ophthalmic optics files

5. THE DIFFERENT TYPES OF OPHTHALMIC LENSES
CHAPTER 3

Different Types of Ophthalmic Lenses

1. Single Vision Lenses (continued)

Prismatic Lenses

• The prism
  - definition
  - trial frame prisms
  - prism scales (Behrens)
  - optical properties
  - small angle prisms
  - vision through a prism
  - other uses of a prism
  - units of power and measurement
  - combining 2 prisms

• Prismatic effect made on a lens by decentration

• Uncut spherical and astigmatic lenses
  - Stock lenses
  - Surfaced lenses
  - Tolerances on centration of uncut lenses
  - prismatic lenses decentred at the edging stage

• Fresnel prisms
  - “press on”
Prisms in Ophthalmic Optics

Although less frequently used than spherical or astigmatic lenses, prismatic lenses are nevertheless of interest as:

- they are often used for measuring eye movements, vergences, ductions, phorias and squints. Their function will be described in the chapter on Basic Data.
- they are used for the re-education of binocular vision. They can be used as plano or press-on prisms or incorporated into a spherical or astigmatic correction.
- they are used in the design of a large number of optical instruments.

N.B.: Prismatic effects must be considered in the interpretation of the peculiarities of certain types of lenses (e.g. multifocals) and in the centration of single vision lenses.
Prismatic Lenses

A prism deviates an incident ray of light. The angle of deviation $D$ is measured between the direction of the incident ray before it reaches the prism and the emergent ray.

The prism

- **Definition**

  A prism is a piece of transparent material whose refracting surfaces are inclined at an angle to each other. The **apex** is the intersection of the two refracting surfaces. The surfaces forming the apex are inclined at an angle $\hat{A}$. The **principal section** is the plane of surfaces perpendicular to the apex. The **base** is the side of the triangle opposite angle $\hat{A}$ (the apical angle) (on Fig. 2, BC).

  A prism is often represented by its principal section ABC (see Fig. 2). The prism apex is an angle $\hat{A}$ and the prism base is the side which subtends angle $\hat{A}$.

  In practice, the apex is the thinnest edge, the base the thickest.
**Prism formulae**

Let us take a prism of apical angle A and refractive index n. An incident ray of light falls on the first surface, is refracted as it enters the prism following II' by which it reaches the second surface which it leaves along I'R. Prism formulae are those enabling us to follow the path II'R of the ray of light.

1) The law of refraction (Snell's Law) states that 
\[ n \sin i = n' \sin i' \]
which, when applied to Fig. 3 becomes 
\[ \sin i = n \sin r, \text{ as the prism is in air } n = 1 \]

2) The law of refraction at I' 
\[ \sin i' = n \sin r' \]

3) The relationship between r, r' and A 
\[ r + r' = A \]

4) The angle of deviation D experienced by the incident ray of light 
\[
D = i - r + i' - r' \\
D = i + i' - (r + r') \\
D = i + i' - A
\]

**Small angle prisms**
when the sine and the angle can be taken as equal 
\[ i = nr, i' = nr' \]
\[ r + r' = A \]
\[ D = nr + nr' - A = nA - A \]
\[ D = A(n - 1) \]
when \( n = 1.5 \) 
\[ D = \frac{A}{2} \]

**Numerical examples**

For a given prism, for example, where \( A = 60^\circ \) and \( n = 1.5 \), one may successively calculate \( r, r', i' \) and \( D \) for different values of the angle of incidence \( i \), between \( 20^\circ \) and \( 90^\circ \). The results are tabulated below.

<table>
<thead>
<tr>
<th>i</th>
<th>( \sin \frac{r}{n} - \frac{1}{n} \sin i )</th>
<th>r</th>
<th>( r' - A - r' )</th>
<th>( \sin i' = n \sin i' )</th>
<th>i'</th>
<th>D = i + i' - A</th>
</tr>
</thead>
<tbody>
<tr>
<td>20°</td>
<td>0.342</td>
<td>13°</td>
<td>47°</td>
<td>&gt; i</td>
<td></td>
<td>impossible</td>
</tr>
<tr>
<td>30°</td>
<td>0.500</td>
<td>21°</td>
<td>39°</td>
<td>0.943</td>
<td></td>
<td>70°</td>
</tr>
<tr>
<td>40°</td>
<td>0.588</td>
<td>23°</td>
<td>37°</td>
<td>0.903</td>
<td></td>
<td>65°</td>
</tr>
<tr>
<td>50°</td>
<td>0.766</td>
<td>31°</td>
<td>29°</td>
<td>0.727</td>
<td></td>
<td>47°</td>
</tr>
<tr>
<td>60°</td>
<td>0.866</td>
<td>35°</td>
<td>25°</td>
<td>0.634</td>
<td></td>
<td>40°</td>
</tr>
<tr>
<td>70°</td>
<td>0.940</td>
<td>39°</td>
<td>21°</td>
<td>0.587</td>
<td></td>
<td>40°</td>
</tr>
<tr>
<td>80°</td>
<td>0.985</td>
<td>41°</td>
<td>19°</td>
<td>0.489</td>
<td></td>
<td>29°</td>
</tr>
<tr>
<td>90°</td>
<td>1.000</td>
<td>42°</td>
<td>18°</td>
<td>0.463</td>
<td></td>
<td>28°</td>
</tr>
</tbody>
</table>

**Variations of angles r, r', i' and D when A = 60° and n = 1.5 showing that D passes through minimum.**
Under certain conditions the ray is totally internally reflected and will not leave the prism through the opposite face.

Critical angle (Fig. 4)
When a ray of light passes from air into a more refractive medium (glass e.g. n = 1.52), it is refracted according to the law:
\[
\sin i = n \sin r \\
i = 90^\circ, \quad r = C \\
\sin 90^\circ = n \sin C \\
l = n \sin C \\
\sin C = \frac{l}{n} \\
\text{if } n = 1.52, \quad \sin C = \frac{1}{1.52} \quad C = 41^\circ
\]

Total internal reflection
If a ray of light passes from glass into air, it would make an angle of emergence of 90° for the angle of incidence C. But if the angle of incidence is greater than C, the ray will not emerge but will be totally internally reflected.

In Fig. 5, for example $\theta = 60^\circ$; $n = 1.52$; $C = 41^\circ$

This shows a grazing incident ray. If $i$ is given its maximum value of 90°, $i'$ will be its minimum value of 36°.

This is a grazing emergent ray. If $r'$ is 36°, the ray will be reflected against the third surface.
**Minimum deviation (Dm)**

The deviation is at a minimum when the ray of light inside the prism is perpendicular to the plane which bisects the apical angle of the prism (Fig. 6).

In this case:

\[ i = i' \quad \text{and} \quad r = r' = \frac{A}{2} \]

This property is used when taking spectrometer readings.
• **Trial prism frames**

These are two plano prisms, usually round, of diameter 35 to 40 mm, (Fig. 7), mounted in holders. Two small marks show the base apex direction, i.e. the line joining the thinnest side, the apex, to the thickest, the base. Schematically, such small angle prisms are represented by a section giving a small rectangular triangle (Fig. 8).

• **Prism Bar** (Fig. 9)

These prisms are often easier to use than the single prism of a trial case, the prism is comprised of a series of prisms of increasing power. The base and the apex lines of the prisms are all orientated in the same direction. Separate prism bars are available, one with the bases orientated vertically, the other horizontally.

• **Optical properties**

By applying the laws of refraction to each surface it is possible to determine the path of a ray of light passing through the prism (Fig. 10).
The small angle prism
This relationship can be directly established when considering an incident ray of light arriving perpendicular at the first refracting surface and entering the prism of refractive index n without deviation (i = 0; r = 0) (Fig. 11).
This ray of light will meet the second surface at i' making the angle equal to A, measured between the ray and the normal to the face. It emerges from the prism in direction l'R whilst making an angle of i' with the normal to that surface NN'. By applying the law of refraction at l',
\[ n \sin A = \sin i' \]
and as the angles are small
\[ nA = i' \]
the deviation, as is shown by Fig. 11, is thus:
\[ D = i' - A \]
therefore
\[ D = nA - A = A(n - 1) \]
and if \( n = 1.5 \), \( D = \frac{A}{2} \)

White light spectrum
White light is comprised of all the colours of the visible spectrum, each colour corresponding to a specific wavelength. On refraction, each wavelength is deviated by a different amount, the shorter the wavelength, the greater the deviation will be, so that violet is deviated more than red.
A narrow beam of light, produced by a slit, will demonstrate the visible spectrum which can be projected onto a screen (Fig. 12).

Dispersion of white light by a glass prism.
**Small angle prisms**

In practice, when the apical angle is small, we can replace the sine by the angle in radians. The angle of deviation $D$ is half angle $\frac{\alpha}{2}$ when $n = 1.5$

$$D = \frac{\alpha}{2}$$

Thus a prism with an angle of 6° produces a deviation of 3° (Fig. 13).

The dispersion of white light is only minimal and can be ignored, but objects viewed through a small prism will be edged with colour.

For some squints, prisms with large apical angles are required, in which case, it is not possible to assume that the prism is "thin".

---

**Vision through a prism**

*Image of an object point P*

With an emmetropic eye viewing a distant point $P$, the image is formed at $P'$ on the retina. If a prism is placed in front of the eye, the rays, as they are deviated downwards, appear to come from point $P''$, i.e. the image of $P$ seen through the prism appears to move towards the apex (see Fig. 14).

---

For example: for a 30° prism, the deviation is not $\frac{\alpha}{2}$, i.e. 15° but 17°.

(The general formula needs to be applied to obtain the true value of deviation.)
To view P, the eye rotates towards the apex of angle $\alpha$ equal to the angle of deviation $\frac{A}{2}$.

This ensures that the image is re-aligned onto the fovea F. This explains why a prism in front of each eye with bases turned inwards, will cause the eyes to diverge and when the bases turned outwards, the eyes will converge.

- Other applications for prisms

In spectrosopes or spectrographs prisms are used to split up incident light. In other instruments they deviate rays of light in prescribed directions. Often applying the characteristics of total internal reflection (Fig. 16).
The diagram shows how total internal reflection by prisms, is used in optical instruments.

Fig. 17 A prism used in prism binoculars

Fig. 18 A roof prism

Fig. 19 Pentagonal prism (Pentaprism)
(Frequently used in SLR cameras)
• Units of prism power and measurement (tolerances)

- The prism degree is a unit of apical angle. A prism of 6° is a prism whose apex angle is 6° or which subtends an angle of 6°. It gives a deviation of 3° (if n = 1.5). Prisms for trial frames and prism scales are sometimes calibrated in prism degrees.

- The prism dioptr is a unit of prism deviation. A prism of 1 prism dioptr (1 △) gives a linear displacement of 1 cm on a scale placed at 1 m, or 5 cm if it is placed at 5 m etc. See the example for a 4 △ prism (Fig. 20).

![Diagram of a 4 dioptr prism](image)

- Relationship between the prism degree and the prism dioptr

For a material of refractive index 1.5 the following holds true:
9 △ = 10° (approximately)
the margin of error when interchanging degrees and dioptries is of the order of 10%, which is negligible as long as small angle prisms are being used.

Focimeter measurement
If no lens is being measured, the target of the instrument is focussed on the centre of the crosslines. When a prismatic lens is placed in the instrument, the target will appear displaced (Fig. 21). The position of the centre of the target will indicate the power of the prism in prism dioptries. This can be read from the focimeter scale. The displacement of the target is in the direction of the base of the prism.

![Diagram of focimeter measurement](image)

- Orientation of prisms

To orientate a prism in front of the eye, one would choose a reference system. Usually the Tabo chart is used because of the similarity with the notation of the axis of a cylindrical correction. The sense of the base on this chart is indicated with an arrow or with the mention up or down to describe which half of the semi-circle is being considered.

![Diagram of prism orientation](image)

<table>
<thead>
<tr>
<th>Prism power (△)</th>
<th>Prism power tolerance (△)</th>
<th>Prism axis tolerance (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 1.5</td>
<td>± 0.12</td>
<td>8</td>
</tr>
<tr>
<td>1.75 to 3.00</td>
<td>± 0.25</td>
<td>6</td>
</tr>
<tr>
<td>3.25 to 6.00</td>
<td>± 0.25</td>
<td>5</td>
</tr>
<tr>
<td>6.25 to 9.00</td>
<td>± 0.37</td>
<td>4</td>
</tr>
<tr>
<td>Above 9.00</td>
<td>± 0.50</td>
<td>3</td>
</tr>
</tbody>
</table>

Tolerances on base setting of bifocals and multifocals.
Relationship between degrees and prism dioptres

Let us take a prism with an apical angle of 1° and refractive index $n = 1.5$. The deviation will be $D = (n - 1)A = 0.5^\circ$ (Fig. 23).

The linear deviation of $x$ cm on a screen placed at 1 m will give us: $x = 100 \tan D$, $D = 100 \tan 0.5^\circ$

As angle $D$ is small, we can substitute the tangent with the angle expressed in radians;

$$\operatorname{tg} 0.5^\circ = 0.5 \times \frac{\pi}{180}$$

$$x \text{ cm} = 100 \times 0.5 \times \frac{\pi}{180} = 0.9 \text{ cm}$$

A $1^\circ$ prism therefore gives a deviation of 0.9 cm or 0.9 prism dioptre.

<table>
<thead>
<tr>
<th>apical angle degrees</th>
<th>prism dioptre $\Delta$</th>
<th>apical angle degrees</th>
<th>prism dioptre $\Delta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.9</td>
<td>11</td>
<td>9.6</td>
</tr>
<tr>
<td>2</td>
<td>1.7</td>
<td>12</td>
<td>10.5</td>
</tr>
<tr>
<td>3</td>
<td>2.6</td>
<td>13</td>
<td>11.4</td>
</tr>
<tr>
<td>4</td>
<td>3.5</td>
<td>14</td>
<td>12.3</td>
</tr>
<tr>
<td>5</td>
<td>4.3</td>
<td>15</td>
<td>13.2</td>
</tr>
<tr>
<td>6</td>
<td>5.2</td>
<td>16</td>
<td>14.1</td>
</tr>
<tr>
<td>7</td>
<td>6.1</td>
<td>17</td>
<td>14.9</td>
</tr>
<tr>
<td>8</td>
<td>7.0</td>
<td>18</td>
<td>15.8</td>
</tr>
<tr>
<td>9</td>
<td>7.8</td>
<td>19</td>
<td>16.7</td>
</tr>
<tr>
<td>10</td>
<td>8.7</td>
<td>20</td>
<td>17.6</td>
</tr>
</tbody>
</table>

Conversion table for prism degrees and prism dioptres.

E.g. a prism with apex angle of $10^\circ$ is a prism of 8.7 prism dioptres and vice-versa (if $n = 1.5$).
Assuming two different prisms, P1 & P2, have been prescribed with the axes of both prisms perpendicular to each other.

This is found when the prescriber wishes to compensate for both a horizontal and vertical phoria. The resulting prism is represented by the diagonal of a rectangle constructed to show the two components. A vector diagram is used to obtain the result (Fig. 24).

Example:
3 \( \Delta \) Base 90° = 5 \( \Delta \) Base 180° = 6 \( \Delta \) Base 35°
The combination of two prisms

Prisms of equal power
If two prisms of the same power are placed with the base apex lines in the same direction, so that the base of the first prism aligns with the apex of the second prism, the result is zero (Fig. 25A).
This method forms the basis of hand neutralising a prism.

Rotary prisms (Fig. 26)
Two prisms of the same power are mounted in a mechanical device to rotate them in opposite directions by the same amount. In this way, the power of the combination can be made to vary from zero power (Fig. 25A) to the sum of the two prisms (Fig. 25B). The resultant base apex direction remains constant. The orientation of the resultant can be adjusted by rotating the complete unit.
Rotary prisms are usually found on refractor heads.

Unequal prisms or prisms of any orientation
This rarely occurs in practice though the solution can be found by the use of a vector diagram, by calculation or by putting the lens combination on the focimeter, when this is possible.
Compounding two prisms $P_1$, $P_2$ making an angle of $\theta$ between them

Let Ox be an axis passing through $P_1$; Oy is drawn perpendicular to Ox (Fig. 27).

The parallelogram constructed on $OP_1$ and $OP_2$ gives the resultant $P$ (represented by the diagonal $OP$) making an angle of $\alpha$ with Ox.

\[
\begin{align*}
OP \cos \alpha &= P_1 + P_2 \cos \theta \\
OP \sin \alpha &= P_2 \sin \theta
\end{align*}
\]

These relationships are obtained by projecting $OP$ on to the axes Ox and Oy. By squaring these two equations and summing them whilst bearing in mind that

\[
\sin^2 \alpha + \cos^2 \alpha = 1, \quad \sin^2 \theta + \cos^2 \theta = 1
\]

we get

\[
OP^2 = P_1^2 + P_2^2 + 2P_1P_2 \cos \theta
\]

and therefore

\[
OP = \sqrt{P_1^2 + P_2^2 + 2P_1P_2 \cos \theta}
\]

Then, by combining these two equations, using \(\frac{\sin \alpha}{\cos \alpha} = \frac{P_2 \sin \theta}{P_1 + P_2 \cos \theta}\)

**Example:**

What is the resultant of the combination:

4 $\triangle$ Base $30^\circ = 6 \triangle$ Base $70^\circ$ (standard notation)

Let $P_1 = 4 \triangle$; $P_2 = 6 \triangle$; $\theta = 70^\circ - 30^\circ = 40^\circ$

\[
\begin{align*}
OP &= \sqrt{16 + 36 + 48 \times 0.766} = 9.4 \triangle \\
\tan \alpha &= \frac{6 \times 0.643}{4 + 6 \times 0.766} = 0.45 \\
\alpha &= 24^\circ
\end{align*}
\]

returning to standard notation, the resultant is orientated at $30 + 24 = 54$

The same solution would be reached using a graphical construction (Fig. 28).

If two prisms are placed at $90^\circ$ to each other (Fig. 29)

\[
OP = \sqrt{P_1^2 + P_2^2}
\]

\[
\tan \alpha = \frac{P_2}{P_1}
\]

These expressions follow from those shown above but with $\theta = 90^\circ$, and therefore $\cos \theta = 0$ and $\sin \theta = 1$
Prismatic effect obtained by the decentration of a lens with two spherical or astigmatic surfaces

Spherical lenses
As a rule, when a ray of light traverses any spherical lens, it follows exactly the same path as it were traversing a prism whose refracting surfaces $T_1$ and $T_2$ were tangential to the curved surfaces of the lens at the points of incidence $l_1$ and emergence $l_2$ (Fig. 30). From this we may conclude that:

- A spherical lens can be considered as a series of prisms where the power increases from the centre towards the edge and where the bases point towards the optical centre of a converging (positive) lens and away from it if it is a diverging (negative) one.

At the optical centre, the tangents to the lens surface are parallel and therefore any ray of light passing along the axis will experience zero prism.

- For any given lens, the prismatic effect increases the further we move from the optical centre (Fig. 31).
The prismatic effect produced at a point on a spherical lens

![Diagram of prismatic effect on convex and concave lenses](image)

**Convex lens**  **Concave lens**

NB: the deviations are in opposite directions

---

**The prismatic effect produced by a spherical lens**

The prismatic effect \( P \) can be expressed as the power of the lens in dioptres multiplied by the distance from the optical centre to the point being expressed, in cms.

\[
i.e. \ P = C \times F
\]

e.g. for a point 1 on a \(-6.00\)D lens which is situated 0.5 cm from the optical centre, the prismatic effect is

\[
P = 0.5 \times 6 = 3 \Delta
\]

---

**The prismatic effect produced by a cylinder**

The axis of a cylinder can be regarded as a series of optical centres. Perpendicular to the axis is the power meridian. The prismatic effect at any point on the cylinder can be expressed as the power of the cylinder \( x \) the distance along a line perpendicular to the cyl axis from the point to the axis.

---

**The prismatic effect at a point on an astigmatic lens (sph & cyl)**

The prismatic effect on a sph/cyl lens can be regarded as the sum of the cylindrical and spherical components.
Value and direction of the prismatic effect made by a decentralation of d cm

The deviation of a ray of light in $\Delta$ is measured on a scale at 1 m. The similar triangles IOR and ISF give us

$$\frac{e \text{ (cm)}}{1 \text{ (m)}} = \frac{d \text{ (cm)}}{1 \text{ (m)}}$$

but

$$\frac{1}{1 \text{ (m)}} = F' \text{ (D)}$$

and therefore

$$\frac{e \text{ (cm)}}{1 \text{ (m)}} = e (\Delta) = d \text{ (cm)} F \text{ (D)}$$

as $e (\Delta)$ is usually notated as $P$ we get the well known equation $P = d \cdot F$.

When the lens is available, the simplest method is to take measurements directly with a micrometer.

But we may want to know the prismatic effect at any point of an astigmatic lens for which we only have the Rx. In this case a graphical solution is simpler. The method is as follows:

1. Draw in the horizontal and vertical axes which will intersect at 0 the optical centre of the lens.

2. Locate the two power meridians $P_1$ and $P_2$.
3. Mark point at which the prismatic effect is to be found, using a suitable scale.
4. Resolve the decentralation onto the two power meridians $P_1$ and $P_2$ parallel to the 2 principal meridians.
5. Measure the resultant decentralation along each of the power meridians.
6. Calculate the prismatic effects corresponding to those decentralations.
7. Transfer the values thus obtained to the principal meridians in the correct direction depending on the base direction found, i.e. opposite to $d$ if $F$ is $+ \text{VE}$ and vice-versa, if $- \text{VE}$.
8. Resolve the two oblique prisms to a single resultant prism, which is then measured using a ruler and a protractor. If the result is required in the more usual form where it is expressed as the horizontal and vertical components. This resultant can be resolved to the horizontal and vertical axis.
9. Result: the resultant prismatic effect is the diagonal of the rectangle constructed on $e_1$ and $e_2$ for which we must use scale I. Its direction may be measured using a protractor. The direction may be measured using a protractor set along the horizontal axis at $0^\circ$ (Fig. 35).
**Calculation**

The method is as follows:

1. Resolve the decentration $d$ along the 2 power meridians, $P_1$ and $P_2$.

2. Calculate the prismatic effects $P_1$ and $P_2$ using the relationship $P = d \ (\text{cm}) \times F \ (\text{dioptres})$

   Plot these prismatic effects as shown on Page 19. A decentration along a plus meridian gives a prismatic effect with its base in opposite to the direction of the decentration; and vice versa if the power is negative.

3. Combine these two prismatic effects as shown on the diagram.

   e.g. a patient is wearing the following prescription (Fig. 36)

   - Right Eye = $-2.00 \/ / -1.00 \times 160^\circ$
   - Left Eye = $-3.50 \/ / -1.50 \times 30^\circ$

   The distance between the pupils is 62 mm, but the lenses are mounted centrally in a frame with a datum centre distance of 68 mm. What is the prismatic effect experienced by the patient?

---

![Figure 36](image_url)

**Fig. 36**

![Figure 37](image_url)

**Fig. 37**

![Figure 38](image_url)

**Fig. 38**
Right eye

\[ d_1 = 3 \cos 20^\circ = 3 \times 0.940 = 2.82 \text{ mm} \]
\[ d_2 = 3 \cos 70^\circ = 3 \times 0.342 = 1.036 \text{ mm} \]
\[ P_1 = 0.282 \times 2 = 0.564 \Delta \]
\[ P_2 = 0.1036 \times 3 = 0.311 \Delta \]
\[ P = \sqrt{0.564^2 + 0.311^2} = 0.65 \Delta \]
\[ \tan \alpha = \frac{0.311}{0.546} \Rightarrow \alpha = 28^\circ \]

when measured from horizontal axis \( \alpha' = 28 - 20 = 8^\circ \)

the prismatic effect for the right eye is:

\[ P_R = 0.65 \Delta \text{ base up and in along axis } 8^\circ \]

Left eye

\[ d_1 = 3 \cos 30 = 3 \times 0.866 = 2.60 \text{ mm} \]
\[ d_2 = 3 \cos 60 = 3 \times 0.5 = 1.50 \text{ mm} \]
\[ P_1 = 0.26 \times 3.5 = 0.91 \Delta \]
\[ P_2 = 0.15 \times 5 = 0.75 \Delta \]
\[ P_L = \sqrt{0.91^2 + 0.75^2} = 1.17 \Delta \]
\[ \tan \alpha = \frac{0.91}{0.75} \Rightarrow \alpha = 50^\circ \]

when measured from horizontal axis \( \alpha' = 160^\circ \)

the prismatic effect for the right eye is:

\[ P_L = 0.75 \Delta \text{ base up and in along axis } 160^\circ \]

The results by calculation or a graphical solution should be the same but the graphical method is less precise (Fig. 39).

Results

Although the decentralizations take place along a horizontal line, the resulting prism bases are slightly tilted upwards on the nasal side.

In consequence, since the deviation of the prisms is inwards and upwards, there is a tendency for the eyes (wishing to maintain fixation) to diverge and track downwards, as the image seen through a prism is moved towards the apex.
Uncut spherical and astigmatic lenses

- **Stock Lenses**

These lenses are generally manufactured round and of given diameter and in such a way that the optical centre of the lens is also the geometric centre. The lens is then said to be centred. This can be checked on the focimeter. An astigmatic or spherical lens can be identified visually:
- if it is a spherical lens, its edge thickness is constant over its whole circumference,
- if it is an astigmatic lens, its edge thicknesses are identical at the 2 extremities of the axis and at the 2 extremities of the axis at 90° to it.

- **Surfaced Lenses**

A prism may have to be worked on a lens to produce the required decenteration or because it is indicated in the Rx. In this case it is individually surfaced to include, in addition to its power, the prism required.
In this case, the edge thickness of the lens will vary over its circumference. By placing the geometric centre (GC) of the lens in the centre of the aperture of the focimeter, the value can be read directly by the position of the target.

- **Tolerances on centration of uncut lenses**

The geometric centre of an uncut lens is the point of reference. The optical centre OC must be positioned within the following tolerances:

<table>
<thead>
<tr>
<th>Power</th>
<th>Deviation tolerance ( \Delta )</th>
<th>Decentration tolerance of the optical centre (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plano to ( \pm 0.50 )</td>
<td>0.12</td>
<td></td>
</tr>
<tr>
<td>from ( \pm 0.50 ) to ( \pm 2.00 )</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>above ( \pm 2.00 )</td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

for lenses of power \( 0 \) to \( \pm 0.50 \), the distance \( d = GC/OC \) can be ignored and only the resulting prismatic effect taken into account. In plano-cylindrical lenses, this is very important as decenterations along the axis (zero power), however large, does not result in any prismatic effect.

- **Prismatic lenses decentered at the edging stage**

When the lens has a high power, required prismatic effect may be obtained by decentering the lens, during edging operations. If the lens itself is available, it must be positioned on the focimeter and moved until the target centre shows the value of the prism and the direction of the axis. If the lens is not available, the problem must be solved by calculation or graphically, so that an uncut of the correct diameter may be ordered.
Having marked the lens in this position, the required decenteration can be applied to align it with the patient’s pupillary distance.
**Using a decentred uncut lens**

An uncut can be supplied decentred and as a result the effective diameter will be considerably increased. The effective uncut diameter obtained is the blank diameter + 2d.

If the distance between the pupillary centres is the same as the datum centre distance, the minimum uncut size will be:

\[
\left( \frac{\text{Datum lens size}}{2} + d \right) \times 2
\]

In this case:

\[
\left( \frac{50}{2} + 5.7 \right) \times 2 = 61.4 \text{ mm}
\]

As the person cutting the lens will require some material to form the bevel to fit into the groove in the frame, the uncut diameter chosen will be at least 62 mm.

If the pupillary distance is smaller than the datum centre distance a further decentration (d') is needed.

Uncut Diameter = \( \left( \frac{\text{Dat. lens size}}{2} + d + d' \right) \times 2 \)

---

**Lens decentration during glazing**

**Note:**

The prescription includes a prism - what is the diameter of the uncut out of which the shape can be cut (Fig. 41):

Right Eye = 3.50 Sph 2 base out.

Shape 50 x 40 determined by the choice of frame.

The decentration needed therefore is:

\[
d_{cm} = \frac{P}{F} = \frac{2}{3.5} = 0.57 = 5.7 \text{ mm}
\]
Fresnel prisms

Plano-prismatic lenses can be very thick at the base particularly when a large prism is required. Because of this, it may be difficult for them to be worn permanently, especially by a child. In this instance, a Fresnel prism may be preferred, as it is made of a series of small identical prisms placed side by side. For example, a prism of 15 Δ may be made up of 10 small prisms each having an angle giving a deviation of 15 Δ (Fig. 42).

- “press on”

These prisms are now made in a flexible plastic so that they may be attached to a glass or plastic lens.

The thickness is always about 1 mm for powers between 0.5 Δ and 30 Δ. It is the number of elementary prisms that varies. Flexible Fresnel prisms may be attached to cambered surfaces.