Brien Holden Vision Institute

ASTIGMATIC LENSES

THINK

Spherical lenses can correct hyperopia, myopia and presbyopia – but there is one refractive error that spherical lenses cannot correct, namely astigmatism.

If a person has astigmatism they will need a special type of lens to allow them to see clearly.

AIM

This unit will explain how cylindrical and sphero-cylindrical lenses focus light to correct astigmatism.

LEARNING OUTCOMES

When you have worked through this unit you should be able to:

- list the types of refractive error that astigmatic lenses can correct
- explain the difference between a cylindrical lens and a sphero-cylindrical lens
- describe the principal meridians of a cylindrical lens
- recognise the shapes of astigmatic lenses
- explain how astigmatic lenses focus light
- write and interpret the power of a sphero-cylindrical lens.

REVIEW: ASTIGMATIC LENSES

LENSES	• Light rays that enter lenses can be bent or refracted. • Spherical lenses can be plus or minus lenses. • Plus lenses converge light rays, while minus lenses diverge them. • Astigmatic lenses can be cylindrical or sphero-cylindrical lenses.
LENSES AND REFRACTIVE ERROR	• Lenses can be used to correct refractive error. • Spherical lenses correct hyperopia, myopia and presbyopia: - Plus lenses correct hyperopia and presbyopia; - Minus lenses correct myopia. • Astigmatic lenses correct astigmatism.
SPHERICAL LENS SHAPE	• Plus lenses are thicker in the middle than at the edge. • Minus lenses are thinner in the middle than at the edge.
FOCAL LENGTH	• Focal length is the distance between the lens and the focal point. • Focal length (f) is related to the power (F) of the lens: f = 1/F or F= 1/f
REFRACTIVE ERROR	• A person who has a refractive error will need to wear spectacles (glasses) or contact lenses so that they can see clearly and comfortably. This is because their eye is not the correct size and shape. • There are four main types of refractive error: myopia, hyperopia, astigmatism and presbyopia.

ASTIGMATIC LENSES

ASTIGMATIC LENSES AND THE EYE

Astigmatic lenses are used to correct the focus of the eye of people with astigmatism. Astigmatic lenses can be put into spectacle frames to help people with astigmatism see clearly.

Astigmatic spectacles also correct the focus for people who have astigmatism combined with another refractive error such as:

- astigmatism and hyperopia
- astigmatism and myopia
- astigmatism and presbyopia.

There are two types of astigmatic lenses: cylindrical lenses and sphero-cylindrical lenses.

A sphero-cylindrical lens is a cylindrical lens combined with a spherical lens.

Cylindrical and sphero-cylindrical lenses have other names also:

- Cylindrical lens = cylinder lens, cyl lens

Sphero-cylindrical lens = sphero-cylinder lens, sphero-cyl lens.

The extraocular muscles move the eyeballs to point in different directions.

ASTIGMATIC LENSES (cont.)

MERIDIANS

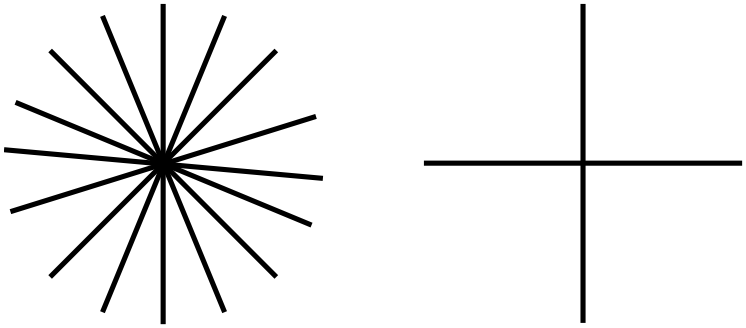
A meridian is an imaginary line which crosses a lens at its optical centre. A lens has many meridians (depending on the direction the line travels through the optical centre), but there are only two main or "principal" meridians.

The "principal" meridians of every astigmatic lens are perpendicular (at 90°) to each other. The maximum power of the astigmatic lens lies along one of these principal meridians, while the minimum power lies in the other principal meridian (perpendicular to it).

An astigmatic lens has two principal meridians:

- axis meridian (has the minimum power)
- power meridian (has the maximum power)

Usually we do not think about spherical lenses as having meridians because all the meridians of a spherical lens have the same power. Only astigmatic lenses have different powers in different meridians.



Sphere **Cylinder**

Figure 5.1: *Spherical lenses have the same power in all meridians, no matter what the direction of the meridian is. An astigmatic lens has two principal meridians and these are perpendicular to each other*

Astigmatic lenses have different powers in different meridians.
Spherical lenses have the same power in all meridians.

CYLINDRICAL LENSES

CYLINDRICAL LENSES

Cylindrical lenses (Figures 5-2A and 5-2B) may be minus or plus powered – just like spherical lenses may be minus or plus powered.

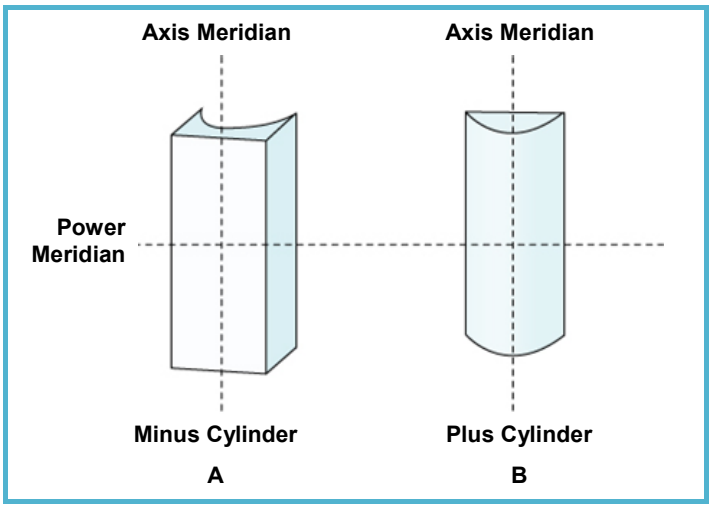


Figure 5.2: *Minus and plus cylindrical lenses*

A good way to understand the differences between cylindrical lenses and spherical lenses is to imagine cutting the lenses through their optical centres.

CUTTING SPHERICAL LENSES

Figure 5.3 shows what a plus spherical lens looks like when it is cut in half through its optical centre.

If you look at the inside of the lens (the cut surfaces) you can see that this plus spherical lens has one flat (plano) edge and one convex edge.

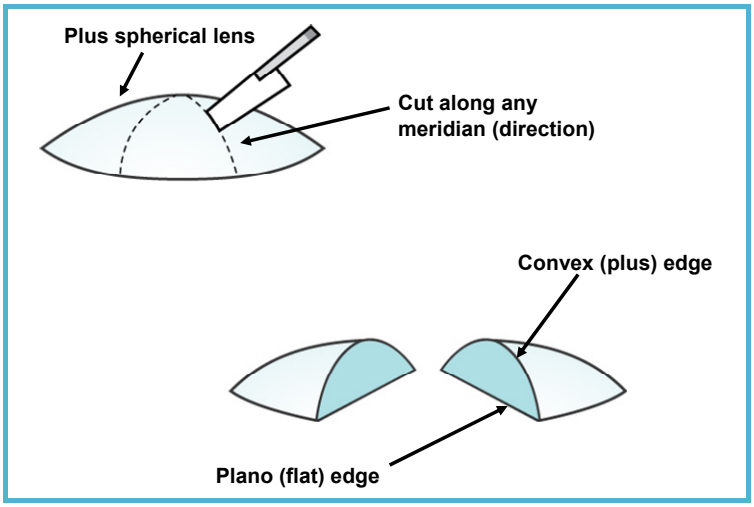


Figure 5.3: *Cutting a plus spherical lens in half to show the inside of the lens (the cut surfaces)*

We can cut the lens through the optical centre of a spherical lens in any direction (or meridian) and the shape of the two cut surfaces will always be the same. This is because a plus spherical lens has the same power in all meridians.

CYLINDRICAL LENSES (cont.)

CUTTING CYLINDRICAL LENSES (cont.)

If we cut a cylindrical lens *along the power meridian*, we get two halves as shown in Figure 5.4. You can see that the inside cut surfaces are the same shape as those for the plus spherical lens. There is a flat (plano) edge and a convex edge. This means that in this meridian there is plus focusing power.

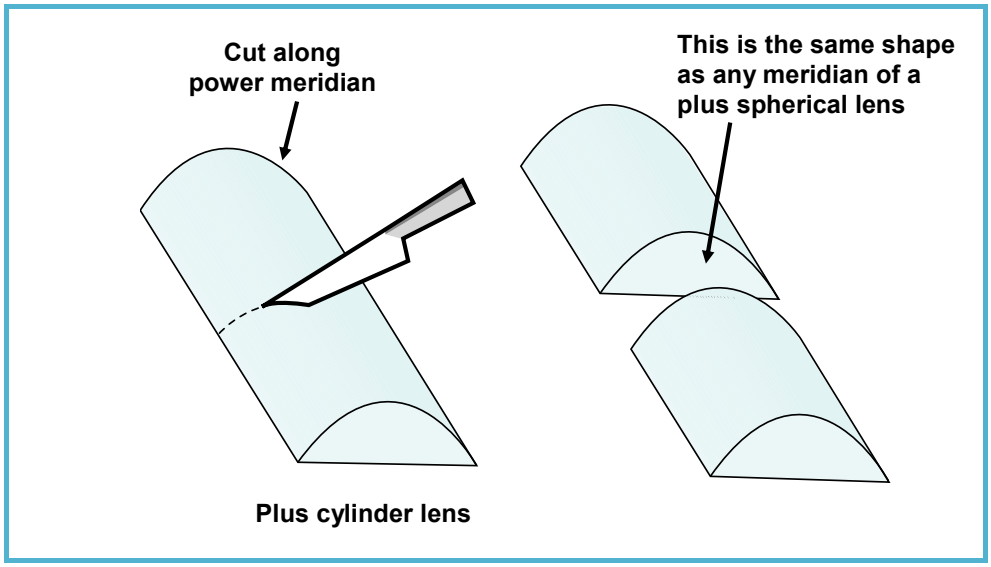


Figure 5.4: *Cutting a plus cylindrical lens in half along its power meridian*

If we now cut the cylindrical lens *along its axis meridian* (Figure 5.5) we get cut surfaces that have two flat (plano) edges. Both edges are straight and parallel, which means the axis meridian has no focusing power and no prism.

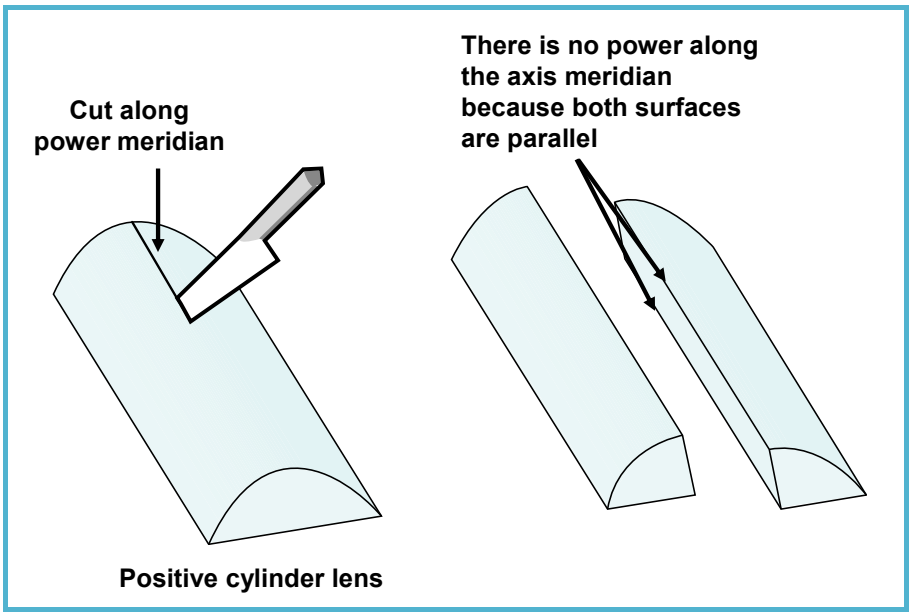


Figure 5.5: *Cutting a plus cylindrical lens in half along its axis meridian*

CYLINDRICAL LENSES (cont.)

CUTTING CYLINDRICAL LENSES (cont.)

Now, if we cut the cylindrical lens in any direction between the power meridian and the axis meridian (Figure 5.6), the upper surface becomes less curved the closer the cut is to the axis meridian. This means that the maximum power of a cylindrical lens is only along the power meridian, and the power at any meridian becomes less as it gets closer to the axis meridian where the power is zero.

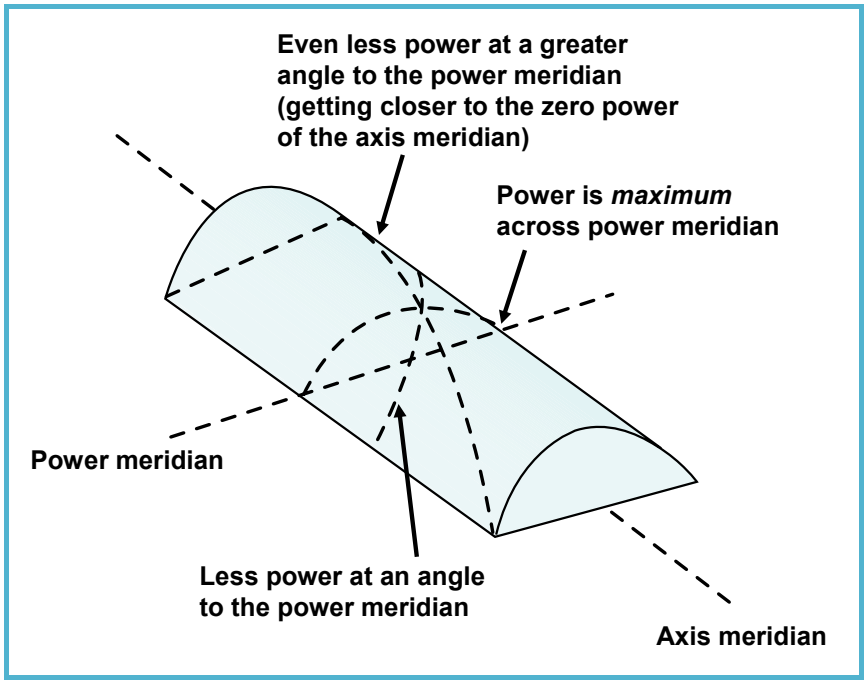


Figure 5.6: *Power and axis meridian*

REFRACTION OF LIGHT THROUGH A CYLINDRICAL LENS

Cylindrical lenses and spherical lenses refract light rays differently:

- Spherical lenses refract incident parallel light rays to a single focal point or virtual focal point.
- Cylindrical lenses refract incident parallel light rays to a focal line or virtual focal line.

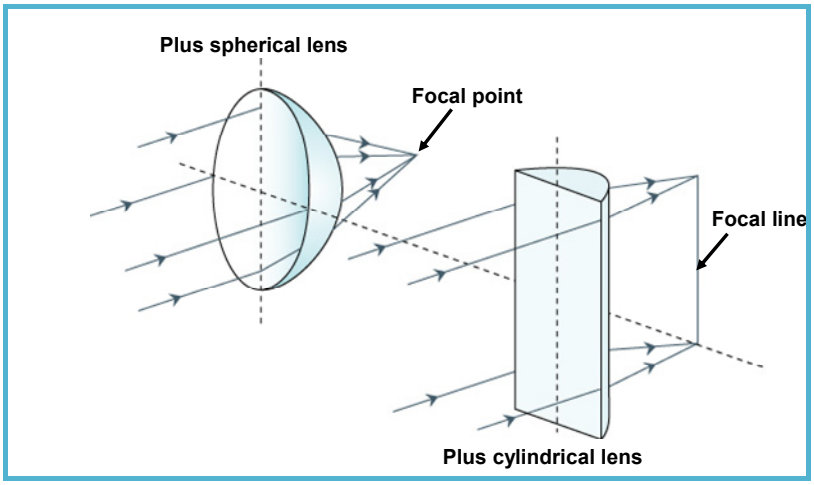


Figure 5.7: *A plus spherical lens and a plus cylindrical lens refracting incident parallel light*

Figure 5.7 shows the plus spherical lens refracting the incident parallel rays to a single focal point; while a plus cylinder lens refracts light to a focal line rather than a single focal point. You can see that the focal line is perpendicular (at 90°) to the power meridian.

CYLINDRICAL LENSES (cont.)

REFRACTION OF LIGHT THROUGH A CYLINDRICAL LENS (cont.)

Figure 5.8 shows parallel incident rays of light being refracted by a minus spherical lens and a minus cylindrical lens. The minus spherical lens forms a virtual focal point. The minus cylindrical lens forms a virtual focal line.

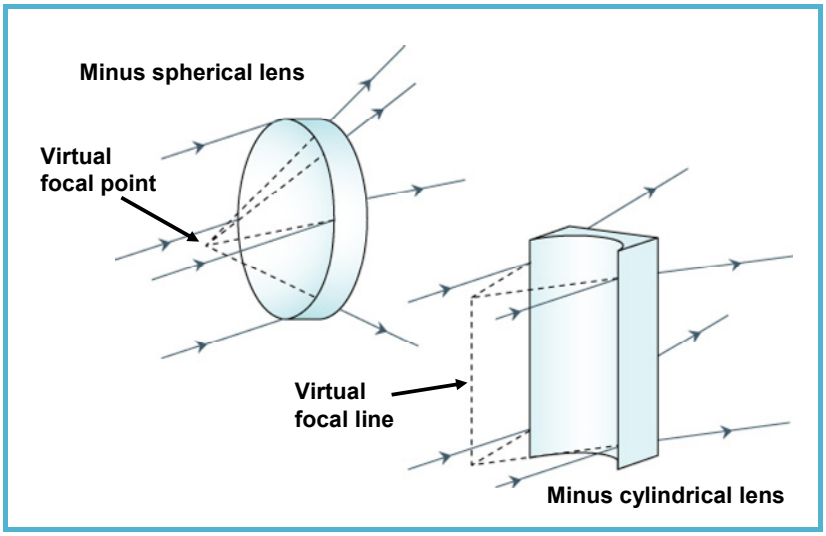


Figure 5.8: *A minus spherical lens and a minus cylindrical lens refracting incident parallel light*

SPHERO-CYLINDRICAL LENSES

Sphero-cylindrical lenses are also called sphero-cylinder lenses or just sphero-cyls.

Even though sphero-cylindrical lenses are just single lenses, they can be thought of as:

- two cylindrical lenses that have been stuck together perpendicularly (at 90°), or
- a spherical lens that is stuck to a cylindrical lens.

Sphero-cylindrical lenses have power in both principal meridians, but a different power in each:

- The power meridian has the maximum focusing power;
- The axis meridian has the minimum focusing power.

Unlike cylindrical lenses, the axis meridian of a sphero-cylindrical lens has a power that is greater than zero. This means that a plus sphero-cylindrical lens forms two focal lines, and a minus sphero-cylindrical lens forms two virtual focal lines (not just one like a cylindrical lens).

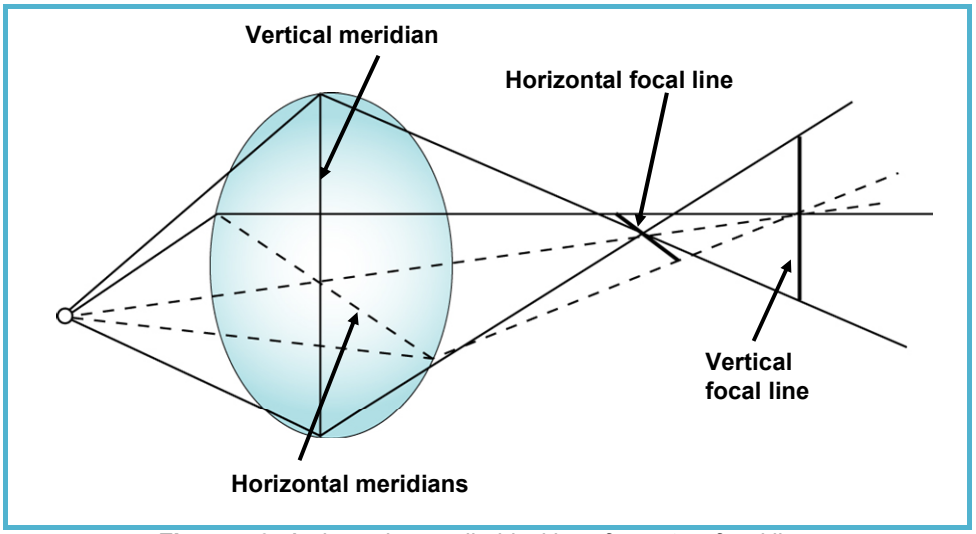


Figure 5.9: *A plus sphero-cylindrical lens forms two focal lines*

STANDARD AXIS NOTATION

Standard notation is used to show the direction of the power meridian of a cylindrical or a sphero-cylindrical lens.

For both right and left eyes we measure anti-clockwise from the horizontal meridian in degrees (º).

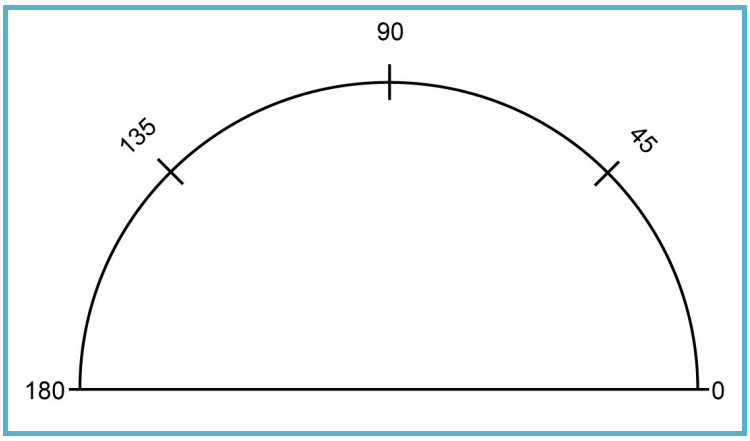


Figure 5.10: *Axis scale used for measuring the orientation of cylindrical lenses*

Although the horizontal line is both 0 and 180, we always call it 180. Therefore, the axis of a cylindrical or sphero-cylindrical lens can be anything between 1 and 180.

Usually, we also do not use the degree sign (º) because it can be confused with a zero (0).

POWER OF ASTIGMATIC LENSES

We measure the power of astigmatic lenses in dioptres cylinder. The short way of writing this is DC.

WRITING SPHERO-CYLINDRICAL LENS POWERS

When you write a sphero-cylindrical lens prescription, you need to write both the spherical part and the cylindrical part of the lens power. You also need to write what orientation (direction) the axis of the cylinder is in using standard axis notation.

Example:

Sphere power

–4.00 D

–1.00 DC x 90

Cylindrical power

Axis

or: **–4.00 D / –1.00 DC x 90**

or simply: **–4.00 / –1.00 x 90**

We say: "**Minus four, minus one, axis ninety**".

ASTIGMATIC LENS SHAPE

The thickness of the edge of an astigmatic lens is different at different places around its edge.

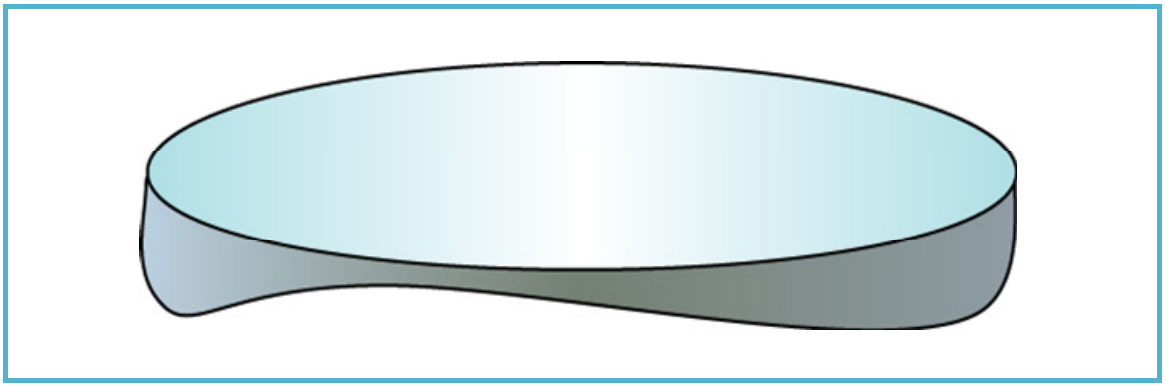


Figure 5.11: *The edge thickness of a cylindrical lens varies*

Just like spherical lenses, astigmatic lenses can come in different shapes.

Astigmatic lens surfaces can be:

- Plano (flat)
- Convex (curved like the outside of a ball)
- Concave (curved like the inside of a ball).

SUMMARY: ASTIGMATIC LENSES

ASTIGMATIC LENSES

Astigmatic Lenses and the Eyes:

- Cylindrical lenses correct astigmatism.
- Sphero-cylindrical lenses correct astigmatism combined with another refractive error (hyperopia, myopia or presbyopia).

Meridians:

- A meridian is an imaginary line which crosses a lens at its optical centre.
- An astigmatic lens has two principal meridians:
  - axis meridian (minimum power meridian)
  - power meridian (maximum power meridian).
- The meridians of a spherical lens are all equal in power.

CYLINDRICAL LENSES

- Cylindrical lenses correct astigmatism.
- Cylindrical lenses can be minus or plus powered.
- The two principal meridians of a cylindrical lens have different powers:
  - the power meridian has the maximum focusing power
  - the axis meridian has the zero focusing power (plano).

Refraction of Light Through a Cylindrical Lens:

- Spherical lenses refract incident parallel light to a single focal point or virtual focal point.
- Cylindrical lenses refract incident parallel light to a single focal line or virtual focal line.
- The focal line of a cylindrical lens is perpendicular to its power meridian.

SPHERO-CYLINDRICAL LENSES

- Sphero-cylindrical lenses correct astigmatism that is combined with myopia, hyperopia or presbyopia.
- Sphero-cylindrical lenses are single lenses, but they are like:
  - two cylindrical lenses that have been stuck together, or
  - a spherical lens that is stuck to a cylindrical lens.
- The two principal meridians of a sphero-cylindrical lens have different powers:
  - the power meridian has the maximum focusing power
  - the axis meridian has the minimum focusing power.

Refraction of Light Through a Sphero-Cylindrical Lens:

- Sphero-cylindrical lenses refract incident parallel light to two focal lines or virtual focal lines.

STANDARD AXIS NOTATION

- Used to show the direction of the power meridian of an astigmatic lens.
- Measured in degrees in an anti-clockwise direction from 1 to 180.

POWER OF ASTIGMATIC LENSES

- We measure astigmatic lens power in dioptres cylinder. The short way of writing this is DC.
- Writing a sphero-cylindrical lens prescription, you need to write:
  - spherical part of the lens power;
  - cylindrical part of the lens power;
  - axis of the cylinder using standard axis notation.

ASTIGMATIC LENS SHAPE

- The thickness of an astigmatic lens changes at different places around its edge.
- The thickness of a spherical lens is constant around its edge.

TEST YOURSELF QUESTIONS

1. **How is an astigmatic lens different from a spherical lens?**

_____

_____

2. **What are the two principal meridians of an astigmatic lens? How are they different?**

_____

_____

3. **Is the focal line formed by a cylindrical lens in the same direction as the power meridian or the axis meridian?**

_____

_____

4. **What kind of refractive error(s) does a sphero-cylindrical lens correct?**

_____

_____

5. **What is the axis of this sphero-cylindrical lens: –5.25 / –1.25 x 67?**

_____

_____