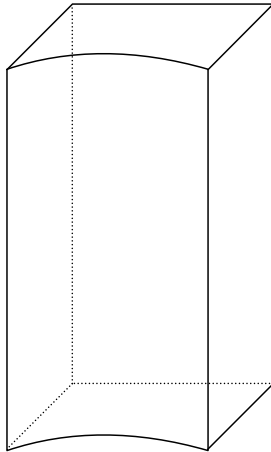
Cylinders may be concave or convex, and both will be found in normal trial sets. However, we will only consider minus (concave) cylinders.

Spherical lenses have the same power all over the lens surface, and bring light to a point focus. Cylinder lenses have power in one meridian only. There are two principal meridians on a cylinder lens, the power meridian, and the axis meridian at right angles (90°) to the power meridian. These lenses will make a point of light appear as a line of light at the focal point of each meridian.

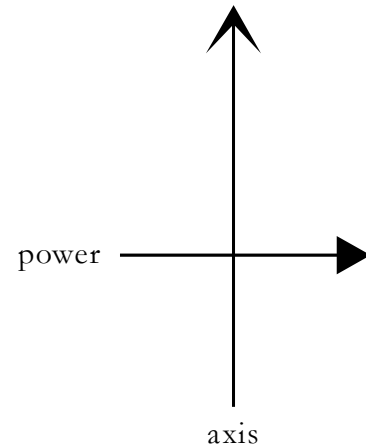


Positive/plus/convex cyl.

Power is in one meridian only and this is at right angles to its axis.



Negative/minus/concave cyl.

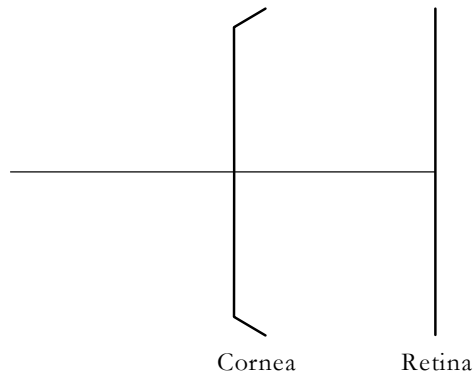


An object viewed through a cyl will appear to be elongated or distorted. Cyls are used to correct astigmatism. The axis of the cyl must be aligned with the axis of the astigmatism in the eye if the correction is to be effective.

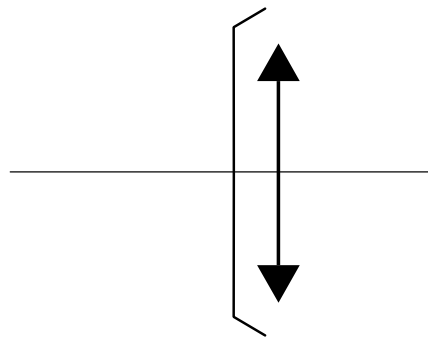
The correction of refractive error normally uses a combination of spherical and cylindrical powers. This is covered in more detail later.

Optical Diagrams

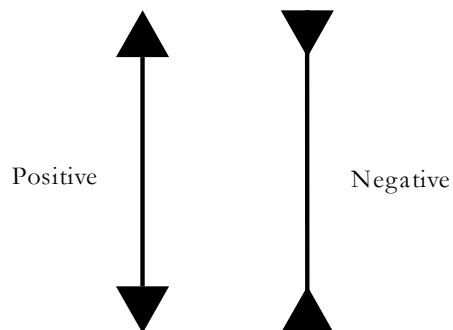
For convenience, rather than drawing an eye each time we draw a ray diagram, which is quite difficult, we use the following form of diagram -



You will note that the natural lens is not drawn. This is because we normally consider the eye to be relaxed, or unaccommodated. However, if we consider the effect of accommodation, the diagram would be -



Diagrammatically, we represent lenses as follows -



3. Vision and Visual Acuity

We need to show the difference between visual acuity obtained with and without glasses. The measurement of how well the eye can see detail without glasses is called **Vision (V)** whilst with correction is called **Visual Acuity (VA)**.

There are several ways that vision and visual acuity can be recorded. The system that seems to be most commonly used is the Snellen Fraction notation. This shows two numbers, the first (numerator) tells us the distance at which the test is done and the second (denominator) is a measure of the eye's standard of vision. This number represents the distance at which a 'normal' eye would be able to see the letter.

Examples

- **6/6** - the test is done at 6 metres, and the patient can see the letter that you would expect the eye to be able to see at 6 metres. Therefore, this eye is 'normal'.
- **6/60** - the test is again at 6 metres, but this time the patient only sees the largest letter at 6 metres, which a 'normal' patient could see at 60 metres.

You should decide on which notation to use, based on that used by your colleagues, and use this one exclusively. In this manual we will use Snellen measure in metres and not in feet.

Table of different systems of visual acuity notation

| Snellen Letters 6m | Snellen Letters 20ft | Decimal Notation | Percentage Notation |
|--------------------|----------------------|------------------|---------------------|
| 6/6 | 20/20 | 1.0 | 100 |
| 6/9 | 20/30 | 0.67 | 67 |
| 6/12 | 20/40 | 0.5 | 50 |
| 6/18 | 20/60 | 0.33 | 33 |
| 6/24 | 20/80 | 0.25 | 25 |
| 6/36 | 20/120 | 0.17 | 17 |
| 6/60 | 20/200 | 0.1 | 10 |

Snellen Charts

This is the normal letter chart used for vision testing. They can have normal lettering, reverse lettering (for use with a mirror), 'illiterate E' or numbers. Some charts have pictures, but these are not so successful. The chart is normally designed for use at 6 metres, either directly or in a mirror.

Each eye is tested separately, with the other eye occluded. The patient reads the letters (or indicates which way the 'E' is pointing) until he can read no further. Do not assume that this is his visual acuity, however, and you must encourage him to try to read further! Guessing must be encouraged, as you will often find that the patient can read further. Note that you need to watch the patient to make sure they do not look around the occluder.

Near Vision Testing

There are several charts available for near vision assessment. They are mainly 'Times Roman' styles, with the letter sizes marked in N point size (e.g. N5). The Jaegar scale may also be found in use. We normally use the 'N' scale.

To test near vision the patient needs to hold the book at their normal reading distance. Do not tell the patient where this is, let them decide! This will frequently explain their visual problems as they read too close. The normal reading distance is between 33 and 40 cm. This will be covered in more detail later.

We always attempt to obtain N5 vision with each patient. However, N8 is the equivalent of normal newsprint, so we are trying to obtain better vision than necessary. If this is possible, then the normal near vision tasks are made easy and comfortable.

Asking patients, who need to sew, to thread a needle is also a near vision test!

Other Vision Tests

With children, it is often difficult to determine vision with our normal tests. There is a test called the **Sheridan-Gardiner** test which may overcome these problems. It requires the patient to be able to match letters, without them actually having to know what the letters are.

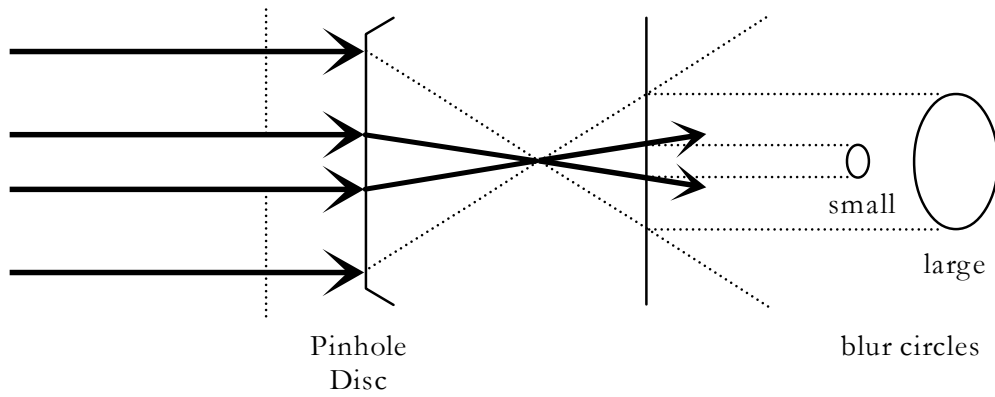
Problems

In all tests, vision will be affected if:

- The chart is dirty (which reduces the contrast available)
- There is poor lighting for the test
- There is a refractive error present
- If there are corneal or lenticular opacities, or retinal pathology is present

The Pinhole Disc

If poor vision is found, then use of the pinhole will show us whether the vision may be improved with glasses. This works by reducing the blur circle caused by refractive errors.

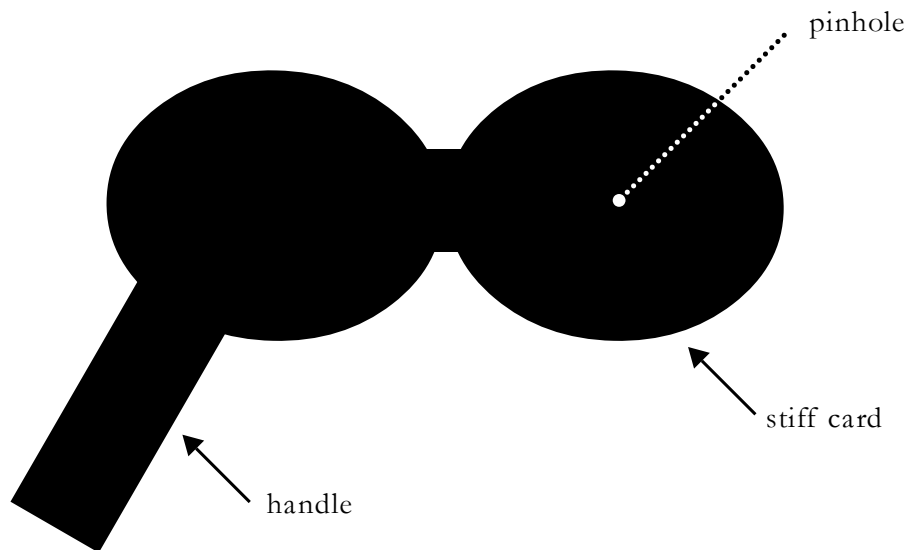


It is important, when checking vision with a pinhole, that the patient is able to see through the pinhole to the chart!

There are a few occasions when you will find improved vision with a pinhole that will **NOT** improve with glasses. They are all medical conditions:

- Lenticular opacities
- Corneal opacities or scarring
- Keratoconus
- Marfan's Syndrome

It is possible to make a pinhole from stiff card or thin plywood. E.g.



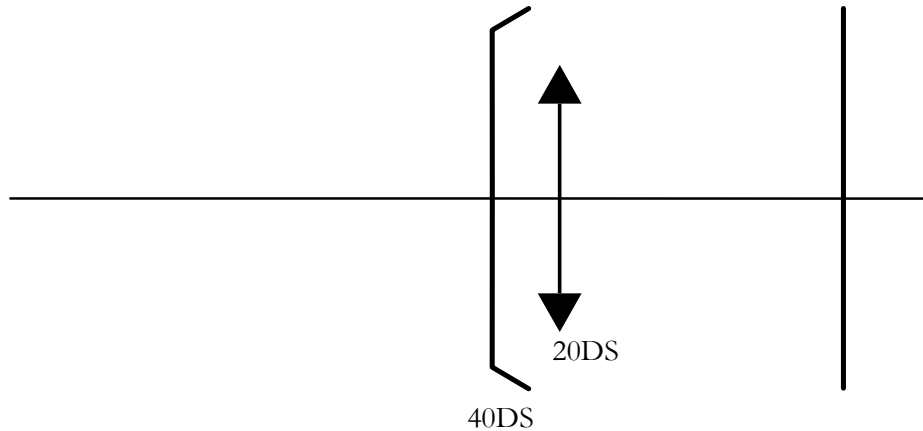
4. Refractive Errors

Emmetropia

This is the normal eye, having no refractive error. It is an unaccommodated eye in which the rays of light from a distant object are focused onto the retina.

The **CORNEA**: This is an unchanging refractive surface with a power of about 42.00 DS.

The **NATURAL CRYSTALLINE LENS**: This is a variable, refractive body which can **ACCOMMODATE** (focus) to increase its power. In its unaccommodated condition it has a power of around 20.00 DS and this power increases with accommodation.



Ametropia

This is the general term applied to an eye with any refractive error, with the eye unaccommodated. In an ametropic eye, light rays do not focus onto the retina, but focus in front of, or behind the retina.

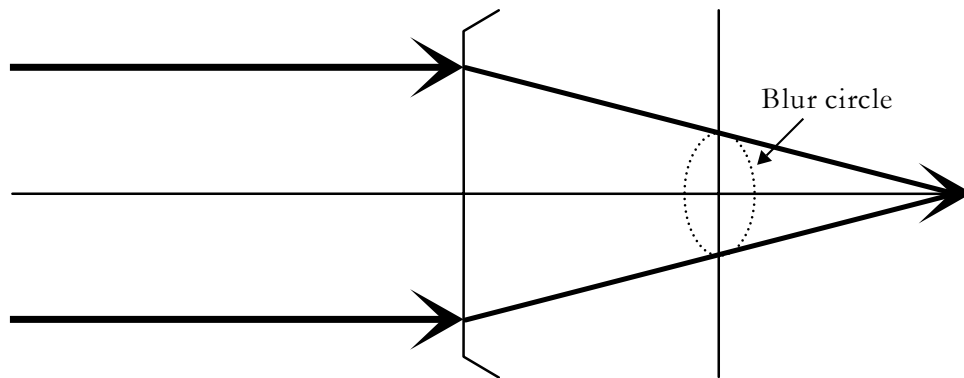
There are three main classes of ametropia

- Hypermetropia
- Myopia
- Astigmatism

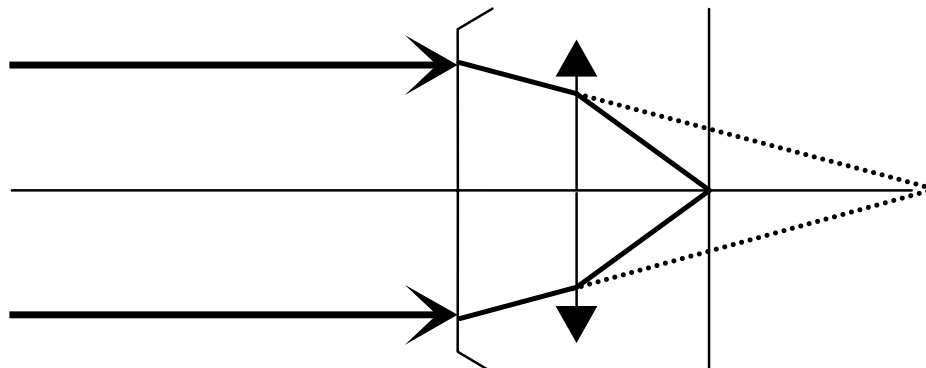
Hypermetropia

(Hyperopia, long sight)

Rays of light are focused behind the eye, when the eye is unaccommodated. This can be due to the eye being too short or the refractive components of the eye too weak.



By accommodation (focusing), objects can be brought into focus and seen clearly.



The constant effort required to maintain accommodation in hypermetropia can result in **aesthenopia** (eyestrain), giving symptoms of headache, tired and aching eyes, and even watering eyes (lacrimation).

Hypermetropia in more detail

Hypermetropia is divided into several parts, based on the ability of the eye to cope with the refractive error.

- **Total Hypermetropia** is the full amount of hypermetropia
- **Latent Hypermetropia** is the portion of the total error which is easily overcome by accommodation, and any attempt to correct this will result in blurring the vision
- **Facultative Hypermetropia** is the portion that can be corrected by lenses, or by accommodation
- **Absolute Hypermetropia** is the portion that cannot be corrected by accommodation

Example

Let us assume that a patient has vision of 6/24. If we add positive lenses we will reduce the remaining refractive error and improve vision.

We add + 3.00 DS and find that the vision has now improved to 6/6. We then add more positive power to make + 5.00 DS, and the visual acuity remains at 6/6. Adding any more positive power blurs the vision. We then do a refraction under cycloplegia (see later) and find that the patient accepts +6.50.

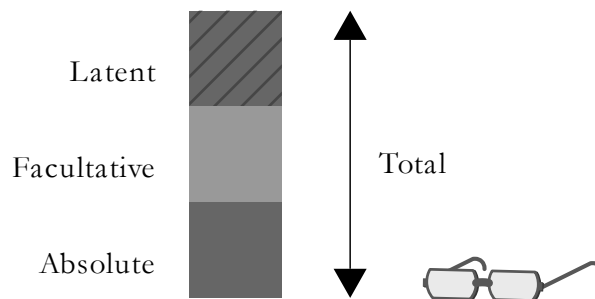
Cycloplegia gives us the **total** hypermetropia which is therefore + 6.50 DS

The initial + 3.00 DS which improved the visual acuity corrected the **absolute** hypermetropia.

The addition of power up to + 5.00 DS reveals more about the hypermetropia. This amount is the sum of the absolute and facultative hypermetropia. Thus the facultative hypermetropia is + 2.00 DS.

Addition of further positive power blurs the patient. The **latent** hypermetropia is + 1.50 DS. We calculate this by deducting the absolute and facultative from the total hypermetropia.

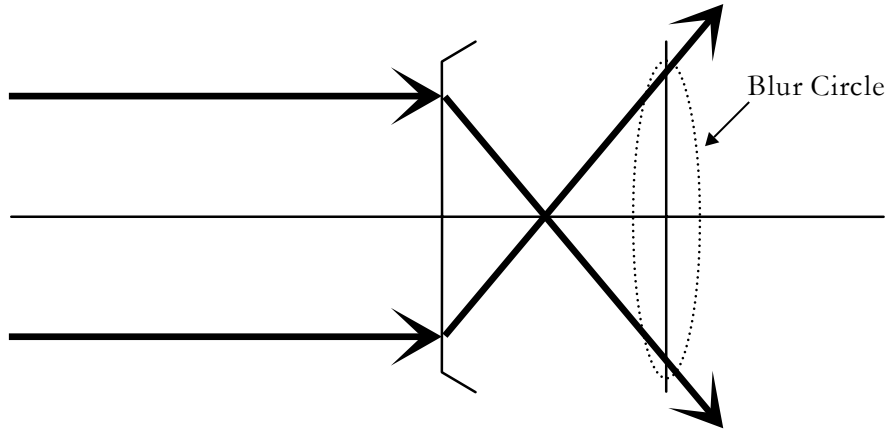
Therefore, **Total = Latent + Facultative + Absolute**



Myopia

(Short sight)

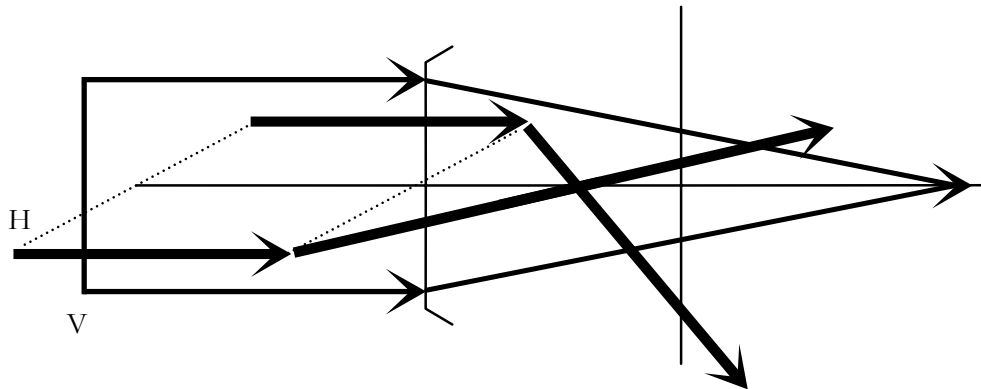
This time rays of light are focused in front of the retina, whether or not the eye is accommodating. In fact, accommodation will result in even more blurring. Myopia is due to either the eye being too long or the refractive components too strong.



Astigmatism

Astigmatism - Regular

Here, the eye has a different refractive power in different meridians of the eye - this means that the eye is not spherical. For example, vertical rays entering the eye may be focused behind the retina while horizontal rays focus in front of the retina. The two meridians are always at right angles (90°) to each other in regular astigmatism. This type of astigmatism is correctable with cylinders.



Between the two focal points there is the **circle of least confusion** or **blur circle**. This is the position that gives the least blurring of vision for the eye.

There are several categories of astigmatism:

- **'With the rule'** where the stronger refracting meridian is vertical and the weaker horizontal. The minus cyl axis is at about 180°
- **'Against the rule'** where the stronger meridian is in the horizontal. The minus cyl axis is at about 90°
- **Oblique astigmatism**, where the axes are around 45° and 135°

Oblique astigmatism has a greater effect on vision than with or against the rule. It is also necessary to prescribe for oblique astigmatism carefully as the distortion caused can be more difficult to adapt to.

Each of these, when combined with a spherical element, can also be sub-divided into 5 groups:

- Compound myopic - both meridians are myopic
- Simple myopic - one meridian is plano, the other myopic
- Mixed - one meridian is hypermetropic, the other is myopic
- Simple hypermetropic - one meridian is plano, the other hypermetropic
- Compound hypermetropic - both meridians are hypermetropic

Astigmatism may be due to:

- Corneal - the corneal surface, which has a refractive power of about 42.00 D, may not be spherical and has radius of curvature which is greater in one meridian than the other
- Lenticular - due to the lens tilting within the eye. This is normally a maximum of 0.50 DC and is against the rule

Frequency of astigmatic corrections.

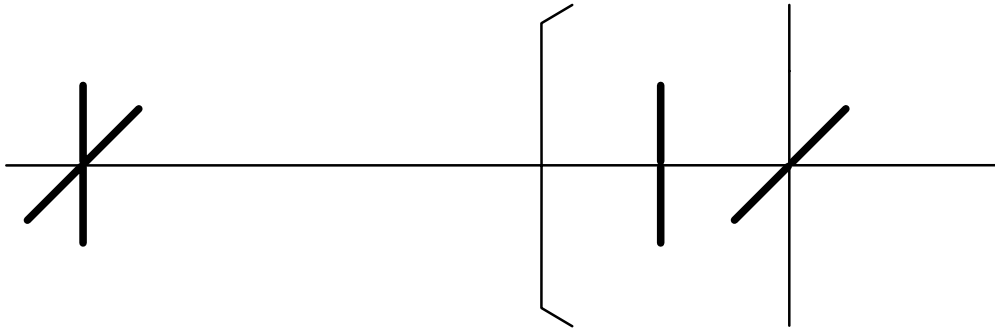
- With the rule 80%
- Against the rule 10%
- Oblique Astigmatism 10%

Astigmatism - Irregular

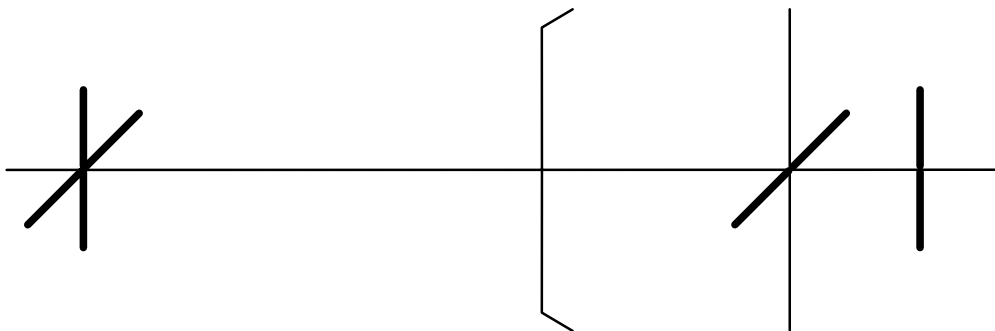
This is normally due to a medical condition such as keratoconus, pterygium, intra-orbital space occupying lesion, etc. These conditions should be referred.

Ray Diagrams for Astigmatism

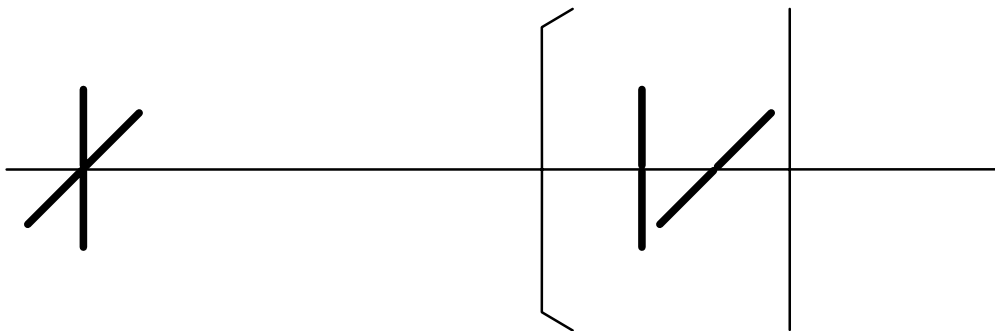
Simple Myopic Astigmatism - One meridian is focused in front of the retina, the other on the retina.



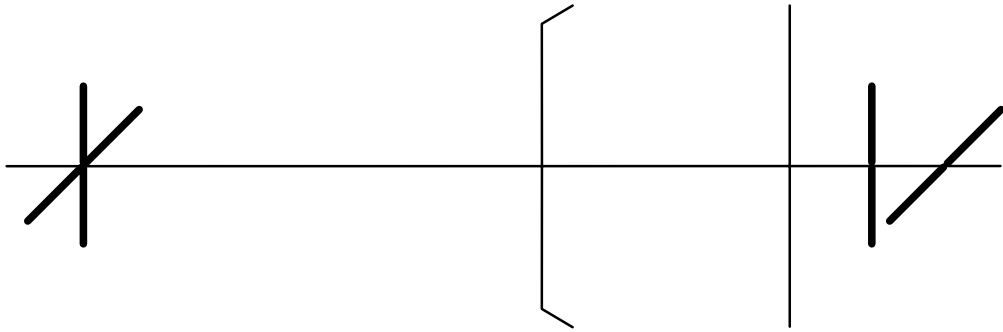
Simple Hypermetropic Astigmatism - One meridian is focused behind the retina, the other on the retina.



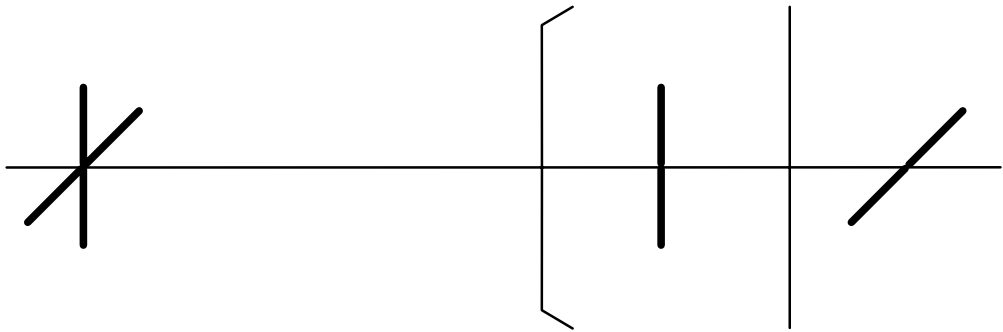
Compound Myopic Astigmatism - Both meridians are focused in front of the retina.



Compound Hypermetropic Astigmatism - Both meridians are focused behind the retina.



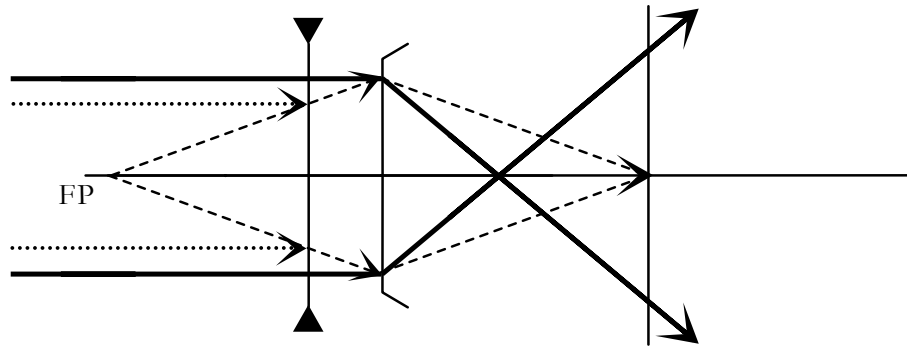
Mixed Astigmatism - One meridian is focused in front of the retina, the other behind.



5. Correction of Ametropia

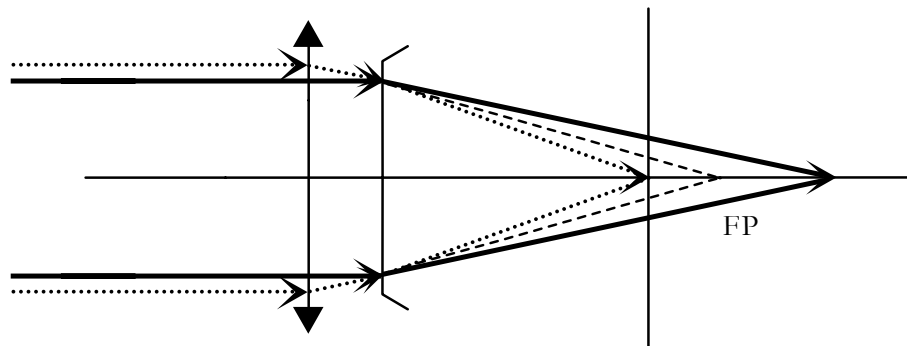
Myopia

- Light from infinity is focused in *front of* the retina.
- Light from the far point is naturally focused *onto* the retina.
- Therefore, we want to provide a spectacle lens that will make light from infinity *appear* to come from the far point. By doing this we correct the refractive error. In myopia we need to use negative lenses.



Hypermetropia

- Light from infinity is focused *behind* the retina.
- Light from the far point is naturally focused *onto* the retina.
- Therefore, we, again, want to provide a spectacle lens that will make light from infinity *appear* to come from the far point. In hypermetropia we need to use positive lenses.



Astigmatism

Here we need to use a sphere and cyl combination to correct both principal meridians to make light from infinity appear to come from the respective far points.

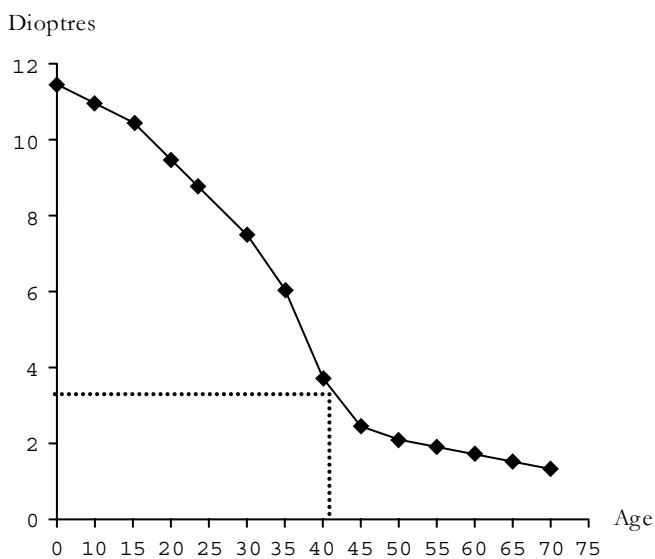
6. Accommodation

Accommodation is the process in which the eye focuses onto an object. When we want to look at a close object we must accommodate or change the focus of the eyes in order to see clearly.

What happens in the eye when we accommodate is, the ciliary muscle contracts which allows the zonules attached to the lens to **relax** and the elastic lens capsule can then increase its curvature. This makes the lens more powerful and shortens its focal length.

The ability to accommodate, therefore, depends largely upon the elasticity of the lens capsule and the lens itself. As we get older, this elasticity decreases and thus our accommodative ability reduces. This follows a normal pattern which is shown in the graph.

Graph showing minimum amplitude of accommodation vs. age



The line drawn at 3.50 DS indicates the average age at which reading problems should be evident. It has been found that African races in hot climates have lower amplitudes of accommodation than Caucasians in temperate climates.

In the graph we compare **amplitude of accommodation** to age. The amplitude of accommodation is the maximum amount of accommodation that can be exerted, and is measured in dioptres. This is normally done when the eye is fully corrected for distance, and we then measure the

nearest point that the patient can accommodate to.

As you can see from the graph, children and young adults have high amplitudes of accommodation and can focus easily on objects at any distance. However, as we get older, that ability reduces, and we find it more difficult to focus on near objects. When this affects our near vision this is known as **presbyopia** ('old sight').

When we are refracting children we need to be careful to make sure the patient is not accommodating as this will affect our results. It may be necessary to use a cycloplegic drug to paralyse accommodation before an accurate result can be obtained. This is covered later in the manual.

Also, it is only possible to sustain the use of half to two thirds of the accommodative ability available. This means that, even if a patient has the ability to accommodate on close work, if he is using more than the comfortable amount, he will have symptoms of eye strain.

7. Presbyopia

This is the reduction in amplitude of accommodation with advancing age, and is caused by hardening of the crystalline lens. The patient will complain of close work difficulties, particularly with seeing small detail and in poor lighting. This will affect reading, sewing, knitting, etc.

In myopes, this problem is delayed if the patient removes their glasses as he is naturally focused up close.

In temperate climates, presbyopia is expected in the early to mid 40's. However, in Africa the problem occurs earlier, normally around the age of 40. Some people believe that presbyopia starts earlier than this, but the reading problems that occur before the age of 40 are more likely to be due to photophobia than by genuine presbyopia, and sunglasses should be advised as the first choice treatment. These can be purchased throughout Africa from the hawkers!

Presbyopia is corrected by use of simple positive spherical lenses *on top of* the distance prescription. This is known as the **reading addition** or **add**. In doing this we effectively make the eye myopic, so we will prevent the patient seeing in the distance when wearing the reading glasses. Remember, although the patient may not read, they may still need glasses for close work such as sewing or knitting.

When prescribing for presbyopia, we want to allow the patient to use their remaining accommodation. Thus, we only give them the *minimum* amount of reading add in order for the patient to be able to perform their near tasks.

As a rough guide, the following applies:

| Age | Near Addition |
|------------|-----------------|
| 40 to 45 | +1.00 to + 1.50 |
| 45 to 50 | +1.50 to + 2.00 |
| 50 to 55 | +2.00 to + 2.50 |
| 55 upwards | +2.50 to + 2.75 |
| Aphakes | +2.75 to + 3.00 |

However, the most important consideration in determining the reading addition is the requirements of the patient - how near do they have to work and what close work tasks do they have to perform.

Remember that the reading addition is added to the power required for distance. Thus a + 2.00 DS hypermetrope aged 50 will probably need + 4.00 DS in his reading glasses. Also, a 50 year old - 3.00 DS myope will need - 1.00 DS glasses for reading, but could read at 33 cm without glasses!

Consider what a 40 year old - 1.00 DS myope will need for reading. The reading add will be + 1.00 DS. This means that the reading power would be plano and the patient will be able to read without any glasses.

A presbyope should only need a change in reading addition every 4 to 5 years and then it will be a change of +0.50 DS only.

Spectacle Corrections for Presbyopia

A correction for reading can be made up in two distinct ways - **single vision reading spectacles** or **bifocals**. There are several considerations that need to be made before prescribing either of these.

1. Amount of distance and reading corrections - are they worth giving?
2. Improvement in visual acuity - is it enough to be worth giving glasses?
3. What does the patient need to do - are bifocals more suitable or single vision?
4. What does the patient want?
5. What can the patient afford?
6. What is practically available (maybe certain lens types are not available locally)

Bifocals should be avoided when distance prescription is large. If there is a large difference between the refractive error of the 2 eyes bifocals may not be successful unless there is a big difference in visual acuity between the two eyes.

8. The Written Prescription

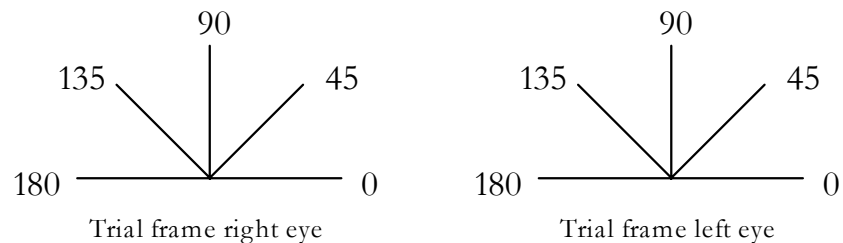
There is a standard way of writing a prescription in order to prevent confusion. The prescription for the right eye is always written first.

| | Sph | Cyl | Axis | Prism | Base | Reading add |
|----|---------|---------|------|-------|------|-------------|
| R) | +2.00 / | -1.00 × | 90 | 1.0 | OUT | +2.50 |
| L) | +2.50 / | -2.00 × | 110 | 1.0 | OUT | +2.50 |

The reading add can be written underneath the distance prescription. The add is normally the same for each eye. The main exception to this is in monocular aphakia when the aphakic eye will normally have a larger add than the phakic eye.

Prisms are prescribed according to their power and the direction of the base (IN, OUT, UP, DOWN). We will not be covering how to prescribe for prism in this manual.

The cylinder axis is placed at a specific angle. This is measured in degrees, but the degree sign is not written as it can be mistaken for a zero (0). The trial frame has a protractor scale from which we can determine the axis.



The spoken prescription!

There is a system for speaking the prescription too! Get used to it as, again, it will avoid confusion.

Examples

+ 0.25: plus owe (0) two five

+ 0.50: plus owe fifty

+ 0.75: plus owe seven five

+ 1.00: plus one

- 1.50: minus one fifty

- 2.25: minus two two five

+ 10.00: plus ten

- 10.50: minus ten fifty

The decimal point is *never* mentioned.

9. Neutralisation and Focimetry

There are several ways available to determine the power of a lens. A **focimeter** (or lensmeter) may not always be available, but you should have your trial lenses available. It is possible to get a good idea of the power by using these.

Hand Neutralisation

If you look at an object through a lens and move the lens, the object will appear to move. If the lens is convex (positive) the object will appear to move in the **opposite** direction to the movement of the lens. This is called an **against** movement. If you look at an object through a concave (negative) lens the movement appears to move in the **same** direction, and this is known as a **with** movement. This will allow us to tell, by a quick check on the glasses, if the patient is hypermetropic or myopic.

If you place a pair of lenses together of equal, but opposite, powers there will be no movement of the object viewed as the net power is plano. These lenses have **neutralised** each other.

Therefore using a combination of lenses to neutralise the movement of the object, it is possible to determine what the unknown lens power is.

Technique

To find the power (or prescription) of a lens we use trial lenses and an object to view. The best object is a cross as this allows us to assess astigmatic corrections.

1. Hold the lens so that the crossed lines can be seen, and move the lens, noting the direction of movement.
 - **WITH = MINUS LENS**
 - **AGAINST = PLUS LENS**
2. Rotate the lens. If the lines appear to twist, or 'scissor', then there is an astigmatic element to the lens power.
3. If there is a with movement, then this is a minus lens and needs to be neutralised with a plus lens; if against then a minus lens is needed to neutralise.
4. Select a trial lens and hold it against the lens and assess the movement. If there is no movement then the lens is neutralised, and the power is equal to, but of the opposite sign to the trial lens.
5. If, when neutralising, there is a remaining movement, then another trial lens is needed. Consider the remaining movement and select an appropriate trial lens to proceed with.
6. If there is astigmatism, then rotate the lens until the cross lines run through the lens continuously, vertically and horizontally. Keep the lens at this angle and move the lens along each line in turn. The movement will be different in each direction.
7. Neutralise **all** with movement first (or, if both are against, the smaller with movement). This will leave an against movement in the other meridian, and this meridian is the **axis** of the cylinder.
8. Neutralise the remaining meridian (against movement) with a minus sphere. This second lens will be equal but opposite in power to the cylinder power in the lens

Always remember that the lens that is used to neutralise is opposite in power to the one you are measuring, but of the same size.

Focimetry

A focimeter or lensmeter is an instrument which is used to measure the power of a lens. It is much more accurate than neutralisation, but not always available to use. The sphere and cyl powers can be measured, the axis determined, and the optical centre of the lens found. It is also possible to measure the bifocal addition on most lenses. There are 2 types of target in focimeters, but both use the same principles.

Note: Before trying to measure any lenses with a focimeter, the eye piece **MUST** be focused for you to see clearly. This is done by setting the machine to read plano, and then adjusting the eyepiece so that the target and graticule markings in the focimeter are in focus.

European dot target

A spherical lens will simply blur the dots, and adjusting the power dial will bring them into sharp focus. The power can now be read and noted.

If there is cylinder power, the dots are blurred into lines which can be brought into 2 foci. The **most positive** (or least negative) is the spherical power, and the **difference between the 2 powers** is the cyl power. The axis is the axis for the **more negative** power reading. We will normally record lens powers in **MINUS CYL FORM**.

American crossed line target

This has two, crossed lines, instead of the circle of dots, which can be rotated through 180° so that we can determine cylinder axis. Again, a spherical lens will simply blur the target and can be corrected easily.

The technique is the same for both machines.

1. Place the lens in the lensmeter, and adjust the dioptre scale until it shows a well focused target (spherical lens) or until one meridian is clearly in focus (astigmatic lens) and note the power and axis. On the American system, the cylinder wheel needs to be adjusted so that the astigmatic lines are aligned.
2. Refocus to obtain the second set of lines (at 90 to the first axis) and note the power and axis again.
3. To calculate the sphero-cyl power in negative cyl form, select the more positive/less negative power as your sphere.
4. Calculate the difference between the main powers (take the sphere power from the other) remembering the power signs - this is the cylinder power. Be very careful with the maths doing this.
5. The axis is the one found with the second power (*not* the one selected as the sphere).

Example

$$+ 1.00 \times 90 \text{ and } + 3.00 \times 180$$

The second power is the more positive and is therefore chosen as the sphere power. The difference between the powers is $+ 1.00 - (+ 3.00) = - 2.00$. The axis is taken from the second, less positive power. In this case it is 90. Therefore the spherocyl power is $+ 3.00 / - 2.00 \times 9$

Example

$$+ 1.50 \times 60 \text{ and } - 2.50 \times 150$$

The first power is the more positive and is therefore chosen as the sphere power. The difference between the powers is $- 2.50 - (+ 1.50) = - 4.00$. The axis is taken from the second, less positive power. In this case it is 150. Therefore the spherocyl power is $+ 1.50 / - 4.00 \times 15$

Questions

1. $+ 2.50 \times 65$ and $+ 1.00 \times 155$ =
2. $+ 1.50 \times 85$ and $- 1.00 \times 175$ =
3. $- 3.75 \times 45$ and $- 1.00 \times 135$ =
4. plano $\times 90$ and $+ 1.75 \times 180$ =
5. $- 0.25 \times 10$ and $+ 1.50 \times 100$ =
6. $+ 6.00 \times 90$ and $- 1.00 \times 180$ =
7. $+ 10.00 \times 80$ and $+ 12.00 \times 170$ =
8. $- 1.75 \times 180$ and plano $\times 90$ =
9. $+ 3.00 \times 125$ and $- 3.00 \times 35$ =
10. $- 4.75 \times 25$ and plano $\times 115$ =

(Answers on page 42)

Note! The power of a lens can be written in three different ways

- $+ 1.00 \times 90 / + 2.00 \times 180$ - Crossed cylinder form
- $+ 1.00 \text{ DS} / + 1.00 \times 180$ - Plus cylinder form
- $+ 2.00 \text{ DS} / - 1.00 \times 90$ - Minus cylinder form

These are all the same power! The focimeter works with crossed cylinder form, and we should work with minus cylinder form.

10. Transposition

The prescription for a lens can be written in several different forms. We will consider the two most commonly used forms: the **PLUS CYLINDER** form and the **MINUS CYLINDER** form.

For both forms the lens is effectively the same, but the written form looks very different. To transpose from one form to the other -

1. The cylinder **POWER** stays the same.
2. The cylinder **SIGN** always changes.
3. The cylinder axis always changes by 90 (if less than 90 add 90, or more than 90 subtract 90 to give an axis between 1 and 180 inclusive).
4. **ADD** the old sphere power and the old cyl power (always remembering the signs) to obtain the new sphere power.

Examples

- + 1.00 / + 3.00 × 90 = + 4.00 / - 3.00 × 180
- + 5.00 / - 1.00 × 75 = + 4.00 / + 1.00 × 165
- - 6.00 / + 2.50 × 125 = - 3.50 / - 2.50 × 35
- - 3.00 / - 1.25 × 20 = - 4.25 / + 1.25 × 110
- + 2.00 / - 4.00 × 180 = - 2.00 / + 4.00 × 90
- - 1.50 / + 3.50 × 45 = + 2.00 / - 3.50

Questions

1. + 2.50 / - 1.50 × 40 =
2. + 6.00 / + 2.50 × 130 =
3. - 1.00 / + 2.00 × 55 =
4. - 3.00 / - 2.25 × 175 =
5. + 5.00 / - 4.25 × 95 =
6. + 2.25 / - 2.25 × 160 =

(Answers on page 42)

Spherical Equivalent

1. There are several reasons why we will not prescribe toric lenses.
2. This manual is not designed to teach you to refract for astigmatism very accurately. All we require from you is recognition of the presence of astigmatism. If the spherical equivalent gives good enough vision, you should prescribe this.
3. Many patients cannot tolerate cylindrical prescriptions, and experience is needed to be able to prescribe it successfully.
4. The costs involved for the patient in having toric lenses is high, and the lenses are not always readily available, so we should avoid prescribing them unless they are of sufficient benefit to the patient.

Spherical equivalent power is calculated from the sphere and cylinder powers. The resulting sphere should be tried subjectively to make sure that the patient is getting the best possible spherical correction.

A spherical equivalent must, obviously, obtain an improvement in vision over the unaided acuity! It may well produce worse acuity than the full prescription including the cyl.

RULE: Add half the cylinder power to the sphere power.

If we use the examples from above -

| Sphero-cyl | Spherical equivalent |
|--|----------------------|
| + 1.00 / + 3.00 × 90 | + 2.50 |
| + 1.00 + half (+ 3.00) = + 1.00 + 1.50 = + 2.50 | |
| + 5.00 / -1.00 × 75 | + 4.50 |
| - 6.00 / + 2.50 × 125 | - 4.75 |
| - 3.00 / -1.25 × 20 | - 3.50 or -3.75 |
| + 2.00 / -4.00 × 180 | plano |
| - 1.50 / + 3.50 × 45 | + 0.25 |

Questions (as page 26)

Answers on page 42.

11. Best Sphere

This is a subjective technique which is used to improve the prescription after retinoscopy and also can be used when the retinoscope is not available or when the retinoscope reflex is so poor that retinoscopy is impossible.

The best sphere lens is the spherical lens that focuses light onto the retina. In astigmatism, it is the *circle of least confusion* that is on the retina. (It is also the spherical equivalent of the prescription).

The best sphere is the maximum plus (or minimum minus) power lens which gives the best possible visual acuity. It is found by increasing the plus power until vision **becomes worse**, or adding minus power until the vision **does not get better**.

It is important to ask questions which offer a simple choice of answers. For example:

- Are the letters better with or without this lens?
- Are the letters clearer with or without the lens?
- Is this lens the same or less clear / worse? (plus lens)
- Is this lens the same or more clear / better? (minus lens)

Remember, we want to prevent the patient having to accommodate. We therefore give the **maximum plus** or **minimum minus**.

To find the best sphere, firstly consider the vision. If this is good, start by using a + 0.50 DS lens. If this is the same, leave this in place and keep adding more + 0.50 DS until the patient reports that the lens makes vision worse. If the vision is poor, then a power larger than + 0.50 DS should be used.

If positive lenses make the vision worse immediately, then the patient may be myopic and minus lenses should be used to improve vision in a similar way to that described above for plus lenses.

When you think you have found the best sphere you need to check that you have not over-corrected the patient. **If hypermetropic, addition of - 0.50 DS should not make vision better (the patient should report that this is the same). If myopic, then addition of + 0.50 should make vision worse.**

If the patient is uncertain of an answer it often means that there is little difference (answer = same)!

Blur Test

The + 1.00 blur test is a simple and quick screening test for low hyperopia, and also a check to ensure that you have given the correct prescription.

By placing a + 1.00 DS lens in front of the patient, their visual acuity should reduce by at least 2 or 3 lines on the chart. If there is less reduction in acuity, you must re-check the prescription.

12. Retinoscopy

The retinoscope is the most important tool in refraction. It is invaluable in allowing us to assess the refractive state of the eye with little, or no, co-operation from the patient. We call this an objective method (as opposed to a subjective method where we depend on the patient to give accurate answers to our questions!).

The retinoscope is relatively inexpensive and portable, and it can be used on all types of patients. In the hands of an experienced user it may be the only way of getting a result, particularly with young children.

There are essentially two types of retinoscope - the spot and the streak. The spot, as the name suggests, projects a spot of light which can normally be focused to produce a smaller, but brighter beam. The streak projects a rectangular patch of light onto the patient's retina and this can be focused to a thin line of light. The patch can also be rotated through 360°.

Of course, the retinoscope only works if there are batteries in it and the bulb is working. Get used to the retinoscope, know how to change the batteries and, most importantly, the bulb!

When the light is shone into the patient's eye some of the light is reflected out of the eye and this you will see. This is called the retinoscopic reflex (or ret reflex). When the light is passed over the eye, the reflex will be seen to move. This movement helps us to assess the patient's refractive error. The movement can be with (hypermetropia), against (myopia) or 'scissor' (astigmatism), or no movement (emmetropia) will be seen. This direction of movement is a guide to refractive error. Also, if there are different movements in different meridians this is astigmatism.

The relative speed of movement of the reflex is also useful in determining refraction - the slower the movement, the higher the refractive error. The speed of movement does not depend on the speed of movement of the retinoscope, but *is* related to that movement.

The brightness of the reflex gives some information too. If the reflex is dull, then a high refractive error is present.

Thus we need to consider, when examining a ret reflex, the following four characteristics.

- **Direction** - is it with or against?
- **Brightness** - is it bright or dull?
- **Speed** - is it fast or slow?
- Is the movement the same in all meridians?

A **with** movement is corrected with a **positive** lens.

An **against** movement is corrected with a **negative** lens.

Scissors movement is corrected with a combination of spherical and cylindrical lenses, with the cyl axis aligned correctly.

Basic Principles

Retinoscopy is done at arms length from the patient, around 50 to 66 cm. This is known as the **working distance** and is used for convenience and accuracy.

The aim of retinoscopy is to find the lens that will stop the ret reflex moving. This is done by adding lenses to make the reflex brighter, move faster, and, ultimately, stop (or neutralise) the movement. This point is known as the **end point** or **point of reversal**. *To do this the patient must look at distant object (to prevent accommodation) and retinoscopy must be performed as close as possible to the patient's visual axis.*

At the end point, the patient's eye is focused on the retinoscope - in other words the patient is now myopic.

The working distance is now of importance as we can calculate how myopic the patient is. Using the formula $P = 100 / f$ we know that, if the working distance is 66 cm, we need a 1.50 DS lens. Likewise, if the working distance is 50 cm, the working distance lens will be 2.00 DS. This is the working distance lens, and we need to subtract this from our result.

Clinical Retinoscopy

1. Place your working distance lens ('retinoscopy lens') in the trial frame.
2. Before testing an eye, the other eye **MUST** be blurred to prevent accommodation. This only takes a few seconds as the movement in all meridians must be **against** in this eye - add positive sphere until this is the case.
3. In a darkened room, assess the ret reflex horizontally, vertically and then each diagonal.
4. If 'with' movement is seen, add plus sphere until all with movement is removed. If 'against' movement is seen, add minus sphere until you just see a 'with' movement in one meridian.
5. In clinical practice, a 'with' movement is seen more easily than an 'against'. The end point is almost impossible to recognise. Thus, the end point is found when adding + 0.25 produces an 'against' movement and addition of - 0.25 produces a 'with' movement. Alternatively, moving slightly closer to the patient (shortening your working distance) should produce a 'with' movement, and moving away should produce an 'against' movement. **You should always obtain this reversal as proof that you have reached and passed the end point/point of reversal.**
6. If the reflex is the same in all meridians we have reached the end of the retinoscopy routine for this eye when the point of reversal is found. If there is astigmatism, however, we need to correct the more positive/least negative meridian with a sphere, leaving the other meridian with an 'against' movement (i.e. simple myopic astigmatism). Note the *axis* of the against movement as this is the *axis* of the astigmatism.
7. With astigmatism, we now need to correct the cylinder element of the prescription. This 'against' movement should now be neutralised using a minus cylinder lens, **leaving the sphere in place.**

8. You should now have in the trial frame the working distance lens, a sphere and a cyl. Check the reflex in all meridians to ensure that all astigmatism has been corrected and that there are no remaining movements. The cyl axis may need to be modified.
9. Repeat the procedure for the other eye.
10. Remove the working distance lenses from the trial frame and proceed to subjective refinement of the prescription.

THINK

Is the movement with or against?

- If the movement is **WITH**, add a **POSITIVE** lens
- If the movement is **AGAINST**, add a **NEGATIVE** lens

Is the reflex bright or dull?

- If the reflex is dull, then start with a relatively large power
- If bright a smaller power can be used

Is the movement fast or slow?

- If the movement is fast, then a smaller lens power should be used
- If slower, a larger power should be used

Is the movement the same in all meridians?

- Astigmatism!

Note: The decision of which power to use is a matter of experience and guess-work!

13. The Crossed Cylinder Lens

A **crossed cylinder (cross-cyl, or x-cyl)** lens is used to find, subjectively, the astigmatic component of a patient's prescription. This will be after retinoscopy is done or best sphere is determined.

The cross-cyl lens is mounted in a rim with a handle. The lens is formed from a plus cyl at right angles to a minus cyl of equal power. The axis of a cross cyl is at 45° to the axes of the cyls, and this is in line with the handle. The axes of the cyls are marked, and normally engraved with their powers.

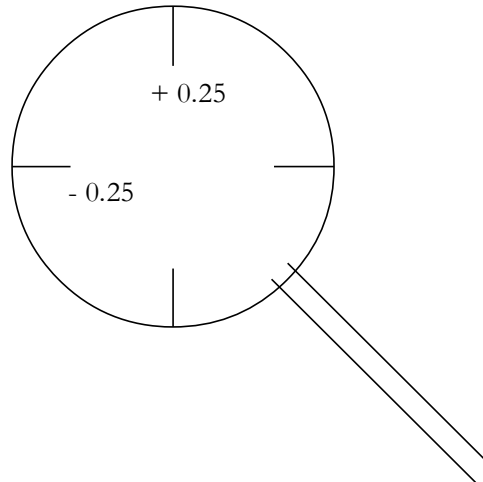


Figure: The Jackson Crossed Cylinder.

The markings refer to the axes of the cylinders. This is a ± 0.25 x-cyl.

Cross cyls are available in powers of ± 0.25 , ± 0.50 and ± 1.00 .

A ± 0.50 cross cyl has the following power

- + 0.50 DC / - 0.50 DC
- + 0.50 DS / -1.00 DC
- - 0.50 DS / + 1.00 DC

These are all the same power!

What is the spherical equivalent of a ± 0.50 cross-cyl?

(Answer on page 42)

Crossed Cylinder Technique

The technique is very simple and quick, but very hard to describe so the following text will make it look far worse than it actually is! We are mainly concerned with the minus axis in refraction.

Technique for axis

After retinoscopy we need to check the power and axis of the astigmatism found. This is done in a systematic way, as follows:

1. The patient should have one eye occluded (or blurred), and asked to look at a suitable target letter - rounded letters (O, U, C) are better than ones with horizontal and vertical lines (H, T, E). The 6/12 or 6/18 letter should be used, if the patient is able to see these letters clearly.
2. The sphere should be reduced by 0.50 DS (add - 0.50 DS) to allow some accommodation for this test.
3. Place the cross cyl with the **handle in line** with the axis line of the cylinder lens and rotate the x-cyl about its axis, asking the patient whether he sees the target more clearly with the first position or the second. **(Question: Is the letter more clear with lens 1 or lens 2)**
4. Move the axis of the trial lens towards the better position of the minus axis on the x-cyl. This should be about 20° movement first time, and reduced as the axis is refined.
5. Repeat the process, always making sure that the handle is lined up with the axis line of the cylinder lens.
6. When the patient reports that there is no difference between the two positions (or you are back where you started!) you have now found the axis. NOTE IT DOWN!

Technique for power

1. This time you need to line up the power markings on the x-cyl lens with the axis line of the cylinder lens. Twirl the lens as before and note if the plus or minus axis is the clearer position.
 - If PLUS is better, **reduce** the cylinder power
 - If MINUS is better, **increase** the cylinder power
2. As the cyl power is altered, so too must the sphere power in order to maintain the same spherical equivalent, e.g. if the cylinder power is increased by - 1.00 DC, you need to add + 0.50 to maintain the spherical equivalent
3. Check the VA. How does it compare to the retinoscopy VA?
4. Repeat for the other eye.

If retinoscopy has not been possible, the x-cyl can still be used after best sphere has been found.

1. Find best sphere. Add - 0.50 to allow some accommodation.
2. Twirl the x-cyl about 90°/180°. If neither position is better, try at 45°/135°. If none of these are better then there is no astigmatism.

3. If one position is better then place a - 1.00 DC at that axis. Then check the axis and power as before.
4. Repeat for the other eye.

Remember

To use the x-cyl successfully, you need to hold the x-cyl firmly, supporting your hand or arm to keep the lens steady.

Question the patient clearly - **Which is more clear - number 1 or number 2?** (or any suitable question). It is often useful to alter the number as the patient will often keep replying with the same number each time!

- Select a suitable fixation target for the patient
- To check the cylinder axis, you must place the x-cyl handle in line with the axis line of the trial lens
- To check the power, the power markings on the x-cyl must be lined up with the axis line of the cylinder lens

Depending on what you are checking, you must always orientate the crossed-cylinder lens so that it is in line with the axis of the trial lens

14. Refraction Routine

In order to assess a patient quickly and efficiently you will need to follow a systematic approach to refraction, so that you cover all the necessary tests in a logical order, and not repeat tests unnecessarily. We will, obviously, only be concentrating on the refraction aspects of your work, and you will need to sort out how this is added to your system for the general eye work.

Firstly, write everything down on the patient's record card for future reference as well as to prevent the need to repeat tests unnecessarily. By keeping a thorough record of your findings you are able to tell whether or not the patient is improving with the treatment you are giving.

1. Record vision and visual acuity with current distance spectacles, monocularly.
2. Symptoms - question the patient and record the symptoms. Assess the symptoms - are glasses likely to help?
3. Measure and record the patient's pupillary distance (PD). Adjust the trial frame to fit the patient properly.
4. Retinoscopy - use clean trial lenses!
5. Record your result and check the visual acuity monocularly.
6. Adjust the spherical power subjectively to obtain best possible visual acuity, using maximum plus (or minimum minus).
7. Use x-cyl to refine the cylindrical power and axis.
8. Record subjective refraction result and VA.
9. Check spherical equivalent subjectively and record VA with this lens.
10. Repeat for the other eye.
11. Uncover both eyes and check binocular VA - this is often a line better than monocularly.
12. Assess near vision ability. Is there presbyopia? If so, prescribe an appropriate reading addition.
13. Write out final prescription, and explain your findings and recommendations.

15. Cycloplegia

There are many drugs used in eye work. In refraction we are only concerned with cycloplegics.

Our main aim of using a cycloplegic is to prevent accommodation. There are several choices - atropine, homatropine, cyclopentolate, hyoscine and tropicamide - so which is most suitable for our needs in refraction?

We need a drug which will:

- Have rapid onset (act quickly)
- Be short acting
- Achieve maximum cycloplegia
- Be non-toxic
- Be readily available and cheap

Cyclopentolate is, actually, the most suitable of all the choices. Cycloplegia is sufficient after 20 minutes, the effects last 5 to 6 hours, and there is sufficient amount of action. It is relatively non-toxic, although there can be some adverse reactions to it.

Atropine is still used, but the effects last too long and it is far too toxic to be of safe use.

Cyclopentolate

To obtain good cycloplegia for refraction, we will normally use a 1% solution and instil one drop in each eye, repeated five minutes later. At least 20 minutes should be allowed before carrying out the refraction

There are a few side effects of cyclopentolate which are unhelpful. The main problem is the mydriasis which reveals peripheral distortions in the reflex. The central portion of the reflex is what we need to consider. Also, the cycloplegia will wear off within about 6 hours, but the mydriasis lasts for around 24 hours, which makes the patient light sensitive. The patient needs to be advised about this.

Uses of Cycloplegia

The patient will, generally, not thank you for giving them a cycloplegic! So, why is it important to use it?

The main patients who need cyclopentolate are the young, uncooperative ones. Remember that the patient needs to look in the distance whilst you do retinoscopy. Children are not going to co-operate so well! I suggest that, if the patient is not cooperating, use cyclopentolate.

There is some discussion as to how much of the cycloplegic correction should be given, as the muscle tonus around the lens may be affected. I consider that it is unnecessary to modify the result for young children as their world is close to them and not far away. However, some people will reduce the prescription by 0.50 DS or even 1.00 DS. For atropine refractions, allowance does need to be made. Again, opinion varies. I suggest allowing 1.00 DS, or better still, don't use atropine for refractions!

If there is a convergent squint then cyclopentolate **MUST** be used to find the full refractive error as the squint may be due to high hypermetropia. The full correction should be given in these cases.

As the patient gets older there is much less need to use cyclopentolate, and there are, indeed, good reasons **NOT** to. As cyclopentolate dilates the pupil, it is possible that the drainage route for aqueous can be blocked causing an increase in the intraocular pressure - i.e. you could give them an attack of acute glaucoma.

Note

It is often necessary to maintain your own supply of cyclopentolate. It should be available locally, or you may need to order it. Some pharmacies will sell it under a 'trade name', but the ingredients will always include cyclopentolate.

16. When to Prescribe

- We have touched on this subject already. Glasses are not necessarily the best treatment for a patient. Always bear in mind that the glasses must be of sufficient benefit to the patient to be worth the money spent on them. Do not give glasses to satisfy a patient's demands unless they will help anyway.
- Low hyperopes, especially the young, can cope without glasses as they can easily accommodate to overcome the error. Certainly + 0.25 and + 0.50 (and perhaps even + 0.75) should not be prescribed.
- Remember that low myopes will survive without reading glasses, and - 0.25 (and even - 0.50) should not be prescribed.
- Remember that a person who does not read does not need reading glasses, but may need glasses for sewing, knitting, sorting rice, etc.
- Do not encourage people to have bifocals if their distance prescription is small.
- If the astigmatic element is high, and spherical equivalent is not satisfactory, then refer. Warn the patient first that these glasses will be more expensive, otherwise the referral may be a waste of time.
- If you obtain less than one line improvement in vision there is no real benefit in prescribing new glasses.
- Aim for 6/9 or better.

17. Optical Lenses

Lenses are available in glass and plastic. Plastic lenses scratch too easily and should be avoided. Glass lenses are heavier and more fragile, but will last much longer than plastic. In time the situation may change, as optical plastic is now much more resistant to scratching and can be coated to improve this further, but this is expensive. Photochromic lenses are always made in glass and are more expensive than ordinary, 'white' glass. This is the best way of tinting lenses as the tint is in, rather than coated onto, the lens. In other words, you cannot tint a white glass lens.

The following lens powers are standard in CBM optical workshops in white glass only.

| | | | |
|----------|----------|----------|----------|
| +/- 1.00 | +/- 1.50 | +/- 2.00 | +/- 2.50 |
| +/- 3.00 | +/- 3.50 | + 9.00 | + 10.00 |
| + 11.00 | + 12.00 | + 13.00 | + 14.00 |

Ordering outside this range will lead to delays in the return of the order and also increased expense for the patient as these lenses will have to be ordered specially.

Frames

Some optical workshops supply a standard frame which comes in a range of sizes. The CBM standard frame is the PS 80 and is available in several sizes and colours, ranging from 40 to 52 mm eye size and several bridge sizes. The colours are smoke (grey), tan (brown), lilac and champagne (yellow). Smoke and tan are the most popular colours in Africa.

18. Spectacle Dispensing

- It is very important to select a suitable size of frame for the patient. The PS 80 frame (CBM standard) comes in several sizes to help manage this.
- You must always state the patient's pupillary distance (PD) and near centration distance (CD, otherwise called the near PD) on the order. Although this is not normally a problem, in higher powers and bifocals it is essential.
- Choice of lens is fairly limited, but you need to know the advantages and disadvantages of bifocals, in order to offer the patient the best possible correction.
- The side length needs to be adjusted to make the glasses fit the patient on collection.
- Order writing **MUST** be clear. Remember the correct notation.
- Avoid large frames if the prescription is big as the glasses will be heavy and the lenses much thicker.
- If a patient has two pairs of glasses (distance and reading) it is useful to supply different colour frames to help identify what the glasses are for.

Answers to Questions

Neutralisation (from page 26)

1. $+ 2.50 \times 65$ and $+ 1.00 \times 155 = + 2.50 / - 1.50 \times 155$
2. $+ 1.50 \times 85$ and $- 1.00 \times 175 = + 1.50 / - 2.50 \times 175$
3. $- 3.75 \times 45$ and $- 1.00 \times 135 = - 1.00 / - 1.75 \times 45$
4. plano $\times 90$ and $+ 1.75 \times 180 = + 1.75 / - 1.75 \times 90$
5. $- 0.25 \times 10$ and $+ 1.50 \times 100 = + 1.50 / - 1.75 \times 10$
6. $+ 6.00 \times 90$ and $- 1.00 \times 180 = + 6.00 / - 7.00 \times 180$
7. $+ 10.00 \times 80$ and $+ 12.00 \times 170 = + 12.00 / - 2.00 \times 80$
8. $- 1.75 \times 180$ and plano $\times 90 =$ plano $/ - 1.75 \times 180$
9. $+ 3.00 \times 125$ and $- 3.00 \times 35 = + 3.00 / - 6.00 \times 35$
10. $- 4.75 \times 25$ and plano $\times 115 =$ plano $/ - 4.75 \times 25$

Transposition (from page 27)

1. $+ 2.50 / - 1.50 \times 40 = + 1.00 / + 1.50 \times 130$
2. $+ 6.00 / + 2.50 \times 130 = + 8.50 / 2.50 \times 40$
3. $- 1.00 / + 2.00 \times 55 = + 1.00 / - 2.00 \times 145$
4. $- 3.00 / - 2.25 \times 175 = - 5.25 / + 2.25 \times 85$
5. $+ 5.00 / - 4.25 \times 95 = + 0.75 / + 4.25 \times 5$
6. $+ 2.25 / - 2.25 \times 160 =$ plano $/ + 2.25 \times 70$

Spherical Equivalent (from page 28)

1. $+ 2.50 / - 1.50 \times 40 = + 1.75$
2. $+ 6.00 / + 2.50 \times 130 = + 7.25$
3. $- 1.00 / + 2.00 \times 55 =$ plano
4. $- 3.00 / - 2.25 \times 175 = - 4.00$ or $- 4.25$
5. $+ 5.00 / - 4.25 \times 95 = + 3.00$ or $+ 2.75$
6. $+ 2.25 / - 2.25 \times 160 = + 1.25$ or $+ 1.00$

The Crossed Cylinder Lens (from page 33)

Spherical equivalent of a crossed cylinder lens = plano!

Acknowledgements

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